IEEE SA STANDARDS ASSOCIATION

IEEE planet positive 2030

Strong Sustainability by Design

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

An Initiative supported by the IEEE Standards Association

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IEEE

Strong Sustainability by Design

This Compendium has been created by committees of the IEEE Planet Positive 2030 Initiative supported by the IEEE Standards Association (IEEE SA). The IEEE Planet Positive 2030 Initiative community is composed of several hundred participants from six continents, who are thought leaders from academia, industry, civil society, policy and government in the related technical and humanistic disciplines. At least one hundred seventy members of this community from about thirty countries have contributed directly to this Compendium and have worked to identify and find consensus on timely issues.

The Compendium's purpose is to identify specific issues and recommendations regarding sustainability and climate change challenges to achieve "Planet Positivity" by 2030, defined as the process of transforming society and infrastructure by 2030 to:

- Reduce Greenhouse Gas (GHG) emissions to 50% of 2005 GHG emissions by 2030.
- Significantly increase regeneration and resilience of the Earth's ecosystems.
- Be well on the path to achieving net zero GHG emissions by 2050 and negative GHG emissions beyond 2050.
- Continue to widely deploy appropriate technology as well as design and implement new technological solutions in support of achieving technological solutions designed and deployed to achieve "Planet Positivity."

In identifying specific issues and pragmatic recommendations, the Compendium:

- Provides a scenario-based challenge (how to achieve "Planet Positivity by 2030") as a tool to inspire readers to get engaged.
- Advances a public discussion about how to build from a "Net Zero" mentality to a "Net or Planet Positive" ("do more good," that is, doing "more" than "don't harm") societal mandate for all technology and policy.
- Continues to build a diverse and inclusive community for the IEEE Planet Positive 2030 Initiative, prioritizing the voices of indigenous and marginalized members whose insights are acutely needed to help make technology and other solutions more valuable for all. Of keen interest is how to encourage more in-depth participatory design in these processes.
- Inspires the creation of technical solutions that can be developed into technical recommendations (for example IEEE SA recommended practice for addressing sustainability, environmental stewardship and climate change challenges in professional practice, IEEE P7800™) and associated certification programs.
- Facilitates the emergence of policies and recommendations that could potentially be intraoperative between different jurisdictions (e.g., countries).

By inviting the general public to read and utilize *Strong Sustainability by Design*, the IEEE Planet Positive 2030 community provides the opportunity to bring multiple voices from the related scientific and engineering communities together with the general public to identify and find broad consensus on technology to address pressing environmental and social issues and proposed recommendations regarding development, implementations and deployment of these technologies. You are invited to Join related IEEE activities, such as standards development and initiatives across the organization.

- For further information, learn more at the IEEE Planet Positive 2030 Initiative website
- Get in touch at: PlanetPositive2030@ieee.org to get connected to and engaged with the IEEE Planet Positive 2030 community.
- Please, subscribe to the IEEE Planet Positive 2030 newsletter here.

If you're a journalist and would like to know more about the IEEE Planet Positive 2030 Initiative, please contact: Standards-pr@ieee.org.

Disclaimers

Strong Sustainability by Design is not a code of conduct or a professional code of ethics. Engineers and technologists have well-established codes, and the IEEE Planet Positive 2030 community respectfully recognizes the formative precedents surrounding issues of sustainability and the professional values these codes represent. These codes provide the broad framework for the more focused domain addressed in this Compendium, and it is hoped that the inclusive, consensus-building process around its design will contribute unique value to technologists and society as a whole.

This Compendium is also not a position, or policy statement, or formal report of IEEE or any other organization with which IEEE is affiliated. It is intended to be a working reference tool created through an inclusive process by those in the relevant scientific and engineering communities prioritizing sustainability considerations in their work.

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A Note Regarding Recommendations in This Document

Strong Sustainability by Design was created in two versions ("draft" and this current edition) that were iterated over the course of two years. The IEEE Planet Positive 2030 Initiative follows a specific consensus building process where members contributing content identify specific potential issues and proposed recommendations.

Membership

IEEE Planet Positive 2030, an initiative supported by the IEEE Standards Association as part of the Industry Connections Program, Sustainable Infrastructures and Community Development program (SICDP), currently has more than four hundred experts involved, and remains eager for new voices and perspectives to join in this work.

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The Institute of Electrical and Electronics Engineers, Incorporated
3 Park Avenue, New York, NY 10016-5997, USA

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Maike Luiken, Editor in Chief and Chair, IEEE Planet Positive 2030 Initiative
John C. Havens, Global Director, IEEE Planet Positive 2030 Initiative

Contact: planetpositive2030@ieee.org

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- The many members, committees and groups across IEEE working on addressing sustainability and climate change challenges:
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    - IEEE Technology Center for Climate
    - The IEEE Industry Engagement Committee
    - The Joint IEEE Organizational Units (OU) Sustainable Development Ad-hoc committee
    - The IEEE TAB Climate Change Program
    - The IEEE TAB Future Directions Committee
    - The IEEE FDC SusTech Initiative
    - The IEEE Humanitarian Technologies Board (formerly the Humanitarian Activities Committee)

- All the organizers of conferences and events supporting members of The IEEE Planet Positive 2030 Community

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***Maike Luiken*, Chair, IEEE Planet Positive 2030 Initiative**
***John C. Havens*, Global Director, IEEE Planet Positive 2030 Initiative**
***Mila Aliana,* Chief Weaver, IEEE Planet Positive 2030 Initiative**

With Deep Gratitude

The members of the Planet Positive 2030 community wish to express their deep gratitude to Brian Friedrich who played a pivotal role on our Metrics Committee and in the Initiative. It is with deep sadness we mourn his passing during the development of *Strong Sustainability by Design.* We celebrate his warmth, humor, enthusiasm for and seminal insights contained in this work.

STRONG SUSTAINBILITY BY DESIGN

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

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STRONG SUSTAINBILITY BY DESIGN

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

Executive Summary

Imagine the future we[1] can build together.

This is the vision driving the work of **IEEE Planet Positive 2030**, an initiative created and supported by the IEEE Standards Association[2] that brings together a global, diverse, open community of experts to help chart a path for all people to achieve a flourishing future for 2030 and beyond.

The first step to imagine this future is to recognize the planet Earth and all its ecosystems and biodiversity form a part of all of us.[3] The air we breathe, the water we drink, and the food Earth provides comprise who we are. We cannot continue to treat planet Earth as a "resource" from which to be extracted—planet Earth is finite with finite resources.[4] We should, instead, prioritize the health of our planetary biosphere and recognize that we humans are a part of the system, not above it or outside it.

In 1987, the United Nations Brundtland Commission defined "sustainability" as "meeting the needs of the present without compromising the ability of future generations to meet their own needs".[5] This implies "sustainability" is the long-term resilience of people and the planetary biosphere in unison. Achieving sustainability for millennia to come requires a shift from the zeitgeist of competition defining the Anthropocene[6] era to a culture of care for the land and one another, a "culture of sustainability," the ultimate goal/vision we can imagine, share, and achieve together.

A key intersection for sustainability involves technology and the context of how and when it is applied and/or used. Quoting *Herbert Simon (1916–2001), Nobel prize laureate 1978, A. M. Turing award 1975:*

> *"We must look ahead at today's radical changes in technology, not just as forecasters but as actors charged with designing and bringing about a sustainable and acceptable world. New knowledge gives us power for change: for good or ill, for knowledge is neutral. The*

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[1] "We" refers to "all of us people"—our responsibility for "Now" and "Future Generations" of humanity and the Earth's biosphere.

[2] IEEE Planet Positive 2030 is part of the Sustainable Infrastructures and Community Development Industry Connections program of IEEE SA.

[3] "Us" refers to all people on Earth.

[4] For instance, according to the 2024 World Wildlife Fund's 2024 Living Planet Report, there is "an average 73% decline in wildlife populations since 1970." In other words, nature is dying.

[5] See the definition of "sustainable development" on page 41 of *Our Common Future: Report of the World Commission on Environment and Development* from the UN General Assembly, Development and International Economic Co-operation: Environment, A/42/427 (annex), originally published 4 Aug. 1987.

[6] From Anthropocene by Andrew Goudie: "Paul Crutzen and colleagues introduced the term 'Anthropocene' (e.g., Crutzen 2002; Steffen, et al. 2007) as a name for a new epoch in Earth's history—an epoch when human activities have 'become so profound and pervasive that they rival, or exceed, the great forces of Nature in influencing the functioning of the Earth System."

problems we face go well beyond technology: problems of living in harmony with nature, and most important, living in harmony with each other. Information technology, so closely tied to the properties of the human mind, can give us, if we ask the right questions, the special insights we need to advance these goals."[7]

The IEEE Planet Positive 2030 process builds on IEEE experience considering the potential positive and negative impacts of the applications of technologies on people[8] to also address impacts to our planet. It leverages previous work and vision created by IEEE taking an in-depth look at Artificial Intelligence, its applications and potential impacts as detailed in *Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems*:[9]

"Ultimately, our goal should be ***eudaimonia****, a practice elucidated by Aristotle that defines human well-being, both at the individual and collective level, as the highest virtue for a society. Translated roughly as 'flourishing,' the benefits of eudaimonia begin with conscious contemplation, where ethical considerations help us define how we wish to live."*[10]

Human well-being has many facets: health, education, social networks among others. Fundamentally, it is dependent on planet Earth, its climate, and the health of the Earth's ecosystems. It requires that nature be honored so it can flourish in unison with all people and species, that we as individuals and organizations recognize and respect planetary boundaries, the role of and limits to natural capital. This leads to the concept of **Strong Sustainability.**

"Strong Sustainability" builds on the concept of "Sustainability" and stipulates that substitutability of natural capital and ecosystem services (by manufactured capital) be severely restricted to ensure availability of these resources for future generations, for human existence and well-being. The "consumption of natural capital is usually irreversible" (for example, loss of biodiversity).[11] Strong Sustainability provides boundary conditions for technological design and implementation based on the reality that Earth's ecosystems will function and evolve as they will despite any human economic or cultural imperatives.

Put simply: We need Nature. Nature doesn't need us.

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[7] Salvatore T. March and Fred Niederman, "The Future of the Information Systems Discipline: A Response to Walsham,"*Journal of Information Technology* 27, no. 2 (2012). Includes quote by Herbert A. Simon (2000).

[8] Technology and Society," IEEE Society on Social Implications of Technology (SSIT), https://technologyandsociety.org.

[9] The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, *Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems*, 1st ed. (IEEE, 2019).

[10] In *Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems*, the first three principles are:

1. **Human Rights** – Artificial Intelligence Systems (AIS) shall be created and operated to respect, promote, and protect internationally recognized human rights.
2. **Well-being** – Artificial Intelligence Systems (AIS) creators shall adopt increased human well-being as a primary success criterion for development.
3. **Data Agency** – Artificial Intelligence Systems (AIS) creators shall empower individuals with the ability to access and securely share their data, to maintain people's capacity to have control over their identity.

[11] Jérôme Pelenc, Jérôme Ballet, and Tom Dedeurwaerdere, "Weak Sustainability versus Strong Sustainability, brief for GSDR 2015.

It is this recognition of our need to account for and honor Earth that the title of our compendium is ***Strong Sustainability by Design: Prioritizing Ecosystem and Human Flourishing with Technology-Based Solutions***. Eudaimonia must embody conscious contemplation, "healing," and conservation of our planetary biosphere, that is our natural world with a healthy atmosphere and ecosystems for all the living organisms it contains.

The name of the IEEE Planet Positive 2030 Initiative tells the story of how we[12] are approaching and doing our work:

- **Planet**: Our focus. The Earth we must heal, protect, and sustain for humans and nature to flourish for seven generations[13] and beyond.
- **Positive**: Our purpose. The design to give back more to the planet with technology than is removed and not to harm the biosphere/planet[14].
- **2030**: Our urgency. The timeframe guiding our work inspiring responsible, bold, systems thinking to inspire accountable contextualized solutions, standards, policy, and pragmatic change.
-

Each chapter of *Strong Sustainability by Design* begins with a "IEEE Planet Positive vision of 2030" written as if the expert committee members authoring the content are in that future positive reality where the two "impossible goals"[15] have been achieved. Discussions of "Issues" and "Recommendations" provide a pathway to get from today's reality to the visions of 2030 as will be complemented by the feedback received as part of this process.

Many experts have collaborated, cooperated, and shared their insights to prepare this living document in an effort to not only imagine the future we can build but also identify potential technologies, standards, and solutions that can be implemented now to achieve "planet positivity" by 2030.

Now we call on you, on all interested people, to provide advice, input, and suggestions.

You are invited.

Imagine the future we can build together.

Your participation and insights will help build this future.

To achieve Planet Positivity for 2030 and beyond.

[12] We—the many contributors and participants of the Planet Positive 2030 Initiative.

[13] For more information about the Seventh Generation Principle, see the 30 May 2020 blog post of the Indigenous Corporate Training, Inc., entitled "What is the Seventh Generation Principle?" When involving Indigenous communities, it is recommended to consider and prioritize the rights of Indigenous peoples, including the principle of free, prior, and informed consent. For more details, see: UN Human Rights, Office of the High Commissioner, "Free, Prior and Informed Consent of Indigenous Peoples," from Sept. 2013.

[14] Versus a "climate neutral" mindset.

[15] Goal One: Transform society and infrastructure to achieve Planet Positive 2030 means reducing GreenHouse Gas (GHG) emissions to 50% of 2005 emissions by 2030 and significantly increasing regeneration and resilience of Earth's ecosystems (as noted in the UN Convention on Biological Diversity's First Draft of the Post-2020 Global Biodiversity Framework from 5 July 2021, created as part of COP 15 UN Biodiversity Conference).Goal Two: Identify the current technological solutions that need to be deployed widely as well as technology gaps for which we need to design, innovate, and deploy new technological solutions to reach Planet Positive 2030.

The Foundation

The need for a flourishing planet, human rights, and values

The foundation for the guiding principles is the need for a long-term flourishing planet Earth to sustain all life. The guiding principles are built upon the United Nations Universal Declaration of Human Rights; Declaration on the Rights of Indigenous Peoples; Declaration on the Rights of Disabled Persons; Declaration on the Right to Development; Rio Declaration on Environment and Development; Resolution on the Human Right to a Clean, Healthy and Sustainable Environment; Convention on the Rights of the Child; regional human rights declarations; and the IEEE Code of Ethics.

Human dignity and the human values of peace, freedom, social progress, and equal rights form the values basis underlying *Strong Sustainability by Design*. Enshrined within the UN's Charter and its Universal Declaration of Human Rights for nearly three-quarters of a century, these broad values have guided the UN's efforts to fairly represent the world's diverse nations and cultures.

Alignment with UN values embraces a powerful declaration for universal human values that guide human societies. Having those values form the basis for *Strong Sustainability by Design*'s guiding principles provides a powerful, cultures-wide foundation for guiding the efforts of humans as caretakers and caretaker advocates of a flourishing planet.

Essential to the success of the guiding principles are awareness of the problem, accountability, transparency, freedom of expression, and protection of whistleblowers. The goal is a long-term flourishing planet Earth with a thriving biosphere—all nations, all peoples, all life, and all that supports life.

The goal of a long-term, flourishing planet Earth, planet Earth with a healthy planetary biosphere, can be attained if the current warming trend of the Earth's atmosphere is first halted and then reversed. Reduction of current and future GHG emissions as well as—in the longer term beyond 2050—reduction of the elevated GHG levels in the atmosphere is a paramount goal. Achieving this goal is imperative, but it is not sufficient to attain a long-term healthy planetary biosphere. While shifting from fossil fuel-based economies to largely GHG-free economies is the foremost agenda to address the looming climate crisis, it is equally important to transform the current, mostly linear, resource management into a circular economy (see Ellen MacArthur Foundation, "What is a Circular Economy" and "The Circular Economy in Detail), along with regenerative practices and environmental stewardship. Throughout, we, that is humans, need to observe a balance for all stakeholders between the urgency of today's environmental, biodiversity, and societal needs, the urgency of avoiding tomorrow's looming climate catastrophe and achieving a long-term, flourishing planet Earth.

Embracing complexity throughout the pursuit of this goal is vital. The increasing recognition of interdependencies between society and the environment, our home, means that the transition to a sustainable future is a complex or "wicked problem" (Rittel & Webber, 1973). The process of transitioning to a planet-positive society will not be easy or straightforward. Competing goals and problem sets, different cultural and/or governance approaches, and moving and/or unmeasurable targets imply that this journey will not be linear and will not be without political—or other forms of—disagreements or conflict. Indeed, addressing and responding to the realities of global warming may be the most important and complex problem humanity has ever faced. Failure to do so will have lasting harmful impacts and consequences for all stakeholders, including present and future humanity and the planetary biosphere. Honoring, recognizing, and including the large diversity in stakeholder cultures and in local, regional, and global conditions and needs requires flexibility and a diversity of approaches to creating a planet-positive society.

The very succinct **definition of planetary sustainability** by an unknown participant from Africa at the United Nations meeting in Johannesburg (Rio + 10), **"Enough for All—Forever"** can serve as a key guidepost. Individual, institutional, business, industry, government, organizational, academic, and societal stakeholders share the responsibility to "take care" of the planet Earth and its biosphere, humanity's—our—home.

The **guiding principles** of *Strong Sustainability by Design* are intended to provide a framework for the document's strategies and recommendations capturing both the desire for long-term planetary sustainability and the complexity that is inherent in fulfilling this desire. They embody the overall "impossible" goals of the IEEE Planet Positive 2030 Initiative.

Ten Guiding Principles

These Principles are designed to provide high-level considerations and are not listed in any order of importance. This has been done purposefully so readers can provide recommendations including the potential ranking of these Principles by specific criteria that address the needs of their audience and stakeholders.

1. **Responsible and ethical leadership from governments, individuals, businesses, organizations, academic institutions, and communities**

   The responsibilities of individuals, organizations, academic institutions, and communities should be broadened to include an increased role in addressing the challenges of climate change, sustainability, and socioeconomic and environmental stewardship. New knowledge brings responsibility and demands action. Leadership requires collaboration and cooperation with all stakeholders impacted by decisions. Implementation of technology and policy development should always consider environmental flourishing and human wellbeing in accordance with specifics established by guidelines such as the United Nations Sustainable Development Goals (UNDESA, "The 17 Goals").

2. **Justice, diversity, equity, and inclusion**

   Championing justice, diversity, equity, and inclusion should be a part of sustainability, regeneration, and climate change strategies recognizing that climate change impacts are often felt most by those with the least resources. It is the responsibility of those with the most resources to support those who lack resources in an equitable manner. Addressing climate change impacts and environmental and sustainability challenges should reduce conflict, violence, and inequity.

3. **Global energy systems transformation**

   The transition from a fossil fuel-based energy system to a system that is based on clean and sustainable sources of energy should maintain energy accessibility, affordability, sustainability, reliability, and resiliency through all phases of the transition. This transition should also help ensure access for all to affordable, reliable, sustainable, and modern energy (UNDESA, Goal 7). A successful energy transition will enable GHG emission reductions not only in the energy/power sectors but in all sectors using energy, thereby supporting the decarbonization and electrification of these sectors.

4. **Climate change mitigation and adaptation**

   In responding to the challenge of climate change, and to prevent a climate catastrophe, society needs to both mitigate (that is, reduce) GHG emissions and adapt to the impacts of a changing climate. Both goals require urgent action. The goals of mitigation and adaptation may come into conflict, society will have to balance these conflicts.

5. **The regenerative imperative and a circular economy**

   Thinking, planning, and action must broaden beyond current economic, business, societal, and resource utilization models to achieve sustainability and for people and the Earth's biosphere to flourish for many generations to come. Future economic, societal and cultural, and business models should emphasize new public imperatives and values such as circularity, ecological regeneration, zero waste, and human flourishing and well-being.

6. **Balance between today's needs and the needs of the future**

   In the course of transitioning societies and the global economy toward a sustainable future, today's short-term needs must balance with the long-term, global aspirations for a flourishing planet. This balanced approach should address all human needs, including access to food and clean water, health care, and other essential goods and services necessary for a healthy standard of living, and the need for healthy ecosystems globally.

7. **Alignment of global goals with local goals and actions**

   The transition to a more sustainable future will be driven and implemented by local actions that should also produce positive global benefits. Local actions and global goals should support each other.

8. **Culture of sustainability**

   Strategies and actions should move societies toward building a culture of sustainability and "doing good" that is based on respect for all living beings and for the planet Earth. Sustainability efforts must move beyond minimizing harm to restoring and regenerating human and environmental systems.

9. **Responsible use of technology and technology labeling**

   The design, development, implementation, use, and handling/treatment at end-of-current-use of technology should be a dynamic ongoing process for evolving an appropriate, timely response to both negative impacts—the unforeseen consequences of technology on people and planet—and positive impacts—the opportunities to relieve suffering, increase flourishing and equity, and better steward the planet.

10. **Knowledge-based decisions, transparency, and accountability**

    Decisions should be based on metrics, sound data, relevant information, context, experience, and perspective; these factors all contribute to informed decisions, knowledge, and accountability. Knowledge-based decisions are thus made on the basis of good evidence and sound reasoning; this, in turn, can make hard decisions more defensible and accountable. Application of appropriate metrics and reevaluation of decisions should be carried out at appropriate time intervals to enable accountability, transparency, and corrective actions.

The Following text extracts identified issues from the various chapters of the compendium. For a detailed description of backgrounds to issues and recommendations, please visit the individual chapters.

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GUIDING PRINCIPLES

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CHAPTER 1: GUIDING PRINCIPLES

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GUIDING PRINCIPLES

Committee Members

Committee Co-Chairs

- Maike Luiken, Chair of the IEEE Planet Positive 2030 Initiative, Sarnia, Ontario, Canada
- Mike McMeekin, President/Executive Director, Engineering Change Lab – USA, Omaha, Nebraska, United States

Committee Members

- Greg Adamson, Honorary Principal Fellow, University of Melbourne, Melbourne, Australia
- Kathy Baxter, Principal Architect, Responsible AI & Technology, Salesforce, California, United States
- Anahiby Becerril, Specialist in Governance, Human Rights and Culture of Peace, Universidad Castilla-La Mancha, Spain
- Chait Harel, Ph.D. Candidate, Bar Ilan University, Ramat Gan, Israel
- Gokce Cobansoy Hizel, Human Rights and New Technologies Law Coordinator, Turkey
- Caitlin C. Corrigan, Executive Director, Institute for Ethics in Artificial Intelligence, Munich, Bavaria, Germany
- Henry Dobson, Melbourne, Victoria, Australia
- Mei Lin Fung, Co-Founder with Vint Cerf, People Centered Internet, California, United States
- David Gonzalez, California, United States & Colombia
- Tomasz Hollanek, Postdoctoral Research Fellow, Leverhulme Centre for the Future of Intelligence, University of Cambridge, Cambridge, United Kingdom
- Sigmund (Sigi) Kluckner, Vienna, Austria
- William (Bill) Lesieur, Capgemini, United States
- Marlon Patrick P. Lofredo, Ph.D., Director, Center for Social Innovation & Research, St. Paul University, Philippines; Professor, American University of Sovereign Nations, Arizona, United States
- Chuck Metz Jr., Writer and Researcher, Knoxville, TN, United States
- Jose Meza, University of Technology, Sydney, NSW, Australia
- Anand (Sunny) Narayanan, Research Faculty, Florida State University, Tallahassee, Florida, United States
- Jourdan Saunders, CEO & Founder, The Resource Key, Arlington, Virginia, United States
- Tapan Shah, Senior Scientist, General Electric Research
- Max Song, Climate Tech Entrepreneur, Digital Climate Policy Researcher, Board Member of PingAn One Connect Bank, Hong Kong, China

- Frank Stein, Virginia Tech, Intelligent Systems Faculty, Center for Environmental Security Affiliated Faculty, Vienna, Virginia, United States
- Matthew Studley, Bristol Robotics Laboratory
- George Tilesch, PHI Institute for Augmented Intelligence
- Yonah Welker, Visiting Lecturer, Evaluator – EU Commission Projects, Former Tech Envoy, Advisor of Ministry of AI, Geneva, Switzerland
- Laszlo Zsolnai, Professor and Director of the Business Ethics Center, Corvinus University of Budapest, Budapest, Hungary

GUIDING PRINCIPLES

Future Vision

It is 2030.

Greenhouse gas (GHG) emissions are significantly reduced, and the Earth's lands and ecosystems are on the way to recovery as imagined by the 2022 United Nations (UN) Convention on Biodiversity—a recovery that will enable planetary-scale environmental regeneration and resilience.

The catalyst for this transformation was a profound sense of urgency stemming from the looming *climate emergency* as the Earth moved closer to the climate tipping point (*the point of no return*; see UNU-EHS, "2023 Executive Summary"). The transformation has been driven by a reformed sense of leadership and planetary-scale collaboration informed by the notion of *deep care*—for the environment, for the Earth's biospheres, and for human dignity (ascribed to all people, including historically marginalized populations, equally).

Decision-makers have adopted caregiving and long-term sustainability as guiding principles for action to address both the need for reduction of GHG emissions and adaptation to the unavoidable impacts of climate change. The majority of global political, business, and community leaders, many of whom represent groups marginalized in the past, have more fully embraced the values of justice, diversity, equity, and inclusion in shaping new policies, new economic and business models, new tools for measuring growth, and new standards of practice.[16] Sustainable behavior that balances today's needs with the needs of future generations is now integral to cultures around the globe—for individuals as well as for organizations.

The concept of an economy based on the concept of "sufficiency" is finding more and more acceptance (Barbiroglio, 2022; Suski, Palzkill, & Speck, 2023; Schaffer, 2018).

Humans are sharing the planet's resources with a vast variety of other organisms. Emerging technologies, including responsibly developed artificial intelligence systems (AIS), are being applied to implement climate change mitigation and adaptation strategies. Humans have developed sustainable and regenerative practices and have recognized that they are caretakers of the planet. Change is driven by an increased awareness of the interconnectedness and interdependence among different types of stakeholders.[17]

[16] The UN "Guiding Principles on Business and Human Rights" contain three chapters, or pillars: protect, respect, and remedy. These pillars define specific, actionable steps for governments and companies to take to meet their respective duties and responsibilities aimed at preventing human rights abuses in company operations and provide remedies if such abuses occur. These guiding principles are valid for all kinds (and sizes) of businesses.

[17] Stakeholders, in this context, are human-centric and other lifeforms and the environment, including: the Earth's biospheres, peoples, individuals, institutions, businesses, industries, governments, organizations, academia, and society at large.

Introduction

The goal of a long-term, flourishing planet Earth, planet Earth with a healthy planetary biosphere, can be attained if the current warming trend of the Earth's atmosphere is first halted and then reversed. Reduction of current and future GHG emissions as well as—in the longer term beyond 2050—reduction of the elevated GHG levels in the atmosphere is a paramount goal. Achieving this goal is imperative, but it is not sufficient to attain a long-term healthy planetary biosphere. While shifting from fossil fuel-based economies to largely GHG-free economies is the foremost agenda to address the looming climate crisis, it is equally important to transform the current, mostly linear, resource management into a circular economy (see Ellen MacArthur Foundation, "What is a Circular Economy" and "The Circular Economy in Detail), along with regenerative practices and environmental stewardship. Throughout, we, that is humans, need to observe a balance for all stakeholders between the urgency of today's environmental, biodiversity, and societal needs, the urgency of avoiding tomorrow's looming climate catastrophe and achieving a long-term, flourishing planet Earth.

Embracing complexity throughout the pursuit of this goal is vital. The increasing recognition of interdependencies between society and the environment, our home, means that the transition to a sustainable future is a complex or "wicked problem" (Rittel & Webber, 1973). The process of transitioning to a planet-positive society will not be easy or straightforward. Competing goals and problem sets, different cultural and/or governance approaches, and moving and/or unmeasurable targets imply that this journey will not be linear and will not be without political—or other forms of—disagreements or conflict. Indeed, addressing and responding to the realities of global warming may be the most important and complex problem humanity has ever faced. Failure to do so will have lasting harmful impacts and consequences for all stakeholders, including present and future humanity and the planetary biosphere. Honoring, recognizing, and including the large diversity in stakeholder cultures and in local, regional, and global conditions and needs requires flexibility and a diversity of approaches to creating a planet-positive society.

The very succinct **definition of planetary sustainability** by an unknown participant from Africa at the United Nations meeting in Johannesburg (Rio + 10), **"Enough for All—Forever"** can serve as a key guidepost. Individual, institutional, business, industry, government, organizational, academic, and societal stakeholders share the responsibility to "take care" of the planet Earth and its biosphere, humanity's—our—home.

The **guiding principles** of *Strong Sustainability by Design* are intended to provide a framework for the document's strategies and recommendations capturing both the desire for long-term planetary sustainability and the complexity that is inherent in fulfilling this desire. They embody the overall "impossible" goals of the IEEE Planet Positive 2030 Initiative.

The foundation: The need for a flourishing planet, human rights, and values

The foundation for the guiding principles is the need for a long-term flourishing planet Earth to sustain all life. The guiding principles are built upon the United Nations Universal Declaration of Human Rights; Declaration on the Rights of Indigenous Peoples; Declaration on the Rights of Disabled Persons; Declaration on the Right to Development; Rio Declaration on Environment and Development; Resolution on the Human Right to a Clean, Healthy and Sustainable Environment; Convention on the Rights of the Child; regional human rights declarations; and the IEEE Code of Ethics.

Human dignity and the human values of peace, freedom, social progress, and equal rights form the values basis underlying *Strong Sustainability by Design*. Enshrined within the UN's Charter and its Universal

Declaration of Human Rights for nearly three-quarters of a century, these broad values have guided the UN’s efforts to fairly represent the world's diverse nations and cultures.

Alignment with UN values embraces a powerful declaration for universal human values that guide human societies. Having those values form the basis for *Strong Sustainability by Design*'s guiding principles provides a powerful, cultures-wide foundation for guiding the efforts of humans as caretakers and caretaker advocates of a flourishing planet.

Essential to the success of the guiding principles are awareness of the problem, accountability, transparency, freedom of expression, and protection of whistleblowers. The goal is a long-term flourishing planet Earth with a thriving biosphere—all nations, all peoples, all life, and all that supports life.

Ten Guiding Principles

These Principles are designed to provide high-level considerations and are not listed in any order of importance. This has been done purposefully so readers can provide recommendations including the potential ranking of these Principles by specific criteria that address the needs of their audience and stakeholders.

1. **Responsible and ethical leadership from governments, individuals, businesses, organizations, academic institutions, and communities**

   The responsibilities of individuals, organizations, academic institutions, and communities should be broadened to include an increased role in addressing the challenges of climate change, sustainability, and socioeconomic and environmental stewardship. New knowledge brings responsibility and demands action. Leadership requires collaboration and cooperation with all stakeholders impacted by decisions. Implementation of technology and policy development should always consider environmental flourishing and human wellbeing in accordance with specifics established by guidelines such as the United Nations Sustainable Development Goals (UNDESA, "The 17 Goals").

2. **Justice, diversity, equity, and inclusion**

   Championing justice, diversity, equity, and inclusion should be a part of sustainability, regeneration, and climate change strategies recognizing that climate change impacts are often felt most by those with the least resources. It is the responsibility of those with the most resources to support those who lack resources in an equitable manner. Addressing climate change impacts and environmental and sustainability challenges should reduce conflict, violence, and inequity.

3. **Global energy systems transformation**

   The transition from a fossil fuel-based energy system to a system that is based on clean and sustainable sources of energy should maintain energy accessibility, affordability, sustainability, reliability, and resiliency through all phases of the transition. This transition should also help ensure access for all to affordable, reliable, sustainable, and modern energy (UNDESA, Goal 7). A successful energy transition will enable GHG emission reductions not only in the energy/power sectors but in all sectors using energy, thereby supporting the decarbonization and electrification of these sectors.

4. **Climate change mitigation and adaptation**

   In responding to the challenge of climate change, and to prevent a climate catastrophe, society needs to both mitigate (that is, reduce) GHG emissions and adapt to the impacts of a changing climate. Both goals require urgent action. The goals of mitigation and adaptation may come into conflict, society will have to balance these conflicts.

5. **The regenerative imperative and a circular economy**

   Thinking, planning, and action must broaden beyond current economic, business, societal, and resource utilization models to achieve sustainability and for people and the Earth's biosphere to flourish for many generations to come. Future economic, societal and cultural, and business models should emphasize new public imperatives and values such as circularity, ecological regeneration, zero waste, and human flourishing and well-being.

6. **Balance between today's needs and the needs of the future**

   In the course of transitioning societies and the global economy toward a sustainable future, today's short-term needs must balance with the long-term, global aspirations for a flourishing planet. This balanced approach should address all human needs, including access to food and clean water, health care, and other essential goods and services necessary for a healthy standard of living, and the need for healthy ecosystems globally.

7. **Alignment of global goals with local goals and actions**

   The transition to a more sustainable future will be driven and implemented by local actions that should also produce positive global benefits. Local actions and global goals should support each other.

8. **Culture of sustainability**

   Strategies and actions should move societies toward building a culture of sustainability and "doing good" that is based on respect for all living beings and for the planet Earth. Sustainability efforts must move beyond minimizing harm to restoring and regenerating human and environmental systems.

9. **Responsible use of technology and technology labeling**

   The design, development, implementation, use, and handling/treatment at end-of-current-use of technology should be a dynamic ongoing process for evolving an appropriate, timely response to both negative impacts—the unforeseen consequences of technology on people and planet—and positive impacts—the opportunities to relieve suffering, increase flourishing and equity, and better steward the planet.

10. **Knowledge-based decisions, transparency, and accountability**

    Decisions should be based on metrics, sound data, relevant information, context, experience, and perspective; these factors all contribute to informed decisions, knowledge, and accountability. Knowledge-based decisions are thus made on the basis of good evidence and sound reasoning; this, in turn, can make hard decisions more defensible and accountable. Application of appropriate metrics and reevaluation of decisions should be carried out at appropriate time intervals to enable accountability, transparency, and corrective actions.

The following sections of this chapter discuss each of the guiding principles in more detail, including providing recommendations.

Guiding Principle 1: Responsible and ethical leadership from governments, individuals, businesses, organizations, academic institutions, and communities

The responsibilities of individuals, organizations, academic institutions, and communities[18] should be broadened to include an increased role in addressing the challenges of climate change, sustainability, and socioeconomic and environmental stewardship. New knowledge brings responsibility and demands action. Leadership requires collaboration and cooperation with ***all*** stakeholders impacted by decisions. Implementation of technology and policy development should always consider environmental flourishing and human wellbeing in accordance with specifics established by guidelines such as the United Nations Sustainable Development Goals (UNDESA, "The 17 Goals").

Background

Professional communities include technical and nontechnical professionals[19] who are committed to a sustainable future and who are experienced and knowledgeable regarding the paths toward this future. There is an imperative for leadership from this community to inspire global cooperation and collaboration at all levels of society.

This leadership imperative applies to both individuals and organizations. Individual responsibility includes the choices and actions of our lives and our roles in leading change within organizations. Organizations, including academic institutions, play a significant role in achieving long-term sustainability of the Earth's biospheres since their decisions and activities impact the planet on both community and global scales. Organizations should see themselves as both agents for increasing "collective good" and understanding imperatives to implement necessary structural and operational changes. In doing so, professional communities make key contributions towards achieving a flourishing planet, that is a flourishing planetary biosphere.

Increased engagement in public policy that is focused on creating a more sustainable world will be necessary. Professional communities will need to utilize technical knowledge and understanding of stakeholder concerns and leadership skills to help guide public investment decisions and promote necessary regulatory shifts.

Recommendations

1. **Broaden the definition of professional responsibility.** Work with engineering and other professional organizations to broaden their definitions of professional responsibility to place greater emphasis on sustainability, climate change, environmental stewardship, and responsible technology. Associations of technical professionals globally should provide leadership.

[18] Individuals, organizations, academic institutions, businesses, governments, and communities will be referred to hereafter as stakeholders.

[19] Includes professionals from various technical, scientific, and nontechnical disciplines.

2. **Individuals may, for example, contribute to the IEEE P7800™ Working Group's *IEEE Recommended Practice for Addressing Sustainability, Environmental Stewardship and Climate Change Challenges in Professional Practice*.**
3. **Engage with the public with science-based information and conclusions.** Engage in activities focused on educating, communicating, and engaging with the public regarding the science behind climate change, the value that the natural world provides to society, and the future impacts of climate change. This would also include discussing and addressing out-of-date information and misconceptions.
4. **Raise awareness of the risks and challenges and potential impacts of climate change.** That is to raise awareness of the potential impacts of climate change to civilization and the planetary biosphere, the challenge of limiting climate change and the need for sustainability and environmental stewardship. Transparency is essential.
5. **Encourage and lead the development of an accountability system that is transparent and features external audits and verification.**
6. **Lead in the development of a cross-sectoral information system that links changes in climate, GHG levels in the atmosphere, ocean warming, and other indicators to countries' responsibilities, and compensatory mechanisms.**
7. **Include concepts of sustainability, climate change, and environmental stewardship in leadership and other professional training programs.** Support efforts to incorporate leadership in sustainability and programs of technical skills related to sustainability, climate change action, and environmental stewardship in the curriculum for professional education and other fields of study, including material within the IEEE Learning Network.
8. **Support the application of metrics, analytics, tracking and reporting.** Support efforts and highlight best practices related to the inclusion, application, tracking and reporting of sustainability, environmental, social, and governance (ESG) metrics, or equivalent/similar/improved metrics, for all types of organizations.
9. **Support the sustainability leadership initiatives of other organizations and collaborate with these organizations for increased impact.**
10. **Engage in public policy advocacy at all levels of government that supports the goals of the IEEE Planet Positive 2030 Initiative.**[20]

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Engineering Change Lab—USA

   According to Engineering Change Lab—USA, there are two key elements to the leadership imperative:

[20] The Two "Impossible" Goals of the IEEE Planet Positive 2030 Initiative: 1) Transform society and infrastructure to achieve Planet Positivity; 2) Identify the technological solutions we need to design, innovate and deploy to reach Planet Positive 2030.

a. Stepping up to leadership roles:
   - Communicating, connecting, convening, and caregiving
   - Challenging the status quo and catalyzing change
   - When necessary, taking the heat and holding steady

b. Building bridges:
   - Collaborating across disciplines and with all other stakeholders
   - Proactively reaching out across divides and between factions
   - Managing polarities and resolving conflicts
   - Committing to an open-source ideology that also recognizes sources
   - Maintaining cultural awareness and empathy

Further resources

1. Annas, George J., Chase L. Beisel, Kendell Clement, Andrea Crisanti, Stacy Francis, Marco Galardini, et al. "A Code of Ethics for Gene Drive Research." *The CRISPR Journal* 4, no. 1 (19 Feb. 2021).
2. Engineering Change Lab USA (website).
3. Engineering for One Planet (website).
4. McMeekin, Mike. "Climate Change Noble Purpose for Engineering Statement." Engineering Change Lab, USA, 28 Oct. 2021.
5. Sustainable Development Technology Canada (website).

Guiding Principle 2: Justice, diversity, equity, and inclusion

Championing justice, diversity, equity, and inclusion should be a part of sustainability, regeneration, and climate change strategies recognizing that climate change impacts are often felt most by those with the least resources. It is the responsibility of those with the most resources to support those who lack resources in an equitable manner. Addressing climate change impacts and environmental and sustainability challenges should reduce conflict, violence, and inequity.

Background

Climate change, sustainability, and environmental challenges affect people differently based on factors such as location and resources. Some of these impacts can be direct, such as how extreme weather events and rising temperatures can disproportionately affect historically marginalized communities who may not have the resources to adapt to these changes. Those with fewer resources are often the most affected and have the least ability to respond to the impacts of climate change and other sustainability-related challenges.

The involvement of historically and currently marginalized populations allows for unique experiences and perspectives to contribute to the decision-making processes of government, especially concerning sustainability. For example, communities of color may face different environmental health risks and challenges compared to other groups, and their input on how to address these issues can be valuable and essential for successful change.

Therefore, it is beneficial for governments and organizations to actively engage with historically marginalized communities, listen to their voices, and take their experiences into account when creating policies and making decisions about sustainability. This will allow for the solutions developed to be more comprehensive, so everyone in society can benefit from a sustainable future.

More specifically, climate change can have a range of impacts on historically marginalized communities. These impacts include the health impacts of air pollution, lack of access to clean water and sanitation, rising sea levels, extreme weather events, and other climate-related events. These impacts have—and will—lead to a lowered quality of life (IPCC, 2022).

In addition, intersectionality includes multiple forms of social inequalities and vulnerability that interconnect and overlap with each other. Intersectionality addresses more than the categories of identities; it also includes the intricacies necessary to understand persistent social, political, and structural inequalities that, in turn, translate into various types of vulnerabilities and the unequal sharing of needs and responsibilities.

Technology plays a critical role in managing climate risks and impacts, but historically marginalized communities are often left out from benefiting from these technologies. The Technology for Climate Justice Reporting Framework in Figure 22.4, *Reporting Framework for Technology to Address Loss and Damage and Contribute to Climate Justice* (van den Homberg and McQuistan, 2018) aims to analyze technology needs to reduce losses and damages for decision makers. The framework includes two repositories of technologies: one for technologies currently used to address impacts and risks and another for planned technologies.

Tens of millions of people living in Africa have experienced/are experiencing acute food insecurity, hunger or famine (see The Africa Center for Strategic Studies, 2024). "*Drought…has devastated their living conditions.*

Climate change causes droughts to be more frequent and severe, which" will continue to negatively impact "*the lives of the African people*."

"Indigenous" …peoples, "who are especially reliant on their land for day-to-day survival, are leading the way with initiatives aimed at quelling the environmental disasters they suffer as a result of global warming and extreme weather conditions…

…And yet, despite the discrepancy in how different groups and countries are affected by climate change, many previous negotiations and policy decisions have excluded nongovernmental organizations, activists, civil society, and those most vulnerable to the effects of climate change. These groups, while present, are not allowed an equal opportunity to contribute to policy decisions" (text adapted from Fadahunsi, "Climate Change on the Front Line: Why Marginalized Voices Matter in Climate Change Negotiations"). Human rights should always be respected in the implementation of decarbonization, sustainability and "planet positive" strategies. Technically advanced, wealthier countries have a responsibility to respect the human rights of all people.

Climate change and its impacts are a global challenge that affects both developing and developed nations. While often perceived as a problem of the developing world, its impact is present in developed countries too, particularly among vulnerable communities such as people of color, women, children, the poor, and those with disabilities. (The Data Team, 2018; U.S. Global Leadership Coalition, 2021; Kermal Davis, 2007). For example, the devastation caused by Hurricane Katrina in 2005 highlights this reality. As humanity moves toward 2030, it becomes increasingly important to proactively tackle disparities resulting from climate change. We have an opportunity to collaborate, pooling our resources, technological advancements, and ideas, to support those most affected and to hear all voices in our collective journey toward an inclusive and sustainable future. The proactive discussions at the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 28) regarding Loss and Damage remind us of the power of shared action and responsibility in shaping a world where diversity, equity, and inclusion are at the heart of our climate response (UN Climate Change, "COP 28," 2023).

Recommendations

1. **Utilize resources and disseminate climate information, proposed solutions, and best practices in formats that are accessible to communities** (Shaikh et al., 2021). For example, in Banke and Bardia district in Nepal, community information boards are used to explain "appropriate flood mitigation measures and the community-based early warning system." See Figure 22.1 in "Technology for Climate Justice" (van den Homberg and McQuistan, 2018).
2. **Develop climate change ambassadors.** Develop climate change ambassadors from different communities as messengers, prepared with leadership support, tools, training, and resources to communicate with and engage the public and community partners on their climate change issues (U.S. Fish and Wildlife Service, 2014).
3. **Integrate intersectional thinking.** Focusing on the areas of climate solutions, sustainability, and environmental stewardship **i**ntegrate intersectional thinking, collaboration between communities, policymakers, and other key stakeholders through bridging traditional knowledge and climate science (Raygorodetsky, 2011) and active participation at each stage—from engagement in creating policy and developing technology to implementing solutions and strategies for climate change—and working in collaborative ways with all levels of community and government (Plant, 2021).

4. **Consider development of a minimal level of resource sharing system between nations**. Such a system could help avoid unarmed and armed conflict over natural resources and aid implementation plans for environmental protection and/or regeneration of ecosystems. Such a system could also help address highly varying local impacts of climate change and sustainability challenges.

Case studies

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1. Co-Designing Climate Services to Integrate Traditional Ecological Knowledge: Bali, Indonesia

   Biskupska, Natalia, and Albert Salamanca. *Co-Designing Climate Services to Integrate Traditional Ecological Knowledge: A Case Study for Bali, Indonesia*. Stockholm: Stockholm Environment Institute, Oct. 2020.

2. Climate Justice Case Studies

   Second Nature. "Climate Justice Case Studies." Accessed 15 Jan. 2023.

Further resources

1. Amorim-Maia, Ana T., Isabelle Anguelovski, Eric Chu, and James Connolly. "Intersectional Climate Justice: A Conceptual Pathway for Bridging Adaptation Planning, Transformative Action, and Social Equity." *Urban Climate* 41, art. 101053 (Jan. 2022).
2. Bruine de Bruin, Wändi, and M. Granger Morgan. "Reflections on an Interdisciplinary Collaboration to Inform Public Understanding of Climate Change, Mitigation, and Impacts." *Proceedings of the National Academy of Sciences* 116, no. 16 (Jan. 2019): 7676–7683.
3. UN General Assembly. Declaration on the Rights of Indigenous Peoples. Resolution 61/295. A/RES/61/295. 13 Sept. 2007.
4. UN General Assembly, Human Rights Council. *Analytical Study on the Promotion and Protection of the Rights of Persons with Disabilities in the Context of Climate Change. Report of the Office of the United Nations High Commissioner for Human Rights*. A/HRC/44/30. (Apr. 2020).
5. Zampella, Tony. "True Diversity and Inclusion Requires Equity," *Medium* (blog). 10 Mar. 2021.

Guiding Principle 3: Global energy systems transformation

The transition from a fossil fuel-based energy system to a system that is based on clean and sustainable sources of energy should maintain energy accessibility, affordability, sustainability, reliability, and resiliency through all phases of the transition. This transition should also help *ensure access for all to affordable, reliable, sustainable and modern energy* (UNDESA, Goal 7). A successful energy transition will enable GHG emission reductions not only in the energy/power sectors but in all sectors using energy, thereby supporting the decarbonization and electrification of these sectors.

Background

In 2021, the International Energy Agency (IEA) published a roadmap to building a global energy sector with net zero emissions. The target date was 2050. In the roadmap, the agency called for a "complete transformation of how we produce, transport and consume energy," and that this process hinged "on an unprecedented clean technology push to 2030" (Bouckaert et al., 2021). Covering a broad and interconnected range of human activities (using energy)—power generation, transportation, heating and cooling, use of Information and communications technologies (ICT), industry, agriculture and more, all producing GHG emissions (Ritchie, 2020)—such a complete transformation of the world's energy infrastructure is a truly complex and difficult undertaking.

G20 world leaders, meeting in the United Arab Emirates for the COP 28 summit in 2023, pledged to "pursue and encourage efforts to triple renewable energy capacity globally through existing targets and policies, as well as demonstrate similar ambition with respect to other zero and low-emission technologies, including abatement and removal technologies, in line with national circumstances by 2030." At COP 28, commitments were made to:

- "Triple the world's installed renewable energy generation capacity to at least 11,000 GW by 2030, taking into consideration different starting points and national circumstances.
- Work together in order to collectively double the global average annual rate of energy efficiency improvements from around 2% to over 4% every year until 2030.
- Put the principle of energy efficiency as the "first fuel" at the core of policymaking, planning, and major investment decisions." (UN Climate Change, "COP 28," 2023)

These commitments provide important support towards *the* energy systems transformation and a new low emissions or, better yet, net zero energy systems infrastructure.

This energy system transformation is critically necessary considering that almost three quarters of the global GHG emissions are associated with the energy sector (energy for electricity generation for heating, cooling, transportation, manufacturing, agriculture, and other sectors like the ICT sector); see diagram showing global GHG emissions by sector for 2016 here (Ritchie, Rosado, & Roser, 2024) and the global direct primary energy consumption here, 2023 (Our World in Data, "Global Direct Primary Energy Consumption").

This energy system transformation is feasible as reported by researchers at LUT University and the Energy Watch Group in their report *Global Energy System based on 100% Renewable Energy* (Ram et al., 2019) and by Christian Breyer and team in *On the History and Future of 100% Renewable Energy Systems Research*

(Breyer et al., 2022). Other authors comment that wind and solar may not be enough, as “the only way in which wind/solar could meet all (or nearly all) global energy needs is if energy use is drastically curtailed” (Moriarty & Honnery, 2020). Many degrowth and limits-to-growth experts agree (Hansen, Narbel, & Aksnes, 2017). Nuclear power generation is one suggested fossil fuel alternative that can address baseload requirements for utility and/or power grids and make up renewable energy deficits (Hong Vo et al., 2020; Davis, 2022), but it faces concerns including accidents and nuclear waste management. More recent small modular reactor designs work to address some of these concerns (NEA, “NEA Small Modular Reactor Dashboard;” IEEE-USA, “Commercial Nuclear Energy and Technology Leadership”). And, in 2023, COP 28 leaders committed to mobilizing “investments in nuclear power, including through innovative financing mechanisms,” to advance a global aspirational goal of tripling safe nuclear power generation by 2050 (U.S. Dept. of Energy, 2023). Yet the recognition remains that other emerging energy technologies, such as geothermal and negative emission biofuels, will additionally factor into production deficits. Most scenarios and projections predict it will take a combination of technologies to transition to a fossil-fuel-free global energy system.

The energy system transformation is not limited to switching from GHG-emissions-producing fossil-fuel-based energy sources, it also requires energy efficiency measures and energy conservation. Energy conservation (e.g., turning a device off when not in use) and energy efficiency measures (e.g., replacing high-intensity discharge light bulbs with LED lighting for street lighting) are the low-hanging fruit. Furthermore, the energy systems transformation is expected to address new and additional energy demands, such as providing access to electricity to those who are currently without access (more than 700 million in 2023; see Statista 2024) and growing electricity demands anticipated by the expanding ICT sector, such as electrical power demands by a growing number of data centers and increasing use of AI processes.

It is essential that this transition addresses the disposition of the elements of the currently deployed energy system(s) through integration into the new system, reuse, and waste minimization. Depending on local and regional contexts, this may or may not be extraordinarily difficult for both technical and human or social reasons. It will be technically complex due to the interconnectedness of competing needs, often expressed as the *food/land-water-energy nexus*, for example for biofuels (SDSN/FEEM, 2021). Agriculture and solar panels may compete for land use or provide for new opportunities such as the development of agrivoltaics or agrovoltaic farming (Hall, 2022). Energy production may have significant water requirements (IEEE, 2010); for example, electrolysis to generate hydrogen (H_2) from electricity requires a minimum of 9 liters of water per kilogram of H_2.

During this energy systems transition, integrated systems planning should pay careful attention to the critical life-sustaining balance in the energy-water-food nexus. It is easy to focus upon one aspect to the detriment of other necessary components. Maintaining this balance should obey circular economy, regeneration, and sustainable principles (see Guiding Principle 5), and it should be based upon technical standards and regulations for the interoperability of regulations between jurisdictions. Examples for integrated systems planning include the following:

- Hydrogen is widely considered an energy carrier for transport and storage. IEEE SA has a program that considers the use of “Green Hydrogen” (IEEE SA, “Green Hydrogen). Many countries, such as Canada, have developed a hydrogen strategy (Government of Canada, 2020). *Planning considerations:* Hydrogen production requires water—depending on water quality, on the order of 9–20 or more liters per kilogram of hydrogen. On the other hand, when using fuel cell technology to generate electrical power from hydrogen, water is a co-product. Essentially, hydrogen transports not only energy, but also (virtual) water. Depending on the technology used, this water can be of drinking water quality.

- Another example is the increased use and application of ICT and the associated energy and water consumption in production and operation of the infrastructure (for example, data centers), balancing the increased application of ICT to potentially produce efficiencies, including energy efficiencies, in other sectors, like the energy sector.

These types of technical and economic relationships support regenerative and sustainable goals.

Perhaps more difficult will be the human and social challenges (Pasqualetti, 2011); political constraints (Bayulgen & Ladewig, 2017) and economic challenges (Dorian, Franssen, & Simbeck, 2006). Steering this transition through so many conflicting challenges will not be an easy task. But the cost of maintaining the existing energy infrastructure is far higher—the future of our planet's ecosystems. It is claimed that renewables-based energy generation use will be more cost-effective than current fossil-fuel-based energy systems (Ram et al., 2019). Depending on geographical location and associated technology performance, this cost prediction from 2019 has already been achieved (UN Climate Action, "Renewables: Cheapest Form of Power").

This difficult transition must balance between *short-term pain and long-term gain* AND between human and planetary needs—an *equitable* balance. That is, while it would presumably be most beneficial for planetary ecosystems to curtail human GHG emissions producing activities very quickly and severely, the energy transition should be a "just transition". A "just transition" as described by the Stockholm Environment Institute is "a transition that minimizes disruption for workers and communities reliant on unsustainable industries and energy sources" (Piggot et al., 2019). This transition provides for accessibility, ubiquitous access, affordability, sustainability, and reliability for the differing cultural and economic needs of diverse multitudes, as it develops and implements clean and sustainable energy sources for all.

Ultimately, despite these challenges and complexities, this energy system transformation is a *doable task.* According to Julia Steinberger, an ecological economist at the University of Lausanne, the process "is entirely doable, and it is doable fast, but it will come with a price tag which will then be repaid forever after in a prosperous and healthy society" (Meredith and Handley, 2021). There will be innumerable benefits. They will result in economic opportunities, particularly for less developed countries, as economies are built upon access to energy resources. Societies will experience a tremendous positive health impact in response to clean air and water (Gai et al., 2020), for example, preventing premature deaths and reducing health-care costs. There will be many others.

Models exist, such as leveraging innovations from the space industry and other environments where sustainability principles are critical (Deep Space Food Challenge). System inertia, e.g. thermal energy in the ocean, needs to be taken into account when modeling the impact of potential actions. There are other roadmaps and resources to help guide the way.

Most importantly, energy systems transformation is achievable—it is a *doable* task.

Recommendations

1. **Prioritize realization of energy efficiencies across all energy consumption as an early target.** Realizing energy efficiencies across all types of energy consumption, applications, and sectors is the low-hanging fruit regarding GHG emissions reduction. Note, best practices should be context specific. A couple of examples representing many ways of realizing energy efficiencies:
    a) **Replacing conventional street lighting** (e.g. high-pressure sodium) **with LED lighting.**
    b) **Avoiding losses due to standby power, also called *Phantom Power*** (IESO, "What's Phantom Power and How Can You Track It?")

2. **Employ digitalization and AI as appropriate to optimize energy systems efficiency and to track performance metrics as well as verify the level of attainment of key performance indicators** (KPIs).
3. **Address the energy transition from fossil-fuel-based to a no- or low-emission, clean electricity-based energy system as a priority and in a contextualized, sustainable way.** Low-emissions energy replacing fossil fuels, coal, natural gas, and oil is the enabler for other sector transitions as these sectors electrify. Associated water, food, and communications (i.e., connections to the internet and services) challenges will be easier to resolve as the new low-emissions or no-emissions energy generation and distribution system spreads across geographies and cultures, making clean, sustainable, mostly renewable, resilient electricity widely accessible. Context matters: for example, Kenya's electricity supply is generated to more than 40% from geothermal energy and to about 30% from hydro (IEA, "Kenya").

   Customer Benefit: Power customers purchasing no-emissions (very close to no emissions associated with the power generation) electricity can report effectively Scope 2 zero emissions, if electricity is the only energy purchased for (customer) operations.
4. **Observe new technology developments for incorporation into "energy planning scenarios."** Technologies under consideration should include geological hydrogen also called white hydrogen (USGS, "The Potential for Geologic Hydrogen for Next-Generation Energy"); modern nuclear fission technology, like small modular reactors; electricity generation, potentially, from nuclear fusion at some point in the future; and new technologies for harvesting energy from the ocean—the ocean represents a vast store of energy—among others. Technology development is ongoing not only with respect to electricity generation, but also with regard to energy efficiencies, circularity of infrastructure, and so on.
5. **Collaborate among all nations on the energy transition process, while factoring inequity differences between countries.** Consider all nations as being part of the energy transition process including nations that may not have the wealth or resources available to acquire renewable energy systems. All nations should feel confident that the international community will provide the necessary support, for example, knowledge, information, and best practices for transitioning their economies from fossil fuel dependence to renewable, sustainable, resilient energy-based systems. No nation should be excluded or unable to participate in this transition, nor should the transition pose too great an economic burden. Such a barrier would hinder active participation with the rest of the global community. This transformation should be economically affordable, technologically sustainable, reliable, and available to all nations regardless of their economic status.
6. **Implement the United Nations recommendations for the renewable energy transition** (UN Climate Action, 2022):

   a) **"Make renewable energy technology a global public good via radically increased actions in policy, education, media, and other venues"** (Komor & Bazilian, 2005; Groh & Möllendorff, 2020).

   b) **"Improve global access to components and raw materials via financial incentives, public-private partnerships, governmental and private sector support"** (Sovacool, 2013).

   c) **"Level the playing field for renewable energy technologies versus fossil fuel-based energy"** (Pershing & Mackenzie, 2006).

   d) **"Shift energy subsidies from fossil fuels to renewable energy"** (Merrill et al., 2017).

   e) Triple investments in renewables.

7. **Encourage and support government, industry, and business commitments to COP 28** (UN Climate Change, Summary of Global Climate Action at COP 28)
8. **Decentralize and diversify energy production as much as practical and feasible.** Distributed power generation increases resilience, reliability, and reduces transport (Grosspietsch, Saenger, & Girod, 2019) and provides opportunities for contextualization of approach to power generation.
9. **Encourage and incentivize energy conservation—energy not used, need not be produced—energy not used, need not be paid for**:
   - **a) Use widespread educational campaigns and possibly sharing metering devices for individuals to test power consumption of devices.**
   - **b) Incentivize energy efficient devices of all kinds, for example, from light bulbs to vehicles.**
   - c) **Give ownership "of energy consumption" to the user through education, data sharing and access, and choices, for example, the London Hydro Green Button program.** (London Hydro, 2022).
10. **Strongly enable participation by small- and medium-sized enterprises in the energy sector.** This will help decentralization and diversification as well as contextualization of energy production and development of energy-efficient devices and services and, at the same time, support economic development.
11. **Increase technical literacy in general and technical knowledge/know-how.** Encourage workforce retraining and development (Macdonald Fueyo, 1988) to support appropriate procurement and use of technology as well as safe, knowledgeable operation and maintenance of deployed technologies.
12. **Educate for a future literacy mindset** (Miller, 2015).
13. **Share best practices and know-how widely.** Easily accessible knowledge and knowhow for communities and businesses around the globe will foster implementation in parallel with communities (Owens, 2002).
14. **Communicate widely to share best practices and know-how.** Dispel misconceptions and address incorrect 'information' in an inclusive fashion. Individuals of all ages would like to be 'in the know' and be part of the solution. There are many public sources sharing current best practices that individuals can adopt.
15. **Develop technical standards that support "sustainability by design."** These technical standards should not only include considerations of the environmental impacts of implementation—potentially to scale—of the technology, but also the potential societal impacts (socio-technical standards). These standards would be expected to also provide a basis for the development of regulations by regulatory bodies and should lead to interoperability of regulations between jurisdictions.
16. **Design and implement new energy systems infrastructure such that the systems are "sustainable by design."** This includes component production, transport, deployment, storage, use and end-of-use processes from the outset such that the components enable a circular economy (as much as possible) (Desing et al., 2019) and incorporate regenerative design principles if at all possible.
17. **Provide for ubiquitous reliable access to resources. Strive** to provide ubiquitous reliable access to clean, affordable sustainable energy and access to water, clean air, food, and services around the globe as the transition completes.

18. **Observe and – for planning of any new facilities - take the implications of the water-energy-food nexus into account**, for example**:**

    a. Hydrogen (H_2) production using electrolysis requires 9 liters of water for the actual chemical process plus additional water for water purification to the level required by the electrolysis process and process cooling. The estimated total water consumption is a range between 20-30 L or more of water to produce 1 kilogram of H_2 (Turner et al., 2007). Hence, careful consideration should be given to the siting of green hydrogen production facilities to avoid putting pressure on potentially constrained water supplies.

       On the other hand, using a fuel cell to produce electricity from H_2 also produces water and heat as co-products (pulling oxygen from the air). Hence, this is an opportunity for delivering co-products: electricity and potable water (Pacheco, 2023; U.S. DoE, *Fuel Cells*).

    b. Some nuclear facilities require significant amounts of cooling water.

    c. Data centers require significant energy in the form of electricity as well as cooling. Both the electricity supply as well as cooling water (if cooling using water is the cooling technology deployed) could pose a potential issue to the water supply at the siting location.

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Blind Spots in Energy Transition Policy: Case Studies from Germany and USA

   Elshurafa, Amro M., Hind M. Farag, and David A. Hobbs. "Blind Spots in Energy Transition Policy: Case Studies from Germany and USA." *Energy Reports* 5 (Nov. 2019): 20–28.

2. Japan's Resilient, Renewable Cities

   Fraser, Timothy. "Japan's Resilient, Renewable Cities: How Socioeconomics and Local Policy Drive Japan's Renewable Energy Transition." *Environmental Politics* 29, no. 3 (17 Mar. 2017): 500–523.

3. Renewable Energy Transition in the Caribbean

   Harrison, Conor. "Geographies of Renewable Energy Transition in the Caribbean: Reshaping the I sland Energy Metabolism." *Energy Research & Social Science* 36 (Feb. 2018): 165–174.

4. Renewable Energy Cooperatives, Rotterdam, The Netherlands

   Hentschel, Moritz, Wolfgang Ketter, and John Collins. "Renewable Energy Cooperatives: Facilitating the Energy Transition at the Port of Rotterdam." *Energy Policy* 121 (Oct. 2018): 61–69.

5. A Multiple Case Study on the German Energy Transition

   Lutz, Lotte Marie, Lisa-Britt Fischer, Jens Newig, and Daniel Johannes Lang. "Driving Factors for the Regional Implementation of Renewable Energy: A Multiple Case Study on the German Energy Transition." *Energy Policy* 105 (June 2017): 136–147.

6. Contributions from Community Sustainable Energy Transitions in Thailand and the Philippines

   Marquardt, Jens. "Reimagining Energy Futures: Contributions from Community Sustainable Energy Transitions in Thailand and the Philippines." *Energy Research & Social Science* 49 (Mar. 2019): 91–102.

7. Public Participation in Renewable Energy Transitions, India

   Pandey, Poonam, and Aviram Sharma. "Knowledge Politics, Vulnerability and Recognition-Based Justice: Public Participation in Renewable Energy Transitions in India." *Energy Research & Social Science* 71, art. 101824 (Jan. 2021).

8. Renewable Energy and Transition-Periphery Dynamics, Scotland

   Robertson Munro, Fiona. "Renewable Energy and Transition-Periphery Dynamics in Scotland." Environmental Innovation and Societal Transitions 31 (June 2019): 273–281.

9. Clean Energy Transition of Heating and Cooling in Touristic Infrastructures Using Shallow Geothermal Energy, Canary Islands

   Santamarta, Juan C., Alejandro Garca-Gíl, María del Cristo Expósito, Elías Casañas, Noelia Cruz-Pérez, Jesica Rodríguez-Martín, Miguel Mejías-Moreno, et al. "The Clean Energy Transition of Heating and Cooling in Touristic Infrastructures Using Shallow Geothermal Energy in the Canary Islands." *Renewable Energy* 171 (June 2021): 505–515.

10. Energy Poverty and Low Carbon Just Energy Transition, Lithuania, Greece

    Streimikiene, Dalia, Grigorios L. Kyriakopoulos, Vidas Lekavicius, and Indre Siksnelyte-Butkiene. "Energy Poverty and Low Carbon Just Energy Transition: Comparative Study in Lithuania and Greece." *Social Indicators Research 1*58 (Apr. 2021): 319–371.

Further resources

1. Barnett, Michael N., Jon C. W. Pevehouse, and Kal Raustiala, eds. Global Governance in a World of Change. Cambridge: *Cambridge University Press*, 2021.
2. Blohm, Marina. "An Enabling Framework to Support the Sustainable Energy Transition at the National Level." *Sustainability* 13, no. 7 (2021).
3. Bouckaert, Stéphanie, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner. Net Zero by 2050: A Roadmap for the Global Energy Sector. Paris: IEA, 2021.
4. Hammons, T. J., J. C. Boyer, S. R. Conners, M. Davies, M. Ellis, M. Fraser, E. A. Holt, and J. Markard. "Renewable Energy Alternatives for Developed Countries." *IEEE Transactions on Energy Conversion* 15, no. 4 (Dec. 2000): 481–93.
5. Jaiswal, Krishna Kumar, Chandrama Roy Chowdhury, Deepti Yadav, Ravikant Verma, Swapnamoy Dutta, Km Smriti Jaiswal, SangmeshB, et al. "Renewable and Sustainable Clean Energy Development and Impact on Social, Economic, and Environmental Health." *Energy Nexus* 7, art. 100118 (Sept. 2022).
6. Mangla, Sachin Kumar, Sunil Luthra, Suresh Jakhar, Sumeet Gandhi, Kamalakant Muduli, and Anil Kumar. "A Step to Clean Energy—Sustainability in Energy System Management in an Emerging Economy Context." *Journal of Cleaner Production 242, art. 118462* (Jan. 2020).

7. Nowotny, Janusz, John Dodson, Sebastian Fiechter, Turgut M. Gür, Brendan Kennedy, Wojciech Macyk, Tadeusz Bak, et al. "Towards Global Sustainability: Education on Environmentally Clean Energy Technologies." *Renewable and Sustainable Energy Reviews* 81 (2018): 2541–51.
8. Ockwell, David, Robert Byrne, Joanes Atela, Victoria Chengo, Elsie Onsongo, Jacob Fodio Todd, Victoria Kasprowicz, and Adrian Ely. "Transforming Access to Clean Energy Technologies in the Global South: Learning from Lighting Africa in Kenya." *Energies* 14, no. 14 (2021): 4362.
9. Pereira, Laura, Timothy Karpouzoglou, Samir Doshi, and Niki Frantzeskaki. "Organising a Safe Space for Navigating Social-Ecological Transformations to Sustainability." *International Journal of Environmental Research and Public Health* 12, no. 6 (May 2015): 6027–6044.
10. Perlaviciute, Goda, Linda Steg, Nadja Contzen, Sabine Roeser, and Nicole Huijts. "Emotional Responses to Energy Projects: Insights for Responsible Decision Making in a Sustainable Energy Transition." *Sustainability* 10, no. 7 (2018).
11. Piggot, Georgia, Michael Boyland, Adrian Down, and Andreea Raluca Torre. *Realizing a Just and Equitable Transition Away from Fossil Fuels, SEI Discussion Brief.* Seattle, WA: Stockholm Environment Institute, Jan. 2019.
12. Sachs, Jeffrey D., Guillaume LaFortune, Christian Kroll, Grayson Fuller, and Finn Whelm. Sustainable Development Report 2022. From Crisis to Sustainable Development: Includes the SDG Index and Dashboards. Cambridge: *Cambridge University Press*, 2022.
13. Sareen, Siddharth, ed. Enabling Sustainable Energy Transitions: Practices of Legitimation and Accountable Governance. Switzerland: *Springer Nature* (Palgrave Pivot), 2020.
14. Sareen, Siddharth, and Håvard Haarstad. "Bridging Socio-Technical and Justice Aspects of Sustainable Energy Transitions." *Applied Energy* 228 (2018): 624–32.
15. Srirangan, Kajan, Lamas Akawi, Murray Moo-Young, and C. Perry Chou. "Towards Sustainable Production of Clean Energy Carriers from Biomass Resources." *Applied Energy* 100 (2012): 172–86.
16. Steg, Linda, Goda Perlaviciute, and Ellen van der Werff. "Understanding the Human Dimensions of a Sustainable Energy Transition." *Frontiers in Psychology* 6 (2015).
17. van Vuuren, DP, N. Nakicenovic, K. Riahi, A. Brew-Hammond, D. Kammen, V. Modi, M. Nilsson, and και KR Smith. "An Energy Vision: The Transformation Towards Sustainability—Interconnected Challenges and Solutions." *Current Opinion in Environmental Sustainability* 4, no. 1 (Feb. 2012): 18–34.
18. Vanegas Cantarero, Maria Mercedes. "Of Renewable Energy, Energy Democracy, and Sustainable Development: A Roadmap to Accelerate the Energy Transition in Developing Countries." *Energy Research & Social Science* 70, art. 101716 (2020).

Guiding Principle 4: Climate change mitigation and adaptation

In responding to the challenge of climate change, and to prevent a climate catastrophe, society needs to both mitigate (that is, reduce) GHG emissions and adapt to the impacts of a changing climate. Both goals require urgent action. The goals of mitigation and adaptation may come into conflict, society will have to balance these conflicts.

Background

Upon releasing a new IPCC report in February 2022, the IPCC noted in a press release:

> *The report clearly states Climate Resilient Development is already challenging at current warming levels. It will become more limited if global warming exceeds 1.5 °C (2.7 °F). In some regions it will be impossible if global warming exceeds 2 °C (3.6 °F). This key finding underlines the urgency for climate action, focusing on equity and justice. Adequate funding, technology transfer, political commitment and partnership lead to more effective climate change adaptation and emissions reductions. (IPCC, 2022)*

As of 2022, the Nationally Determined Contributions (NDCs) by countries to mitigate GHG emissions to limit warming to less than 1.5 °C (as agreed by the Paris Accord to be the target to protect the planet) is currently viewed as insufficient (Climate Action Tracker, 2023).

In early 2023, the IPCC AR6 Synthesis Report stated in 2.1. under the headline: Observed Changes, Impacts and Attribution:

> *Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase over 2010-2019, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and between individuals (high confidence). Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts on food and water security, human health and on economies and society and related losses and damages to nature and people (high confidence). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (high confidence). (IPCC, 2023)*

Mitigation

As soon as feasible, mitigate human caused GHG emissions. GHGs include carbon dioxide, which form the bulk of the problem, as well as methane and nitrous oxide, which also hold heat in the atmosphere. It is not possible to instantly stop all processes that create GHG emissions because they are intertwined with the daily lives of citizens. It is necessary to find and implement sustainable solutions that generate energy, products, and services without generating GHG emissions or, at the very least, significantly reduce GHG emissions. In some cases, this will require research, development, and innovation—very quickly.

Time is of the essence. According to a UN Intergovernmental Panel on Climate Change (IPCC) report finalized on April 4, 2022, to limit warming to 1.5 °C, global GHG emissions should peak before 2025 and be reduced by 43% by 2030. Methane must be reduced by 34% by 2030. Even if we are willing to tolerate warming of 2 °C, global GHG emissions must peak before 2025 and be reduced by 27% by 2030 (Shukla et al., 2022). At COP 28 (Nov. 2023) several major oil and gas companies promised to reduce methane leaks from their pipelines, but the UN Secretary-General Guterres said these "clearly fall short of what is required." As of September 2024, "the observed growth in methane emissions follows the Intergovernmental Panel on Climate Change's most pessimistic greenhouse gas scenarios, which predict global temperatures could rise above 3 °C by the century's end if such trends continue" (ESA, "The 2024 Global Methane Budget Reveals Alarming Trends").

All sectors of the economy will have to contribute. Key sources of GHG emissions are illustrated in Figure TS.6 of the IPCC mitigation report (Pathak et al., 2022). This figure illustrates direct plus indirect GHG emissions by end-user sector for 2019: industry 34%, agriculture/forestry/land use 22%, buildings 16%, transportation 15%, and other 12%.

It is not just about electricity production. Electricity and heating production contributes 23% of total direct carbon dioxide (CO_2) equivalent GHG emissions distributed across the sectors above (Figure TS.6 of the IPCC mitigation report). While ground transportation may be able to transition to electricity, innovations will be needed to transition food production, protect nature, and produce steel, cement, and other industrial processes. For example, much of the anthropogenic methane emissions come from agriculture and livestock production. Notably, rice contributes 1.5% of global GHG emissions and about 48% of GHG emissions from croplands globally, and rice production uses about 40% of the global freshwater resources (Food Forward NDCs, "Reducing Emissions from Rice Cultivation").

GHGs linger in the atmosphere for hundreds of years. While reforestation, biomass, and other natural systems can sequester carbon (ocean, land, soil sequestration), innovative breakthroughs are needed to achieve decarbonization—even if the mitigation goals are met. Carbon capture and storage is one of the approaches. Because carbon capture and storage require energy (endergonic systems), it is necessary to power carbon sequestration and storage with non-GHG "green" energy sources such as solar energy.

Adaptation

Adapt to the climate changes that people are and will be facing. In this document, adaptation is a method—or methods—for being resilient; that is, it is the ability of society to maintain essential functions and structures as well as to generate the capacity for its transformation. This adaptation will also require dealing with extreme weather events that climate change is making more frequent and more intense. Unfortunately, there is a significant gap between the current state of adaptation and the needed adaptations (IPCC, 2022).

Preparing for extreme weather. Climate change is making extreme weather more intense and more frequent. Reducing the risks caused by extreme weather requires planning, building resilient infrastructure, and strengthening natural systems like dunes and lagoons.

Preparing for extreme climate. Adaptive actions are needed to reduce vulnerability of natural and human systems. For example, changes in farming and land management practices will be needed, including the identification and development of species of crops and livestock with increased resilience.

Adaptations are usually planned and implemented as a response to extreme events and are focused on the specific risks they bring. For example, coastal flooding may result in new adaptation projects such as ecosystem replanting or building hard infrastructure such as levees. These projects may buy time to consider longer-term projects such as relocating people and structures from harm's way. The adaptations recommended below are organized by the specific risk they pose.

The 2022 IPCC report warns that "Available evidence on projected climate risks indicate that opportunities for adaptation to many climate risks will likely become constrained and have reduced effectiveness should 1.5 degree C global warming be exceeded" (Pörtner et al., 2022).

Our generation's responsibility to future generations. We must expeditiously solve the climate crisis so that we leave future generations a world that is supportive and nurturing.

Recommendations for mitigation of GHG emissions

1. **Electrify and/or use other GHG-emission-free energy for all land-based transportation.** Land-based transportation contributes about 10% to global GHG emissions.Passenger cars, trucks, and buses are the low-hanging fruit of the transportation sector for quick electrification. There are few technology problems to be solved. Government policy action could begin to mandate this as well as establish a recharging infrastructure. The Infrastructure Investment and Jobs Act (U.S. 117th Congress, 2021) allocated US $7.5 billion towards building a network of electric vehicles including public and private charging stations (IEA, "Infrastructure and Jobs Act: Nationwide Network of EV Chargers"), which is planned to be implemented by 2030. Hydrogen appears to be a viable fuel alternative for rail transportation.
2. **Reduce emissions from aviation and maritime transportation.** Reduce emissions from planes (1.8% of GHG emissions) *and ships* (1.6% of GHG emissions) and invest in research and development (R&D) for biomass fuels—provided they are sustainable, improved fuel efficiency, and electrification. Technology challenges around the latter include the weight and energy density of batteries. Other research and development (R&D) ideas include using hydrogen either as a fuel for combustion or as an energy carrier for energy transportation and storage to be converted using fuel cells into electricity, assuming hydrogen can be produced with green electricity or geological hydrogen (USGS, "The Potential for Geologic Hydrogen for Next-Generation Energy").
3. **Switch/transition the electricity grid (23% of GHG emissions globally) to use renewable, clean electricity generation.** There is little reason to delay this transition and continuation of building new fossil fuel power plants prolongs the carbon emissions. Further R&D is needed for energy storage and for building the necessary infrastructure to handle distributed generation (e.g., solar panels on houses and buildings). Consideration should also be given to electricity generation from nuclear power, geothermal opportunities, power generation from ocean-based technology, and potential new technologies under development.
4. **Electrify heating (5% of GHG emissions) *and cooking* (1% of GHG emissions).** There are no technological barriers to decarbonizing buildings and house heating and cooking.
5. **Reduce emissions from agriculture, livestock, and food supply (11% of GHG emissions).** This could be accomplished through demand-side changes (reducing eating of beef for example), improved efficiencies (e.g., **reducing food waste**), and technological changes to reduce emissions on the production side (e.g., lower energy methods of making fertilizer and changing the diet of cows and rice growing methods to reduce methane emissions).

6. **Cap abandoned oil and gas wells to prevent further methane gas emissions from these wells.**
7. **Reverse deforestation and protect the ocean.** Trees and the ocean store a tremendous amount of carbon. Oceans store approximately 6 billion metric tons of carbon per year, with trees/soil storing another 0.3 billion metric tons/year (Woods Hole, 2022; Café Thorium, “Ocean Twilight Zone”).
8. **Reduce GHG emissions coming from industry, including from the production of cement, steel, plastic, and other manufacturing** (24% of GHG emissions). Using cement as an example, reducing emissions could include: replacing cement with other materials (e.g., wood), replacing the fossil fuels used in the production with renewable energy, process improvements to reduce the carbon footprint, and adopting different raw materials in the process. All of this requires further R&D and investment.
9. **Develop and/or deploy carbon dioxide removal methods to counter residual emissions.** While all the above recommendations will reduce the amount of new carbon in the atmosphere, it is still necessary to eliminate the carbon people have been generating since the industrial revolution. While some of this can be done by enacting policies to encourage tree planting, reforestation, and low-till farming, it is likely innovations will be needed to capture and sequester additional atmospheric carbon. Another option may be increased ocean-based carbon sequestration [marine Carbon Dioxide Removal—mCDR; see IEEE SA, “Marine Carbon Dioxide Removal (MCDR)”].

   While not all GHG-emitting industrial processes may be replaced by decarbonized processes in the short term, the emissions produced by these installations should be captured to avoid adding further to the atmospheric GHG levels (Buesseler, 2022, p. 90). To overcome obstacles to carbon capture and sequestration, financial incentives are needed to make existing methods viable, policy changes are needed to support the transport of carbon dioxide from where it is captured to where it can be stored (usually underground earth formations), and R&D is needed to create new technologies that may capture and store carbon at lower costs. Carbon mineralization and geological storage of CO_2 in basalt have been shown in recent years to be permanent and fast - in the order of days to less than 10 years. (Ferreira et al., 2024)

   Another path of carbon sequestration that is being pursued is carbon capture, including direct air capture, and the use of the captured carbon in new products.

   Carbon dioxide removal and sequestration has led/is leading to a new industry sector: the products are carbon credits. Associated with that is the new Monitoring (or Measuring), Reporting and Verification Sector (MRV Sector) (see Climate-KIC, “Monitoring, Reporting and Verification Sector”).
10. **Clearly capture, analyze, and publicize actionable information on GHG contributions from products, services, and sectors to allow company, organizational, and personal decision-making to reduce GHG emissions.** See also Guiding Principle 9.
11. **Create a reporting system to measure progress, maybe globally confederated (hubs and spokes), to report on activities and achievements versus agreed upon GHG emissions reduction and other climate change mitigation KPIs**.

Recommendations for adaptation to climate change

Unlike mitigation responses, which have a global impact, adaptation tends to be done at the local level, in the local context, and focused on specific risks.

It is impossible to list all potential responses, but this list of recommendations provides examples of actions to address some of the common threats.

1. **Strengthen coastal socio ecological systems:**
    a. **Harden coastal defenses. Dikes, seawalls, flood barriers, and other hard infrastructure provide temporary protection but may worsen the problem in the long run by allowing unsustainable development** (an example of "maladaptation").
    b. **Implement integrated coastal zone management.** Ecosystem-based approaches (setting aside wetlands at the blue-green interface, replanting coastal grasses and salt marshes) provide additional space for coastal systems to migrate inland.
    c. **Plan coastal retreat when other approaches become insufficient or unaffordable**.
2. **Support terrestrial systems:**
    a. **Implement forest-based adaptation.** Implement sustainable forest management, forest conservation and restoration, reforestation, and afforestation, restoring natural vegetation and wildfire regimes.
    b. **Implement sustainable aquaculture and fisheries.** Eliminate overexploitation and reduce pollution and runoff.
    c. **Practice biodiversity management and ecosystem connectivity**.
3. **Help maintain water security:**
    a. Improve water use efficiency and reduce leaks in water systems.
    b. **Improve water resource management.** Set aside additional reservoirs, catchments, and wetlands to catch and maintain water during variable rainfall.
    c. Prepare for rationing and use of "gray water" in times of severe drought.
4. **Help maintain food security:**
    a. **Improve cropland management.** Implement earlier planting, changes in crop varieties, improvement in water management for crops, use of heat-and drought-adapted genotypes, soil improvements, soil moisture conservation, and agricultural diversification.
    b. **Implement efficient livestock systems.** Implement improvements in water management for livestock, genetic improvements for heat and drought varieties, and reduced intensification of livestock management to improve resilience.
    c. **Implement efficient fisheries management and aquaculture.** Include ecosystem restoration and regenerative practices.
    d. **Support R&D related to cultivating agricultural and livestock species with increased resilience to temperature, water, and other climate stressors.** Develop new practices, including regenerative practices, and promote existing practices, for example Indigenous-knowledge-based, to conserve food and live with weather extremes.

5. **Improve urban infrastructure to become more resilient:**
    a. **Implement green/blue urban infrastructure. Utilize urban agriculture, urban trees, green roofs, parks and open spaces, rain gardens, and watershed restoration.**
    b. **Create sustainable land use and urban planning.** Consider reforestation in and around urban areas, allocating additional land to sea level rise and disincentivizing development in vulnerable areas.
    c. **Require new buildings to be resilient and able to withstand extreme weather conditions.** Older buildings should be similarly renovated. Modify building codes to consider climate change risks locally to require energy backup systems, emergency water tanks, raising buildings above the flood protection elevation level, reinforcing roofs, and building in wildfire resistance, as appropriate.
    d. **Implement sustainable urban water and sanitation management.** Harden infrastructure to work during floods and droughts.
    e. **Improve knowledge at the local and regional levels (hydraulic studies, flood zones, risk assessments), raise awareness in local communities of the risks, create threat monitoring capabilities (e.g., stream and river monitoring), and establish plans to reduce vulnerability to existing and new buildings.** More specific data (hyperlocal) would help people and communities better understand the risks they face.
6. **Update energy systems to become more sustainable and resilient:**
    a. **Make community power systems more resilient to extreme weather events–for infrastructure critical to society and our economy.** With the transition to electric transportation vehicles, factories, heating, and so forth, the need for reliable energy systems becomes increasingly important.
    b. **Consider the potential impact to power systems of multiple risks simultaneously: extreme heat increasing demand, drought reducing cooling water for power systems, widespread heat waves reducing the ability to source power from neighboring areas.** In the southwestern United States and other drought-prone areas, hydroelectric systems are at risk of reducing power output, requiring other systems to shoulder increased loads. Electric vehicles are creating a new and significant demand on domestic power networks. Energy demand used for air-conditioning could triple by 2050 (Birol, 2023).
    c. **Enhance the electricity grid infrastructure.** Integrate distributed energy sources such as solar panels as well as storage systems to buffer the loads and provide more resilience.
    d. **Improve the efficiency of cooling equipment.** As cooling is increasingly needed in many locations around the planet, it will be important to improve the cooling provided per kilowatt of power.
7. **Protect human health:**
    a. **Develop health information systems.** Implement integrated risk management, early warning systems, and disease tracking and management (e.g., Lyme disease, malaria, new virus strains).
    b. **Create health system adaptations.** Implement vaccine development for existing and new disease coverage, mental health support, improved heat resistance of the built environment, and advanced water and sanitation systems.

c. **Prepare for heat stress.** Implement heat action planning, cooling centers, air-conditioning subsidies, and cooling suits for outdoor workers.

d. **Secure water quality/quantity.** Provide clean drinking water as local water resources dry up.

e. **Develop health emergency response plans**. Disasters and climate change-induced health issues require more emergency response capabilities.

8. **Promote equitable living standards and equity:**

    a. Provide education/reeducation to allow livelihood diversification as climate change eliminates some jobs.

9. **Enable peace and mobility:**

    a. **Plan for relocation and resettlement**. Limits to adaptation are already being reached in some areas for both animals and humans. Some experts consider mobility to be a response rather than an adaptation, which approaching 2050, may be necessary as additional locations of the Earth become uninhabitable due to sea level rise, heat, or drought. Society must reduce the impacts of relocating vulnerable populations and infrastructure due to sea level rise, wildfires, heat, and drought.

    b. **Enable human migration for climate reasons.** Barriers to voluntary migration and resettlement should be addressed.

    c. **Support ecosystem migration.** Many species are moving to cooler climates where possible. Humans need to assist in this effort where necessary to help sustain the ecosystem on which we depend.

10. **Encourage cross-cutting solutions:**

    a. Integrate climate change into all planning (e.g., federal, state, city, and company plans) and implementation of conservation and environmental management.

    b. **Organize disaster risk management.** Society must prepare for extreme events caused by climate change, such as floods, heat waves, drought, hurricanes, tornadoes, wildfires, and insect and disease outbreaks. Companies, organizations, and communities must develop personnel disaster risk-management strategies to prepare for extreme weather and climate conditions.

    c. **Create early warning systems.** Speed the development of systems to forecast and warn of extreme events, provide situational awareness, and communicate important information.

    d. **Develop social safety nets.** Strengthen social services for extreme events and climate change-induced disruption such as food insecurity.

    e. **Create risk-spreading and cost-sharing systems.** Develop community seed banks, wells and water systems, and power systems.

    f. Develop a systems-oriented approach to reduce the conflict and trade-offs between mitigation and adaptation and to support long-term resilience.

    g. **Support research into solar radiation modification (SRM), which seeks to reflect more sunlight back into space, reducing the heating of Earth.** Further study is needed to understand its benefits and risks. See for example, "The Ocean Twilight Zone's Role in Climate Change."

h. **Support research and development in all areas of adaptation to speed adaptation and reduce costs.** The long-term goal is to flow investment into mitigation projects to reduce the GHG emissions and climate heating.

i. **Establish regional, national, and international cooperation capabilities to respond to extreme weather conditions**, for example, a regional transmission organization to share electric load and water system partnerships to improve water system reliability and system capability.

11. **Communicate, communicate, communicate.** Share success stories and current best practices. Engage people in discussion about misconceptions. Dispel misinformation in an inclusive fashion.

12. **Create a reporting system to measure progress, maybe globally confederated (hubs and spokes), to report on activities and achievements versus agreed upon climate change adaptation KPIs.**

Further resources

1. Doerr, John, with Ryan Panchadsaram. *Speed and Scale: An Action Plan for Solving Our Climate Crisis Now.* Portfolio/Penguin, 2021.
2. Engineering for One Planet (website).
3. Gates, Bill. How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need. UK: Allen Lane, 2021.
4. Pörtner, Hans, Debra C. Roberts, Helen Adams, Ibidun Adelekan, Carolina Adler, Rita Adrian, Paulina Aldunce, et al. *Technical Summary in Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY: Cambridge University Press, 2022.
5. Project Drawdown (website).
6. Stern, Nicholas. *The Global Deal: Climate Change and the Creation of a New Era of Progress and Prosperity*. PublicAffairs, 2009.
7. UN Climate Change Conference (United Arab Emirates: 30 Nov.–12 Dec 2023) (website).
8. Fifth National Climate Assessment 2023 (website).

Guiding Principle 5: The regenerative imperative and a circular economy

Thinking, planning, and action must broaden beyond current economic, business, societal, and resource utilization models to achieve sustainability and for people and the Earth's biosphere to flourish for many generations to come. Future economic, societal and cultural, and business models should emphasize new public imperatives and values such as circularity, ecological regeneration, zero waste, and human flourishing and well-being.

Background

THE REGENERATIVE IMPERATIVE

Embracing the regenerative imperative and circular economy imperatives in resource management offers a hopeful and actionable roadmap toward a sustainable and thriving planet Earth. This approach requires a paradigm shift in our relationship with the environment. Exploitation needs to transition to regeneration to reverse the Earth's biosphere degradation. Designing systems that model natural processes can create resilient, adaptive, and flourishing ecosystems that support biodiversity and provide for the needs of current and future generations.

Many interconnected factors have contributed to the declining health and resilience of the Earth's biological systems. Changes in land use, overexploitation of natural resources, and pollution of the environment are three major human activities driving this process.

Changes in land use over millennia have diminished the land's ability to support a burgeoning population. The conversion of forests into agricultural land, urban areas, and other uses has reduced carbon sequestration capacity—a significant factor in global climate change. It has also resulted in fragmented and lost habitats, making it more difficult for some species to survive. This resulting biodiversity loss has diminished ecosystem resilience and the ability of natural systems to adapt to environmental changes.

Overexploitation of natural resources has led to resource depletion, loss of biodiversity, and a reduction in ecosystem services essential for life on Earth. Unsustainable agriculture, overfishing, and illegal wildlife trade have further stressed the planet's ecosystems. For example, bottom trawling destroys ocean floor ecosystems and releases previously sequestered carbon on the ocean floor into the water and further—over a decade—into the atmosphere (Atwood, 2024; Atwood et al., 2024).

Pollution and GHG emissions (not all GHGs are pollutants, e.g. water vapor) have further compounded these problems. Releasing toxic substances into the air, water, and soil has adversely affected wildlife, ecosystems, and human health. Plastic pollution, chemical runoff from agriculture, and industrial pollutants have contaminated ecosystems, leading to degradation of water quality, soil fertility, and air quality of both land and the ocean.

Climate change is the ultimate result—through global warming—of this heavy burden on the Earth's ecosystems. In the face of the ongoing degradation of the planetary biosphere, adopting an approach rooted in the regenerative imperative, sustainability values, and the principles of a circular resource economy offers a transformative pathway toward long-term sustainability. This approach not only mitigates harm but can be net positive; it can renew, restore, and revitalize ecosystems and human, social, and economic systems.

THE CIRCULAR ECONOMY IMPERATIVE

Humanity faces an imperative: the need to transition from this wasteful linear economy to a system both sustainable and regenerative. A circular economic system is needed: a system in which finite resources are turned into items that not only have a history but a future.

This means taking a resources stewardship approach, which maintains resources indefinitely for future generations. As popularized in William McDonough's seminal book, *Cradle to Cradle: Remaking the Way We Make Things*, this necessitates moving from linear *cradle-to-grave* resource usage to *cradle-to-cradle* circular utilization in which nothing goes to waste (McDonough & Braungart, 2002). Resources are extracted once from the planet, and after extraction, they enter a circular, ongoing usage cycle. The end-of-life cycle for one item sees its components rebirthed in others. The planet does this naturally, as in nature, there is no waste. The by-product of one process is the feedstock for another process.

Waste management is one goal of an emerging circular economy. Waste is a major indicator of human impact and characterizes our linear economy. Single-use items from finite resources are discarded into landfills and float in vast ocean patches, wash onto beaches, spill across forests, and soil lakes and streams. Material waste produced by a throwaway economy is destroying entire ecosystems. Coupled with energy waste fueled by fossil fuels pumped from finite reserves, the damage is further compounded by material waste in many geographic locations/areas—even as other locations around the globe struggle with not having even basic energy needs met. The GHGs from these efforts, in turn, are warming the Earth's finite atmosphere and fueling a climate crisis that threatens the future of the planet—and life itself.

Governments should promote and support circular economies that manage waste toward zero, maximize resources, and incorporate "de-manufacturability." Common steps and targets in such transitions are available and known. Steps to taking a "circular economy" approach and ranging from smarter product manufacture to recovery of materials are detailed here (Morseletto, 2020). In 2022, a proposal for a new Ecodesign for Sustainable Products Regulation (ESPR) became a cornerstone of EU support for more environmentally sustainable and circular products. The proposal builds on the existing Ecodesign Directive, which currently only covers energy-related products. As part of that proposal a new "Digital Product Passport" (DPP) will provide information about products' environmental sustainability (EC, "Ecodesign for Sustainable Products Registration") and other information like repair records. The DPP is potentially a tremendous opportunity to enable sustainable procurement choices and, hence, foster a *sustainable supply system*.

> *Circular Economy has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs. (Ghisellini, Cialani, & Ulgiati, 2016)*

The challenges and successes are similar to implementing a space habitat such as the International Space Station or communities able to survive for generations in inhospitable (hot, cold, dry) environments. In the context of resources, experiences, knowledge, and so forth, space habitats are based on the premise of circular design closed-loop systems that minimize and utilize waste as much as possible.

Implementing these targets will not be an easy task. Technologies must be expedited to capture and reuse/recycle the many types of linear waste. Social structures will have to be developed to foster the transition from linear economics to a circular or no-waste economy counterpart. This is a complex and challenging undertaking with changes anticipated at most points in today's very complex global supply system.

Resource management is the second critical challenge. This requires the reuse of components of manufactured items either directly or, potentially reduced to the molecular level, as feedstock for new products. It also requires regeneration of the Earth's ecosystems and, hence, the biosphere that sustains life on Earth. This includes regenerative farming practices, restoring ecosystems like mangrove forests and coral reefs (to name a few), and reversing desertification in many places around the world.

Both the regenerative imperative and circular economy require changes in the way products and services are designed, used, and handled at the end-of-use. Design requirements for strong sustainability must include "design for de-manufacturability", in fact, design for strong sustainability needs to be strengthened to become Regenerative Design, where appropriate.

In December 2022, COP 15 adopted an equitable and comprehensive framework to address "overexploitation, pollution, fragmentation and unsustainable agricultural practices; safeguard the rights of indigenous peoples and recognize their contributions as stewards of nature"; and provide "finance for biodiversity and alignment of financial flows with nature to drive finances toward sustainable investments and away from environmentally harmful ones."

Recommendations

1. **Develop policies at all levels of government that encourage and support development and implementation of new innovations**. **Support should also be given to businesses and organizations who are applying these innovations and building circularity and regenerative practices into their business and organizational models, including their supply chains/systems/networks, products, and services.**
    a. Given the challenges and risks associated with these new features, businesses should be rewarded for their ambition and leadership whenever they succeed in proving that new economic and business models are both viable and profitable.
    b. The philosophy behind a circular economy is one that sees multiple, collaborative social segments as forces for good. **Business, government, academia, community, and society-at-large all should become domains in which innovative solutions can be created for tackling global problems and achieving planetary sustainability.**
2. **Devise policies and governance structures that support the shift towards regenerative and circular economies.** This involves creating regulatory frameworks that incentivize the restoration of ecosystems, the circular flow of materials, and the equitable distribution of resources. Financial instruments such as green bonds and environmental impact investing can fund regenerative projects. At the same time, participatory governance models should promote policies that are co-created with communities, aligning with local needs and ecosystems.
3. **Empower communities to lead regeneration efforts.** This involves education and capacity-building around the principles of circular economy and regenerative design, equipping individuals and communities with the knowledge and skills to innovate and implement sustainable practices. Community-led initiatives can pilot new approaches to circular living, creating models that can be scaled and adapted elsewhere.
4. **Integrate education for circularity, regeneration, and sustainability into all levels of education, fostering a new generation of thinkers and doers committed to sustainability.**

5. **Communicate best practices, knowledge, information and data on circularity, regeneration, and sustainability widely and easily accessible**. That should also include discussion of updated information, misinformation and misconceptions.
6. **Set targets, R&D milestones, and develop policies and resources to implement action plans**. For example:
    a. **Necessary social infrastructure around waste reclamation and reuse.** Paradoxically, waste reclamation often "ironically increases the risk of creating a demand for these waste streams, which thereby may become commodified" and increase linear economy path dependencies (Greer, von Wirth, & Loorbach, 2021)—an unintended consequence to be avoided.
    b. **Creation of future *economic and business models* expanding upon, and emphasizing, regeneration, human flourishing, and well-being** (Ghisellini, Cialani, & Ulgiati, 2016; Shrivastava & Zsolnai, 2022).
    c. **Natural ecosystem regeneration—both on land and in water—such as reversal of desertification, restoration of wetlands and coastal ecosystems,** and so forth.
7. **Set policy for and practice contextualized regenerative farming and food production.** Circular agriculture focuses on creating closed-loop systems that recycle nutrients, minimize waste, and regenerate soil health. Practices such as permaculture, agroecology, and holistic grazing integrate food production with ecosystem restoration. Emphasizing soil regeneration, these practices enhance soil carbon sequestration, support water retention, and rebuild biodiversity. By viewing waste as a resource—much like our ancestors' and indigenous peoples' practice—circular agriculture utilizes agricultural by-products as inputs for other processes, fostering resilience and productivity.
8. **Prioritize restoration and the creation of self-sustaining ecosystems that provide economic, ecological, and social benefits in forest management**. This includes reforestation and afforestation and the integration of permaculture principles to design forest systems that mimic natural forests. Such practices enhance biodiversity, sequester carbon, and support local livelihoods while harmoniously producing food, fiber, and other materials with nature.
9. **For regenerative water and ocean management, involve designing systems that learn from natural hydrological cycles, enhancing the quality and availability of water.** This includes creating landscapes that capture, store, and purify water through natural processes, such as constructed wetlands and biofiltration systems. Rainwater harvesting, graywater recycling, and restoring natural water bodies are integral to creating resilient water systems that support human and ecological needs. This includes regeneration of ocean ecosystems such as coastal areas, mangroves, wadden seas (see UNESCO, "Wadden Sea"), salt marshes, and coral reefs.
10. **Prioritize natural ecosystem regeneration—both on land and in water—such as reversal of desertification, restoration of wetlands and coastal ecosystems.** This should help limit further loss of wildlife (WWF, 2024) and biodiversity (Alves, 2024).
11. **Expedite research, development, deployment, and adoption of technologies promoting ten common circular economy strategies** (Morseletto, 2020).
    a. ***Refuse*.** Eliminate unnecessary single-use products.
    b. ***Rethink*.** There are two aspects: 1) production of multipurpose "widgets" rather than a number of single-use "widgets" and 2) develop a sharing economy (equipment rental) and/or sharing community (neighborhood sharing).

c. ***Reduce*.** There are two aspects: 1) using less resources in production of "widgets" and 2) reduction of consumption of goods.

d. ***Reuse*.** Develop a sharing economy, passing items from one user to another.

e. ***Repair*.** The right to repair should be inherent with every product.

f. ***Refurbish*.** Rebuilding, refurbishing with repaired or improved parts.

g. ***Remanufacture*.** De-manufacture "widgets" into reusable parts for other products or the same type of product.

h. ***Repurpose*.** Innovative use of widgets for purposes other than originally intended—as a whole or in part or with additional parts.

i. ***Recycle*.** Sorting end-of-life items for reuse of materials.

j. ***Recovery*.** Recovery of materials through separation of materials into feedstock streams for the "next" semi-permanent product.

12. **Design systems and products from the outset for circularity, regeneration, and sustainability.**

    a. **Design, implement, and operate installations and/or devices to include end-of-use plans for circularity.**

    b. **Design systems for zero waste** (minimizing waste) and maximizing efficiencies. In the circular economy, waste is designed out of systems. This perspective transforms waste management practices, focusing on the recovery and regeneration of materials as feedstock for new production. Circular waste management strategies include industrial symbiosis, where one industry's waste becomes the input/feedstock for another, and the development of biodegradable materials that can be composted to regenerate soils. Innovations in recycling technologies also play a crucial role in keeping materials in use for as long as possible, reducing the need for raw materials and minimizing environmental impact.

    c. **Design for modularity, repairability, high efficiency, and long service.**

    d. **Design for net-positive societal and environmental impacts.**

13. **Make accounting more encompassing regarding values.** Move forward from gross domestic product (GDP) accounting toward accounting inclusive of other metrics (environmental, biosphere, well-being, etc.). GDP does not capture unpaid work of caregivers and other aspects of the caring economy; volunteer efforts that contribute to the economy; leisure time; and other aspects that are important to human well-being.

14. **Include externalities into the accounting systems.** For example, IEEE P3469™ inspired by a concept of the E-Liability Institute to include GHG emissions as part of the accounting ledger (Kaplan & Ramanna, 2021).

15. **Develop "Technical Standards" to include sustainability, regenerative, social and circular economy values/principles "by design."** Also referred to as socio-technical standards.

16. **Develop and deploy tools that will provide sufficient information and access to data to permit knowledge-based sustainable procurement**. That is, tools such as the Digital Product Passport, a tool that will show extensive product information along with information about the associated supply system, including the suppliers' "sustainability performance." The Digital Product Passport is part of the EU Ecodesign for Sustainable Products Regulation.

17. **Transition to regenerative energy systems.** Transitioning to regenerative energy systems—in addition to renewable and net zero energy systems—should include moving beyond merely reducing emissions to designing energy solutions that positively impact the environment. This includes the widespread adoption of renewable energy and other clean sources that regenerate local ecosystems, such as bioenergy with carbon capture and storage (BECCS), and the development of energy systems that mimic natural processes to improve resilience and biodiversity. Energy systems should be decentralized and designed to empower communities, enhancing energy democracy and resilience. And the systems infrastructure should support a circular economy—no waste at end-of-use.

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Singapore Turns Sewage into Clean, Drinkable Water, Meeting 40% of Demand

   "The tiny island nation has little in the way of natural water sources and has long had to rely principally on supplies from neighboring Malaysia. To boost self-sufficiency, the government has developed an advanced system for treating sewage involving a network of tunnels and high-tech plants."

   Agence France-Presse. "Singapore Turns Sewage into Clean, Drinkable Water, Meeting 40% of Demand." VOA News. 10 Aug. 2021.

2. Zero-Waste Communities Across the Globe

   "Eight cities in Asia, Europe, and North and South America, along with four online communities, showcase approaches to zero waste."

   "Zero Waste Communities Across the Globe." *Zero Waste* (blog). 3 Mar. 2021.

3. Nine Examples That the Transition to a Regenerative Economy is Underway

   "Southface Institute has created the following series of case studies to share success stories from regenerative economy pioneers. Each case study examines its subject through the interdependent lenses of the natural environment, the social environment and the built environment."

   Shea, Bailey, and Shane Totten. "Nine Examples That the Transition to a Regenerative Economy is Underway." *Southface Institute* (blog). 23 Mar. 2021.

4. 9 Ways to Create a Local Regenerative Economy

   "Nine steps towards creating decentralized cooperative local economies that emphasize local production with local resources to meet local needs to build local wealth."

   Bjonnes, Roar. "Nine Ways to Create a Local Regenerative Economy." Shareable, 11 Aug. 2021.

5. Achieving One-Planet Living Through Transitions in Social Practice: A Case Study of Dancing Rabbit Ecovillage

   "This article examines DR's extraordinary energy and resource savings through the lens of social practice theory, which focuses on the meanings, competencies, and materials that individuals combine to form everyday practices."

   Boyer, Robert H. W. "Achieving One-Planet Living through Transitions in Social Practice: A Case Study of Dancing Rabbit Ecovillage." *Sustainability: Science, Practice and Policy* 12, no. 1 (2016): 47–59.

6. The EU's New Digital Product Passport

   The EU's new Digital Product Passport *"will provide information about products' environmental sustainability. This information will be easily accessible by scanning a data carrier and it will include attributes such as the durability and reparability, the recycled content or the availability of spare parts of a product. It should help consumers and businesses make informed choices when purchasing products, facilitate repairs and recycling and improve transparency about products' life cycle impacts on the environment. The product passport should also help public authorities to better perform checks and controls"*

   European Commission. "Ecodesign for Sustainable Products Regulation." Energy, Climate Change, Environment; Standards, Tools and Labels; Products, Labeling Rules and Requirements; Sustainable Products.

7. Circular Economy of digital devices

   The APC's "Guide to the Circular Economy of Digital Devices" includes the right to repair.

   Association for Progressive Communications (APC). "A Guide to the Circular Economy of Digital Devices."

Further resources

1. Awasthi, Abhishek Kumar, Jinhui Li, Lenny Koh, and Oladele A. Ogunseitan. "Circular Economy and Electronic Waste." *Nature Electronics* 2 (Mar. 2019): 86–89.
2. Barreiro-Gen, Maria, and Rodrigo Lozano. "How Circular is the Circular Economy? Analysing the Implementation of Circular Economy in Organisations." *Business Strategy and the Environment* 29, no. 8 (July 2020): 3484–94.
3. Bennett, Nathan J., Jessica Blythe, Andrés M. Cisneros-Montemayor, Gerald G. Singh, and U. Rashid Sumaila. "Just Transformations to Sustainability." *Sustainability* 11, no. 14 (July 2019).
4. Capital Institute (website).
5. Climate Justice Alliance (website).
6. Cole, Christine, Alex Gnanapragasam, and Tim Cooper. "Towards a Circular Economy: Exploring Routes to Reuse for Discarded Electrical and Electronic Equipment." *Procedia CIRP* 61 (2017): 155–60.
7. Corvellec, Hervé, Alison F. Stowell, and Nils Johansson. "Critiques of the Circular Economy." *Journal of Industrial Ecology* 26, no. 2 (Apr. 2022): 421–32.
8. Ellen MacArthur Foundation. "The Circular Economy in Detail."

9. Fath, Brian D., Daniel A. Fiscus, Sally J. Goerner, Anamaria Berea, and Robert E. Ulanowicz. "Measuring Regenerative Economics: 10 Principles and Measures Undergirding Systemic Economic Health." *Global Transitions* 1 (2019): 15–27.

10. Geng, Yong, Joseph Sarkis, and Raimund Bleischwitz. "Economy. "Nature 565 (2019): 153–155.

11. Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. "A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." *Journal of Cleaner Production* 114 (2016): 11–32.

12. Govindan, Kannan, and Mia Hasanagic. "A Systematic Review on Drivers, Barriers, and Practices Towards Circular Economy: A Supply Chain Perspective." *International Journal of Production Research* 56, no. 1–2 (Jan. 2018): 278–311.

13. Heyes, Graeme, Maria Sharmina, Joan Manuel F. Mendoza, Alejandro Gallego-Schmid, and Adisa Azapagic. "Developing and Implementing Circular Economy Business Models in Service-Oriented Technology Companies." *Journal of Cleaner Production* 177 (Mar. 2018): 621–632.

14. Howard, Mickey, Peter Hopkinson, and Joe Miemczyk. "The Regenerative Supply Chain: A Framework for Developing Circular Economy Indicators." *International Journal of Production Research* 57, no. 23 (2019): 7300–7318.

15. Jain, Yashi. "Regenerative Economies: A New Approach Towards Sustainability." *No Poverty*, part of the *Encyclopedia of the UN Sustainable Development Goals* book series. Springer, Cham, 2020.

16. Khan, Shahbaz, and Abid Haleem. "Investigation of Circular Economy Practices in the Context of Emerging Economies: A CoCoSo Approach." *International Journal of Sustainable Engineering* 14, no. 3 (2021): 357–67.

17. Kirchherr, Julian, Denise Reike, and Marko Hekkert. "Conceptualizing the Circular Economy: An Analysis of 114 Definitions." *Resources, Conservation and Recycling* 127 (2017): 221–32.

18. Lovins, L. Hunter, Stewart Wallis, Anders Wijkman, and John Fullerton. A Finer Future: Creating an Economy in Service to Life. *New Society Publishers,* 2018.

19. Marrucci, Luca, Tiberio Daddi, and Fabio Iraldo. "Do Dynamic Capabilities Matter? A Study on Environmental Performance and the Circular Economy in European Certified Organisations." *Business Strategy and the Environment* 31, no. 6 (Jan. 2022): 2641–57.

20. Moraga, Gustavo, Sophie Huysveld, Fabrice Mathieux, Gian Andrea Blengini, Luc Alaerts, Karel Van Acker, Steven de Meester, et al. "Circular Economy Indicators: What Do They Measure?" *Resources, Conservation and Recycling* 146 (2019): 452–61.

21. Moreno, Mariale, and Fiona Charnley. "Can Re-distributed Manufacturing and Digital Intelligence Enable a Regenerative Economy? An Integrative Literature Review." Conference paper published in *Sustainable Design and Manufacturing 2016*, Rossi Setchi, Robert J. Howlett, Ying Liu, and Peter Theobald, eds. Part of the *Smart Innovation, Systems and Technologies* book series, vol. 52. Springer, Cham, 2016.

22. Morseletto, Piero. "Targets for a Circular Economy." *Resources, Conservation and Recycling* 153 (2020).

23. Narvaez, Darcia, Four Arrows, Eugene Halton, Brian Collier, and Georges Enderle. Indigenous Sustainable Wisdom: First-Nation Know-How for Global Flourishing. Peter Lang International Academic Publishers, 2019.

24. Net Impact. "The Regenerative Economy: Exploring Regenerative Principles for Business and Innovation. Net Impact's Virtual Event Series." Regenerative Economy Resources.
25. Peña, P. (2020). Bigger, more, better, faster: The ecological paradox of digital economies. In Global Information Society Watch 2020 – Technology, the environment and a sustainable world. https://giswatch.org/node/6245
26. Pires, Ana, and Graça Martinho. "Waste Hierarchy Index for Circular Economy in Waste Management." *Waste Management* 95 (July 2019): 298–305.
27. Rouse, Jonathan R. "Seeking Common Ground for People: Livelihoods, Governance and Waste." *Habitat International* 30, no. 4 (Dec. 2006): 741–53.
28. Sharma, Yogesh Kumar, Sachin Kumar Mangla, Pravin. P. Patil, and Shaofeng Liu. "When Challenges Impede the Process: For Circular Economy-Driven Sustainability Practices in Food Supply Chain." *Management Decision* 57, no. 4 (Feb. 2019): 995–1017.
29. Silvestri, Francesco, Francesca Spigarelli, and Mattia Tassinari. "Regional Development of Circular Economy in the European Union: A Multidimensional Analysis." *Journal of Cleaner Production* 255, art. 120218 (May 2020).
30. Tisserant, Alexandre, Stefan Pauliuk, Stefano Merciai, Jannick Schmidt, Jacob Fry, Richard Wood, and Arnold Tukker. "Solid Waste and the Circular Economy: A Global Analysis of Waste Treatment and Waste Footprints." *Journal of Industrial Ecology* 21, no. 3 (Mar. 2017): 628–40.
31. United Nations. "Make the SDGS a Reality." Department of Economic and Social Affairs, Sustainable Development.
32. Urbinati, Andrea, Davide Chiaroni, and Vittorio Chiesa. "Towards a New Taxonomy of Circular Economy Business Models." *Journal of Cleaner Production* 168 (Dec. 2017): 487–98.
33. Velenturf, Anne P. M. and Phil Purnell. "Principles for a Sustainable Circular Economy." *Sustainable Production and Consumption* 27 (2021): 1437–57.
34. World Economic Forum, Centre for the New Economy and Society (website).
35. Zimring, Carl A., and William L. Rathje, eds. Encyclopedia of Consumption and Waste: The Social Science of Garbage, vol. 1 & 2. Thousand Oaks, CA: *SAGE Publishing*, 2012.

Guiding Principle 6: Balance between today's needs and the needs of the future

In the course of transitioning societies and the global economy toward a sustainable future, today's short-term needs must balance with the long-term, global aspirations for a flourishing planet. This balanced approach should address all human needs, including access to food and clean water, health care, and other essential goods and services necessary for a healthy standard of living, and the need for healthy ecosystems globally.

Background

At the heart of sustainability is the understanding that our resource utilization cannot surpass the rate of resource availability and reuse. There is only one Earth in our planetary system. If the Earth's biosphere gets destroyed, there is no new home for life on Earth. With this in mind, the aim is to reduce resource waste through an understanding of current needs and needs of the future to avoid Earth Overshoot Day (the point at which our consumption outstrips the planet's biocapacity in each annual cycle) (https://overshoot.footprintnetwork.org/). Therefore, a required understanding of our present socioeconomic capacity contextualized among individuals and communities—locally to globally—is needed while integrating the multifactorial conditions that determine resource utilization, availability, and rate and the effects of these on our environment.

Another way of expressing this imperative is that decisions should follow the *Seventh Generation Principle* in which "decisions made today should result in a sustainable world seven generations into the future" (Indigenous Corporate Training, 2022). This intergenerational mindset should see all people concerned for the health and well-being of future generations, that is, all people's children's children and the generations beyond, just as much as people are concerned for their own health and well-being today.

Healthy humanity depends upon a healthy planetary biosphere, both directly through the ecological services that it offers and indirectly through the positive impacts of the living environment on stress and mental health. It also requires an understanding of how needs differ across demographics and how climate change may influence these needs, while accounting for future adaptations and changes. For example, if consumption outstrips production, people today impoverish their children. Overconsumption is not the only issue; for example, a lack of recycling of wastes that contaminate the environment will also have direct and indirect population effects. There is no return from extinction!

We need to develop adjustment mechanisms that allow us to constantly improve our social and economic systems such that we can provide for our short-term needs with one hand while working on the long-term transformation process with the other—with the goal of achieving a long-term healthy planetary biosphere for all.

Recommendations

1. **Consider stakeholder needs and the impacts of projects in the short, medium, and long term.**
2. **Design for maintainability, sustainability, repair, reuse, recycling, and end-of-use material reuse as feedstock for new widgets.**
3. **Maintain the right to repair and the right to tinker.**
4. **As much as possible, avoid creating single-use products.**
5. **Develop collaborations between programs, organizations, and institutions (e.g., government, academic, and nonprofits) that have an understanding of and data available for individual and community needs.**
6. **Develop and use a predictive information system (or systems) for prognosis and planning to achieve this "balance" between today's needs and the needs of the future for all stakeholders: the Earth's ecosystems and humans.**

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Balancing Socioeconomic Development with Ecological Conservation towards Rural Sustainability, China

   Li, Qirui, Hua Ma, Zhuqing Xu, Hao Feng, and Sonoko D. Bellingrath-Kimura. "Balancing Socioeconomic Development with Ecological Conservation towards Rural Sustainability: A Case Study in Semiarid Rural China." *International Journal of Sustainable Development & World Ecology* 29, no. 3 (Oct 2021): 246–262.

2. Quantifying the Sustainability of Water Use Systems: Calculating the Balance between Network Efficiency and Resilience

   Li, Y., and Z. F. Yang. "Quantifying the Sustainability of Water Use Systems: Calculating the Balance between Network Efficiency and Resilience." *Ecological Modelling* 222, no. 10 (May 2011): 1771–1780.

3. Sustainable Linear Infrastructure Route Planning Model to Balance Conservation and Socioeconomic Development

   Wu, Shuyao, and Binbin V. Li. "Sustainable Linear Infrastructure Route Planning Model to Balance Conservation and Socioeconomic Development." *Biological Conservation* 266, art. 109449 (Feb. 2022).

Further resources

1. Hisano, Masumi, Eric B. Searle, and Han Y. H. Chen, "Biodiversity as a Solution to Mitigate Climate Change Impacts on the Functioning of Forest Ecosystems." *Biological Reviews* 93, no. 1 (July 2017): 439–456.
2. Rastelli, Eugenio, Bruno Petani, Cinzia Corinaldesi, Antonio Dell'Anno, Marco Lo Martire, Carlo Cerrano, and Roberto Danovaro, "A High Biodiversity Mitigates the Impact of Ocean Acidification on Hard-Bottom Ecosystems." *Scientific Reports* 10, no. 1 (Feb. 2020): 1–13.
3. U.S. Department of Defense. "Designing and Developing Maintainable Products and Systems." Philadelphia, PA: Navy Publishing and Printing Office, 1997

Guiding Principle 7: Alignment of global goals with local goals and actions

The transition to a more sustainable future will be driven and implemented by local actions that should also produce positive global benefits. Local actions and global goals should support each other.

Background

Ultimately, local actions and local implementations of local, regional, and global plans are at the pinnacle of addressing climate change adaptation and mitigation as well as long-term planetary biosphere sustainability goals. The more that local societies align their own goals and actions with global goals and objectives, the greater the likelihood we—that is, *humanity*—will achieve a fundamentally sustainable planet. Local communities across the globe have been, are, and will be impacted directly and indirectly by climate change. Moreover, there are local differences across communities: at the individual level; family level; housing level; neighbor and community level; village, town, and city level; and at the county, state, and national level. At *all* levels, we—*society*—will benefit by integrating relevant data and information from diverse sources that contextualize, weigh, and evaluate outputs that educate our decision-making to produce positive global benefits. From this approach, local actions will match and move towards our global goals.

This is significant and beneficial, as this approach accounts for the diverse and multifactorial effects of climate change. The people of communities most impacted by climate change may also be poor, disadvantaged, or underserved and, therefore, less able to respond appropriately and effectively. These may also include agricultural, fishing, manufacturing, and environmental goods communities, where climate events can directly and indirectly lead to socioeconomic impacts that have global implications.

An example of a conflict is bottom trawling. Trawling the seafloor may provide much nutrition for many people while harming the ecosystem on the ocean floor, discarding unwanted fish species, leaving damaged equipment behind and stirring up sequestered carbon from the ocean floor. The amount of freed up carbon is globally in the order of the entire CO_2 emissions amount reported annually by Great Britain. Thus, locally or regionally, bottom trawling may provide food, while on the global scale it damages ecosystems and frees up carbon (Horn-Muller, 2024).

Thus, the impacts of climate change are expected to lead to increased competition and conflict, lower general quality of life and health, and increased inequities. By balancing socioeconomic factors globally through technological means—and in a manner that is also beneficial for distributed local communities in need—not only can climate change be successfully addressed, but socioeconomic issues faced by communities across the world as well—such as poverty, lack of education, and lack of socioeconomic mobility and support—while also addressing potential conflicts and inequities. In turn, this can lead to improved human rights, well-being, competence, and accountability as well as improved outcomes in response to climate change. This strategy is expected to make the best use of resources and collective capacity for the well-being of future generations and to promote a shared and heightened understanding of human cultures and experiences in a technology-supported world.

Recommendations

1. **Organize and/or research local to global relationships.** Organize and/or research local to global relationships accounting for differences in a multifactorial approach of human (e.g., demographic, health, occupation, and education) and environmental factors (e.g., temperature, humidity, flora, and fauna), independently and dependently, regionally, and across time (past, present, and future).
2. Connect low-income, high-risk, and high-need communities with programs and organizations that can provide immediate, short-term, and/or long-term support.
3. **Engage organizations and communities to foster the use of sustainable technologies and programs.** Organize, develop, guide (from preexisting initiatives, new initiatives, and also, ideally, integrated collaborations), and engage relevant technologies and communities—for example, government, organizations, academia, and industry—that address and support recommendations 1 and 2, with emphasis and priority given to technologies and programs that apply sustainable practices and knowledge that are inexpensive, simple, approachable, relevant, and long-lasting and that minimize resource utilization and waste.
4. **Share diversity, equity, inclusion, and accessibility information in support of sustainable programs.** Organize details and share diversity, equity, inclusion, and accessibility information that is adapted for and empathetic toward individual, cultural, and socioeconomic differences and circumstances in support of sustainable programs.
5. **Develop action plans.** Develop timelines and objectives that are adaptive in real time and in the short and long term and are based on priorities and factors related to local and global contexts from the above recommendations and that balance, align, and integrate local and global goals and initiatives.
6. **Develop knowledge sharing and communication mechanisms that connect across backgrounds and professions.** Develop knowledge-sharing and communication mechanisms that teach—both technical and nontechnical—actions and outcomes across backgrounds and professions, realizing that the current intellectual property protection system can pose barriers to sharing solutions.
7. **Develop solutions that address actions with conflicting outcomes such as bottom trawling and limiting the GHG levels in the atmosphere**. Bottom trawling, a somewhat local activity, provides significant amounts of protein—food—and employment while releasing carbon back into the ocean waters and furthermore back into the atmosphere as carbon dioxide.
8. **Develop and support community networks**. There are many community networks and networks of networks around the globe with goals aligned with achieving sustainability and addressing climate change related issues. Community networks offer important alternatives for connectivity based on local, low-cost, and environmentally aware solutions. (IEEE, “The Role of Community Networks in Advancing Universal Access to the Internet”, 2021; The Internet Society, “Connecting the Unconnected”).

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Interconnected Place-Based Social–Ecological Research

   Balvanera, Patricia, Rafael Calderón-Contreras, Antonio J. Castro, María R. Felipe-Lucia, Ilse R. Geijzendorffer, Sander Jacobs, Berta Martín-López, et al. "Interconnected Place-Based Social–Ecological Research Can Inform Global Sustainability." *Current Opinion in Environmental Sustainability* 29 (Dec. 2017): 1–7.

2. Stockholm Royal Seaport

   Holmstedt, Louise, Nils Brandt, and Karl-Henrik Robèrt. "Can Stockholm Royal Seaport be Part of the Puzzle towards Global Sustainability? — From Local to Global Sustainability Using the Same Set of Criteria." *Journal of Cleaner Production*140 (Jan. 2017): 72–80.

3. Systems Integration for Global Sustainability

   Liu, Jianguo, Harold Mooney, Vanessa Hull, Steven J. Davis, Joanne Gaskell, Thomas Hertel, Jane Lubchenco, et al. "Systems Integration for Global Sustainability." *Science* 347, no. 6225 (Feb. 2015).

4. Earth System Science for Global Sustainability: Grand Challenges

   Reid, Walter V., Davidson Chen, Leah Goldfarb, Heide Hackmann, Yuan-Tseh Lee, Khotso Mokhele, et al. "Earth System Science for Global Sustainability: Grand Challenges." *Science* 330, no. 6006 (Nov. 2010): 916–917.

5. Community Networks

   Munshi, Kaivan. "Community Networks and the Process of Development." *Journal of Economic Perspectives* 28, no. 4 (Fall 2014):49-76.

   Clark, A. "Understanding Community: A Review of Networks, Ties and Contacts." ESRC National Centre for Research Methods, 2007.

Guiding Principle 8: Culture of sustainability

Strategies and actions should move societies toward building a culture of sustainability and "doing good" that is based on respect for all living beings and for the planet Earth. Sustainability efforts must move beyond minimizing harm to restoring and regenerating human and environmental systems.

Background

Actions are most powerful and effective when individuals or groups have a clear understanding of what is being done, how it is done, and, perhaps most importantly, why the actions are necessary and important. The more societies understand how human civilization is impacting and changing the world, the more capable and confident we, as a global community, can be to make necessary changes. These changes must be made not only in personal lives but also within the technological systems that underpin societies and the global economy. Indeed, the more we individually and collectively understand the significance of individual choices and the immense power of collective, international actions, today's global problems and challenges should become less threatening and more manageable, if not resolvable. We, individually and collectively, must therefore understand that every action we take should lead us one step closer to achieving a sustainable future.

Many great sustainability initiatives and purpose-driven organizations have been launched in recent years, with the UN SDGs one of the most well-known. Recent research (see Biermann et al., 2022) has shown, however, that while the SDGs have had positive effects in terms of generating global discussion as well as shaping some isolated policy reforms, "there is little evidence that goal setting at the global level leads directly to political impacts in national or local politics." This suggests that goal setting is largely ineffective unless it is also accompanied by a *commitment and willingness to act* at the local level in accordance with the stated goals such as the SDGs.

Acting sustainably, therefore, starts with individuals, communities, organizations, and nations making an explicit commitment to live, work, grow, and prosper in accordance with the necessary courses of action that promote the long-term health and well-being of all living beings and ecological systems on our planet. This commitment needs to be made not only at the level of individuals but also within systems at local, national, and international levels. This commitment then needs to be written into actionable policies. Culture also plays a key role in embedding this commitment to act sustainably within the social psychology of organizations and other large collectives.

This is a global problem, and societies and individuals are all interconnected; therefore, we cannot rely on each nation or region to cease unsustainable actions or implement sustainable ones in isolation. Although poorer countries may be impacted more severely by climate change, they did not contribute the most to the current crisis. Similarly, they may be less able in terms of resources, technology, and time to take significant actions.

Recommendations

1. **Commit to act to achieve long-term planetary health.** We, that is, business, academia, government, society, organizations, communities, and individuals, must recognize and acknowledge that talking about sustainability is futile unless we also seriously commit to taking the necessary actions to achieve long-term planetary health and well-being—actions speak louder than words. That includes transparency, broad communication, and education.
2. **Develop and implement guiding documents like policies and mission statements.** To act sustainably, businesses, industries, governments, institutions, international, and other organizations should inscribe and/or embed their commitment to long-term planetary health and well-being into their policies, codes of conduct, mission statements, and other governing doctrines/documents/regulations.
3. **Establish an ecological consciousness and code of conduct in industry and business.** Businesses and industries need to recognize that they play a central role in how natural resources are either used and/or impacted by their business activities. Businesses and industry need to establish an ecological consciousness. They need to take a proactive role in overseeing how their business is impacting the environment, combined with methods and procedures that not only aim to minimize environmental impact and achieve best practices and optimal use of resources while doing business but also aim to be circular and regenerative. These actions should be consistently invested in and applied to every aspect of business—not just in building design or supply chains but also in artificial intelligence (AI), in work-from-anywhere versus commute policies, and in building, site plans, and employee travel requirements, event-planning practices.
4. **Verify there is no discrepancy between public business claims and advocacy.** Businesses should hold the advocacy groups that lobby governments on their behalf to the same standards that they claim to apply to themselves publicly. Advocacy groups should not lobby for weaker policies or longer implementation periods or greater subsidies on behalf of any organization that is making potentially unsubstantiated sustainability claims.
5. **Encourage businesses to qualify to become ethically certified.** Certification examples are B-Corp, Fair Trade International, Climate Neutral, and People for the Ethical Treatment of Animals (PETA) (Christian, 2022).
6. Develop an accountability framework for ethical business certification and labeling. This should include independent 3rd party verification.
7. **Deliver on treaties, generate and implement action plans to achieve climate, sustainability, and biodiversity targets.** Governments need to make national commitments and develop action plans to deliver on their commitments to treaties such as the Paris Agreement and Kyoto Protocol and to global climate summits such as the Conference of the Parties (COP). Such commitments can be further accomplished by passing climate targets into law.
8. **Practice integrated systems planning at all levels of government to avoid unintended and unanticipated impacts of actions.**

9. **Develop strategic plans and pursue policies at local and other government levels.** Examples are included below.
    a. **"Shift energy subsidies from fossil fuels to renewable energy"** (Merrill et al, 2017).
    b. **Encourage major economies to donate sustainable materials for renewable energy and regenerative agriculture to economies that cannot afford them.**
    c. **Invest in "carbon-sucking" concrete** (Clancy, 2021).
    d. **Address the use of "tax havens" and other strategies to avoid contributing to the tax base needed to fund these initiatives.**
    e. **Heavily invest in water recycling and reuse** (Visram, 2021).
    f. **Plant more trees,** especially in neighborhoods where pollution is higher and where residents are less likely to have air conditioning (temperatures rise significantly higher in areas with no trees) and where residents are more likely to have underlying health conditions.
    g. **Restore/regenerate ecosystems and biodiversity.**
    h. **Restore the ocean and waterways** (Johnston, 2022).

Case studies

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1. Corporate Mission Statements

   There are many corporations with inspiring mission statements including sustainability, climate change, biodiversity and/or other similar goals.

2. Finland's Plans: It Aims to be Net Zero by 2035 and Net Negative by 2040

   Lo, Joe. "Finland Sets World's Most Ambitious Climate Target in Law." *Climate Home News*, 31 May 2022.

3. "Aiming for Sustainability Isn't Good Enough—The Goal Is Much Higher"

   Former CEO Paul Polman Says "Aiming for Sustainability Isn't Good Enough—The Goal Is Much Higher". Companies should "take responsibility for that total impact in the world. I call it the total handprint, all consequences intended or not."

   Polman, Paul. "Former Unilever CEO Paul Polman Says Aiming for Sustainability Isn't Good Enough—The Goal is Much Higher." By Adi Ignatius. *Harvard Business Review,* 19 Nov. 2021.

4. How to Make Supply Chains/Systems More Sustainable

   "More intractable sources of a company's carbon footprint, Scope 3 emissions, include everything outside of direct operations, such as travel, waste, and supplies."

   Lapan, Tovin. "How Salesforce Wants to Make Its Supply Chain More Sustainable." *Fortune*, 22 June 2021.

5. Carbon Emissions

McKibben, Bill. "Could Google's Carbon Emissions Have Effectively Doubled Overnight?" *The New Yorker*, 20 May 2022.

6. IoT Emissions

Freedman, Andrew. "First Look: Salesforce Teams Up with AT&T to Cut Emissions." *Axios*, 23 June 2022.

7. The World's Most Sustainable Companies

Annual rankings since 2007 by Corporate Knights

Mc Carthy, Shawn. "The Global 100 List: How the World's Most Sustainable Corporations Are Driving the Green Transition." Corporate Knights, 17 Jan. 2024.

Further resources

1. "The Business Guide to Carbon Accounting." Salesforce, 9 May 2022.
2. CK Staff. "Global 100 Resources." *Corporate Knights*, 3 Apr 2021.

Guiding Principle 9: Responsible use of technology and technology labeling

The design, development, implementation, use, and handling/treatment at end-of-current-use of technology should be a dynamic ongoing process for evolving an appropriate, timely response to both negative impacts—the unforeseen consequences of technology on people and planet—and positive impacts—the opportunities to relieve suffering, increase flourishing and equity, and better steward the planet.

Background

Each wave of new technology has also resulted in unforeseen consequences: fire, language, writing, printing, electricity, computing, transistors, AI, and more. The responsible design, development, use, and disposal of technology is a dynamic cyclical process, not a two-step binary dance of *backlash* followed by *laws and regulations*. Drug and nutrition labeling recognized the need to alert customers about how they would be affected by what they consume. Today people consume technology 24/7, and it affects both their health and their lives.

Advanced technologies such as AI and machine learning present great opportunities for enhancing our own human capabilities for tackling climate change and other global problems. These same technologies also pose serious risks and dangers to the health, well-being, and dignity of human life and to the broader fabric of our societies and the environment. Advanced technologies will not lead to nor generate beneficial outcomes automatically. It is therefore up to those who are technologists to decide how technology is designed and developed and whether technologies are being built to work and serve in the best interests of humanity.

All technologists bear some degree of responsibility in the production process of the technologies that they are working to create. Should instances of irresponsible or unethical uses of technology occur, those involved in their creation and development should be able to raise concerns in a way that can help prevent any risks or dangers from occurring downstream, in the real world. The technology industry and the community of technical professionals needs to be receptive to these concerns and be brave enough to call out instances where technology is not being developed in a responsible way.

Responsible use of technology also applies to the way in which organizations and businesses use technology for their own purposes; industrial use of technology should not perpetuate activities that are inherently unsustainable and that work against our ultimate objective of creating long-term sustainability. Responsibility requires, first, an awareness of what constitutes “good and bad” actions and behaviors and, second, the willingness to encourage and promote “good” actions and behaviors while also preventing or calling out “bad” actions and behaviors when they are noticed. Failing to develop and use technology ethically and responsibly will result in risks and dangers occurring in the world that could have otherwise been prevented.

Recommendations

1. **Accompany technology development by a responsible technology checklist. This responsible technology checklist should attest if the development and deployment of the technology is:**
   a. **Centered on the person or people;**
   b. **Respectful of the natural environment and stewardship of the planet;**
   c. **Sustainable by design;**
   d. **Preserving desired privacy and security by design;**
   e. **Protecting personal information with timely, specific informed consent on the private or public use of data;**
   f. **Accountable to the people who use it and to the planet—in addition to the people who fund and manage it;**
   g. **Ethical;**
   h. **Deployed in solutions that are appropriate to the context of the problem (not all problems need technology);**
   i. **Deployed where a human is in the loop with respect to overseeing and managing technological systems; and**
   j. **Developed with due respect for justice, fairness, the law, and public interest.**
2. **Implement a standardized feedback process for technology innovation with checkpoints to catch dangerous or irreconcilable issues.** Development of technology should take into account feedback; track and measure deployment of technology at the innovation and experimentation stage; and filter out technology that triggers undue backlash.
3. **Develop "responsible technology" standardized labels for robustly tested technology and certification of responsible technology**. For example, see the Digital Product Passport initiative in Europe and Guiding Principle 5, case studies. These types of labels are expected to enable sustainable procurement and support/lead to sustainable supply systems.

Case studies

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1. Drug/Pharmaceutical Labels

   Drug labels came into widespread use in the 1800s. Early pharmacy labels can be found on the website of the Bristol-Myers Squibb European Apothecary here and the AIHP "History of Drug Containers and Their Labels here.

   Wallace Janssen discusses the history of US laws regarding the Food and Drug Act of 1906.

"The United States was slow to recognize the need for a national food and drug law. Frederick Accum's "Treatise on Adulterations of Food and Methods of Detecting Them" had been published in London and Philadelphia in 1820, and Great Britain's first national food law was passed in 1860. A variety of U.S. state laws dated from colonial times." (Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer. June 1981. page 1.) "Changes from an agricultural to an industrial economy had made it necessary to provide the rapidly increasing city population with food from distant areas. But sanitation was primitive compared to modern standards".

Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981, pg. 3.

2. The 1962 drug amendments

"The Drug Amendments of 1962, passed unanimously by the Congress, tightened control over prescription drugs, new drugs, and investigational drugs. It was recognized that no drug is truly safe unless it is also effective, and effectiveness was required to be established prior to marketing—a milestone advance in medical history. Drug firms were required to send adverse reaction reports to FDA, and drug advertising in medical journals was required to provide complete information to the doctor—the risks as well as the benefits."

Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981, pg. 12.

3. Vehicle Information Labels

Vehicle information labels in the United States include the 17-digit vehicle identification number (VIN) and also some or all of these: the vehicle emissions label, the certification (safety) label, tire information label, service parts identification label, air-conditioning label, coolant label, and belt routing diagram.

U.S. Tape & Label (USTL). "The Complete Guide to Automotive Labels."

Tiberio, Guy. "Vehicle Information Labels: The Stickers You Need to Know!" Slide Presentation.

4. The Trend Toward Prevention

One theme in the FDA's history is the change from primarily "criminal statute—protecting consumers through the deterrent effect of court proceedings—to" laws that are primarily "*preventive,"* including "informative regulations and controls before marketing" can begin. "The laws requiring approval" before marketing formed important changes in the FDA's methods regulating food and drugs in the United States (www.fda.gov). "They specifically required the agency to issue regulations explaining the requirements and procedures. The 1962 Drug Amendments" (see above) "called for current good manufacturing practice" (GMP) "regulations to set standards for plant facilities, maintenance," and l"aboratory controls," and to help "prevent errors or accidents" that "could harm consumers." In 1969, the first GMPs for food establishments were issued based on actual industry practices.

Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981.

5. Nutrition Labels

   The Nutrition Labeling and Education Act of 1990 (NLEA) “marked the culmination of a groundbreaking effort to provide information on food labels to help consumers make better choices and encourage food companies to produce healthier food.” “The NLEA required food packages to contain a detailed, standardized nutrition facts label with information such as: serving size; the number of calories; grams of fat and saturated fat; total carbohydrate, fiber, sugars, and protein; milligrams of cholesterol and sodium; and certain vitamins and minerals.” The 2020 Nutrition Facts label required “the largest food manufacturers (those with over $10 million in annual food sales) to use the revised label after the U.S. FDA announced an extension to its 27 May 2016 final rule.”

   Food Insight. “The Nutrition Facts Label: Its History, Purpose and Updates.” Food Insight (website). 9 Mar. 2020.

   Greenberg, Eric F. “The Changing Food Label: The Nutrition and Education Act of 1990.” *Loyola Consumer Law Review* 3, no. 1 (1990).

   U.S. Food and Drug Administration (FDA). *FDA Extends Nutrition Facts Label Compliance Dates*. 3 May 2018.

   U.S. Food and Drug Administration (FDA). *FDA in Brief: FDA Issues Final Rule to Extend Compliance Date on Updated Nutrition Facts Label and Serving Size Rules to Allow Industry More Time to Make Required Changes.* 3 May 2018.

   U.S. Food and Drug Administration (FDA). *Food Labeling: Revision of the Nutrition and Supplement Facts Labels.* FDA-2012-N-1210-0875. 21 CFR Part 101. 27 May 2016.

Further resources

1. Cavoukian, Ann. *Privacy by Design: The 7 Foundational Principles.* Toronto, ON: Information and Privacy Commissioner of Ontario, 2011.
2. “Estándares Iberoamericanos” (“Standards for Personal Data Protection for Ibero-American States”). Red Iberoamericana de Protección de Datos, Documentos, Estándares Iberoamericanos (website).
3. European Parliament and the Council of the European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016. *Official Journal of the European Union*. 4 May 2016.
4. Food Insight. “The Nutrition Facts Label: Its History, Purpose and Updates.” Food Insight (website). 9 Mar. 2020.
5. Janssen, Wallace F. “The Story of the Laws Behind the Labels.” FDA Consumer. June 1981.

Guiding Principle 10: Knowledge-based decisions, transparency, and accountability

Decisions should be based on metrics, sound data, relevant information, context, experience, and perspective; these factors all contribute to informed decisions, knowledge, and accountability. Knowledge-based decisions are thus made on the basis of good evidence and sound reasoning; this, in turn, can make hard decisions more defensible and accountable. Application of appropriate metrics and reevaluation of decisions should be carried out at appropriate time intervals to enable accountability, transparency, and corrective actions.

Background

The IEEE Planet Positive 2030 Initiative sets goals that require new designs, models, and ongoing discovery of processes that support coherent strategies and build collective knowledge of our entire ecosystems—putting the emphasis on contextual parameters, "systems," and "systems of systems." Metrics and accountability are essential for charting progress towards goals.

Information-based systems require meaningful metrics that measure the impact of the entire system on people and the planet, while developing new models for organic growth. Such information-based systems rely on metrics and measurements and, thus, build confidence and trust in our reporting. Furthermore, such accountable systems enable meaningful communications, inform new models for transitioning to performance improvement, and leverage technology to provide scenarios for transformation to sustainable systems.

To achieve sustainable and equitable outcomes, decision-making processes require refinement and precision based on scientific, data-driven methodology, including contributions by nontechnical disciplines (e.g., culture, history, education, communication, and policy). All stakeholders are accountable and have a responsibility as caretaker advocates to speak up about and share findings that may be expected to be impactful to the environment and biospheres—whether they are positive or negative impacts.

Technology is essential to achieving knowledge-based decisions, transparency, and accountability. There are real or perceived technology gaps and/or opportunities for significant improvements and technology development in a number of technology areas. For example, these may include sensors for data collection, information handling and information reliability, analysis, data security, data governance, AI, and AI explainability as well as tools—modeling tools, prediction and prognosis tools, communications technology, blockchain, and other collective intelligence processes as they are being developed.

There is a huge variety of sensors as part of the Internet of Things (IoT). Comprehensive data collection is one of the first goals for knowledge-based decision-making. The ever-increasing need for data requires tremendous amounts of sensors with different capabilities, sizes, functional life, power-requirements, and other features. For example, one area where there is a profound lack of data collection is in the ocean. One of the issues associated with ocean-based data collection is the limited life of the batteries powering sensors and associated transmitters and the lack of opportunity to replace or recharge these batteries.

As stated above: The IoT provides an increasing array of sensors for data collection, however the arena is problematic as there are gaps in labeling, licensing, IoT authorized/certified identity, and device registration over the lifecycle of the device. Data collection is especially hindered due to lack of interoperability between some of the IoT device and sensor types. The lack of Label, License, Identity, Interoperability (LLII) means that manufacturers design proprietary tests and descriptions while the procurers must rely on these ("Caveat Emptor") unless they are large enough to do their own quality assurance (QA) and testing on acceptance of the device, and during device operation on the data that is collected.

The European Union (EU) Digital Product Passport (DPP) initiative may address some of the LLII when the DPP gets designed and implemented for electronic devices. See also Guiding Principle 9.

Recommendations

1. **Determine organizational actions, behaviors, and public policy based on firstly comprehensive data, reliable information, and knowledge-based decision-making.** The increasing complexity, nonlinearity, and rapid pace of change in societies and environments render the transition to a sustainable future a "wicked problem" (Rittel & Webber, 1973). The planetary biosphere, ecosystems, and human societies are approaching tipping points. Transparency—at least—should be vital to any decision-making process.
2. **Involve multidisciplinary, interdisciplinary, and transdisciplinary teams in developing climate change, regenerative, circular economy, and sustainability policies for all jurisdictions and at all levels: at the business, academic, governmental, and political levels.**
3. **Show how data and analysis can help minimize errors and inaccuracies.** All organizations should be able to show and describe how data collection and the use of data (e.g., models, simulations, projections) have minimized inaccuracies and errors (e.g., bias, discrimination, race/gender skews) or at least account for variation, which can produce false or inaccurate outputs/reports. These may be from poor, biased, or insufficient data, poor methodology, lack of contextualizing, poor leadership, unethical behavior, and inaccurate representation.
4. **Practice and apply careful oversight and consideration with regard to the technological systems used for generating data-driven knowledge and outputs.**
5. **Engage an appropriate independent party to scrutinize decision-making processes for verification and validation with respect to relevant guiding principles.**
6. **Develop and implement policies about transparency, accountability, reporting, and decision-making processes. This is a request to all organizations.**
7. **Provide education and training about transparency, accountability, reporting, and decision-making processes throughout all organizations.**
8. **Continue to address the need for ever more inexpensive sensors with long functional life.** These sensors need to be designed for a circular economy; that is, at the end of use, the materials used to build any given sensor should be reusable as feedstock for new devices or, potentially, be biodegradable.
9. **Ensure source and validity of any data and information including accuracy, completeness, and process of and limitations on the data collection.** Associate a tracking record with data and information to be able to duplicate/verify said data and information. For critical information/data and information handling processes, a registry may be a tool to ensure reliability of the data, information, and associated processes.
10. **Develop standards for data analysis, data security, data governance, AI, and associated processes.** A majority of data collection, handling, reliability tests, analysis, security procedures for data, how

the data is governed, and the algorithms and pattern recognition incorporated in AI models may not be well regulated, and not subject to third party oversight.

11. **Develop interoperative regulation between different jurisdictions to address all aspects of information and data handling, governance, security, modeling, and AI**. For example:
    a. *Information handling:* Decision-makers need to be able to rely on trustworthy information and data. Standardized formats, processes, and oversight should be researched, developed, and implemented. An independent registry for" information handling" for information and data may be an option.
    b. *Information reliability and accuracy:* The user needs to know how reliable and accurate the data and/or information is. For example, the same type of data collected over time and/or across many jurisdictions around the globe will most likely have been collected using different sensors, thus leading to different data quality and accuracy. Data and information needs to be accompanied by process and accuracy information to attest to its reliability and accuracy. Furthermore, alteration needs to be prevented.
    c. *Data and information security and ownership:* It is essential that data governance be clear to all stakeholders and that security is a priority. Data privacy and security matters.
    d. *Education of the stakeholders of data, information, analysis, modeling, and AI:* Technology is being developed very fast—for example AI. It is essential that technologists, researchers, government examiners—for example patent officers—and users are well informed on all aspects of developing and implementing new technologies to enable them to critically evaluate technologies and their applications. This elevated level of training should also enable stakeholders and communities to engage early on as new models and modeling tools are developed.

Further Resources

1. Knight, Richard V. "Knowledge-Based Development: Policy and Planning Implications for Cities." *Urban Studies* 32, no. 2 (Mar. 1995): 225–60.
2. Masson-Delmotte, Valérie, Panmao Zhai, Anna Pirani, Sarah. L. Connors, Clotilde Péan, Yang Chen, Leah Goldfarb, et al., eds. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY: *Cambridge University Press*, 2021.
3. Matso, Kalle E., and Mimi L. Becker. "What Can Funders Do to Better Link Science with Decisions? Case Studies of Coastal Communities and Climate Change." *Environmental Management* 54 (2014): 1356–71.
4. Moser, Susanne C. and Julia A. Ekstrom. "A Framework to Diagnose Barriers to Climate Change Adaptation." *Proceedings of the National Academy of Sciences* 107, no. 51 (Dec. 2010): 22026–22031.
5. Wise, R. M., I. Fazey, M. Stafford Smith, S. E. Park, H. C. Eakin, E. R. M. Archer Van Garderen, and B. Campbell. "Reconceptualizing." *Global Environmental Change* 28 (Sept. 2014); 325–36.
6. Yousefpour, Rasoul, Christian Temperli, Jette Bredahl Jacobsen, Bo Jellesmark Thorsen, Henrik Meilby, Manfred J. Lexer, Marcus Lindner, et al. "A Framework for Modeling Adaptive Forest Management and Decision Making under Climate Change." *Ecology and Society* 22, no. 4 (2017).

References

1. The Africa Center for Strategic Studies. "Famine Takes Grip in Africa's Prolonged Conflict Zones." 15 Oct. 2024.
2. Alves, Bruna. "Biodiversity Loss: Statistics & Facts." Statista, 30 Apr. 2024.
3. Atwood, Tricia. "New Research Documents Bottom Trawling as Major Source of Carbon Added to Atmosphere." Utah State Today, Utah State University, Land & Environment, 18 Jan. 2024.
4. Atwood, Tricia, Anastasia Romanou, Tim DeVries, Paul E. Lerner, Juan S. Mayorga, Darcy Bradley, Reniel B. Cabral, Gavin A. Schmidt, and Enric Sala. "Atmospheric CO2 Emissions and Ocean Acidification from Bottom-Trawling." *Frontiers in Maritime Science* 10 (17 Jan. 2024).
5. Barbiroglio, Emanuela. "Choosing Sufficiency for Greater Fulfillment and Satisfaction." *Horizon: The EU Research & Innovation Magazine*, 25 July 2022.
6. Bayulgen, Oksan, and Jeffrey W. Ladewig. "Vetoing the Future: Political Constraints and Renewable Energy." *Environmental Politics* 26, no. 1 (2017): 49–70.
7. Biermann, Frank, Thomas Hickmann, Carole-Anne Sénit, Marianne Beisheim, Steven Bernstein, Pamela Chasek, Leonie Grob, et al. "Scientific Evidence on the Political Impact of the Sustainable Development Goals." *Nature Sustainability* 5 (2022).
8. Birol, Faith. "Seven Steps to Make Electricity Systems More Resilient to Climate Risks." World Economic Forum, 15 July 2021, accessed 30 Jan. 2023.
9. Bouckaert, Stéphanie, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner. *Net Zero by 2050: A Roadmap for the Global Energy Sector*. Paris: IEA, May 2021.
10. Breyer, Christian, Siavash Khalili, Dmitri Bogdanov, Manish Ram, Ayobami Solomon Oyewo, Arman Aghahosseini, Ashish Gulagi, A. A. Solomon, Dominik Keiner, Gabriel Lopez, Poul Alberg Østergaard, Henrik Lund, Brian V. Mathiesen, Mark Z. Jacobson, Marta Victoria, Sven Teske, Thomas Pregger, Vasilis Fthenakis, Marco Raugei, Hannele Holttinen, Ugo Bardi, Auke Hoekstra, and Benjamin K. Sovacool. "On the History and Future of 100% Renewable Energy Systems Research." *IEEE Access* 10 (2022): 78176 –78218.
11. Buesseler, Ken et al. and The Ocean Twilight Zone Team at Woods Hole Oceanographic Institution. *The Ocean Twilight Zone's Role in Climate Change*. Edited by Jesse Ausubel et al. The Ocean Twilight Zone Project.
12. Café Thorium. "Ocean Twilight Zone." Woods Hole Oceanographic Institution.
13. Clancy, Heather. "Carbon-Sucking Concrete Is Capturing Attention and Funding." GreenBiz, 6 May 2021.
14. Climate Action Tracker. "The CAT Thermometer." Dec. 2023.
15. Climate-KIC. "Monitoring, Reporting and Verification Sector." Co-funded by the European Union.
16. Christian, Kayti. "Sustainability Certifications: What Do They Actually Mean?" The Good Trade, 15 Apr. 2022.
17. The Data Team. "Climate Change Will Affect Developing Countries More Than Rich Ones." *The Economist*, 9 May 2018.

18. Davis, Anna J. "The Role of Nuclear Energy in the Global Energy Transition." The Oxford Institute for Energy Studies, Aug. 2022.

19. Davis, Kermal. "Devastating for the World's Poor: Climate Change Threatens the Development Gains Already Achieved." UN Chronicle, from vol. XLIV, no. 2 "Green Our World!" 2007.

20. Deep Space Food Challenge (website).

21. Desing, Harald et al. "Powering a Sustainable and Circular Economy—An Engineering Approach to Estimating Renewable Energy Potentials within Earth System Boundaries." *Energies* 12, no. 24 (Dec. 2019).

22. Dorian, James P., Herman T. Franssen, and Dale R. Simbeck, MD. "Global Challenges in Energy." *Energy Policy* 34, no. 15 (2006): 1984-1999.

23. Earth Overshoot Day (website).

24. Ellen MacArthur Foundation. "What is a Circular Economy?" Circular Economy Introduction.

25. Ellen MacArthur Foundation. "The Circular Economy in Detail." Circular Economy, 15 Sept. 2019.

26. European Commission (EC). "Ecodesign for Sustainable Products Regulation." Energy, Climate Change, Environment; Standards, Tools and Labels; Products, Labeling Rules and Requirements; Sustainable Products.

27. European Space Agency (ESA). "The 2024 Global Methane Budget Reveals Alarming Trends." 9 Oct. 2024.

28. Fadahunsi, Olayemi. "Climate Change on the Front Line: Why Marginalized Voices Matter in Climate Change Negotiations." Global Witness (blog). 9 Aug. 2017.

29. Ferreira, Alanielson, Roberto Ventura Santos, Tarcísio Silva de Almeida, Maryene Alves Camargo, José André Filho, Caetano Rodrigues Miranda, Saulo de Tarso Alves dos Passos, Alvaro David Torrez Baptista, Colombo Celso Gaeta Tassinari, Valentina Alzate Rubio, and Gabriel Godinho Capistrano. "Unraveling the Rapid CO2 Mineralization Experiment Using the Parana Flood Basalts of South America." *Scientific Reports* 14, no. 8116 (6 Apr. 2024).

30. Food Forward NDCs. "Reducing Emissions from Rice Cultivation."

31. Gai, Yijun et al. "Health and Climate Benefits of Electric Vehicle Deployment in the Greater Toronto and Hamilton Area." *Environmental Pollution* 265, pt. A (2020).

32. Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati, "A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." Journal of Cleaner Production 114 (2016): 11–32.

33. Government of Canada. *Hydrogen Strategy for Canada: Seizing the Opportunities for Hydrogen, A Call to Action*. Natural Resources Canada, Dec. 2020.

34. Greer, Rachel, Timo von Wirth, and Derk Loorbach. "The Waste-Resource Paradox: Practical Dilemmas and Societal Implications in the Transition to a Circular Economy." *Journal of Cleaner Production* 303 (2021).

35. Groh, Elke D., and Charlotte v. Möllendorff. "What Shapes the Support of Renewable Energy Expansion? Public Attitudes between Policy Goals and Risk, Time, and Social Preferences." Energy Policy 137 (2020).

36. Grosspietsch, David, Marissa Saenger, and Bastien Girod, "Matching Decentralized Energy Production and Local Consumption: A Review of Renewable Energy Systems with Conversion and Storage Technologies." *WIREs Energy and Environment* 8, no. 4 (9 Jan. 2019).

37. Hall, Stephen. "Can Crops Grow Better Under Solar Panels? Here's All You Need to Know About 'Agrivoltaic Farming." World Economic Forum, Industries in Depth, 26 July 2022.

38. Hansen, J. P., P. A. Narbel, and D. L. Aksnes. "Limits to Growth in the Renewable Energy Sector." *Renewable and Sustainable Energy Reviews* 70 (2017).

39. High Ambition Coalition for Nature and People (website).

40. Hong Vo, Duc, Anh The Vo, Chi Minh Ho, and Ha Minh Nguyen. "The Role of Renewable Energy, Alternative and Nuclear Energy in Mitigating Carbon Emissions in the CPTPP Countries." *Renewable Energy* 161 (2020).

41. Horn-Muller, Ayurella. "This Destructive Fishing Style Doesn't Just Harm Marine Life." *National Geographic*, 18 Jan. 2024.

42. IEA. "Infrastructure and Jobs Act: Nationwide Network of EV Chargers." 10 July 2024.

43. IEA. "Kenya." IEA 50, Countries & Regions, Africa.

44. IEEE. "IEEE Code of Ethics," adopted by the IEEE Board of Directors, 2020, accessed Feb. 2023.

45. IEEE. "The Role of Community Networks in Advancing Universal Access to the Internet." IEEE Position Statement, 2021.

46. IEEE. "Special Report: Water vs. Energy." *IEEE Spectrum*. 28 May 2010.

47. IEEE Standards Association (IEEE SA) "Green Hydrogen." Industry Connections Activities.

48. IEEE Standards Association (IEEE SA). *IEEE 7800, IEEE Recommended Practice for Addressing Sustainability, Environmental Stewardship and Climate Change Challenges in Professional Practice*.

49. IEEE Standards Association (IEEE SA). *IEEE P3469, Draft Standard for an Environmental Liability Process Model for Accounting in Systems Engineering*.

50. IEEE Standards Association, Industry Connections. The Sustainable Infrastructures and Community Development Industry Connections Program (website).

51. IEEE-USA Board of Directors. *Commercial Nuclear Energy and Technology Leadership*. IEEE-USA Position Statement, 24 June 2022.

52. Independent Electricity System Operator (IESO). "What's Phantom Power and How Can You Track It?" Save on Energy: Power What's Next.

53. Indigenous Corporate Training (website), accessed 16 Aug. 2022.

54. The Internet Society. "Connecting the Unconnected."

55. IPCC. "AR6 Synthesis Report." In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva, Switzerland: IPCC, 2023: 35-115.

56. IPCC. "Climate Change: A Threat to Human Wellbeing and Health of the Planet. Taking Action Now Can Secure Our Future." Press release no. 2022/08/PR. 28 Feb. 2022.

57. Kaplan, Robert S., and Karthik Ramanna. "Accounting for Climate Change: The First Rigorous Approach to ESG Reporting." *Harvard Business Review*, Nov–Dec. 2021.

58. Komor, Paul, and Morgan Bazilian. "Renewable Energy Policy Goals, Programs, and Technologies." *Energy Policy* 33, no. 14 (2005).

59. Johnston, Whitney. "Salesforce Unveils New Policy Priorities to Protect the Ocean." Salesforce, 8 June 2022.

60. London Hydro. "Green Button Platform."

61. Macdonald Fueyo, Judith. "Technical Literacy versus Critical Literacy in Adult Basic Education." *Journal of Education* 170, no. 1 (Jan. 1988).

62. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point Press, 2002.

63. Meredith, Sam and Lucy Handley. "'It Is Entirely Doable, and It Is Doable Fast': Experts on How to Navigate the Energy Transition." *CNBC*, 22 Nov. 2021.

64. Merrill, Laura et al. *Making the Switch: From Fossil Fuel Subsidies to Sustainable Energy*. Nordic Council of Ministers, 10 May 2017.

65. Miller, Riel. "Learning, the Future, and Complexity. An Essay on the Emergence of Futures Literacy." *European Journal of Education* 50, no. 4 (10 Dec. 2015).

66. Moriarty, Patrick, and Damon Honnery. "Feasibility of a 100% Global Renewable Energy System." *Energies* 13, no. 21 (22 Oct. 2020).

67. Morseletto, Piero. "Targets for a Circular Economy." *Resources, Conservation, and Recycling* 153 (2020).

68. Nuclear Energy Agency (NEA). "NEA Small Modular Reactor (SMR) Dashboard."

69. Our World in Data. "Global Direct Primary Energy Consumption."

70. Owens, Gene for U.S. Agency for International Development, Office of Energy, Environment & Technology, Global Bureau Environment Center. *Best Practices Guide: Economic and Financial Evaluation of Renewable Energy Projects*. Washington, DC: USAID, 2002.

71. Pacheco, Miguel. "Have Your Energy Drink and Drink It Too: How Hydrogen Fuel Cells Can Supply Drinking Water Along with Electricity." *Medium*, 16 May 2023.

72. Pasqualetti, Martin. "Social Barriers to Renewable Energy Landscapes." *Geographical Review* 101, no. 2, (Apr. 2011).

73. Pathak, Minal et al. *Technical Summary in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by Priradarshi R. Shukla et al. Cambridge, UK and New York, NY: Cambridge University Press (2022): 66.

74. Pershing, Jonathan, and Jim Mackenzie. "Removing Subsidies: Leveling the Playing Field for Renewable Energy Technologies." In *Renewable Energy.* Edited by Dirk Assmann. London: Routledge, 2006.

75. Piggot, Georgia et al. *Realizing a Just and Equitable Transition Away from Fossil Fuels.* Seattle, WA: Stockholm Environment Institute, Jan. 2019.

76. Plant, Katelyn. "Accessibility, Inclusivity & Climate Change Action." The Gaia Project (online resource), 10 May 2021.

77. Pörtner, Hans, Debra C. Roberts, Helen Adams, Ibidun Adelekan, Carolina Adler, Rita Adrian, Paulina Aldunce, et al. *Technical Summary in Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY: Cambridge University Press, 2022.
78. Ram M., Bogdanov D., Aghahosseini A., Gulagi A., Oyewo A.S., Child M., Caldera U., Sadovskaia K., Farfan J., Barbosa LSNS., Fasihi M., Khalili S., Dalheimer B., Gruber G., Traber T., De Caluwe F., Fell H.-J., Breyer C. *Global Energy System Based on 100% Renewable Energy—Power, Heat, Transport and Desalination Sectors.* Study by Lappeenranta University of Technology and Energy Watch Group. Berlin: Lappeenranta University of Technology, Mar. 2019.
79. Raygorodetsky, Gleb. "Why Traditional Knowledge Holds the Key to Climate Change." United Nations University (online resource), 13 Dec. 2011.
80. Ritchie, Hannah. "Sector by Sector: Where Do Global Greenhouse Gas Emissions Come From?" *Our World in Data* (online resource), 18 Sept. 2020, accessed 5 Sept. 2022.
81. Ritchie, Hannah, Pablo Rosado, and Max Roser. "Breakdown of Carbon Dioxide, Methane and Nitrous Oxide Emissions by Sector." Our World in Data, Jan. 2024
82. Rittel, Horst W. J., and Melvin M. Webber. "Dilemmas in a General Theory of Planning,"*Policy Sci* 4 (1973): 155–169.
83. Schaffar, Wolfram. "Alternative Development Concepts and Their Political Embedding: The Case of Sufficiency Economy in Thailand." *Forum for Development Studies* 45, no. 3 (2018): 387–413.
84. SDSN/FEEM 2021. *Roadmap to 2050: The Land-Water-Energy Nexus of Biofuels.* Sustainable Development Solutions Network (SDSN) and Fondazione Eni Enrico Mattei (FEEM). 2021.
85. Shaikh Khatibi, Farzaneh, Aysin Dedekorkut-Howes, Michael Howes, and Elnaz Torabi. "Can Public Awareness, Knowledge and Engagement Improve Climate Change Adaptation Policies." *Discover Sustainability* 2, no. 1 (23 Mar. 2021): 1–24.
86. Shrivastava, Paul, and Laszlo Zsolnai. "Wellbeing-Oriented Organizations: Connecting Human Flourishing with Ecological Regeneration." *Business Ethics, the Environment & Responsibility* 31, no. 2 (2022): 386–397.
87. Shukla, Priyadarshi R. et al., ed. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY: Cambridge University Press, 2022.
88. Sovacool, Benjamin K. "Expannding Renewable Energy Access with Pro-Poor Public Private Partnerships in the Developing World." *Energy Strategy Reviews* 1, no. 3 (2013): 181–192.
89. Statista 2024. "Number of People Without Access to Electricity Worldwide in Selected Years from 2000 to 2023, by Region." Statista, Energy & Environment.
90. Suski, Pauline, Alexandra Palzkill, and Melanie Speck. "Sufficiency in Social Practices: An Underestimated Potential for the Transformation to a Circular Economy." *Frontiers in Sustainability* 3 (4 Jan. 2023).
91. Tiberio, Guy. "Vehicle Information Labels: The Stickers You Need to Know!" Slide Presentation.
92. UN Climate Action. "Five Ways to Jump-Start the Renewable Energy Transition Now." May 2022.
93. UN Climate Action. "Renewables: Cheapest Form of Power." 19 July 2022.
94. UN Climate Change. "COP 28: What Was Achieved and What Happens Next?" 2023.

95. UN Climate Change. "Global Renewables and Energy Efficiency Pledge." UN COP28, UAE.

96. UN Climate Change. "The Paris Agreement."

97. UN Climate Change. *Summary of Global Climate Action at COP 28*. UNFCC, Global Climate Action, 11 Dec. 2023.

98. UN Department of Economic and Social Affairs (UNDESA). "Goal 7: Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All." Sustainable Development, accessed 9 Nov. 2022.

99. UN Department of Economic and Social Affairs (UNDESA), "The 17 Goals." Sustainable Development, accessed Feb. 2023.

100. UN Educational, Scientific and Cultural Organization (UNESCO). "Wadden Sea." World Heritage Convention.

101. UN Environment Programme (UNEP), Convention on Biological Diversity, Conference of the Parties, Kunming-Montreal Global Biodiversity Framework. CBD/COP/15/L.25 (18 Dec. 2022).

102. UN General Assembly. *Convention on the Rights of the Child*. Resolution 44/25, A/RES/44/25 (20 Nov. 1989).

103. UN General Assembly. *Declaration on the Right to Development*. Resolution 128, A/RES/41/128 (4 Dec. 1986).

104. UN General Assembly. *Declaration on the Rights of Disabled Persons.* Resolution 3447, A/RES/3447 (9 Dec. 1975).

105. UN General Assembly. *Report of the United Nations Conference on Environment and Development* (3–14 June 1992), Annex I: Rio Declaration on Environment and Development. A/CONF.151/26 (vol. I) (12 Aug. 1992).

106. UN General Assembly. *Universal Declaration of Human Rights.* Resolution 217 (III), A/RES/217 (III) (10 Dec. 1948).

107. UN Human Rights, Office of the High Commissioner. *Guiding Principles on Business and Human Rights*. HR/PUB/11/04. New York & Geneva, 2011.

108. UN News. "UN General Assembly Declares Access to Clean and Healthy Environment a Universal Human Right." United Nations, 28 July 2022, accessed 5 Sept. 2022.

109. UN University-Institute for Environment and Human Security (UNU-EHS). "2023 Executive Summary (website)."

110. U.S. 117th Congress. *Infrastructure Investment and Jobs Act*. H.R. 3684. Public Law No: 117-58. (15 Nov. 2021).

111. U.S. Department of Energy (DoE). "Declaration to Triple Nuclear Energy." Press release, 2 Dec. 2023.

112. U.S. Department of Energy (DoE). *Fuel Cells*. Energy Efficiency & Renewable Energy, Fuel Cell Technologies Office. Nov. 2015.

113. U.S. Fish and Wildlife Service, National Wildlife Refuge System. *Climate Change Communications and Engagement Strategy for the National Wildlife Refuge System.* Feb. 2014.

114. U.S. Geological Survey (USGS). "The Potential for Geologic Hydrogen for Next-Generation Energy." 13 Apr. 2023.

115. *U.S. Global Leadership Coalition* (blog). "Climate Change and the Developing World: A Disproportionate Impact." Mar. 2021.

116. U.S. Tape & Label (USTL). "The Complete Guide to Automotive Labels."

117. van den Homberg, Marc, and Colin McQuistan. "Technology for Climate Justice: A Reporting Framework for Loss and Damage as Part of Key Global Agreements," chap. 22 in *Loss and Damage from Climate Change: Concepts, Methods and Policy Options.* Edited by Reinhard Mechler, Laurens M. Bouwer, Thomas Schinko, Swenja Surminski, and JoAnne Linnerooth-Bayer. *Climate Risk Management, Policy and Governance* book series. Springer Open: 29 Nov. 2018.

118. Visram, Talib. "Low-Income Neighborhoods Have Fewer Trees. Here's Why That's a Problem." *Fast Company*, 22 June 2021.

119. The White House. "Biden-Harris Administration Announces Plan to Maximize Purchases of Sustainable Products and Services as Part of the President's Investing in America Agenda." Press release. 1 Aug. 2023.

120. World Wildlife Fund (WWF). Living Planet Report 2024 A System in Peril. Gland, Switzerland, 2024.

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METRICS/INDICATORS

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CHAPTER 2: METRICS/INDICATORS

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- Monique Morrow, Zurich, Switzerland
- Sadas Shankar, Ph.D., Research Technology Manager, Microelectronics, SLAC National Accelerator Laboratory, Stanford University, United States

Contributing Writers

- James Barbour, Livingston, Scotland, United Kingdom
- Chandramauli Chaudhuri, London, United Kingdom
- Flavio S Correa da Silva, University of Sao Paulo, Sao Paulo (SP), Brazil
- Robert Fish, Princeton University, New Jersey, United States
- Ruth Lewis, Melbourne, Australia
- Chandra Vadhana Radhakrishnan, Stanford University, United States

The Metrics & Indicators Committee acknowledges the Contribution of the following individuals:

- Maike Luiken, Contributing editor
- John C Havens, Technical Editor

METRICS/INDICATORS

Future Vision

It is 2030.

Sustainability has become an overall institutional framework that drives the human mindset and goal setting, rather than simply being a compliance exercise. This shift informed decision-making and clear commitments (e.g., targets, action steps, and transparent relevant information sharing) brought about by globally converging regulatory changes, and by interlocking mission-driven (Mazzucato,2015, 2018) innovation-enabling programs incentivizing regenerative socioeconomic transformations at both the company and global supply chain levels.

These alterations have been duly reflected in national and globally supported accounting and reporting rules. The Industrial and Information Ages brought innovations and developments that tied individuals and communities across our world closer together but also led to direct and indirect impacts on our planet, as evidenced by data from individual, societal, company, and government programs on sustainable development outcomes. Companies from all industries across the world have now recognized the necessity for every organization, individual, and society to work together to address gaps in the achievement of sustainable development goals.

By gaining knowledge and understanding of the problems, factors, and contributions to climate change through support and collaboration among organizations, a growing number of corporations now base their operations' success on data-driven decision-making and key performance indicators (KPIs) that now reflect how the products and services they design and develop increase long-term environmental and human flourishing. Countries, companies, and communities have changed their organizational structure and socioeconomic means to be results-driven, positive, and appreciative of global sustainability goals that improve life on Earth for current populations and for future generations to come.

Prices for products and services reflect the true and relative ecological footprint cost of overall resources, so net-zero or net-positive products and services are comparatively less expensive and much more attractive. Products are incentivized to be built to be sustainable and upgradable, rather than being disposable. These products and services are of benefit to poor countries in particular, which are more sensitive to rising temperatures and extreme weather due to reliance on rain-fed agriculture as well as a lack of financing and institutional capacity to implement programs in response to climate change.

These socioeconomic, institutional, and cultural shifts would not have been possible without the development of metrics and systems to measure, monitor, and influence progress towards a net-positive, regenerative society in ways that are innovative and flexible. Standard setters and policymakers have collaborated to assist in ensuring that metrics used to identify, measure, monitor, aand report on the impacts of sustainable development and climate risks on organizations and the impact of organizations on the environment are understandable, meaningful, and consistent.

Countries have taken on board the principles as set out in the **2015 Paris Agreement goals** and by the subsequent follow-up events and mechanisms serving its implementation, including the United Nations (UN) Sustainable Development Goals (SDGs) on Diversity, Equality & Inclusion targets and parameters.

Figure 1: Planet Positive 2030 Metrics & Indicators Committee/We Support the Sustainable Development Goals
(Image: See the Sustainable Development Network of the UN)

The measures of success against the Sustainable Development Goals (SDGs) have served and continue to serve to measure our collective progress in managing our planet's valuable resources.

Countries have recognized the importance of transparency and accountability and are now reporting actions taken and progress in climate change mitigation, adaptation measures, and dedicating resources to full transformation to optimize the use of resources and impact on the entire ecosystem. This has further driven stakeholders, agencies, organizations, and companies to take the necessary actions to meet agreed targets, with failure to meet these requirements resulting in increased costs of securing debt and for reconstruction efforts required by the increasing number and disruptive effects of events constitutive of the accelerating climate crisis. The information gathered through the increasingly sophisticated prevention and monitoring processes feeds into the global inventory, which assesses the collective progress toward long-term climate goals.

The journey has begun but much more has to be done to enable this vision to become a reality. As Earth continues its journey hurtling around the sun at an average speed of 30 km/s, the clock is ticking and there is much to be done, but the connected ingenuity of the human race, augmented by an ethically deployed AI, can make us all proud to be human again.

Introduction

Metrics and indicators are essential because, as the adage says, "what gets measured gets managed." Without metrics, we have no baseline, no means to measure against standards or requirements, and no means of assessing progress. Well-defined, consistent, and practical frameworks of metrics and indicators are the foundation for capacity building toward effective monitoring and management processes, fair and objective incentive and reward systems, enforcement programs, and accountability systems. By organizing and establishing a set of metrics, this allows for data-driven decision-making in addressing issues that our planet faces.

New climate change and sustainability-oriented measurements are essential to align *systems* with transparency and accountability for the single and collective impact on individuals, organizations (e.g., government, organizations, academia, and industry, also stakeholders), societies, and total ecosystems. New infrastructure design is required to support real-time agility, to adapt to changes, and to develop these systems with increased capability considering the limits to growth (Meadows et al., 1972), while improving life quality for all humans, species, and the planet.

Metrics and indicators provide measurements that afford us better understanding of processes, tracking of results, and discovery of optimized pathways, enabled by effective application of technology to deliver scenarios and prescriptive intelligent models, both as stand-alone systems as well as being part of a larger ecosystem. The science of measurements, standardized reporting frameworks, glossaries and definitions of terms, and weighted values of both quantifiable and qualitative measures are dimensions to overall sustainability that universally affect and interplay with all organizations and living systems.

To measure and guide this transition, it is imperative to leverage digital and other technologies for a sustainable future. If used responsibly, technology can have a profoundly positive impact on the environment and global sustainability goals, while also holding accountable technology's effect on our environment.

Effective use of metrics and indicators strongly relies on consistent measurements that meet relevant standards and recommends strategies for the increased use of ethically designed advanced technologies that deliver new insights on outputs/outcomes. The recommendations further outline strategies for developing reliable data with statistically proven principles that provide scientifically proven indicators that measure impact on the wider ecosystem, thus eliminating the trade-offs in the zero-sum game.

These technological applications will be aided by interdisciplinary and transdisciplinary approaches utilizing high-dimensional statistical models supported by artificial intelligence (AI)/machine learning (ML) approaches. In short, development of holistic designs that provide quantitative/qualitative measures of ecosystem impact and that map pathways with evidence-based data will facilitate our reaching goals of shared benefit to people and the planet.

The green and digital "twin transitions" also offer the promise of leveraging digital technologies for a sustainable future. Technologies like AI, blockchain, and the Internet of Things (IoT) can be harnessed for the renewable energy transformation, improve environmental forecasting and modeling, and accelerate scientific innovation for clean technologies (Clutton-Brock et al., 2019). They can also be a cornerstone of a future circular economic paradigm (Ellen MacArthur Foundation; William McDonough; Masterton & Shine, 2022) that replaces the current linear economic model that contributes to global sustainability challenges such as the climate crisis, biodiversity degradation, and pollution (One Planet Network, 2023). Consequently, the IEEE Planet Positive 2030 initiative aims to "identify the current technological solutions that need to be deployed widely as well as technology gaps for which we need to design, innovate and deploy new technological solutions" (IEEE Planet Positive 2030).

At the same time, digital technologies can also have a negative impact on the environment and sustainability goals. This ranges from the direct environmental impact of digital infrastructure such as data centers and the energy and resource requirements of advanced technologies such as AI (OECD, 2022) to the deployment of technology for business models and economic activities that run counter to climate and sustainability targets (Lange & Santarius, 2022). As digital technologies are often regarded as a crucial element in future systems such as decentralized renewable energy networks (IEA, 2022), it is paramount that technological solutions are designed in a way that maximizes positive sustainability impacts while minimizing and mitigating negative impacts such as energy use, GHG emissions, and resource consumption (Lange & Santarius, 2022).

This is why metrics, indicators, and standards play such a significant role in conceiving and implementing true *Strong Sustainability by Design*. The example of AI systems shows how difficult an environmental impact assessment can be for advanced technology—not only are standards and metrics for the energy, water, carbon, and resource use of AI systems often missing, a holistic impact assessment would also need to include the second- and third-order effects of the application of an AI system, such as rebound effects (OECD, 2022). Common metrics and indicators, consequently, are at the center of an initiative such as IEEE Planet Positive 2030 and its purpose to "give back more to the planet with technology than is removed and not to harm the biosphere/planet" (IEEE SA Planet Positive 2030).

Issue 1: Metrics development does not universally honor nature

Background

A balance of metrics and indicators is needed to shift away from the current—2023—win/lose focus of developing a "business case" driven by classical and neoclassical economics where scarce resources need to be allocated among projects that pit profits against social goals. Instead, metrics and indicators need to enable decision-making that facilitates improved resource access and enactment that supports the full vision of prosperity aiming to improve the life quality of present and future generations (Brundtland Commission, 1987) to live in harmony with nature.

The necessary paradigmatic change towards nature-prioritized metrics is intertwined with a profound multi-institutional shift toward a non-zero-sum decision-making approach that enables identifying and implementing multiple-win solutions regarding resource allocation. Such a shift, enabling extended and upgraded (mass) cooperation, has to be intertwined with recognizing and implementing in practice the consequences of human–nature interdependence. This pattern facilitates moving away from the institutional dual primacy of a zero-sum approach and resource scarcity view that generates exploitative, dominance-seeking, competitive, and collisional socioeconomic dynamism.

From an ethical perspective, this shift indicates priority given to ethics based on virtues, care, and duties instead of utility. It logically entails a drive toward social and economic equilibriums that are not influenced by a pre-established power balance and can be, therefore, truly inclusive and fair with respect to remote and less affluent regions of the planet (Brandt, 1980).

Sustainability should become a core value of human culture rather than just a compliance exercise and, therefore, be considered a system-level goal rather than a behavioral constraint. In such a broader context, the focus on quality metrics will be to help organizations assess if their actions are achieving what they value, rather than if they are hitting compliance targets. Such a robust cultural shift can also lessen the current tendency for short-term thinking driven by perceived immediate gains/targets (Barton, 2011). Instead, it can facilitate social innovation, business models, and pursuit of technologies that aim and show long-term potential of sustainable value creation and altruistic benefits.

Recommendations

1. **Address the need for the complexity of the types of metrics and systems required to measure full environmental impacts and support the pursuit of strong sustainability goals (Daly, 1991), and address the distinct need for technological tools to support the growingly automatic measurement, monitoring, reporting, and visualization of the aggregation of transformational sustainability-oriented processes.** The proper sets and implementation dynamics of metrics and measurements should enable us to elaborate on and implement effective methodologies aiming to radically lower emissions by allowing the "technologies of nature" to work and increase the regeneration, restoration, and resilience of Earth's ecosystems.

2. **Support the development of new, genuinely net-positive businesses (Polman & Winston, 2021) that are required to promote and implement regenerative approaches** (Robinson & Cole, 2015). These businesses should be aiming to and be capable of generating profit by restoring previously triggered (environmental and social) damage, that is, by going beyond avoiding further damage. These models should facilitate personal and collective life quality improvements through fulfillment of nature-prioritized metrics instead of prioritizing mass consumption and self-serving growth.
3. **Support and encourage civil society to play a strong, active role in the elaboration and implementation of such business models by generating favorable demand patterns, legislative (including taxation) environments, and supportive public resourcing.** The civil society players have to identify and get access to proper metrics and indicators, as well as to the capacity of modeling and simulating the possible contents and impacts of the interplay among the multiple components of the required societal and institutional changes that should unfold in various fields.
4. **Encourage cultural transformation such that it can unfold through alterations in the taken-for-granted perceptions that shape the everyday life of citizens (Perez, 2002) ready for "commoning" (Bollier, 2016) and acting as "prosumers" (Toffler, 1980), and provide civil society players with the need access to proper metrics and indicators, enabling them to carry out social agency by "going after the small picture"** (Giddens, 1984). The emergence of an altered green digitalization can be mutually catalytic and constitutive of an emerging Next Society (Reichel, 2012) of a new, collaborative era—a networked knowledge-driven civil society characterized by a more global cooperative and sharing social dynamism (Toffler, 1980, 1995; Perlas, 2000; Benkler, 2006, 2011; Rifkin, 2004, 2011; Reichel, 2012). These new systems interplay with robust institutional (Giddens, 1984) alterations that can aggregate into a societal culture characterized by new dynamics of cooperation going also beyond organizational boundaries.

Further resources

1. Bollier, D. "Beyond Development: The Commons as a New/Old Paradigm of Human Flourishing." Bollier.org, 25 June 2016.
2. Crawford, Kate. The Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press, 2021.
3. Frank, Adam, David Grinspoon, and Sara Walker. "Intelligence as a Planetary Scale Process." *Cambridge University Press* 21, no. 2 (Feb. 2022).
4. Mazzucato, Mariana. The Entrepreneurial State: Debunking Public vs. Private Sector Myths. New York: Public Affairs, 2015.
5. Mazzucato, Mariana. *Mission-Oriented Research & Innovation in the European Union: A Problem-Solving Approach to Fuel Innovation-Led Growth*. European Commission Directorate-General for Research and Innovation Publications Office, 2018.
6. Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens. *The Limits to Growth*. A Potomac Associates Book. New York: Universe Books, 1972.
7. Perlas, N. *Shaping Globalization: Civil Society, Cultural Power and Threefolding*. Center for Alternative Development Initiatives, Global Network for Threefolding, 2000.
8. Reichel, André. "Civil Society as a System." In *Civil Society for Sustainability: A Guidebook for Connecting Science and Society,* edited by Ortwin Renn, André Reichel, and Joa Bauer. Bremen, Germany: Europaeischer Hochschulverlag GmbH and Co. KG, 2012.

9. Sarkar, C. "The Rise of the Collaborative Economy." Interview with Jeremiah Owyang in *The Marketing Journal,* 12 Mar. 2016.

Issue 2: Sustainability reporting standards and indicators fail to measure accomplishment of sustainability goals and impact of actions taken

Background

"What gets measured, gets managed," so it is essential to measure climate and nature-based data and resources that are frequently not incorporated into most financially oriented or prioritized Corporate Social Responsibility (CSR) reporting. Our societies and organizations tend to collect data that is easily accessible and collectible as opposed to data that we may require for evidence-based decisions.

Metrics and indicators provide:

- A baseline against which progress toward sustainability goals can be benchmarked;
- Evidence of compliance with sustainability standards or requirements;
- Evidence-based results to strengthen net zero/sustainability commitments and accountability; and
- Tools to catalyze and drive the accumulation of changes into transformations facilitating the pursuit of net- and nature-positive goals and impacts.

Well-defined frameworks of metrics and indicators are the foundation for effective monitoring and capacity building, fair and objective incentive and reward systems, enforcement programs, and accountability systems. These systems need to be adapted and utilized to focus on evaluating and monitoring factors that make a difference in the pursuit of net-zero and net-positive-enabling regenerative outcomes.

The choice of metrics is also not a "one-and-done" and/or "once-and-done" exercise. Given the vast complexity and interdependence of global and socioeconomic systems, decision makers should recognize that metrics will need to be reevaluated as society moves to adopt sustainable development goals as set forth in the Paris Agreement or similar foundational goals. Unforeseen and unintended consequences need to be identified and addressed. For example, in order to provide Scope 3 (indirect) emissions disclosures, large companies will require information from suppliers, but what will be the impact on smaller organizations that don't have the means and resources to gather the needed information? Will they be excluded from the market? Are tools like the Basic Sustainability Assessment Tool (BSAT)[21] and E-Liability[22] an option for required or desired reporting? As another example, what happens if the practical measures aiming to decrease the world's dependence on beef and to increase plant-based foods lead to unfavorable shifts in biodiversity? These types of questions will require ongoing consideration.

[21] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[22] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

Finally, it is also important to recognize that when metrics are used to support cost and/or value estimates that an organization intends to use for disclosure purposes or to evaluate a project, measurement methods must fully reflect true costs and values. For example, if a company is evaluating the potential return on investment of offering a new product line, the costs included in the evaluation should reflect all costs to develop and produce the product responsibly (in other words, in a manner that adequately considers the needs of employees and other stakeholders, reflects the true value of resources consumed, and provides for remediation of environmental harms and regenerative actions.[23] Projects should not be deemed profitable if they create problems that harm the environment, animals, or human well-being that others will need to fix. This is fundamental to accountability.

Recommendations

Sustainability oriented metrics and indicators need to measure what matters:

1. **Design metrics or systems of metrics to measure what matters.** It is important that metrics (or sets of metrics) work together to support holistic decision-making, reflect priorities, and clearly align with the outcomes being sought. To achieve this, sound indicators linking sustainable goals to the elements being measured and monitored to provide a target and associated corrective actions should be considered (Fatima, Funke, & Lago, 2024).
2. **Design metrics and indicators to be broad enough to support multidisciplinary decision-making across the range of environmental, social, and governance issues that need to be measured and monitored on a country-to-country basis**. In a particular context, this might include elements of emissions produced, resources used, biodiversity impacts, human and social impacts, and other relevant factors to better assess the holistic impact of actions. For example, in addition to environmental impacts, consideration should be given to social consequences of societal shifts, such as:
    a. Job losses in sectors being reduced and retraining that will be needed to shift jobs to sustainable industries;
    b. Inequity in access to resources that support desired changes (such as access to public transit or plant-based food alternatives); and
    c. Unintended impacts on land development or biodiversity.
3. **Reflect and incorporate how legal rights for the planet are shifting, such as the acceptance of the legal personhood of rivers (e.g., Canada, New Zealand) and other ecosystems (**Berge, 2022). These changes provide examples of the way ahead for accepting and respecting the intrinsic value of nature (Barkham, 2021).

[23] In accounting terms, this is typically referred to as Natural Capital Accounting defined by The European Commission as, " a tool to measure the changes in the stock and condition of natural capital (ecosystems) at a variety of scales and to integrate the flow and value of ecosystem services into accounting and reporting systems in a standard way."

4. **Failure to consider the full scope might lead to short-sighted decisions without due consideration of the big picture**. Therefore, the following should be observed:
    a. Metrics should identify, distinguish, and support measurements of direct (primary) and indirect (secondary, tertiary, etc.) factors that cover the entire lifespan of the product/project. This provides a more complete and realistic impact assessment to evaluate options and disclose outcomes.
    b. Metrics must reflect the tensions between human development and broader biodiversity. Robust metrics help decision makers guard against unintended consequences that improve one factor from a human perspective but harm another element. For example, green energy sources such as water turbines and windmills can significantly threaten fish and birds, and these threats also need to be measured and monitored. From a biodiversity perspective, metrics must enable decision makers to interact with and manage the wicked problems emerging from complex systems whose interplay is driving the emergent Anthropocene[24] era.
5. **Support innovation. It is essential to determine appropriate metrics and indicators that will provide the necessary scope of information.** An example of an innovative metric for a particular context is when measuring circularity[25] of a project (where its design is intended to favor reduction, reuse or recycling of materials and resources versus favoring a linear process), consider measuring the "radius of the circle." Nature evolves using small circles in tight geographic areas. In contrast, humans might find a "circular" solution, but if that means building products on one side of the globe, shipping them around the world, and then shipping the obsolete product back around the world for it to be disassembled and reused, the radius of circularity is huge and likely linear in nature and much more wasteful than a smaller radius project.
6. **Develop metrics and indicators as well as the associated data collection and handling systems such that they facilitate the much-needed implementation of more integrated reporting systems that better track progress along net-zero roadmaps and more quickly highlight areas where further action is required.** Such systems should enable more regular, reliable reports to be provided at the board level to help ensure that sustainability is at the heart of organizational strategy.
7. **Measure impact from desired behavior changes, such as individuals choosing to support organizations that prioritize the circular economy or increased awareness and popularity of plant-based food options.**
8. **Design metrics and indicators such that they support investigation of root causes and beneficial actions that both can and should be undertaken to help validate or discredit assumptions that do not measurably increase sustainability goals.**

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[24] The Anthropocene era, as defined by Wikipedia, is a proposed geological epoch dating from the commencement of significant human impact on Earth's geology and ecosystems, including, but not limited to, anthropogenic climate change.

[25] "Circularity" refers here to concepts in design or statistics often referred to as Circular Design, defined by The Ellen MacArthur foundation as, "A systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature."

Issue 3: Operational sustainability metrics and data are not consistently accurate, reliable, and practical

Background

Metrics must reliably and accurately measure the factors that are needed to support decision-making, using the best proven, evidence-based methods available. From a practical perspective, they also need to reflect factors that can be reliably and consistently measured, rather than factors that are believed to be important but where the technology to measure the factors is not readily available or where there is no agreed-upon best-practice approach for measuring or calculating values.

Effective, evidence-based decision-making relies on the ability to evaluate data that is accurate and reliable. For example, when measuring and reporting on emissions levels, water use, or waste production of an organization or jurisdiction, it is essential that estimates be based on measurements, guesstimates and projections that are as accurate and consistent as possible.

The climate and ecosystems being measured are complex and dynamic, and more is being learned on an ongoing basis. It is, therefore, important that metrics be flexible and adaptable to changes as new measurement methodologies emerge and new standards and regulations are developed. For example, for years, a focus for climate-oriented metrics was on measuring carbon dioxide (CO_2) emissions, but current best practice suggests that GHG emissions should be measured using an enhanced GHG protocol that disaggregates measurement of relevant gasses such as methane, nitrous oxide, and CO_2, and considers their dynamic interplay.

In order for metrics to be practical, it is essential that they be defined in such a way that the necessary measurement information can be observed and collected. It does no good to define a metric if there is no reliable way to determine its value. For example, standard setters and regulators such as the United States Securities and Exchange Commission (US SEC) and the International Sustainability Standards Board (ISSB) started implementing requirements for corporations to disclose their Scope 3 emissions. While significant concerns have been raised by some stakeholders because of the challenges of accurately measuring Scope 3 emissions (Kaplan, 2021),[26] improved methodologies, technologies, and policies around these issues are bringing changes to address these needs.

Accurate, reliable, and consistent measurement and monitoring will be made more practical by employing technology and keeping up with enhancements made available by innovation. Depending on the specific application, this might include:

- Machine learning and AI technologies for data collection, interpretation, scenario modeling, prediction, and analysis (including the concept of a “digital twin”)[27];
- Immersive technologies such as virtual reality (VR) and augmented reality (AR) that facilitate simulations that allow for estimates to be determined for metrics in uncertain situations;

[26] One idea on improving Scope 3 emissions reporting can be found in the concept of “e-liability” reporting (as espoused by Robert S. Kaplan and Karthik Ramanna in Accounting for Climate Change), which utilizes traditional auditing methodologies to better balance accountability in overall supply chain reporting.

[27] Digital Twin: a concept providing digital or virtual copies of specific portions of the Earth to model potential climate, weather or ecosystem scenarios based on satellite or other aggregated data.

- Data analysis and storage using computing power centers and programs [e.g., cloud computing platforms, API providers, software (e.g., green software), audience]; and
- Blockchain and decentralized systems for data provenance that support reliability.

Evaluating metrics is made more relevant by benchmarking results against those of comparable projects, organizations, or jurisdictions. For example, investors and lenders are interested in current sustainability results and future potential of corporations, and benchmarking against other similar companies helps with decision-making. More broadly, organizations gain valuable insights as to their comparative progress by benchmarking against similar organizations. This requires reliable data for benchmarking to be publicly available.

Depending on the context, necessary measurement data for benchmarking can be derived from:

- Socioeconomic models [e.g., gross domestic product (GDP), Genuine Progress Indicator (GPI), the Human Development Index (HDI); and the UN Sustainable Development Goals (SDG) Index];
- Earth observation technologies for data acquisition [e.g., National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Institute for European Energy and Climate Policy (IPCC)]; and
- "Opt-in" data portals and repositories (for example, see CDP Open Data Portal and IEEE DataPort)—with suitable anonymization to protect sensitive information.
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Benchmarking results against data repositories does come with a caveat: it is important to recognize that data gets outdated quickly in some contexts and that it often does not transfer from one context to another. This is especially important when training AI (in addition to the general awareness of the impact of potential data bias).

Recommendations

Climate and nature-based metrics need to be chosen such that they are science-based[28], objectively measurable, practical, and reliable. To achieve this:

1. **Consider the challenges and limitations of data collection/measurement and related issues when choosing metrics.** Choose metrics that are practical to measure and interpret, to support consistent application and measurement (within and between organizations and over time) in order to and objectively gauge changes and facilitate progress.
2. **Evaluate new technological innovations to take advantage of ongoing advancement in measuring, analyzing, and monitoring progress/change/status, while being mindful of the limitations of the technologies used.**

[28] The Science Based Targets Network is an established and respected organization that provides metrics along these lines, providing "a collaboration of leading global non-profits and mission driven organizations working together to equip companies as well as cities with the guidance to set science-based targets for all of Earth's systems. This will help them define a clear pathway to ensure they are doing enough across their value chain to address their impacts and dependencies on nature."

3. **Review and assess new measurement approaches, recognizing that systems and countries are complex, adaptive, and interdependent with significant uncertainty and the potential for unintended consequences (both negative and positive).**
4. **Select metrics that can be adequately documented such that they can be independently verified (both for internal confidence and to meet regulatory requirements).**
5. **Benchmark results against trusted data, both internally (to track progress) and externally (to compare results against competitors, best practice results).**
6. **Implement data collection and measurement methods that enable efficiency by allowing data to be collected once and used in multiple ways or formats in compliance with established reporting requirements (subject to privacy legislation, industry standards)**; for example, public health data with organizations such as the World Health Organization (WHO), WHO Collaborating Centers, the Centers for Disease Control and Prevention (CDC), and Training Programs in Epidemiology and Public Health Intervention Networks.

Further resources

1. Clutton-Brock, Peter, David Rolnick, Priya L. Donti, Lynn H. Kaack, Nicolas Miailhe, Raja Chatila, Marta Kwiatkowska, et al. *Climate Change & AI: Recommendations for Government Action.* Climate Change AI, Centre for AI & Climate, and the Global Partnership for Artificial Intelligence (GPAI), 2021.
2. Coalition for Digital Environmental Sustainability (CODES). *Action Plan for a Sustainable Planet in the Digital Age*. 2022.
3. Levidow, Les, and Sujatha Raman. "Sociotechnical Imaginaries of Low-Carbon Waste-Energy Futures: UK Techno-Market Fixes Displacing Public Accountability." *Social Studies of Science* 50, no. 4 (Feb. 2020).
4. Sovacool, Benjamin, Noam Bergman, Debbie Hopkins, Kirsten E. H. Jenkins, Sabine Hielscher, Andreas Goldthau, and Brent Brossmann. "Imagining Sustainable Energy and Mobility Transitions: Valence, Temporality, and Radicalism in 38 Visions of a Low-Carbon Future." *Social Studies of Science* 50, no. 4 (May 2020).

Issue 4: Lack of interconnectedness and trade-offs between society, economic development, and planetary regeneration

Background

Change will require new mindsets and deep engagement of all levels of society, industry, and communities in a systematic way that reflects the interconnectedness of all life and various, often distant, elements on Earth, which must cooperate and combine their efforts to meet these challenges and enable continuous improvement and progress toward real-world aspirations for achieving net-positive results.

A shift in mindset is needed toward a more holistic, nonlinear approach, where sustainability is inherently valued, is a core expectation, and is measured, monitored, and designed accordingly, both for compliance and to drive sustainable innovation. This shift should be supported by a focus on core values that restore dignity and respect for *all life* so that humans can be proud of humanity. Change will require deep engagement at all levels of society, industry, and communities to meet the transformational challenges humanity faces in the coming decade. Monitoring and controlling changes probably will require the capacity to shift among metrics and measurements in various settings as changes unfold, resulting in managing decision trade-offs, as well as observing changes in views and behaviors. The benefit of one decision and focus on a few metrics may in the long term lean to an imbalance in the system, affecting another metric, which may be yet to be identified. The ability to understand the interdependencies and trade-offs can be fostered through physical reminders and simulations.

Recommendations

A fundamental change in mindset is required in order to let nature work, to reestablish its self-healing capacity. Aside from—and beyond—the prevention of new harms and destructions, the human players should monitor and, if necessary, support the (sets of) natural processes that are providing feedback and that can contribute to reestablishing the balanced operation of (particular) ecosystems and their interplay.

1. **Promote experiencing interdependence and interconnectedness in practice, so that we recognize ourselves, our teams, and our societies as interacting parts, active components of the various interplaying ecosystems.** It is important to overcome the destructive perception of being capable of dominating and freely reshaping nature. Instead, we must accept that humans, countries, and their organizations are part of nature, and we must relearn to live in harmony in order to improve our quality of life. Such a fundamental shift in human perception is intertwined, fed back with profound alterations in types and compositions of the various metrics and indicators to be used. The metrics may need to be balanced across the planet, suggesting interdependencies in countries, geographies, and industries. Thus, metrics can help us identify the changes that we need to make and measure the changes and the shifts. Embedding such new perspectives in education, from preschool to universities, will play a crucial role in achieving the desired mindset change and in building awareness and lifelong learning opportunities and should also emphasize qualitative changes to understand our complex world. An example would be technical means (e.g., simulations), rather than measuring learning and behavior.

2. **Improve our educational system such that it will graduate professionals who are knowledgeable about, understand, and employ sustainability-oriented metrics and indicators through their profession.** Metrics can enable us to see the world differently and preserve these interdependencies.
3. **Help local communities measure the effectiveness of various tools to educate and encourage more socially conscientious behavior by harnessing the power of the individual.** The ability to simply focus on the physical reality that is relevant to communities is important. For example, Copenhagen's waste system is an architectural wonder that sits visibly in the middle of the city. What impact has this had on the awareness of the public and their behavioral choices? Metrics need to be able to measure success in these areas, that is, measure and monitor what is resonating with people to support different methods of using tech and education (high and low tech) to change behaviors by improving self-image, self-awareness, and so forth. At the same time, however, we need to recognize that measuring and predicting the outcomes that will result from policy changes is inherently very difficult, given the complexity of the systems and because of the added complexity that results from *human behaviors*, which human models do not fully capture.
4. **Evaluate new technologies to simulate various realistic scenarios.** These technologies allow the user to understand factors that can change future economies: geography, politics, ecology, biodiversity, and human impact. Through these simulations, the individual can gain an understanding of their own role in the ecosystem and what they can personally do to contribute to the wellness of the planet. One example of such a technology is the use of metaverse concepts (extended reality simulations of both augmented and virtual reality), where real-time tracking and alternative future scenarios can be created. These overly personalized immersive experiences at various levels of society might enable individuals and collectives to review and assess their own and others' contributions to the ecosystems of the planet, as well as enabling the understanding of how they can contribute to the future wellness of the Earth.
5. **Consider employing simulations to help test, model, predict, and validate theoretical models and the appropriateness, understanding, and/or interpretation of specific metrics that have been chosen in a given context.** Care will be needed, of course, to avoid unintended consequences by carefully assessing the psychological and physiological impacts of these immersive technologies. And with any simulation, diligence will be required to see if the metrics are sufficient, the data relevant, and the models performing as anticipated under dynamic conditions.
6. **Employ personalization (such as a visualization of the green and sustainable transformation of an individual's own neighborhood) in order to educate and provide awareness of the pathways and agency of each participant to create meaningful change in the world, which can contribute to the change of current worldviews and the mindset in some societies that tends to favor the individual at the expense of the collective good.** Such personalization can capitalize on improved collective capacity of modeling and simulating diverse scenarios and (sets of) impacts of changes. For example, the simple act of advising you of your carbon footprint when booking a flight may change consumer behavior and indirectly affect industry choices.

7. **Use transition design methods and tools extensively.** Transition design methods and tools should include alternative scenarios played out through computer simulations linked to interdependent multiple variables that combine as interlinked systems with other variables that individuals can manipulate to create realistic simulations of outcomes by changing and controlling these variables. Variables as input will be not only based on historical or current data but include qualitative variables, particularly relevant for creating long-term images of the future. For instance, variables and systems analysis may be simulated (e.g., based on the original "Limits to Growth" study by the Club of Rome in 1972 and subsequently updated since then). This computer simulation of planetary boundaries showed that the planetary system cannot support current rates of economic and population growth indefinitely and that this limit can be projected and defined and is dependent on specific resource factors such as agricultural production, population increase, hydrocarbon energy depletion, pollution, and industrial outputs, which are extrapolated into the future.
8. **Use various ways of creating scenarios and simulations for individuals to experience "different futures."** Create simulated "experiential learning." Computer (serious) gaming simulations can be another method for creating visual scenarios of the future, creating opportunities for participants to not only view and change variables but to actually experience each of the projected images of the future. These methods will be critical for creating visceral and fundamental change of mindsets and worldviews, particularly among those with significant power to make fundamental changes in society.
9. **Develop and implement reliable impact assessment tools and simulations.** At a stakeholder level, impact assessment tools that incorporate simulation methodologies can allow organizational decision makers to better predict and evaluate the impacts (positive and negative) of their strategic and operational plans. If these tools are reliable, they will help to shift the mindset and priorities of senior leadership and government functionaries by presenting consequences in a manner that is more certain and less deniable.
10. **Improve ethical use of technology.** All technologies used for scenario simulations and design shall be governed for ethical use and application through strong ethical frameworks and standards, such as the Organisation for Economic Co-operation and Development's (OECD) AI Principles, the upcoming European Union AI Act, and those under development by the IEEE Standards Association.
11. **Consider trade-offs between using technology to support sustainable development and the impact of using the technology on resource use, the environment, and people.** The technology requirements include tools that assist with training; behavior outcomes are from the individual (e.g., coaching) to the community to the organizational stakeholder's level and are integrable, comparable, and adaptable based on environmental contexts and circumstances as well as educational (empathetic) contexts across cultures, circumstances, and ecosystems. AI and immersive reality technologies are not as sustainable as we would wish them to be; hence, the trade-offs are important.
12. **Consider trade-offs such that data collection is meaningful and that associated storage is effective. In other words, consider image, video, or other document storage, where the files are stored in multiple locations—beyond the requirements for effective back-up and retrieval—and without expiry dates (exceptions are files that require deletion due to legislation)**. Do we really need all the data centers?

Issue 5: Lack of recognition of global ecological and environmental interdependence

Background

In an era when individualism favors instant perceived gratification, joining together around the globe to reach net-zero and net-positive goals provides an essential opportunity to restore dignity and respect for all life.

The recognition and acceptance of humanity's global interdependence with nature allows humans to approach the planet with the aim of being in harmony with nature rather than trying to dominate it. Respecting life and accepting that every living being/organism has intrinsic value that should be respected enables humans to seek stewardship rather than domination of nature—that is, not using it solely as a tool and resource to further humanity's own pursuits. By seeing ourselves, that is, humanity, as dependent—but active—parts of nature, we can approach harmonic relationships with the world around us. But this perspective requires overcoming the still mostly dominant, mistaken, destructive—and *self*-destructive—utilitarian perception of seeing humanity as an independent ruler that exists at a remove and freely exploits nature.

Humans are not the only species that inhabits planet Earth, but we are the species that has evolved toward an illusion of domination of the planet and control of its destiny. The responsibilities that result from acceptance of this view have not been adequately considered. The journey of the human race has been one filled with innovation, from learning how to fashion tools and making fire to inventing the wheel, the industrial revolution, and various traveling machines as well as the first computer, the world wide web, and—forthcoming—quantum computing. Until the past 200 years, at no stage did much thought appear to be given to the consequences of our actions on the planet that has greatly benefited past and current generations; instead, humans failed to consider the impact on the generations that will follow. Thankfully, this failure has at least been recognized in the UN's definition of *sustainable development*:

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*
> (Brundtland Commission, 1987)

However, this definition appears to only recognize the human perspective of future generations and should be widened to better reflect biodiversity and the future sustainability of all life on this planet. This would increase alignment with the specific sustainable development goals, which do reflect broader life forms, albeit to a lesser degree. A simplistic example of the domination of the human interest is depicted when a plane is hit by a bird strike. No thought is ever given to the birds destroyed by the plane's engines. Humans were not given wings or wheels, but their ingenuity in enhancing their lifestyle has resulted in threats to other species that inhabit this planet, as can be seen by the amount of wildlife accidentally killed by vehicles on the roads and marine life sickened by industrial waste.

In accepting that interdependence together with a non-zero-sum approach should have institutional primacy, it is important to recognize also the intrinsic value of every—and any—living being. However, the current attempts to use "financialization" and the price signal to set a market value for other species are pointing us in the wrong direction, strengthening a utilitarian, exploitative, and dominance-seeking approach.

Therefore, there is a need for the human race to recognize and address the risks faced by other species. Some humans have already adopted this mindset as they seek to preserve endangered species. This can only happen if more humans take personal responsibility for our actions. This starts with the leaders of the world. The world cannot tolerate the risk of a war that could result in an almost uninhabitable planet on which very few species would survive. This is not a political issue, but the extent to which power is in the hands of just a few individuals is of great concern, as there are no appropriate safeguards to mitigate that risk.

There is also a real risk that the future of the planet will not be determined by the many but by the few who currently dominate the technological powerhouses that, in some ways, govern our lives. There must be a world in which its resources are more equitably shared to allow many more to enjoy a better life. There also needs to be proper accountability, where individuals are held to account for their actions.

There is also the need to consider the future implications of Artificial General Intelligence (AGI) if and when that will be reached. A future with AI raises questions and concerns: Will there be a need to respect the rights of the AI robots or other AI "species"? Is such a circumstance a possibility? To what extent are these concerns relevant for the development of a sustainable future? What metrics and indicators should be monitored to help ensure that human influence in global evolution can continue to be constructive?

While these debates must be held, in the interim, technology will assist us in helping the planet by:

- Helping to appropriately mitigate risks of global warming. Doing so will not only benefit the human race but all other living things on this planet.
- Providing better data on the location of endangered species, thereby assisting in their protection (e.g., the use of infrared sensor technology with AI has assisted in monitoring the location and population of koala bears in Australia, where many have been killed by the recent increase in bushfires).
- Breaking down language barriers with more effective real-time translation.
- Providing a better understanding of the thought and communication processes of other life forms to build broader empathy.
- Assisting in true value assessments, calculations, and feedback loops of the things that are essential for life on this planet.
- Assisting in more accurately predicting incoming asteroids and other space debris that could cause serious damage to Earth, and facilitating means by which we can divert the trajectory of such threats, in the interest of all living things on this planet and others.

Recommendations

1. **Utilize new metrics that measure total impact on the entire ecosystem**. **Resolve the "hierarchy of rights" of species on planet Earth per country.** Genuine changes require overcoming attempts of financialization in order to reflect the (true market) "value" of life, living beings, and nature as we know it. There is a need to properly consider how the broader ecosystem can be prioritized over the desire for growth. This is a key matter to be resolved, since Earth and Earth's resources are finite and current human impacts on the Earth are causing much damage to the biosphere: pollution of air, soil,

and water and ecosystem degradation to name a few. If current trends of human impacts on Earth continue, humans may not have a planet to inhabit in the long run. These will be complex matters to reach agreement on, but addressing these issues can help create the appropriate legal foundations for the sustainable development of the human race and all other life-forms on this planet.

2. **Develop policies and regulations to increase transparency and accountability for total impact on environmental sustainability.** It takes time to change regulation, and, even more so, human behavior. The ultimate success of laws and regulation is to have changed human attitudes and behaviors, for example, bans on smoking in public places.
3. **Define impact in preserving and true value in using natural resources. Measure, test, and apply accurate measurements of the true cost of using natural resources and resulting true value.** Metrics and indicators must align with any new work to properly reflect true cost and value. The acceptance of the legal personhood of rivers (New Zealand, Canada) and other ecosystems provides examples of the way ahead for accepting and respecting the intrinsic value of nature. This approach leads to a paradigm shift that feeds back with overarching transformations in our system of metrics and indicators. These should reflect and contribute to a robust transformation at the organizational level, including our fundamental socio-cultural values serving as drivers of our socioeconomic activities. Because robust economic transformations also affect accountancy, other indicators must be considered in any evaluation of positive transformation.
4. **Prioritize building better datasets to assess, calculate, and monitor progress with indicators that measure total impact.**
5. **Build progress indicators that measure the consequences of human actions in a holistic way and measure the total impact of human actions from a holistic perspective, including feedback loops**. As we move towards a net-positive future, we must also guard against unintended consequences that improve one factor from a human perspective but harm another element. For example, green energy sources such as water turbines and windmills can significantly threaten fish and birds. Short-term human well-being cannot come at the cost of indiscriminate further harm to other life-forms and natural systems. This mandate must be built not only into human decision-making but also into intelligent systems that we develop to aid sustainability, particularly before they are given autonomy over their actions.
6. **Apply a regenerative circular economic approach, where possible, to prioritize reversing past harms as we build a sustainable circular economy for the future.**

Further resources

1. Barkham, Patrick. "Should Rivers Have the Same Rights As People?" *The Guardian*, 25 July 2021.
2. Bennett-Jones, Owen. "Should Animals Have the Same Rights as Humans?" BBC News, 26 May 2015.
3. Global Accounting Alliance. *A Call to Action in Response to the Nature Crisis*.
4. Wikipedia, s. v. "Animal Rights." Last modified 17 Apr. 2023.

Issue 6: Lack of socioeconomic transformation toward sustainability

Background

With strong sustainability by design and accountability as the goal, the UN SDGs form a universally recognized benchmark for transparency, reporting, and a measure of impact. SDG scores can be mapped to environmental, social, and corporate governance goals, and if well deployed and governed, can potentially facilitate and contribute to genuine regenerative socioeconomic transformations.

Effectively tackling the multiplying challenges posed by the climate crisis requires profound and robust socioeconomic transformations, decreasing global material and energy flows, while exceeding neither environmental nor social limits as described, for example, in the doughnut model (Raworth, 2018). Targeted robust and transformative systemic level changes can provide powerful and even game-changing contributions to the necessary transformations. To have real benefit, however, changes need to achieve buy-in and leverage the power of key players, such as the "Carbon Majors" that are currently the source of more than 72% of the global GHG emissions (Climate Accountability Institute).

The likelihood of genuinely transformational alterations can be significantly enhanced by building on business models that enable preservation of the planet and improve outcomes through truly sustainable and regenerative activities. Such business models must enable the owners and operators to reallocate stranded assets, frequently overcoming trillions in US dollars in market value, through truly regenerative activities.

The pathway to transformation requires the definition of goals that will serve to measure results and indicators that measure progress towards these goals. The ability to communicate these results in new and meaningful ways provides transparency and new accountability.

There is a growing awareness and popularity of ESG-related financial activities, products, (hedge) funds, advisors, ratings, and other related investment services that are important users of sustainability-related metrics and indicators along with the underlying complex models and simulations. However, there is still some confusion and lack of consistency about what the ratings are actually measuring. The investment funds often focus on the investors' risks by gauging how well an organization is addressing climate risks from the perspective of *organizational* sustainability (how likely the company is to survive or thrive)[29] (Engler, 2022). These pay less attention to whether the company is positively or negatively impacting environmental and social ecosystems. For example, MSCI's ESG ratings "aim to measure a company's management of financially relevant ESG risks and opportunities" using "a rules-based methodology to identify industry leaders and laggards according to their exposure to ESG risks and how well they manage those risks relative to peers." While this is valuable information for investors, it doesn't answer the larger questions of overall impact of the company and their commitment to ESG innovation and progress.

Use and explanation of the proper metrics, measurements, and indicators are needed to enhance awareness as well as to catalyze targeted education and knowledge dissemination among decision makers, including members of corporate governance bodies and other market and public sector players.

The reporting of quality metrics is an essential element in holding organizations accountable for setting and meeting meaningful goals and complying with regulatory requirements. Under the Sarbanes-Oxley Act in the

[29] What is often termed as single materiality versus double materiality.

United States, for example, chief executive officers (CEOs) and chief financial officers (CFOs) of public companies are required to personally certify the accuracy and completeness of annual and quarterly reports and the adequacy of internal controls with respect to these disclosures.

Recommendations

In order to effectively reduce the global material and energy flows, it is of paramount importance to systematically build and strengthen transparency, especially for corporate accountability. The enhanced transparency can establish trust in reported impact and commitment to goals and promote the effectiveness of actions being taken primarily by the economic players:

1. **As requirements evolve to include disclosure of sustainability metrics, certification exigencies should be mandated for the responsible C-suite positions so that key decision makers are publicly accountable for the information released by their organizations**. In the interim, voluntary certification should also be encouraged.
2. **Organizations should be encouraged to make the CEO directly responsible for sustainability.** For example, IKEA has combined the CEO and chief sustainability officer (CSO) positions at the country level (so country-level CEOs also hold the CSO title).
3. **The personal *remuneration* (salary and benefits) of persons in C-suite positions and individuals active on boards and governing bodies should also be connected with the environmental performance and footprint reduction of the organization(s) for which they are responsible.**
4. **Implement effective monitoring of investments.** Without effectively monitoring their genuine impacts, the large investments often described as sustainability-driven and sustainability-focused constructions can become major facilitators of destructive green washing.
5. **To effectively encourage innovation and net-positive performance (Polman & Winston, 2021), this accountability should be reflected in monetary and nonmonetary rewards for an organization's leadership team and employees at all levels to encourage and reward expected behaviors.** The board of directors can further build accountability for executives in making commitments and taking actions to achieve sustainability by incorporating the relevant performance metrics into the measures shaping their ***remuneration***.
6. **Design and implement a proper set of metrics and measurements that effectively gauges the firms' GHG emissions and carbon footprint while measuring the effect of the transformational business models and such innovative financial tools as ESG.**
7. **Provide visibility for company achievements that simultaneously facilitate enhanced regenerative and financial/profit outcomes while successfully implementing innovative business models.** This is of crucial importance.
8. **Create effective sustainability ratings and indexes. By creating community ratings or other effective sustainability indexes on ESG and performance, all stakeholders—individuals, organizations, corporations, various local peers—could receive feedback and, through transparency, the firms can be benchmarked against other stakeholders and held accountable in their community for their results.** Such transparency can promote the culture of sustainability and quality-of-life-focused public policies in communities and countries by sharing knowledge and following circular economic patterns while using locally available natural resources in networks of green communities, smart cities, and other initiatives building and capitalizing on regenerative efforts.

9. **Enable individuals and organizations by providing trusted information to make purchasing decisions.** Individuals and their self-organized teams can use their purchasing power: buying goods and services from responsible organizations and selecting net-positive products and services by using information from reliable sources such as validated consumer labeling.
10. **Grow public awareness and trust and thus encourage cultural transformation**. Convergence among the relevant metrics and standards can facilitate enhanced awareness and transparency. These, in turn, can contribute to a broadening cultural transformation that reflects and puts into daily socioeconomic practice a robust shift that promotes the genuinely regenerative paradigm (Robinson & Cole, 2015) enabling management of the multifaceted challenges of the climate crisis.
11. **Use a broadly accepted set of relevant metrics and standards to facilitate elaborative models,** carrying out simulations similar to **En-ROADS** (Climate Interactive, En-ROADS Climate Solutions Simulator) and making their findings broadly accessible and personally engaging through visualization by using tools such as dashboards, gamification, AR tools, the metaverse, and so forth.
12. **Foster growing public and individual awareness**. It can contribute to an emerging culture of care and stewardship and, in turn, catalyze both quality-of-life-focused new patterns of (mass) consumption favoring sufficiency and regenerative initiatives of economic players. This interplay can facilitate and capitalize on the emergence of positive feedback loops. An important feature of the dynamic (e.g., rolling) sets of metrics and standards serving effective accountability should be their capacity to facilitate due transformations. These should enable making visible, measurable, and controllable the aggregation of the feedback from changes contributing to these overarching transformations.
13. **Deploy and use technology effectively.** The technology requirements include tools that quantify and define engineering systems and infrastructure to consumption and environmental output levels across demographic, cultural, sustainability, educational, and socioeconomic (e.g., accountability) factors.

Issue 7: Technology does not always contribute to socioeconomic evolution towards ecosystem regeneration and sustainability goals

Background

Achieving meaningful change enabling societies and individuals to overcome the multiple crises characteristic for the Anthropocene (a proposed concept still under much discussion; Zhong, 2024) requires moving beyond mere compliance to a higher level of planetary progress and innovation. To accomplish this, a new green economy and sustainable alternatives must be inherently attractive at both individual and organizational levels. A strong sustainability in organizational context is driven by the acceptance of interdependence and a non-zero-sum approach. As these become core values, it generates a genuine potential for everyday economic activities to become regenerative. As societies shift towards recognizing the inherent benefits of sustainable living as the norm, our regular economic activities will not only fulfill genuine human needs but also contribute to the recovery from previously caused social harms and environmental destruction.

Indeed, a regenerative ecosystem, including the economy, enables conscious and active stewardship, where the restoration of previously affected elements becomes an inherent and fundamental task of economic activities by moving beyond merely avoiding harm to the environment and society (Daly, 1996; Shannon et al., 2022). However, such an approach requires radically different metrics and indicators compared to traditional sustainability. Even to overcome reliance on single and oversimplified indicators, such as growth and/or profit/profitability (Kuznets, 1962; Stiglitz et al., 2009), demands robust shift in measurement. Furthermore, the complexity of the Earth's ecosystem, as the immediate context for human socioeconomic settings, necessitates a mastery of a systemic approach. This involves considering the dynamic feedbacks among multiple factors, often generating interplaying loops. And it requires the conscious overcoming of limitations arising from the dominant logic of linearity and the related sets of metrics and indicators.

An effective organizational capacity for addressing the growing challenges of the emerging Anthropocene depends on managing a rapidly increasing volume of measured data and understanding their genuine dynamics unfolding at systemic level. To handle the expanding quantity of data that the rapidly growing number of sensors globally "pours upon us" a process-oriented approach must replace the commonly deployed variance methodology. This robust methodological challenge is intertwined with an underlying shift to process ontology bringing about significant and demanding epistemological alterations too. Following process epistemology requires powerful transformations in our, that is, people's, visions and perceptions, even in the language we use to perceive and describe reality. Rather than seeing these ontological and methodological approaches as diverse or even contradictory, we should combine them into a coordinated pluralistic view. By doing so, we can forge effective tool sets for perceiving and governing organizations and their activities, allowing us to carry out a praxis that reshapes reality (Van de Ven & Poole, 2005).

The ontological and epistemological claims emerging in connection with effectively addressing the robust challenges inherent in and generated by the multiple crises of the Anthropocene are inseparable from changes in the realm of metrics and indicators. It is crucial to acknowledge that the data required to handle the challenges of the complexity characteristic of the various feedback (sub-)systems are context-dependent. Radically altered methods and tool sets of measurements should be employed to reflect, monitor, and address multiple alterations that should aggregate into systemic—and systematic—transformations. These alterations concerning metrics and indicators are necessary for, and also constitutive of, a growingly urgent socioeconomic shift to a genuinely regenerative systemic setting, enabling us to help ensure the survival of our civilization.

The urgent global need for a truly effective environmental science capable of understanding the Earth's ecosystem at a systemic level makes complex tasks more difficult. We are starting to realize that there are many "unknown unknowns" (Welch, 2023), even in fundamental fields such as the "operation" of the global water system, including the ocean. We must simultaneously tackle the lack of truly significant data while trying to manage a perceived data overflow that is more relative than real. We must grapple not only with *how* to measure but also with the proper identification of *what* and *when* to measure in a particular context.

Furthermore, the potential contributors to the necessary and increasingly urgent collective efforts should rely on state-of-the-art modeling and simulation capacities. These capacities can serve to build communities and reset individual and collective expectations of what is possible and worth pursuing. Such positive impacts can help the public to realize that transformations facilitating deep sustainability are fundamentally in their favor, instead of limiting or prohibiting individual life choices. Resulting demand changes can simultaneously trigger and catalyze attractive trends that both market and public players can capitalize on. Indeed, alterations in demand have robust transformational potential also for the supply side, catalyzing and shaping the emergence of an economy that aims to serve and improve harmony with nature. Its emergence and functioning require well-designed regulatory environments connected with target-oriented public funding and grants. Deploying mission-oriented public innovation management (Mazzucato, 2015, 2018) can provide a favorable framework for creating an attractive environment catalytic for progress.

Public financing, focusing on genuine moonshot projects (i.e., innovative projects with ambitious and lofty goals requiring intense collaborative efforts) carried out on Earth, can bring about significant multiplicative effects during the funding process (Mazzucato, 2015, 2018). Remunerating efforts that contribute to restoring previously generated damages can effectively motivate and incentivize long-overdue transformations. As an example, carbon removal research is both expensive and uncertain and doesn't align with typical company metrics on dashboards, resulting in underfunding. Recognizing both the need and the opportunity, Frontier Climate, a market maker facilitating funding for uncertain projects, is supporting carbon removal through an advance market commitment, pledging to purchase $925 million of permanent carbon removal between 2022 and 2030. Well-orchestrated public facilitation is required to achieve the profitability of economic activities that follow truly regenerative business models. The selection of proper sets of metrics and indicators can serve as drivers and monitoring tools for individual and corporate decision-making, shaping the daily operations of organizations in all sectors.

Developing accessible proper metrics that measure systemic impact presupposes the regular enactment of artificial intelligence, machine learning, and big data—the new technological "holy trinity." Similar state-of-the-art technology sets provide the capacity for both daily monitoring and modeling/simulation of potential ecosystem-level impacts stemming from the deployed governance patterns. However, qualitative and/or low-technology information collections for measurements and indicators should also be used to encompass aspects of the environment, communities, and societies that are not amenable to real-time, periodic, or historical data collection.

This is particularly relevant where access to remote locations, communications, or the internet is unavailable, fragmented, or unreliable, or where greater harm may result within society due to high-technology presence or intervention. It is important to think holistically and systematically about how to collect information about the entirety of planetary health. The collection and analysis of relevant datasets require integrating state-of-the-art technology with proper methodological tools, and the outcome of data processing must be freely available and consciously shared with affected stakeholders. Deploying such data-handling capacities should interplay with regulatory steps (European Union, 2018) and business strategies that drive and utilize the aggregation of local changes into the global transformations required to handle the growing challenges connected to climate change.

In the context of increasingly urgent transformations, the role of digitization and technology, in general, cannot be overstated. There is a pressing need for real-time, local, and systemic-level monitoring of emissions to rapidly influence and transform the characteristic patterns of energy production, usage, or land management, which are important sources of such emissions. More efficient energy and resource management (Shearman & Sterling, 2022) requires the proper combination of artificial intelligence, machine learning, and big data, while the widespread deployment of blockchain technologies can help improve transparency and catalyze trust (IEA, 2023).

A truly regenerative approach requires learning how to let nature carry out genuine systemic healing rather than placing high hopes on attempts similar to massive geo-engineering (IEA, 2023; IPCC, 2018). Measuring the complex feedback processes constitutive of the “routine operations” of nature, however, is a demanding task, also in the context of metrics and indicators. Sufficient and effective governance, security, data provenance, and privacy must be provided and maintained around all data and information collected for the purpose of planetary measurements and indicators. It is important that data provenance and ownership reside within the same society that the collected data represents, and that planetary monitoring does not evolve into a surveillance society. This could create additional harms to the planet and may be misused against individuals within the society.

The target-oriented enhancement of mass awareness and engagement, providing genuine empowerment and readiness to contribute to solutions, can capitalize on enhanced accessibility and effective visualization of data, using, among other tools, dashboards. The dashboard developed in accordance with IEEE Std 7010™-2020 indicates plausible links between human well-being and the impact of autonomous and intelligent systems. A similarly styled dashboard indicating the genuine impact of various attempts to decrease GHG emissions can facilitate mass awareness and contribute to self-organizing mass engagement, catalyzing demand-side changes, decreasing environmental footprints, and improving life quality. Also, serious gaming can facilitate massive voluntary contributions in multiple ways. Freely available interactive tools, similar to En-ROADS and C-ROADS developed within the MIT Sloan Sustainability Initiative (Climate Interactive, En-ROADS Climate Solutions Simulator), can be combined with the deployment of backcasting (pathfinding to nontrivial solutions by “walking back” from normative long-term positive visions) and role-playing (e.g., representing participants of the Paris climate conference and/or COP events).

For the emergence of a regenerative economy, both engineering and social technologies play a constitutive role, interplaying with innovative business models and often robust institutional alterations, including new approaches in economics and accounting. These are mutually catalytic phenomena that simultaneously presuppose and catalyze mass self-organizing, which, in turn, capitalizes on and drives robust cultural shifts. Their interplay can bring about a transformational socioeconomic dynamism, turning strong sustainability into a deeply rooted culture that reshapes daily practices far beyond formal compliance with external, formalized legal requirements. This regenerative path can emerge and sustain itself when technologies are designed and deployed following strong sustainability principles, enabling and capitalizing on enhanced harmony with nature.

Recommendations

Transforming the enactment of engineering technologies into drivers of a regenerative economy requires their conscious combination with social technologies (at multiple levels):

1. **Provide for maintenance and expansion of regulations into a complete portfolio to help prevent further environmental (and social) harms on a per-country basis**. This is of paramount importance.
2. **Verify that regulations are interoperable between jurisdictions.**

3. **Make use of rewards and penalties.** Regulatory decisions can reward or penalize market players (e.g., stakeholders, communities, and individuals) by aligning access to and costs of financing and resources with efforts and policies that genuinely contribute to preventing and addressing climate crisis-related issues. However, tools capable of enhancing profitability for regenerative efforts can be even more effective drivers of necessary systemic changes. These tools should be subsidized and incentivized by national governmental bodies, potentially leading to the growth of commercial companies and the development of new green markets.
4. **Verify that public resources, for example grants, are allocated and managed effectively.** Fragmented grants and subsidies, often triggered by powerful lobbies, frequently disperse available resources without incentivizing necessary (and overdue) transformations. Transparency in the use of such resources and achievement of sustainability is necessary for accountability and to maintain public trust. The availability of proper, effective metrics and measurements, along with publicly available capacities for truly data-driven decision-making, can be of crucial importance to effect the required changes.
5. **Select and deploy technology tools that quantify and facilitate the discovery, innovation, simulation, and implementation of engineering systems and infrastructure, considering consumption and environmental output levels across demographic, cultural, sustainability, educational, and socioeconomic factors** (e.g., accountability).
6. **Provide for the conscious development of state-of-the-art modeling and simulation capacities to meet the urgent global need for effective environmental science, capable of understanding the Earth's ecosystem at a systemic level.** This generates significant methodological challenges, connected with underlying and epistemological issues. These challenges, coupled with the importance of shifting our focus toward a regenerative ecosystem, influence and feed into the very perception and definition of metrics and indicators with the required quality and quantity of data, their sources, methods of collection, and processing.
7. **Employ visualization tools, similar to dashboards used by the International Monetary Fund (IMF), the Massachusetts Institute of Technology (MIT), and others, to increase awareness and facilitate changes in consumer demand** (e.g., IEEE Std 7010™-2020).
8. **Implement appropriate and relevant ethical governance around data collection to help ensure individual and societal privacy, ownership, and provenance are within the same society and that the planetary monitoring does not evolve into a surveillance society.** This should be in accordance with regulations, international agreements, such as the European Union's General Data Protection Regulation, and other applicable regulations as well as international standards, for example, as developed by bodies such as the IEEE Standards Association.
9. **Integrate, where appropriate, real-time data collection and analysis, quantifiable and reproducible, with low-technology and qualitative methods to provide a holistic picture of planetary health in both technology-heavy and non-technology environments.**
10. **Employ visualization tools,** for example, the open source tool **En-ROADS**, similar to dashboards used by the **International Monetary Fund** (IMF), the **Massachusetts Institute of Technology** (MIT), **C-ROADS**, and others, **to increase awareness and facilitate changes in consumer demand** (e.g., IEEE Std 7010™-2020). Other open source tools include the Basic Sustainability Assessment Tool (BSAT).
11. **Select the proper sets of metrics and indicators that can serve as drivers and monitoring tools for individual and corporate decision-making, shaping the daily operations of organizations in all sectors.**

12. **Think holistically and systematically about how to collect data and information about the entirety of planetary health, taking care not to ignore feedback loops.** The collection and analysis of relevant datasets require integrating state-of-the-art technology with proper methodological tools, and the outcome of data processing must be freely available and consciously shared with affected stakeholders. Deploying such data-handling capacities should interplay with regulatory steps (European Union, 2018) and business strategies that drive and utilize the aggregation of local changes into the global transformations required to handle the growing challenges connected to climate change.
13. **Consider using technology that is energy efficient and uses resources effectively.**

Issue 8: Metrics do not always validate compliance with standards, laws, and regulations

Background

The world is moving toward increased standards and regulatory requirements that include performance (such as maximum allowable levels of emissions), reporting and disclosure (such as reporting climate risk impacts and mitigation plans for investors), and assurance (such as standards for sustainability audits) requirements. To be enforceable, such standards need to rely on quality metrics.[30]

The development of robust standards is only meaningful if they are widely implemented, and this requires that the necessary metrics and underlying data for compliance be available and reliable. Currently, much of what gets reported are estimates, and reliable data is lacking. The precarious working conditions underpinning data labeling systems at the heart of AI developments should also be considered. Considerable effort will be needed so that metrics and measurement methods can keep pace with the standards under development, with a goal of harmonizing terminology, definitions, and metrics used to enhance consistency and understandability of reported results. This will require significant multidisciplinary collaboration among standard setters, those responsible for disclosures, and those responsible for measuring the factors and reported elements as well as auditors, rating organizations, consultants, and other market players.

Technology assists these standards by:

- Enabling more accurate capture of the underlying data (including data on emissions) with finer spatial and temporal granularity that are ultimately reported via the requirements contained in the standards;
- Facilitating more rigorous controls over the data once captured to help improve its integrity (this will assist both preparers and assurers in helping to validate the integrity and completeness of the data); and
- Facilitating greater trust in the source of products and raw materials, as well as the source and veracity of reported metrics, via the use of distributed ledger technology offering efficient data access and management in addition to immutability.

[30] See also the "Economics and Regulations" chapter for information on sustainability-related standards.

Recommendations

In order for standards and regulations to serve as a consistent means of assessing performance and facilitating accountability, compliance with such standards must be evidenced by quality metrics. To achieve this:

1. **Metrics required by regulators and standard setters should be well-defined (for example, in terms of allowable measurement approaches, expected level of granularity, etc.), consistent, and objectively measurable.**
2. **Verify that standards reflect appropriate expectations for using technology to improve accuracy, reliability, and objectivity when measuring, monitoring, and reporting on elements.** These expectations should be scalable and consider geographic (e.g., country) differences to reflect the realities of varying levels of technological maturity in different jurisdictions.
3. **Consider targeted benchmarking to help determine whether results are accurately presented when enforcing standards.** If, for example, every company in a particular jurisdiction is scoring poorly in a certain area but one company stands out as vastly better, is it doing something innovative and effective or is it greenwashing? Transparent data and effective traceability of the reported results can help determine this.
4. **Support the development of digital tools that can support a system of sustainability badges (e.g., British kitemarks) certified by trusted entities and that can further motivate and incentivize individuals and organizations to strive for progress in sustainability initiatives.** For example, digital systems could support:
    a. A sustainability rating system for companies and organizations that is similar to—and possibly combined with—credit ratings, which could ultimately integrate to better align corporate/organizational and planetary interests.
    b. Government/jurisdictional ratings that reflect environmental, social, and governance commitments and verified progress against those commitments. Such ratings could also recognize and give credit for supporting developing countries, marginalized communities, and so forth.

Further Resources

1. Gensler, Gary. “Statement on Proposed Mandatory Climate Risk Disclosures.” U.S. Securities and Exchange Commission (SEC). 21 Mar. 2022.
2. International Sustainability Standards Board (website).
3. Task Force on Climate-related Financial Disclosures (TCFD) (website).

Issue 9: Lack of consistent, mandatory, enforced standards and interoperable regulations regarding sustainability measurement, reporting, and verification

Background

Standards, laws, and regulations for measuring, reporting, and independently verifying sustainability-related performance are numerous, not entirely aligned, and voluntary. Voluntary reporting can lead to de facto requirements through societal expectations and pressure, but it can also lead to inconsistency and greenwashing, either intentionally or through error and imprecise estimates.

Over the years, there has been an ever-growing number of organizations developing standards and methodologies for measuring and reporting sustainability-related metrics. The recent heightened spotlight on sustainability allows great opportunities for collaboration and progress but runs the risk of duplicating efforts, jockeying for position between organizations, and propagating inconsistencies between patchwork systems.

Seemingly with this risk in mind, many standard setters in this space are purposefully looking to converge, collaborate, and build on each other's work and, in some cases, are providing tables of concordance to show how systems align and connect. This helps users consider where standards align and where to promote different approaches so that the merits and interoperability of approaches can be assessed in a particular context.

In order for standards to be widely implemented, the necessary metrics and underlying data for compliance must be available and reliable. Broad implementation also requires coordinated action from regulators, lawmakers, the judiciary, and law enforcement. The complexity within and between these different stakeholder institutions leads to challenges such as inconsistent development and interpretation of environmental protection and regeneration mandates between jurisdictions and within any given jurisdiction (i.e., between different branches of government). There is a risk that political pressures will get in the way of progress, which has been suggested with respect to the 2022 US Supreme Court decision to limit the powers of the US Environmental Protection Agency. Similarly, major global challenges resulting from conflicts and wars threaten the will and ability of countries to take bold action toward progress and result in backsliding instead. For example, in May 2022, the G7 energy ministers had agreed to stop taxpayer-funded fossil fuel financing overseas by the end of the year, but this commitment was loosened in June of 2022, in response to the energy shortages resulting from Russia's invasion of Ukraine.

Consistent standards are also needed to require the independent verification (auditing) of reported results. The uncertainty that comes from reporting estimates and the lack of consistent globally recognized reporting standards adds to the challenge in setting high-quality assurance standards. Furthermore, there is a need that those applying the standards and providing assurance on the information reported are professionally competent to do so. As a result, there is a need for high-quality standards not only in reporting but in the provision of assurance as well. Such standards will encompass assurance, quality management, and ethics and independence.

Notwithstanding the need for consistent regulations and reporting requirements to be met by organizations and institutions, there are caveats that must also be considered:

- Requirements for hitting certain benchmarks should be sensitive to the context, such as whether the entity or organization is large or small, developed or developing, well-resourced or poorly resourced, and so forth.
- Incentivizing change needs to involve both the “carrot” of providing benefits and the “stick” of regulatory enforcement in order to shift the momentum.
- Requirements should allow for reasonable tolerances, to avoid tying the hands of organizations or institutions that are legitimately trying to improve and meet net-zero or net-positive results.

These challenges are inherently complex and further illustrate the need for global leaders to prioritize sustainable development goals over personal ambitions, short-term perceived gains, and jurisdictional differences.

Recommendations

1. **Globally recognized standards are needed to attain net-positive goals.** These standards are likely to be developed and promulgated by recognized international standards organizations, led by first-world countries, and can then be leveraged by local jurisdictional standard setters.
    a. **Standards for stakeholder reporting should not only reflect the information on how climate change and other sustainability factors are impacting the entity and how those risks are being managed and mitigated but also the impact the entity is having on the environment and social systems** and so forth. The even closer alignment and potential merger of ISSB and GRI should provide the multistakeholder sustainability reporting framework that is needed, leading to significantly improved connectivity with financial statements.
    b. Verify that assurance engagements are conducted in accordance with high-quality standards.
    c. **Use standards to guide design and development of products and services.** In addition to reporting and assurance standards, requirements for ethical decision-making are essential to guide behavior. To this end:
        i. Standards developed (and under development) by the IEEE Standards Association provide guidance on ethical design and development of products and systems including the application of technology.
        ii. International Codes of Ethics (including International Independence Standards) provide a basis for high-quality standards of professional ethics and independence, applying to both reporting activities and assurance engagements. Additionally, ongoing work in the technology space can help verify that the specific ethics implications of professional accountants utilizing technology are appropriately considered.
    d. **Standards should reflect a holistic multistakeholder approach, recognizing the interdependence of global systems, cultures, and contexts.** These standards need to be robust enough to reflect the breadth of relevant activities undertaken by organizations, stakeholders, communities, and individuals.

2. **All countries—and especially G7/G20 countries—should implement meaningful, robust legislation and regulations to achieve their stated commitments.** Reporting requirements agreed to under the Paris Agreement should be closely monitored and enforced.
3. **Standards should be enacted to require organizations to provide adequate information to consumers and / or purchasing agents for them to make purchasing decisions with sustainability criteria in mind.** For example, product labels should reflect the product's environmental, social, and/or governance impact so that consumers can evaluate cost and value more holistically and trace potential impacts of their purchasing decisions.
4. **Complying with (or exceeding the requirements of) standards should be adequately incentivized:**
    - **a. Executive and senior leadership remuneration packages should adequately reflect expectations for meeting suitable sustainability metrics.**
    - b. **Regulators and legislators should provide clear requirements for organizations, stakeholders, communities, and individuals with respect to standards and verify that they are enforced.** At the same time, however, there is a need to respect the realities within individual jurisdictions and be mindful of the need for flexibility and support for less resourced or less mature entities.
    - **c. Governments should incentivize innovation to meet and exceed standards through tax policy, grants, and similar means.**
    - d. **Governments should adequately price GHG emissions with carbon, methane, nitrous oxide, and other GHG emissions prices based on their vastly different global warming potential** (GWP).
    - **e. Investors should engage with corporations and promote the need for sustainability to be embedded and take action against those companies and their boards that do not place sufficient importance on this.**
5. **As standards are developed, developers should seek out and embrace opportunities to harmonize standards and adopt the best ideas from the range of standard setters.** Collaboration must take precedence over competition. Wherever possible, common terminology should be used to avoid confusion. Consideration should be given to making requirements scalable in order to apply to organizations, communities, countries, and individuals of different size, maturity, resources, level of technology, context of operation, and so forth.
6. **Until appropriate standards become widely adopted, reporting should include sufficient detail regarding the underlying methodologies used.** Such transparency promotes the ability to apply an additive and iterative approach to achieve progress, regardless of which standards become more globally accepted. It will be important to provide for a clear transition from interim systems of measurement to the final accepted standards, including methods to determine and present comparative figures for interim results that reflect the final measurement methodologies chosen (i.e., so that an "apples-to-apples" comparison can be made between results of different periods).
7. **Standard setters should leverage technology to enhance the processes of collaboration and outreach during development to provide appropriate due process and to maximize diverse participation and acceptance and, ultimately, adoption and implementation.**
8. **Similarly, the agencies and organizations responsible for verifying, auditing, and certifying compliance with standards should employ appropriate digital methods to support and add reliability to their work, thereby building trust.**

Additional Resources

Evolving Standards Guidelines

Global Reporting Initiative (GRI):

GRI is an independent, international organization that provides widely used standards for sustainability reporting. The GRI Secretariat is headquartered in Amsterdam, the Netherlands. It has a network of regional offices to help support organizations and stakeholders worldwide.

Greenhouse Gas (GHG) Protocol:

GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains, and mitigation actions.

Building on a 20-year partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), GHG Protocol works with stakeholders, industry associations, NGOs, businesses, and other organizations.

International Auditing and Assurance Standards Board (IAASB):

The IAASB is an independent standard-setting body that serves the public interest by setting high-quality international standards for auditing, quality control, review, other assurance, and related services and by facilitating the convergence of international and national standards. In doing so, the IAASB enhances the quality and uniformity of practice throughout the world and strengthens public confidence in the global auditing and assurance profession.

International Foundation for Reporting Standards (IFRS) and International Sustainability Standards Board (ISSB)

The establishment of the IFRS in 2023 issued the first International Sustainability Standards Board (ISSB) in 2023. The ISSB is an independent standard-setting body within the IFRS Foundation. IFRS Sustainability Standards are developed to enhance investor-company dialogue so that investors receive decision-useful, globally comparable sustainability-related disclosures that meet their information needs. The ISSB is supported by technical staff and a range of advisory bodies:

- Standards and frameworks
- IFRS Sustainability Disclosure Standards
- IFRS translations
- CDSB guidance and framework
- Integrated reporting
- SASB Standards
- TCFD recommendations

IEEE Standards and Publications

1. Adamson, G., J. C. Havens, and R. Chatila. "Designing a Value-Driven Future for Ethical Autonomous and Intelligent Systems." *Proceedings of the IEEE* 107, no. 3 (Mar. 2019): 518–525.
2. "IEEE Draft Model Process for Addressing Ethical Concerns During System Design." IEEE P7000™/D7 (20 April 2021): 1–83.
3. Peters, D., K. Vold, D. Robinson, and R. A. Calvo. "Responsible AI—Two Frameworks for Ethical Design Practice." *IEEE Transactions on Technology and Society* 1, no. 1 (Mar. 2020): 34–47.
4. Schiff, D., A. Ayesh, L. Musikanski, and J. C. Havens. "IEEE 7010: A New Standard for Assessing the Well-being Implications of Artificial Intelligence." *2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (2020): 2746–2753.
5. Schuelke-Leech, B., and M. Janczarski. "Incorporating Societal (Social) and Ethical Implications into the Design, Development, and Deployment of Technologies." *2019 IEEE International Symposium on Technology and Society (ISTAS)* (2019): 1–6.
6. Shahriari, K., and M. Shahriari. "IEEE Standard Review—Ethically Aligned Design: A Vision for Prioritizing Human Wellbeing with Artificial Intelligence and Autonomous Systems." *2017 IEEE Canada International Humanitarian Technology Conference (IHTC)* (2017): 197–201.
7. Spiekermann, S. "From Value-Lists to Value-Based Engineering with IEEE 7000™." *2021 IEEE International Symposium on Technology and Society (ISTAS)* (2021): 1–6.

Standards Boards—Accounting

International Ethics Standards Board for Accountants (IESBA):

The IESBA is an independent standard-setting board that develops, in the public interest, high-quality ethics standards and other pronouncements for professional accountants worldwide. This includes the International Code of Ethics for Professional Accountants (including International Independence Standards), which establishes ethics requirements for professional accountants. The board also supports adoption and implementation, promotes good ethical practices globally, and fosters international debate on ethics issues faced by accountants.

International Sustainability Standards Board (ISSB)**:**

International investors with global investment portfolios are increasingly calling for high-quality, transparent, reliable, and comparable reporting by companies on climate and other environmental, social, and governance (ESG) matters.

On November 3, 2021, the International Financial Reporting Standards (IFRS) Foundation Trustees announced the creation of a new standard-setting board—the International Sustainability Standards Board (ISSB)—to help meet this demand.

The intention is for the ISSB to deliver a comprehensive global baseline of sustainability-related disclosure standards that provide investors and other capital market participants with information about companies' sustainability-related risks and opportunities to help them make informed decisions.

The ISSB standards include a series of metrics (industry-based disclosure requirements) that cover a range of industries. These are substantively based on those of the Sustainability Accounting Standards Board (SASB), which has merged into the ISSB.

The industries covered are:

1. Consumer goods
    a. Apparel, accessories, and footwear
        i. Percentage (by weight) of raw materials third-party certified to an environmental and/or
        ii. Social sustainability standard, by standard
        iii. Number of tier one suppliers and suppliers beyond
2. Appliance Manufacturing
    a. Percentage of eligible products by revenue certified to an energy efficiency
    b. Certification
    c. Percentage of eligible products certified to an Association of Home Appliance Manufacturers (AHAM) sustainability standard
    d. Description of efforts to manage products' end-of-life impacts
    e. Annual production (number of units)
3. Extractives and mineral processing
    a. Building Products and Furnishings
        i. Total energy consumed
        ii. Percentage grid electricity
        iii. Percentage renewable
        iv. Description of efforts to manage product
4. Lifecycle impacts and meet demand for sustainable products
5. Financials
6. Food and beverage
7. Health care
8. Infrastructure
9. Renewable resources and alternative energy
10. Resource transformation
11. Services
12. Technology and communications
13. Transportation

Likewise, the GRI standards also contain various metrics.

International Federation of Accountants (IFAC):

IFAC is a global organization for the accountancy profession, comprising member and associate organizations in many different countries and jurisdictions, representing millions of professional accountants.

See, for example, Championing an Integrated Mindset: Driving Sustainability and Value Creation in which IFAC calls on businesses to integrate financial and sustainability information with an integrated mindset to make better-informed decisions that deliver long-term value creation—financial returns to investors—while taking account of value to customers, employees, suppliers, and societal interests.

Agreements/Frameworks

The Paris Agreement:

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 parties at COP 21 in Paris, France, on December 12, 2015, and entered into force on November 4, 2016.

Its goal is to limit global warming to well below 2 °C, preferably to 1.5 °C, compared to preindustrial levels.

To achieve this long-term temperature goal, countries aim to reach global peaking of GHGs as soon as possible to achieve a climate neutral world by midcentury.

The Paris Agreement is a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects.

A profile or dashboard of indicators (measuring innovation and change) should include the basics, for example:

- Ten committed outcomes
- Ten levers of change
- Aligned performance targets, indicators, and milestones

Ongoing contributions from expert teams should be undertaken to calibrate (or recalibrate) the proper sets of metrics and indicators that fit with the specific circumstances and the required outputs and outcomes. These teams must follow an interdisciplinary approach and be ready to dynamically rearrange their own composition in order to fit the concrete circumstances and the evolution of tasks in the various phases of transformation.

The Kunming-Montreal Global Biodiversity Framework (GBF) agreement

Many are calling this Biodiversity Framework the "Paris Agreement for Nature." The following is information from the COP15 site:

> *The United Nations Biodiversity Conference (COP15) ended in Montreal, Canada, on 19 December 2022 with a landmark agreement to guide global action on nature through to 2030. Representatives from 188 governments gathered in Montreal for this important summit.*
>
> *COP resulted in the adoption of the Kunming-Montreal Global Biodiversity Framework (GBF). The GBF aims to address biodiversity loss, restore ecosystems and protect*

indigenous rights. The plan includes concrete measures to halt and reverse nature loss, including putting 30 percent of the planet and 30 percent of degraded ecosystems under protection by 2030. It also contains proposals to increase finance for developing countries—a major sticking point during talks.

The stakes could not be higher: the planet is experiencing a dangerous decline in nature as a result of human activity. Up to one million plant and animal species may be threatened with extinction, many within decades.

The GBF consists of four overarching global goals to protect nature, including: halting human-induced extinction of threatened species and reducing the rate of extinction of all species tenfold by 2050; sustainable use and management of biodiversity to ensure that nature's contributions to people are valued, maintained and enhanced; fair sharing of the benefits from the utilization of genetic resources, and digital sequence information on genetic resources; and that adequate means of implementing the GBF be accessible to all Parties, particularly Least Developed Countries and Small Island Developing States.

The GBF also features 23 targets to achieve by 2030, including:

- Effective conservation and management of at least 30 percent of the world's land, coastal areas and oceans. Currently, 17 percent of land and *8 percent of marine areas are under protection
- Restoration of 30 percent of terrestrial and marine ecosystems
- Reduce to near zero the loss of areas of high biodiversity importance and high ecological integrity
- Halving global food waste
- Phasing out or reforming subsidies that harm biodiversity by at least $500 billion per year, while scaling up positive incentives for biodiversity conservation and sustainable use
- Mobilizing at least $200 billion per year from public and private sources for biodiversity-related funding
- Raising international financial flows from developed to developing countries to at least US$ 30 billion per year

Requiring transnational companies and financial institutions to monitor, assess, and transparently disclose risks and impacts on biodiversity through their operations, portfolios, supply and value chains.

**Figure taken from Protected Planet* (UNEP "COP15," 2022)

Further references

1. Clutton-Brock, Peter, David Rolnick, Priya L. Donti, Lynn H. Kaack, Nicolas Miailhe, Raja Chatila, Marta Kwiatkowska, et al. *Climate Change & AI: Recommendations for Government Action.* Climate Change AI, Centre for AI & Climate, and the Global Partnership for Artificial Intelligence (GPAI), 2021.
2. Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens. *The Limits to Growth*. A Potomac Associates Book. New York: Universe Books, 1972.

References

1. Barkham, Patrick. "Should Rivers Have the Same Rights As People?" *The Guardian*, 25 July 2021.
2. Berge, Chloe. "This Canadian River is Now Legally a Person. It's Not the Only One." *National Geographic*, 15 Apr. 2022.
3. Barton, Dominic. "Capitalism for the Long Term." *Harvard Business Review*, Mar. 2011.
4. Benkler, Yochai. The Penguin and the Leviathan: The Triumph of Cooperation Over Self-Interest. New York: Crown Business, 2011.
5. Benkler, Yochai. The Wealth of Networks: How Social Production Transforms Markets and Freedom. New Haven and London: Yale University Press, 2006.
6. Brandt, Willy. *North-South: A Program for Survival*. Brandt Report. Cambridge, MA: MIT Press, 1980.
7. Brundtland Commission. *Our Common Future*. World Commission on Environment and Development. Oxford University Press, 1987.
8. Climate Accountability Institute. "Carbon Majors Project."
9. Climate Interactive. The En-ROADS Climate Solutions Simulator (online resource).
10. Clutton-Brock, Peter, David Rolnick, Priya L. Donti, Lynn H. Kaack, Nicolas Miailhe, Raja Chatila, Marta Kwiatkowska, et al. *Climate Change & AI: Recommendations for Government Action*. Climate Change AI, Centre for AI & Climate, and the Global Partnership for Artificial Intelligence (GPAI), 2021.
11. Daly, Herman E. *Beyond Growth: The Economics of Sustainable Development.* Beacon Press, 1997.
12. Daly, Herman E. *Steady State Economics*. 2nd ed. Washington DC: Island Press, 1981.
13. Ellen MacArthur Foundation. "What is a Circular Economy?" Circular Economy Introduction.
14. Engler, Henry. "'Double Materiality': New Legal Concept Likely to Play in Debate Over SEC's Climate Plan." Thomas Reuters, 12 Apr 2022.
15. European Union. "Complete Guide to GDPR Compliance." General Data Protection Regulation (GDPR.EU), 2018.
16. Fatima, Iffat, Markus Funke, and Patricia Lago. "From Goals to Actions: Providing Guidance to Software Practitioners with KPIs." TexchRxiv, 1 Sept. 2023.
17. Giddens, Anthony. The Constitution of Society: Outline of the Theory of Structuration. Cambridge, MA: Polity Press, 1984.
18. IEA. *Net Zero Roadmap: A Global Pathway to Keep the 1,5 C Goal in Reach*. New Zero Emissions. 2023 Update.
19. IEA. *World Energy Outlook 2022.* Paris: IEA, 2022.
20. IEEE Standards Association Planet Positive 20230 (website).
21. Kaplan Robert S, and Karthik Ramanna. "Accounting for Climate Change." *Harvard Business Review*, 2021.
22. Kauppi, Pekka, and Roger Sedjo. "Technological and Economic Potential of Options to Enhance, Maintain, and Manage Biological Carbon Reservoirs and Geo-engineering." In *TAR Climate Change*

2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, 2018.

23. Kuznets, S. "How To Judge Quality." *The New Republic*, 20 October 1962.
24. Lange, Steffen, and Tilman Santarius. "Digital Reset: Redirecting Technologies for the Deep Sustainability Transformation." D4S Digitalization for Sustainability, 2023.
25. Masterton, Victoria, and Ian Shine. "What is the Circular Economy?" World Economic Forum. 14 June 2022, updated 10 Mar. 2023. Circular Economy.
26. Mazzucato, Mariana. The Entrepreneurial State: Debunking Public vs. Private Sector Myths. New York: Public Affairs, 2015.
27. Mazzucato, Mariana. *Mission-Oriented Research & Innovation in the European Union: A Problem-Solving Approach to Fuel Innovation-Led Growth*. European Commission Directorate-General for Research and Innovation Publications Office, 2018.
28. Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens. *The Limits to Growth*. A Potomac Associates Book. New York: Universe Books, 1972.
29. One Planet Network. *Rethinking, Extending, Re-using: Harnessing Digital Technologies for the Circular Economy*. 2023.
30. Organisation for Economic Co-operation and Development (OECD). OECD iLibrary. "Measuring the Environmental Impacts of Artificial Intelligence Compute and Applications: The AI Footprint." 15 Nov. 2022.
31. Perez, Carlota. Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages. Cheltenham, UK, and Northampton, MA: Edward Elgar, 2002.
32. Polman, Paul, and Andrew Winston. "Net Positive: How Courageous Companies Thrive by Giving More Than They Take." *Harvard Business Review Press*, 2021.
33. Raworth, Kate. Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. Chelsea Green, 2018.
34. Reichel, André. "Civil Society as a System." In *Civil Society for Sustainability: A Guidebook for Connecting Science and Society*, edited by Ortwin Renn, André Reichel, and Joa Bauer. Bremen, Germany: Europaeischer Hochschulverlag GmbH and Co. KG, 2012.
35. Rifkin, Jeremy. The End of the Work, The Decline of the Global Labor Force and the Dawn of the Post-Market Era. New York: Penguin, 2004.
36. Rifkin, Jeremy. The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World. Palgrave Macmillan, 2011.
37. Robinson, John, and Raymond J. Cole. "Sustainability." *Building Research and Information* 43, no. 2 (Mar. 2015).
38. Robinson, John, and Raymond J. Cole. "Theoretical Underpinnings of Regenerative Sustainability." *Building Research and Information* 43, no. 2 (Mar. 2015).
39. Shannon, G., R. Issa, C. Wood, and I. Kelman. "Regenerative Economics for Planetary Health: A Scoping Review." *International Health Trends and Perspectives* 2, no. 3 (2022): 81–105.
40. Shearman & Sterling. "A Deeper Look at the Global Framework Principles for Decarbonizing Heavy Industry." Perspectives, 28 June 2022.

41. Stiglitz, Joseph, Amartya Sen, Jean-Paul Fitoussi. *Report by the Commission on the Measurement of Economic Performance and Social Progress*. 2009.

42. Toffler, Alvin. *The Third Wave.* New York: William Morrow, 1980.

43. Toffler, Alvin, and Heidi Toffler. *Creating a New Civilization: The Politics of the Third Wave*. Atlanta: Turner Publishing, 1995.

44. UN Environment Programme (UNEP). "COP15 Ends with Landmark Biodiversity Agreement." News, Stories & Speeches, Story, Nature Action. 22 Dec. 2022.

45. Van de Ven, A. H., and M. S. Poole. "Alternative Approaches for Studying Organizational Change." *Organization Studies* 26, no. 9 (2005).

46. Welch, J. "Visioning Strategy Through the "Johari Window": Discovering Critical "Unknowns" in a Rapidly Evolving Context." *Strategy & Leadership* 51, no. 5 (2023): 30–35.

47. William McDonough (website).

48. Zhong, Raymond. "Are We in the 'Anthropocene,' the Human Age? Nope, Scientists Say." *New York Times*, 5 Mar. 2024, updated 8 Mar. 2024.

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CHAPTER 3: ECONOMICS/REGULATION

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Committee Co-Chairs

- Navroop Sahdev, New York, United States
- Kashyap Kompella, Bangalore, India

Committee Members

- Aleksei Gudkov, Uzbekistan
- Anand Rao, Boston, MA, United States
- Anand Narayanan, FL, United States
- Ashley McNeil, Washington, DC, United States
- Benjamin Yablon, United Kingdom
- Caroline Gans-Combe, Paris, France
- Christine Balagué, Paris, France
- Colleen Dorsey, Minnesota, United States
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- Olivia Erdelyi, New Zealand
- Sindhu Ratna, India/United States
- Sarah Manski, PhD, Fairfax, VA, United States

ECONOMICS/REGULATION

Future Vision

The Journal of Our Sustainability News[31]
–January 1, 2030

A Caring, Inclusive, Circular, Sustainable (CICS) Economy is establishing itself globally.

The last few centuries of economic theories and practices took a long time to change. Until now, more than two billion people were not a full part of the global economy: women (The World Bank, 2022). Now in 2030, less than a decade since the Glasgow Climate Pact, the global thinking surrounding what constitutes success for a nation, for business, for society, and for individuals has completely changed. We have moved from a growth-driven, competitive, extractive, and unsustainable economy to a caring, inclusive, circular, and sustainable economy where *value* comes from very different sources compared to the economic thought of just a decade ago.

Scientists, engineers, economists, policymakers, and, of course, the public have made this happen in less than seven years. Growth and margins are no longer the only mantras of businesses; non-extractive value drivers and caring and well-being metrics are the new norm for businesses. Nations no longer pride themselves only on their growth in gross domestic product (GDP) but boast their march toward the Global Goals—Sustainable Development Goals (SDGs)—and beyond. The year 2028 saw the achievement of more than 75% of the targets set out by the United Nations. We no longer talk about an extractive economy depleting the resources of the planet but of a regenerative economy focused on the diversity of the planet and well-being of all life forms and all of humanity.

This revolution was possible because it was rooted in every single nation and with Indigenous peoples across the world and not just the advanced markets. Businesses are focused not only on the financial profit and loss (P&L) and cash-flow statements but consider the carbon-based P&L and carbon flow statements and overall environmental impact as equally important. Individuals across the globe are tracking their carbon footprint and well-being scores supported by transparent environmental, social, and corporate governance (ESG) product reporting to help each other further reduce waste, enhance air quality, and shrink their carbon footprint. Governments are leading the charge by establishing legal infrastructure and incentives to change the behaviors of businesses and their citizens. Technology is enabling this transition rather than fueling the extractive economy. Open-source data, code, and models are enabling individuals, businesses, and national governments to learn from each other and build on the successes of others.

The sovereign wealth funds, private equity, and venture capital funds of the previous decade have transformed into green funds contributing to the phenomenal investments in technologies and businesses that are building the circular economy. We have shown as a global community that we can take action—swift action—to course correct and create a better future and a better planet for the generations to come.

[31] Fictional journal title. All similarities with other publication titles are unintended.

Issue 1: Conundrum between economic growth and exacerbation of climate crisis

Background

There is a key conundrum between economic growth and the exacerbation of the climate crisis that needs to be addressed in the statistical and other models for how wealth, value, and sustainability are measured, shifting from a competitive framework to a mutually beneficial regenerative framework.

How much of the climate crisis is attributable to economic growth is the real issue for pricing in (or not pricing in) all relevant externalities (e.g., pollution, environmental degradation)[32] and how the economic system can resolve the imbalances.

The main metric in our current economic system revolves around pricing, as it lends itself as a universal tool to translate the valuation of scarce goods and services across an entire society.[33] Within this system, legislative and regulatory frameworks ideally provide balancing impetus in order to shape economic activity according to societal demands. This is common, for example, through most modern tax systems, corresponding tariffs, and governmental regulatory measures. As industrialization has progressed over the past century, frameworks to manage environmental effects, though present, have failed to keep up with the level of degradation that has led to the climate crisis. With relevant externalities not being priced in sufficiently, the environment has suffered and is still suffering, without corresponding costs being captured in economic transactions.

However, while pricing in externalities may resolve to capture environmental degradation costs, and thus ideally steering economic activities towards sustainable paths, it would also lead to an economically disadvantaged position for lower-income countries (LICs).[34] Industrial development has already taken place in higher-income countries; this may no longer be attainable by LICs, as required investment scales may multiply to prohibitive levels.

Furthermore, responsibility for the bulk of CO_2 emissions in the past century sits disproportionally with higher-income countries (Center for Global Development; Climate Watch, 2023), raising questions about equity. Some of these topics have been analyzed already and are part of the United Nations Framework Convention on Climate Change (also known as *COP agreements*).

[32] As background for pricing regarding sustainability oriented measures, the EU's Natural capital accounting tool "measures the changes in the stock and condition of natural capital (ecosystems) at a variety of scales and to integrate the flow and value of ecosystem services into accounting and reporting systems in a standard way."

[33] For a basic intro to GDP, see "Gross Domestic Product—An Economy's All" by Tim Callen.

[34] Further information on this subject: *Climate–Poverty Connections: Opportunities for Synergistic Solutions at the Intersection of Planetary and Human Well-Being* from Project Drawdown, "provides concrete evidence of how climate solutions can also be win-win opportunities for meeting development and human well-being needs while boosting prosperity for rural communities in sub-Saharan Africa and South Asia."

Recommendations

1. **Maximize the impact of incentives.** Do not reserve incentives just for companies that don't harm future environmental growth or cause human harm; instead, only give incentives to organizations/companies whose processes/products actively contribute to better futures.
2. **Transfer of technology to LICs.** Technology transfer to LICs that can help mitigate the impacts of pricing in externalities within current economic and regulatory frameworks.

Further resources

1. The White House. *National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics*. Office of Science and Technology Policy, Office of Management and Budget, Department of Commerce. Jan. 2023.

This U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics" was released in the U.S. as, "a historic roadmap that will kick off a multi-year effort to put nature on the nation's balance sheet for the first time, with an emphasis on better data to understand nature's critical contributions to the U.S. economy and to guide policy and business decisions moving forward." Many are calling this a "GDP for nature," noting that the GDP was never built to measure or account for natural capital.

Issue 2: Growth as the sole indicator of progress

Background

Growth as the sole indicator of progress for economics has accelerated harms to the planet when rapid economic development is prioritized over sustainable human and environmental flourishing.

On the path to sustainability, cutting down growth/limiting consumption often raises questions of equity. No one wants to be left wanting. For example, there are countries still on the road to development who debate why they should have less claim than other countries who have gone before. In this context, sacrifice is not appreciated, nor does it scale. Solutions need to be explored to move from the era of mass consumption to the era of smart consumption.

Recommendations

1. **Use technology to help increase well-being and ecosystem health.** Artificial intelligence (AI) and many emerging technologies could/should be used to identify and increase human well-being (IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems) while prioritizing environmental sustainability (IEEE Standards Association, IEEE Std 7010™-2020). As satisfaction is a key attribute that guides humans, is it possible to use technology to provide the user with an optimal level of satisfaction while conserving resources?
2. **Employ technology to optimize resource use as appropriate.** As an example, consider a house left fully lit while only one room is occupied. The room's occupant is satisfied because it is illuminated, but he has no need to leave all the other rooms lighted. He overconsumes the resource without any real additional satisfaction. Intelligent consumption would be to have the ability to keep the room in use as it is, so its user remains satisfied, while automatically switching off the others, thus combining end-user satisfaction and resource usage optimization. This is only one example, but many such optimization scenarios can be identified.
3. **Redefine societal growth and progress.** Growth has been defined in terms of economic capital growth focused on humans. It should be redefined to also include environmental growth and benefits, and a system that is equitable versus competitive.
4. **Explore change from mass consumption to smart consumption.** Solutions should be explored to move from the era of mass consumption to the era of smart consumption.

Further resources

1. Cafaro, P. “Beyond Business as Usual: Alternative Wedges to Avoid Catastrophic Climate Change and Create Sustainable Societies.” *The Ethics of Global Climate Change* (2011): 192–215.
2. Crawford, K. The Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press, 2021.
3. Dupuy, J. P. Le sacrifice et l'envie: le libéralisme aux prises avec la justice sociale. Calmann-Lévy, 2014.
4. Girard, R. *Le sacrifice*. Bibliothèque Nationale de France-BNF, 2003.
5. Leidy, N. K. “Operationalizing Maslow's Theory: Development and Testing of the Basic Need Satisfaction Inventory.” *Issues in Mental Health Nursing* 15, no. 3 (1994): 277–295.
6. MOBIUS team, combining the INSEEC Business School (for the economic model) and the ECE, engineering school (for the technical designs).
7. Olanrewaju, Temiloluwa Elijah. “Inclusion of Incentive and Punitive Measures in Multilateral Environmental Agreement: A Suggestion on How the United Nations Framework Convention on Climate Change Can be Utilised to Influence the Reduction of Gas Flaring in the Oil and Gas Exploration Fields of Nigeria.” Law diss., Pace University Elisabeth Haub School of Law, 2022.

Issue 3: Need for transparency and stricter laws that reflect ecological norms and ethics

Background

The realization of technological standards regarding environmental rights and regulatory measures calls for transparency and stricter laws that reflect ecological norms and ethics.

Humans have environmental rights.[35] But humans are also the only part of the environment that actively uses natural resources; therefore, they have duties. Human environmental rights are balanced by obligation with respect to nature and society. This obligation may be voluntary, encouraged by law or prescribed by law. Duties include not only the obligation of active regeneration but also the obligation of enhancement of nature. Also, technology can help us learn more about our environment and, in turn, guide regulatory policy and ethics.

Recommendations

1. **Support the development of innovative green technologies by appropriate law, regulation, and policy.** The current national regulatory systems are isolated from each other. It is necessary to build a unified global legal framework, which shall include ex-ante and ex-post policy measures. Social-ecological norms and ethics should be reflected in ESG (Environmental, Social, and Governance) and law (Deloitte).

   The European Union (EU) Green Deal has a framework of regulations and policies formulated by the European Commission that, in turn, become laws for EU countries. It helps us understand how (and with what initiatives) they plan to finance the transition to a greener planet and the regulation required in different areas:

   a. The private sector, out of its own interest, especially to develop its future markets, will direct considerable investments of its own into products and services that will at the same time have a direct effect on the climate, as well as on the profitability of the companies. Thus, we are talking primarily about a wide range of products and processes directly aimed at improving environmental conditions, such as alternative energy production through solar, wind, and geothermal technologies and CO_2-reducing or CO_2-storing techniques and exhaust gas treatment; creation and loss prevention of fresh water and water treatment processes such as seawater desalination; avoidance of industrial chemical substances, for example, in agricultural fertilization; and thousands of other options that are emerging as opportunities for new business.

   b. Public investment and funding in healthy and climate-improving measures. These public funds go either directly into infrastructure projects, such as greening, planting trees, and deconstructing sealed soil areas, or as premiums to promote new forms of mobility, such as tax incentives for electric vehicles. Indirectly, but also belonging to this segment, are budget funds for research and development at universities or research centers that are geared

[35] In July of 2022 the United Nations General Assembly declared that everyone on the planet has a right to a healthy environment.

toward improving living conditions. In the overall picture of budgeting (e.g., in Europe), both at the level of the European Commission and at the national levels, expenditures for research and development may occupy the second highest position—after support for agriculture.

   c. Provision of financial resources. This is seen as the strongest lever in Europe for redirecting the economy toward a green economy. The first means of choice are regulations that affect the financial sector, especially rules that determine where banks and financial institutions should direct their financial resources as a matter of priority. The basic principle here is that financiers must prove that they are directing a sufficiently high proportion into genuinely green projects.

2. **Focus environmental policy on humans and ecosystems.** Environmental policy should be focused not just on the well-being of currently living humans and future generations but also on the welfare of the natural environment (taking into account human and environmental limits) because only then are the most favorable conditions for the flourishing of humans, nature, and the planet created.
3. **Include the following policy measures:**
   a. **Environmental rights.** The environmental rights and duties should be recognized by the international community. If environmental rights are detailed in national constitutions, they can provide for access to justice. Regulation should be broadly construed so that the public's interest is the priority and constructs like "trade secrets" are the extreme exception.
   b. **Legal restrictions.** It is necessary to develop the restrictions of ecologically harmful acts at the appropriate level (e.g., penalties, ban of activities, nonmonetary sanctions).
   c. **Legal stimulus.** It is necessary to develop monetary measures (tax, loans) and nonmonetary initiatives (training, awards).
   d. **International cooperation.** It is necessary to elaborate international measures such as the following:
      i. International cooperative treaties
      ii. International standards and regulations
      iii. International sanctions

Further resources

1. Anton, Donald K., and Dinah L. Shelton. *Environmental Protection and Human Rights*. Cambridge University Press, 2011.
2. Collins, Lynda. The Ecological Constitution: Reframing Environmental Law. Routledge, 2021.
3. Ecological Law and Governance Association (ELGA). "Oslo Manifesto." Oslo Manifesto for Ecological Law and Governance. June 2016.
4. Shelton, Dinah L. Advanced Introduction to International Human Rights Law. Edward Elgar Publishing, 2020.

Issue 4: Adverse mental health fallouts not given enough attention

Background

Adverse fallouts from climate change are an existential crisis that blocks growth and has serious consequences on the public's mental health and well-being,[36] but they are not given enough attention.

Human well-being is tied with basic resources for a good life: health, security—including food security, good social relations, and freedom of choice and action. These are intertwined with direct and indirect drivers of change that can affect the individual, family, community, and environment. Direct drivers of change inlcude local land use and cover, technology adaptations, deployment and use, harvest and resource consumption, and climate change. And indirect drivers of change, which include demographic, economic, sociopolitical, science and technology, and cultural and religious. These are tied with the ecosystem, which evidence is showing has been affected due to climate change.

This change in environment can, directly and indirectly, affect all the aforementioned factors and, in particular, can affect human well-being in the context of physiological, psychological, and behavioral mechanisms. At the individual level, health is tied with income and employment, food, and water availability. Income and employment are tied with production, and some trades (e.g., agriculture) can be directly affected by climate change (e.g., changing weather patterns, increased temperatures, land degradation, etc.), which will in turn affect production, food, water availability, and so forth.

Human physiology, which is directly related to environmental conditions (e.g., temperature, humidity, air quality) and diet (e.g., caloric intake, macro- and micronutrient availability, water quality, and availability) and limitations in care, in particular in developing countries and in disadvantaged, rural, low-resource communities that already face limited or a lack of resources compared with developed countries, will only be further damaged by the effects of climate change. For example, in 2000, worldwide undernutrition accounts for nearly 10% of the global disease burden, which with decreased agricultural production and sharing resulting from extreme weather events, will only be exacerbated. As another example,

"the burden of disease from inadequate water, sanitation, and hygiene totals 1.7 million deaths and results in the loss of at least 54 million healthy life years annually. Along with sanitation, water availability and quality are well recognized as important risk factors for infectious diarrhea and other major diseases."… "Some 1.1 billion people lack access to clean drinking water, and more than 2.6 million lack access to sanitation" (UNEP, Ecosystems and Human Well-Being—Synthesis; Mudur, 2004). Related to these major diseases are vector-borne diseases. These diseases *"cause approximately 1.4 million deaths a year, mainly due to malaria in Africa. These infections are both an effect and a cause of poverty," with the "prevalence of these infectious diseases" appearing to grow, "…and environmental changes such as deforestation, dam construction, road building, agricultural conversion, and urbanization…" as "contributing factors in many cases"* (UNEP, Ecosystems and Human Well-Being—Synthesis). Climate change will only exacerbate these effects.

[36] According to a March 2023 article from The Commonwealth Fund, "more than two-thirds of U.S. adults (68%) have reported having at least some anxiety about climate change."

Psychologically there are also consequent mental health effects, with consequences *"including mild stress and distress, high-risk coping behaviors such as increased alcohol use, and, occasionally, mental disorders such as depression, anxiety, and post-traumatic stress. Climate change-related impacts can also lead to job loss, force people to move" (climate migration), "or lead to a loss of social support and community resources, all of which have mental health" (www.psychiatry.org) effects.* In turn, the combined physiological and psychological effects of climate change may result in negative behavioral outcomes that will only make it more challenging and difficult for individuals, families, and communities to live healthy lives and for societies to work together in addressing the effects of climate change in both the short and long term.

Recommendations

1. **Significantly prioritize caregiving for human physical and mental health**. Human physical and mental health is a driver that will also positively impact environmental sustainability. This is a key factor for all economical metrics.
2. **Support and encourage research and identify adaptation strategies.** Support and encourage studies on how research and quantitative approaches can assess physiological and psychological adaptations resulting from climate change, which can be integrated into economic models as a population factor of productivity/output. Next, identifying strategies and factors (integrated into the economic model) to support improved productivity and output for those based on circumstance are needed.

Further resources

1. Reid, Walter, Harold A. Mooney, Angela Cropper, Doris Capistrano, Stephen R. Carpenter, Kanchan Chopra, Partha Dasgupta, et al. *Ecosystems and Human Well-Being: Synthesis: Millenium Ecosystem Assessment*. Washington, DC: Island Press, 2005.

Issue 5: Helping rural economies thrive

Background

Rural economies are often too dependent upon and/or are linked to urban economies. Also, urban issues may receive greater attention than rural challenges. There is a need to enable rural economies to also thrive and actively participate in sustainability activities.

Thriving rural areas are a condition for the growth of sustainable global communities.[37] The social and economic crisis caused by the COVID-19 pandemic has highlighted further the importance of access to services for vulnerable populations within rural regions and the importance of sustainable food supply chains to neighboring metropolitan areas.

The *green corridors*, which were piloted throughout the COVID-19 pandemic, exemplify the unshakeable connection between rural and urban. Within the EU, the expansive discussion of "smart cities" has transitioned toward "smart cities and communities," bringing forth the capacity to connect these interlinked systems. As a provider of agriculture products for the food industry, the rural region plays a significant role in the security of a country (exemplified by supply chain pressures), while it remains representative of the vulnerability and disparities in various regions (Wästfelt & Zhang, 2016; Moustier, 2017). A very early analysis of the interdependency of urban and rural communities with respect to the supply system, especially food supply, is the work of Johann H. Von Thünen (Von Thünen, 1826).

Rural areas are sparsely populated and often have an aging population (notably for Europe, where Eurostat consistently reports demographic decline and depopulation of large areas). Rural areas have higher poverty rates (25.5%) than cities and towns, 24% and 22%, respectively (Strandell & Wolff, 2017). Wage and labor retention vary significantly between urban and rural areas and between the various rural areas in the EU and globally. FAO 2019 reports that 14% of rural business owners in the EU-28 (including the UK)[38] face difficulties in access to basic digital education. The same is true globally where a significant portion of small and medium farmers face difficulties in acquiring access to digital services and solutions. At the same time, rural areas are expected to adopt a more sustainable approach to agriculture production practices and to reduce greenhouse gas (GHG) emissions for which agriculture is primarily responsible (with one-third of GHG emissions coming from agriculture produce).

Climate change impact is most significantly present within rural economies at local, regional, and global scale with lengthening seasons of droughts (recently exemplified, for example, by record heat waves in Southern Europe) and consistent need for irrigation and support of the ecosystems involved in local production and livelihoods. Ecosystem pressures continue to weigh down produce quantity and quality, affecting food security and human health. The considerable impact, which can be translated to monetizable values, is present in soil pressure and water systems, fundamental to sustain human existence, and under the pressure of sporadic seasonal changes and impact.

The challenges with which rural areas are faced can be summarized in a number of dimensions—demographics (depopulation and aging population, vulnerable groups), economic (access to basic services

[37] As noted by the EPA, "Smart growth strategies can help rural communities achieve their goals for growth and development while maintaining their distinctive rural character."

[38] EU-28 refers to the member states of the European Union (EU) which consists a group of 28 countries (Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, and including the United Kingdom).

and economic growth challenges), climate change challenges (pressures on systems and livelihoods), and digital (equitable access to tools and solutions). These challenges are also quite specific and should be considered from the perspective of regional and geographic context.

Recommendations

1. **Investigate and analyze the contributions of rural ecosystems and economies to the climate change challenges AND the potentially significant role these rural economies can play towards the solution of global climate change issues and to reach the targets of sustainable development goals** (UN SDG 17). There is an interlink between the various challenges and pressures that rural economies face, making them that much more difficult to solve.
    a. Demographic considerations. The creation of jobs and provision of equitable services within rural areas is important for the growth of sparsely populated regions. Rural revitalization is an important consideration for European areas and is covered by the second pillar of the Common Agricultural Policy (CAP); in these [rural] areas growth and cohesion subside, but the demographic trends persist. Further analytics is necessary, which ought to connect policy with long-term outcomes.
    b. Economic considerations. Rural economies are significant producers of goods and services for the food industry. Ecosystems present in rural areas are the "backbone" of biodiversity and species conservation. While the significance of these systems cannot be understated, the income gap between populations in rural areas and within cities continues to grow. Additional considerations are needed for the monetization of rural ecosystem services to support the growth of rural areas and to support their demographics.
    c. Climate change impact considerations. Smart farming solutions can help resolve some of the issues with which rural areas are faced. According to the European Network for Rural Development, precision farming could be utilized to reduce the use of irrigation water by up to 18%, nitrogen fertilizers by up to 35%, and total herbicides by up to 62%, in comparison to conventional farming practice (European Network for Rural Development). But the implementation of digital solutions is still a challenge due to the need for improvement of digital literacy.

Further resources

1. European Commission. "2050 Long-Term Strategy." Climate Action, EU Action, Climate Strategies and Targets.
2. Food and Agriculture Organization (FAO) of the United Nations. "Food Systems Account for More Than One Third of Global Greenhouse Gas Emissions." 9 Mar. 2021.
3. Organisation for Economic Cooperation and Development (OECD). *Adoption Technologies for Sustainable Farming Systems*. Wageningen Workshop Proceedings, 2021.
4. Sciforce. "Smart Farming: The Future of Agriculture." IoT For All. Last updated 25 Jan. 2023.
5. USDA Economic Research Service. "Common Agricultural Policy." Last updated 16 Nov. 2021.

Issue 6: The problem of landfills

Background

Landfills are sources of GHG emissions and disrupt livelihoods of people living near them (U.S. EPA, "Frequent Questions About Landfill Gas"). The core reason for products ending up in landfills is because they are deemed worthless at some point. Recycling products has not been effective for the most part.

There is a need to facilitate a universal framework for producers of goods (such as apparel) that prevents these from ending up in landfills. This requires a playbook based on principles of science, design, and technology to identify production processes and materials to make products and move us toward a circular economy.

Challenges to be addressed include:

- Sustainably made goods becoming affordable to the masses
- Lack of awareness of the negative impact producers have on the environment
- Waste from materials (e.g., synthetic fibers) that cannot be recycled (Cho, 2020)
- Attitudes regarding consumption that vary across the globe
- Brands fearing the loss of profit and resistance to "degrowth"

Recommendations

1. **Develop a framework for responsible practices for waste minimization**. Develop a framework that makes the adoption of responsible practices (i.e., keeping products and materials out of landfills and in circulation for as long as possible) attainable.
2. **Enable producers to take responsibility for the end of life/end of use of their products** using the following:
    a. **Develop best practices for responsible supply chain management on a global scale.**
    b. **Create a global framework for producers to implement responsible supply chain management where products stay out of landfills.**
    c. **Develop economic incentives for producers to adopt the new framework for responsible supply chain management.**
    d. **Incentivize local production.**
    e. **Incentivize product design for a circular economy.**
    f. **Create a fund for universal subventions tailored to producers' production costs, if these are more local, fair priced, and ethical**. Responsible brands should be compensated with subsidies so that their retail price(s) can be reduced to meet consumers' purchase restraints.

g. **Make consumers aware before purchasing how a product will remain the responsibility of the brand/supplier/producer** (or delegate—this could be a government that has levied a fee as part of the product's sale to enable the government to address the end-of-use process locally) **from which it is purchased with respect to warranty and end-of-use process**.

h. **Develop and implement a framework for alternatives to the producer's product responsibility to address issues like a producer's bankruptcy, a producer going out of business for any reason, and geographical distance between producer's location and product's end of use, such as a communal solution for collection of goods that are no longer desired by the consumer and legislated solutions.** See also the EU rules on treating waste electrical and electronic equipment to contribute towards a circular economy [European Commission, Waste from Electrical and Electronic Equipment (WEEE)].

i. **Create a fund to support circular brands whose supply chains meet the standards of these best practices for responsible supply chain management** (i.e., pre-consumer and post-consumer phase).

j. **Develop business models to stimulate degrowth, while increasing job opportunities**.

k. **Enforce the repairability and upgradability** (where appropriate) **of electronic goods for 10 years** (e.g., by making it mandatory for companies to offer free repair services for five years after product purchase (goal: increased quality and less product purchases)).

l. **Frame guidelines and, potentially, fines for dumping pre- and post-consumer goods into landfills so there are negative economic outcomes for not addressing landfills**.

Further resources

1. European Commission. "EU Strategy for Sustainable and Circular Textiles."[39]
2. Organisation for Economic Cooperation and Development (OECD). "Extended Producer Responsibility."[40]

[39] The "EU Strategy for Sustainable and Circular Textiles" addresses the production and consumption of textiles, while recognizing the importance of the textiles sector.

[40] Extended Producer Responsibility (EPR) is a policy approach under which producers are given a significant responsibility—financial and or physical—for the treatment or disposal of post-consumer products.

Issue 7: Lack of openness about data, models, predictions, assumptions, and trade-offs relating to sustainability

Background

All sustainability initiatives must be based on verifiable evidence, transparent assumptions, and economic trade-offs that need to be made at an individual country and specific ecosystem level (forests, rivers, lakes, cities, etc.). This requires organizations to open source their data, software code, and sustainability models for the benefit of all.

Forward thinking sustainability programs aim to bring a multifaceted approach to sustainability, addressing climate change actions required as well as the sustainable use of planetary resources. This requires collecting and curating massive amounts of granular, historical data and documenting and verifying assumptions from a variety of experts. It also demands that policy makers, businesses, and individuals make future projections and trade-offs. This includes:

- Disparate data sources and assumptions
- Models specific to countries/regions or sectors that cannot be scaled easily
- Trade-offs to be made between several interacting factors that remain unclear
- Lack of systemic approach and methodology that is open and transparent

Recommendations

1. **Design and adopt a multi-phased approach from data collection to model interaction.** Sustainability-based organizations should adopt a three-phase approach: first curating existing open data and models, followed by defining best practices and interactions between different models, and finally obtaining funding to expand and integrate models focused on sustainability areas focused on reducing GHGs and increasing ecosystem regeneration.
2. **Create a global repository of data sources by focus areas and by country.**
3. **Create a global repository of government, nongovernmental organizations (NGOs) and private groups addressing similar focus areas.**
4. **Develop key economic trade-offs within each of the major ecosystems' areas.**
5. **Develop best practices for open data and open models for ecosystems and societal-based areas.**
6. **Develop business models to enable the integration and building of models in ecosystems and societal-based areas.**
7. **Create integrated multifactorial data sets that include demographic/population data, environmental/geographic distribution data, as well as weather models** (i.e., which countries are at greater risk of weather events resulting from climate change).

Further resources

1. Botev, Stéphane. "The Importance of Open Source in Tackling Climate Change." Climatiq. Last updated Apr. 2022.
2. Climate Interactive. "Simulators & Science."[41]
3. Climate Interactive. "World Climate Simulation."[42]
4. Green Software Foundation (website).[43]
5. Open Sustainable Technology (website).[44]
6. Stanford University. "Urban InVEST: Designing Resilient Cities by Nature." Natural Capital Project.[45]

[41] En-ROADS simulator models cross-sector policies for energy, transportation, land use, and new technologies to limit climate change. C-ROADS simulator models national and regional gas reductions for China, US, EU, India, and others to meet Paris Agreement targets. Both simulators are freely available.

[42] Role playing game that stimulates country-level action on the speed and level of action required to address global climate change.

[43] Trusted ecosystem of people, standards, tooling, and best practices for green software.

[44] A curated list of open technology projects to sustain a stable climate, energy supply, and natural resources.

[45] Urban Invest provides integrated valuation of ecosystem services and trade-offs.

Issue 8: The challenge of greenwashing

Background

Greenwashing, also called *green sheen*, started as a form of marketing spin in which green public relations (PR) and green marketing were deceptively used to persuade the public that an organization's products, aims, and policies were environmentally friendly. While this continues in many forms, the most recent iterations of the trend are far more insidious and involve more than marketing and PR.

Recommendations

1. **Develop and implement a multifaceted approach to identifying and combating greenwashing** to facilitate the fair and transparent interaction of both private investment and government services to ESG-minded entities.

   This requires a reimagining of the ways in which data is analyzed and shared with the public, including:

   a. Collecting and curating massive amounts of granular, historical data;

   b. Documenting and verifying assumptions from a variety of experts;

   c. Policy makers, businesses, and individuals making future projections and trade-offs; and

   d. Transferring this data into a blockchain or distributed ledger-based system that allows competing actors to reach consensus around appropriate projects.

2. **Analyze the current status of technology and technology options**. There are several steps involved in working toward a solution. First and foremost, analyze the competing technology options from the centralized versus decentralized systems. Next, analyze the following:

   a. Data verification challenges, specifically, understanding how a unified standard of acceptable environmental, social benchmarks are determined and analyzed by machine learning and AI-enabled systems

   b. Discussion concerning environmental impacts of blockchain and distributed ledger technology (DLT) solutions versus traditional methods (carbon intensive bitcoin proof of work versus carbon-negative DLTs).

   c. Use of a self-verifying distributed autonomous organization (DAO) to allow for the elimination of human verifications.

   d. Scalability and reliability of existing and future smart contracts to enable self-verifying digital assets

   e. Models specific to countries/regions or sectors that cannot be scaled easily and the need for a unified approach to data access and audit

3. **Create a global repository of DLT/blockchain-enabled data sources by focus areas and by country.**

4. **Create a global repository of government, NGO, and private groups addressing similar focus areas.**

5. **Create policy measures that de-incentivize greenwashing by imposing negative economic results on entities that indulge in greenwashing.**
6. **Develop a "neutral" measure—a label—of sustainability of a company that has to be displayed on products/company website**, for example, similar to the food traffic lights in the UK (e.g., score for CO_2, methane, water usage, recyclability, air miles), which help consumers compare without in-depth knowledge.

Further resources

1. Vieira de Freitas Netto, Sebastião, Marcos Felipe Falco Sobral, Ana Regina Bezerra Ribeiro, and Gleibson Robert da Luz Soares. "Concepts and Forms of Greenwashing: A Systematic Review." *Environmental Sciences Europe* 32, no. 19 (11 Feb. 2020).
2. Visram, Talib. "What is Greenhushing? The New Sustainability Trend Explained." *Fast Company*, 10 Mar. 2023.

Issue 9: Placing onus of protecting the climate on the consumer alone

Background

Protecting the climate should be framed as a shared responsibility between corporations and consumers. Currently, in the prominent narrative, as well as in existing regulations, the onus lies on the consumer alone.

In a capitalist society, economic success is considered a constant competition between corporations and the workforce as well as countries. Interventions that might temporarily disadvantage a party in this battle are, therefore, understood as unbearable; being slowed down is not an option.

Such framing leads to a detrimental narrative around climate protective measures: Since companies cannot be exposed to serious regulation, the onus is moved downstream to the consumer. If the user would purchase goods that are sustainable, the companies would be nudged toward producing sustainable products, completely without being disadvantaged in the battle of modern capitalism. Therefore, this is considered the most desirable (and most emphasized) way forward.

This causes problems on different levels. Firstly, are the consumers themselves. The narrative puts enormous pressure on their everyday purchase decisions. To be able to select the most sustainable option, extensive knowledge about emissions, water usage, fertilizers, and several other factors is required. Not every consumer has the time—or motivation—to acquire this form of knowledge, and many that attempt to may be feeling overwhelmed. Additionally, the most sustainable purchase decision is often more expensive (e.g., flight tickets versus train, organic food versus discounted conventional food). Moreover, it may require consumers to forgo comfortable habits or experiences, another motivational issue. Holidays on another continent, consuming animal products, or purchasing products that undergo trends are just examples of such possibly pleasurable, but potentially unsustainable choices.

Not everyone is informed, affluent, or motivated enough to undergo such waivers. Additionally, some companies may be incentivized to deceive consumers into believing that they are in line with climate protective measures; e.g., if they can sell more products, and consumers feel relieved from the impossible burden placed upon them. These dynamics produce overwhelmed consumers that are trying to navigate between their own pleasure, their consciousness, the greenwashing campaigns of marketing teams, and the feeling of helplessness in this social goods dilemma—and last but not least—anger. Rightfully, the question emerges why the onus is on them. They are asked to make hundreds of compromises every day—regarding their eating habits, mode of transport, even the number of children they feel entitled to have—many of which can severely compromise their financial and psychological well-being.

Contrasted to this, some companies may be largely untouched by regulations or only negligibly incentivized to steer their course toward sustainability. This is potentially detrimental, if we consider that 70% of the world's GHG emissions can be traced back to 100 companies (Griffin, 2017). It is not surprising that many consumers may reject their responsibility in the face of such openly unfair treatment, paired with the fact that they can only marginally impact overall sustainability through even the most significant of individual behavior changes. They may give up on this constructed battle of responsible individuals against potentially ruthless, largely unregulated companies.

Recommendations

1. **Develop regulation to address the roles and responsibilities of consumers and corporations with respect to climate protection.** The double standard applied between consumers and corporations causes frustration and resignation in this social goods dilemma. This has to be addressed through fair, equally distributed regulation. Additionally, it might be fruitful to appeal to a company's mission, for example, in dialogue with various CEOs to understand and sign their climate pledge (German Zero).

Further resources

1. EcoCart. The Role of Consumers vs Corporations in Combating Climate Change–Who's Responsible? Feb. 2023.
2. Hutcheon, Mark. "Consumers Expect Brands to Address Climate Change." *Wall Street Journal*. 20 Apr. 2021.

Issue 10: Negative impacts of tourism

Background

The tourism industry can potentially worsen the climate crisis and over time it may also negatively impact economies around the world if tourism declines due to climate change impacts, for example, in coastal cities and regions.

Overall, the travel and tourism industry generates $5.81 trillion in economic output, supporting 289 million jobs worldwide and nearly 6.1% of global GDP (World Travel & Tourism Council, "Economic Impact Research"). While the travel and tourism industry significantly contribute to global GDP, it has also contributed to the climate crisis. It is estimated that global tourism emits roughly 8% of global emissions on an annual basis (Sustainable Travel International).

Climate change is already affecting the hospitality sector. Extreme weather is increasing the cost of operations and reducing the number of tourists visiting certain destinations, while local and national environmental policies and penalties are being introduced in cities and countries around the world.

The hotel sector accounts for around 1% of global carbon emissions and this is projected to increase (UNWTO, 2008). Hospitality, like other industries, has a responsibility to manage its impact on our planet.

Research has found that the hotel industry may need to reduce its carbon emissions by 66% per room by 2030 and by 90% per room by 2050 so that the growth forecast for the industry does not lead to a corresponding increase in carbon emissions (Sustainable Hospitality Alliance, *Global Hotel Decarbonisation Report*). The industry will need to go even further to help limit warming to 1.5 ^{o}C and avoid the very worst impacts of climate change (IPCC, 2021).

Recommendations

1. **Create a more sustainable tourism industry.** The tourism industry needs to collaborate with governments to provide incentives (grants and tax credits) to create a more sustainable industry. The following suggestions can help reduce the carbon footprint of the industry:
    a. **Use sustainable fuels, that is, energy from emission-free sources (or near emission-free sources).**
    b. **Implement sustainable building design for new infrastructure builds and for retrofits**
    c. **Practice local sourcing**
    d. **Reduce waste, re-use, recycle, re-purpose, and so forth**
    e. **Increase renewable energy usage**
    f. **Conserve water, recycle water, repurpose water**

Further resources

1. Nuwer, Rachel. "Travel in the Time of Climate Crisis." *Audubon Magazine*. Spring, 2023.

References

1. Callen, Tim. "Gross Domestic Product—An Economy's All." International Monetary Fund (IMF), Finance & Development.
2. Center for Global Development. "Developed Countries are Responsible for 79 Percent of Historical Emissions."
3. Cho, Renée. "Recycling in the U.S. Is Broken: How Can We fix It?" Columbia Climate School, State of the Planet, Sustainability. 13 Mar. 2020.
4. Climate Watch (with major processing by Our World in Data). "Total Greenhouse Gas Emissions, Excluding Land Use and Forestry" (dataset).
5. Deloitte. "Perspectives #1: What is ESG?"
6. European Commission. "Waste from Electrical and Electronic Equipment (WEEE)." Energy, Climate Change, Environment, Waste and Recycling.
7. European Network for Rural Development (website).
8. German Zero. "Creating a Better Climate."
9. Griffin, Paul. *The Carbon Majors Database: CDP Carbon Majors Report 2017*. CDP Report. July 2017
10. Hough, Emily, and Nathaniel Counts. "How Climate Change Affects Our Mental Health, and What We Can Do About It." The Commonwealth Fund, Explainer. 29 Mar. 2023.
11. IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems. "Well-being." In *Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems*. 1st ed. IEEE, 2019.
12. IEEE Standards Association. IEEE Std 7010™-2020, IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being.
13. IPCC. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R.
14. Jameel, Y., C. M. Patrone, K. P. Patterson, and P. C West. *Climate–Poverty Connections: Opportunities for Synergistic Solutions at the Intersection of Planetary and Human Well-Being*. Project Drawdown. 2022.
15. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds. Cambridge and New York: Cambridge University Press, 2021.
16. Moustier, Paule. "Short Urban Food Chains in Developing Countries: Signs of the Past or of the Future?" *Natures Sciences Sociétés* 25, no. 1 (2017): 7–20.
17. Mudur, Ganapati. "Slow Progress on Sanitation Puts 2.6 Billion People at Risk." BMJ 329, no. 7465 (4 Sept. 2004): 528.
18. Strandell, Helene, and Pascal Wolff, eds. Key Figures on Europe: 2017 Edition. Eurostat. European Union, 2017.
19. Sustainable Hospitality Alliance. Global Hotel Decarbonisation Report. Nov. 2017.

20. Sustainable Travel International. "Carbon Footprint of Tourism." Offset.
21. Thünen, Johann Heinrich von. *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie (Vol. 1)*. Hamburg, 1826. In: Deutsches Textarchive.
22. UN Environment Programme (UNEP). *Ecosystem and Human Well-Being—Synthesis*. Millennium Ecosystem Assessment Report, 5 Apr. 2005.
23. UN World Tourism Organization (UNWTO). Climate Change and Tourism: Responding to Global Challenges. 2008.
24. U.S. Environmental Protection Agency (EPA). "Frequent Questions about Landfill Gas." Landfill Methane Outreach Program (LMOP).
25. Wästfelt A., and Q. Zhang. "Reclaiming Localisation for Revitalising Agriculture: A Case Study of Peri-Urban Agricultural Change in Gothenburg, Sweden." *Journal of Rural Studies* 47, no. A (Oct. 2016): 172-185.
26. The White House. National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics. Office of Science and Technology Policy, Office of Management and Budget, Department of Commerce. Jan. 2023.
27. The World Bank. "Nearly 2.4 Billion Women Globally Don't Have Same Economic Rights as Men." Press release no. 2022/047/DEC. 1 Mar. 2022.
28. World Travel & Tourism Council. "Economic Impact Research." Research.

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- Matthew Law, The Hague, Netherlands
- Monika Manalova, Sofia, Bulgaria
- Manijeh Montaghy, West Hills, California, United States
- S. Anand Narayanan, Tallahassee, Florida, United States
- Edson Prestes, Porto Alegre, Rio Grande do Sul, Brazil
- Erica Simmons, Dallas-Fort Worth, Texas, United States & Jamaica
- Marisa Zalabak (Chair), New York, New York, United States

Committee Members, Chapter Contributors

- Olga Afanasjeva, Czech Republic & South Africa
- Nkechi M. Agwu, New York City, United States
- Christina Andersson, Helsinki, Uusimaa, Finland
- Franco Amalfi, Montreal, QC, Canada
- Christina Baladis, California, United States
- Allison Banzon Macey, Orlando, Florida, United States

- Andrew Heppelle, San Francisco, California, United States & Canada
- Eli Ingraham, Boston, Massachusetts, United States
- Rob Gierke, Berlin, Germany
- David Gong, Reno Nevada, United States
- Michael Houghtaling, Tucson, Arizona, United States
- Charlie Jackson, Huntington Beach California, United States
- Matthew Law, The Hague, Netherlands
- Michael Lennon, Washington, DC, United States
- Ruth Lewis, Melbourne, Australia
- Monika Manolova, Sofia, Bulgaria
- Luke Martiros, Boston, Massachusetts, United States
- Manijeh Montaghy, West Hills, California, United States
- Zvikomborero Murahwi, South Africa
- S. Anand Narayanan, Tallahassee, Florida, United States
- Cynthia Picolo, São Paulo, Brazil
- Edson Prestes, Porto Alegre, Rio Grande do Sul, Brazil
- Aiste Rugeviciute, Lithuania
- James Salsman, California, United States
- Erica Simmons, Dallas-Fort Worth, Texas, United States & Jamaica
- Marc Steen, Netherlands
- Keisha Taylor-Wesselink, Ireland
- Amelia Winger-Bearskin, Gainesville, Florida, United States
- Marisa Zalabak, New York, New York, United States

GLOBAL METHODOLOGIES

Future Vision

It is 2030.

And the fundamental imbalance in the relationship between humans and the planet that was out of harmony is now in tune—the planet and all living beings, treated with respect and empathy as a starting point for all personal and civic activities, encompasses global technology and policy. Humans, animals, and the natural spaces they inhabit have become protected in multiple ways that champion the value of lived experiences, communities, and ecosystems.

The awareness of the need to prioritize the planet is present for the majority of people, reflected in their daily activities. Any activity that directly or indirectly involves the use of natural resources has been reimagined, optimized, and modernized to protect, respect, and regenerate the environment. This happened through an evolution in consciousness, a deep global awareness of humans' place in the systems of the Earth, that respect and adherence to the idea of intergenerational stewardship of the world and for the generations of life to come that are now the norm. Regenerative design and sustainable practices and reports [e.g., United Nations Sustainable Development Goals (SDGs) and environmental, social, and corporate governance (ESG)] are used as standards with transdisciplinary collaboration. This applies to modern technologies during the creation, development, and mobilization of products, services, and policies.

This informed agreement has only been made possible due to the identification of a set of methodologies, organized into a global network keeping the methodologies' inherent individual differences and richness. The implementation of this network has taken into consideration different local, regional, and global aspects respecting cultures, tradition, beliefs, and biodiversity across the globe. In this process, regeneration and resilience of Earth's ecosystems has begun and will continue to transform society, further enabling substantial progress toward reducing greenhouse gas (GHG) emissions, improving the social well-being of humanity.

Introduction

An underlying motivator for this work has been the concept of *Ubuntu* (ùɓúnt'ù), a Nguni Bantu term for humanity, translated as "I am because you are," a philosophical belief in interconnectedness—a universal bond that connects humanity through sharing. A shift in mindset to Ubuntu, understanding global interdependence, restored balance and peace and brought happiness and prosperity to all living beings starting in 2022.

In that spirit, this message is offered from Chief Dwaine Perry of the Ramapough Lenape Nation:

> *As we ponder tomorrow, let us remember our grandmother [universe] and begin now to help heal the trauma and degradation which has been visited upon her…for surely each wound, each careless and negative act visited upon Grandma is a scar… a wound visited upon our own health, our future and our children…let us use each moment of this time of restraints as a time to heal our families, our old wounds and our forgotten differences… This is a time to celebrate our humanity…The illness which permeates the atmosphere, impacting our health, may be part of the illness visited upon our Mother [Earth]…May this be a time to renew our spirits. May we reflect on how to become better people–let us live with purpose, may we take the time to listen and understand…Be good to one another, let us live with love for one another. Be encouraged, let us emerge from this difficulty renewed in our traditions, that bring us joy. XwatAnushiik.*
> (MNC Editorial Team, 2021)

The current climate crisis requires identifying avenues for action with no delay. Action will not be perfect, but no action will lead to known devastating consequences. The usefulness of the collective positive planetary ecosystem's proposed recommendations depends on making them operational, with the implementation of ideas that lead to immediate action, change and transformation.

Issue 1: Lack of care for human well-being and sustainability of our planetary biosphere

Background

Current economic and technological trends prioritizing quantifiable outcomes and consumption result in a lack of care for human well-being and sustainability of our planetary environment. Global, regional, and local methodologies for dealing with sustainability issues must do the opposite by embedding care into policies, agendas, expectations, narratives and behaviors. This would include consideration for various continental, geographical, and cultural backgrounds. This definition of *care* includes the well-being of all living beings and longevity of planetary health balanced with a commitment to global sustainability.

This concept of *care* expands the responsibility beyond traditional and modern roles and practices of caretaking (e.g., medical, family) to include all members, organizations, agencies, and institutions in global societies.

Care, in this context, is an ethical theory and practical imperative approach that emphasizes the importance of concern and responsibility for self and others rather than individual rules for compliance (i.e., deontology) or positive consequences for one group (i.e., utilitarianism). Although ethics is a central part in some professions (e.g., medical, legal) this description of care also involves broader applications within natural and social sciences as well as modern technologies. From a state perspective, care refers to the state's inherent obligations toward protecting individuals, especially for those in the ecosystem who are dependent and vulnerable, as described and addressed in the work of several social scientists and social justice activists (e.g., Elinor Ostrum, Rianne Eisler, Rigoberta Menchú Tum, Carol Gilligan, and Nel Noddings).

The lack of care is illustrated by a current trend in the economic marketplace where the majority of players believe competition is needed for survival. This capitalistic trend drives individuals and societies to focus on maximizing product sales and financial profits, which has caused negative consequences to collective human well-being and the living environment. With care as a foundation, success is measured by valuing the well-being of people, planet, and profit versus measuring success solely by financial profit, for example, measuring for well-being and happiness (GNH) versus measuring success based on gross domestic product (GDP).

Science shows that humans are the primary cause for planetary damage; therefore, they have the primary responsibility for mitigation. Damaging factors include shifts to consumer-driven lifestyles, lack of sustainable strategies and structures to accommodate population increases, competing political perspectives, and an emphasis on financial profit (e.g., Daniel Christian Wahl, Dennis Meadows, Paul Polman, John Fullerton). Additional harmful drivers include exploitative economic practices, unequal access to advanced technologies, and other socioeconomic disparities and the need for new models of business practice that consider wellbeing (e.g., James Rhee, Kate Raworth).[46]

Methodologies like Gaia 2.0 (i.e., planetary homeostasis) have explored the self-regulatory ability of Mother Earth (a.k.a. Gaia), which has been disrupted. The Gaia hypothesis states that "living things are part of a planetary-scale self-regulating system that has maintained habitable conditions for the past 3.5 billion years." In this context, the self-regulating capacity of Gaia 2.0 emerged within the Earth's system and over time

[46] This includes standards such as The IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being based on the Wellbeing Chapter of IEEE's Ethically Aligned Design.

altered the climate and atmosphere by enabling the cycling of nutrients. This system operated organically, but the evolution of humans and technologies have interfered negatively. Earth "has now entered a new epoch termed the Anthropocene, and humans are beginning to become aware of the global consequences of their actions" (Lenton & Latour, 2018).

Recommendations

To achieve planetary well-being, we must work to validate the importance of care and proactively bolster care as a methodology that is at once universal and contextually defined through the following actions:

1. **Increase our valuation of care.** By validating and supporting existing care cultures, care professions, and undervalued caretaking work, policy makers can work against current narratives that downplay the universal importance of care. A shift is needed to work toward developing legislative measures and frameworks that foster care and well-being throughout societies into the future. It is important that this focus encompasses supporting human-facing professions as well as those professions oriented towards wildlife and nature conservation.
2. **Prioritize care over profit**. Systems that place efficiency and profits over all else are antithetical to care. To achieve planetary well-being, governments, corporations, and stakeholders must work to prioritize existing care cultures while proceeding with caution and moderation in developing automated mechanisms designed to provide synthetic care, for example, artificial intelligence (AI) chatbot therapy. In practice, this may involve working at the ground level (i.e., holding regular meetings with care practitioners) to understand how to better meet the needs of specific care providers rather than outsourcing growing care responsibilities to third-party systems [e.g., Artificial Intelligence Systems (AIS)]. Here, augmented technology should be created/designed with an idea to empower people instead of replacing them.
3. **Reduce market input on the worth of caregiving**. To drive increased societal valuation of care, we must reduce the role that economic markets play in determining the worth of caregiving. Care for humans, animals, and natural spaces is a collective, longitudinal investment that does not typically lend itself to input–output models of capitalist production. To achieve planetary well-being, supporting and providing care must be viewed as a non-negotiable principle rather than an aspirational anomaly. A key question is how care will be valued and appreciated if it is disconnected from a transactional model with money (and money as a human construct that shapes the planet). For example, can the concept of currency be expanded to value alternative exchanges and interactions (e.g., personal time, carbon credits, etc.)? This will require metrics for human and planetary well-being as described in IEEE P7010™.
4. **Consider and use care as a universal value**. All creatures and spaces require some form of care. As such, it is important to center care as a moral imperative in ongoing discussions of emerging technology, ecological policy, economic frameworks, and updated human rights initiatives while working towards goals for planetary well-being. This includes care for the whole, greater, and the individual self, meeting one's own needs to be able to provide care to others to foster balance and equilibrium. The valuation of care previously engrained (e.g., Adam Smith's maximization principle of own utility/wealth and invisible hand processes in *The Wealth of Nations*, *The Theory of Moral Sentiments*, and *How Adam Smith Can Change Your Life*) vastly misinterpreted the Darwinian narrative of "survival of the fittest," which Darwin revised to "survival of the most adaptable to change."

5. **Define care practices and norms in context.** In recognizing the universality of care as a moral imperative, it is essential to highlight that care practices and norms are contextually defined. In recognizing care practices as locally derived, we can avoid the current proclivity for purporting homogenized ideals as the global standard (e.g., colonialism). Helping ensure that concepts of care that are diverse and rooted in Indigenous and local practices defined by the communities can help avoid furthering established colonialist practices.
6. **Provide education and outreach to support the transformation of practicing care.** Clarifying a definition of *care* to include social well-being and values that support the health of the planet and humanity will require outreach and education to invite engagement for this transformation. This also provides opportunities to educate and share knowledge of diverse topics and subject matter that increase learning of different backgrounds, experiences, and cultures (e.g., mindfulness philosophies, practices, and systems). For example, the integration of technology can be employed to support established Indigenous practices.

This responsibility argues that humans, through self-awareness, could make individual conscious choices alongside collective practices that could add to the Earth's regenerative goals for self-regulation, which could become an effective framework for fostering global sustainability (e.g. Jane Goodall, Thich Nhat Hanh, Pope Francis Laudato Si, and Daniel Christian Wahl).

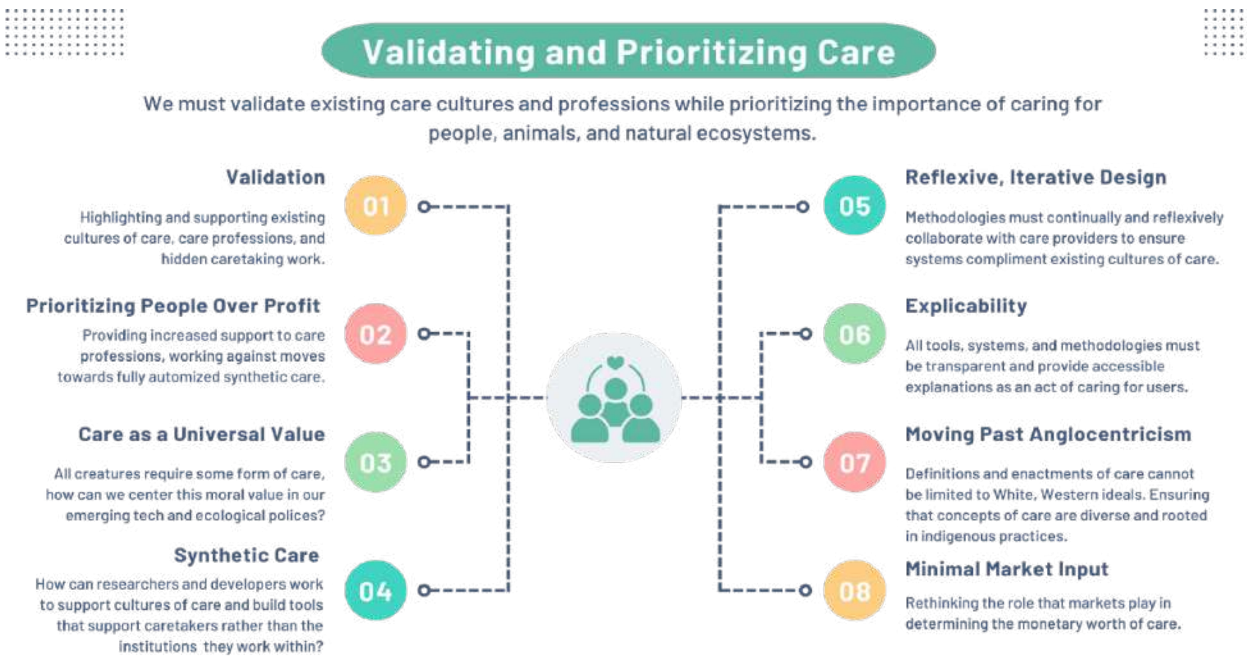

Figure 1. Validating and Prioritizing Care
(Image: Allison Macey Banzon)

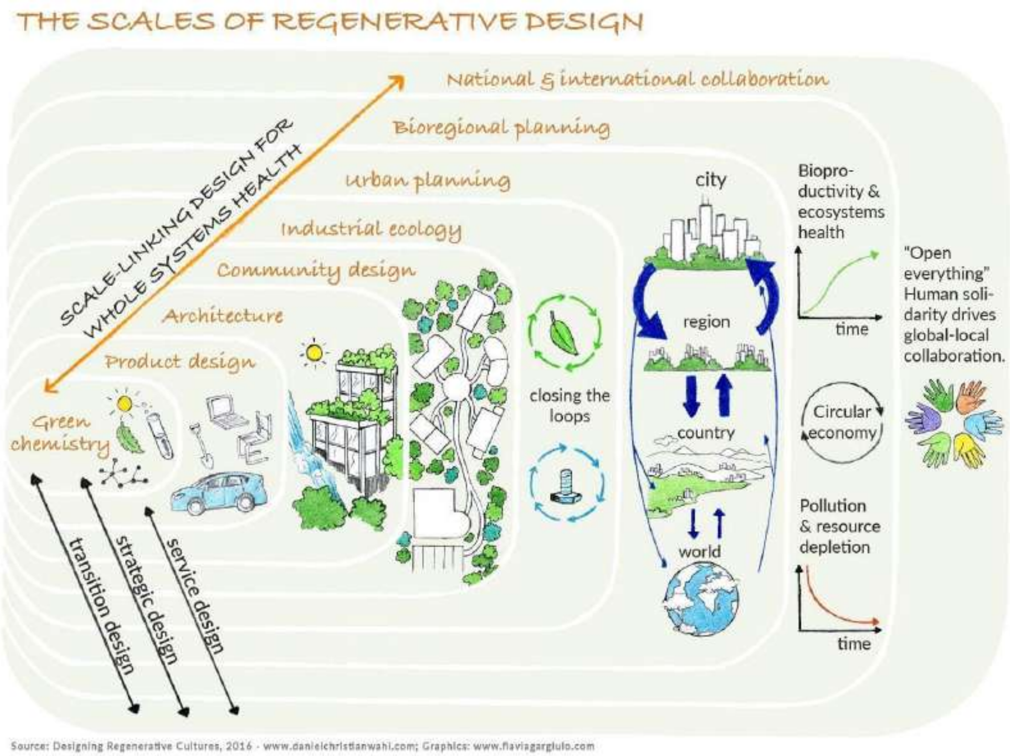

Figure 2. ***Designing Regenerative Cultures***
(Image: Daniel Christian Wahl, Designing Regenerative Cultures, 2016)

Further resources

1. Beever, Jonathan, and Andrew O. Brightman. "Reflexive Principlism as an Effective Approach for Developing Ethical Reasoning in Engineering." *Science & Engineering Ethics* 22 (2016): 275–291.
2. Burgos-Debray, Elizabeth, ed. *I, Rigoberta Menchú. An Indian Woman in Guatemala.* New York and London: Verso, 1984.
3. Center for Partnership Systems (website).
4. The DEAL Team. "What is the Doughnut?" Doughnut Economics Action Lab (DEAL). 15 July 2020.
5. Dermus, Deniz. "Care Ethics and Paternalism: A Beauvoirian Approach." *Philosophies* 7, no. 3 (May 2022).
6. Doughnut Economics Action Lab (DEAL). "About Doughnut Economics."
7. Eisler, Riane T. *The Chalice and the Blade: Our History, Our Future.* San Francisco: Perennial Library, 1988.
8. Eisler, Riane T. *The Real Wealth of Nations: Creating a Caring Economics.* San Francisco: Berrett-Koehler Publishers, Inc., 2007.
9. ETH Zurich Systemic Design Labs (website).
10. Gardels, Nathan. "Planetary Homeostasis." *NOEMA,* 22 July 2022.
11. Gilligan, Carol. "In a Different Voice: Women's Conceptions of Self and of Morality." *Harvard Educational Review* 47, no. 4 (Nov. 1977): 481–517.

12. Global Oneness Project. *Sawubona*. YouTube video. 8 Feb. 2007.
13. Green Swans Book Club. *Regeneration by Paul Hawken*. Volans YouTube video. 9 Nov. 2022.
14. Held, Virginia. *The Ethics of Care: Personal, Political, and Global.* New York: Oxford University Press, 2006.
15. Hug, Laura, Brett J. Baker, Karthik Anantharaman, Christopher T. Brown, Alexander J. Probst, Cindy J. Castelle, Cristina N. Butterfield et al. "A New View of the Tree of Life." *Nature Microbiology* 1, no. 16048 (Apr. 2016).
16. IEEE Standards Association. IEEE P7010™, Draft Recommended Practice for the Well-being Metric for Autonomous and Intelligent Systems (A/IS).
17. Infed (website).
18. International Labour Organization. "50 Million People Worldwide in Modern Slavery." Press release, 12 Sep. 2022.
19. McDonough, William. "William McDonough Articulates Circular Carbon Economy Framework for the G20." William McDonough website. 30 Mar. 2021.
20. Murray, Aphra. "Cobalt Mining: The Dark Side of the Renewable Energy Transition." Earth.org. 27 Sept. 2022.
21. National Park Service. "Indigenous Fire Practices Shape Our Land." Updated 4 Feb. 2022.
22. Noddings, Nel. "Caring: A Relational Approach to Ethics and Moral Education." 2nd ed. Oakland, CA: University of California Press, 2013.
23. Nurture Development. "Asset Based Community Development (ABCD)."
24. Partnerism (website).
25. Pirni, Alberto, Maurizio Balistreri, Marianna Capasso, Steven Umbrello, and Federica Merenda. "Robot Care Ethics Between Autonomy and Vulnerability: Coupling Principles and Practices in Autonomous Systems for Care." *Frontiers in Robotics and AI* 8 (16 June 2021).
26. Prosocial World (website).
27. Resilience (website).
28. Riem Natale, Antonella, and Roberto Albarea, eds. The Art of Partnership: Essays on Literature, Culture, Language and Education Towards a Cooperative Paradigm. Udine, Italy: Forum Editrice, 2003.
29. Royer, Alexandrine. "The Wellness Industry's Risky Embrace of AI-Driven Mental Health Care." Brookings, Tech Stream, 14 Oct. 2021.
30. Slaughter, Anne-Marie. "3 Responsibilities Every Government Has Towards Its Citizens." World Economic Forum, Education, 13 Feb. 2017.
31. UN General Assembly. Universal Declaration of Human Rights. Resolution 217 (III), A/RES/217 (111). 10 Dec. 1948.
32. Wahl, Daniel Christian. "Salutogenic Cities & Bioregional Regeneration (Part I of II)." Medium, Age of Awareness, 20 Mar. 2020.

Issue 2: Need for transdisciplinary collaboration

Background

The novel and interconnected nature of the global challenges calls for a transdisciplinary approach for climate change mitigation and repair. There is a need for holistic observation and analysis of the worldwide challenges in proper context. There is a need to identify and measure more accurately the impact of human behaviors and technologies on the well-being of humans and the living environment. Unfortunately, locally and globally, there is a tendency across sectors to compete and work in silos.

This leads to compartmentalizing disciplines, communities, and stakeholders when it comes to solving the complex problems of sustainability. As noted by Paul Cilliers,

> *Some systems have a very large number of components and perform sophisticated tasks, but in a way that can be analyzed (in the full sense of the word) accurately. Such a system is complicated. Other systems are constituted by such intricate sets of non-linear relationships and feedback loops that only certain aspects of them can be analyzed at a time. Moreover, these analyses would always cause distortions. Systems of this kind are complex.* (Cilliers, 1998)

This idea is illustrated further with a list of characteristics of complex systems (e.g., a "snowflake is complicated, human brain is complex").

This tendency of working in isolation also limits the emergence of regenerative solutions made possible through inclusion of people in discipline and knowledge areas not typically recognized or included in problem-solving spaces (e.g., Indigenous knowledge, social sciences, creative arts, and the lived experiences of those in the Global South most impacted by climate change).

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The global problems faced by humanity are interconnected yet often have been addressed separately by the people who work in individual fields of expertise typically related to the problem. For example, the problem of renewable energy is mostly being solved by engineers and scientists. For renewable energy to be effectively used by everyone, people who will be using it need to be involved and actively participate in the design process. This will require knowledge of the geographical and community context and a balanced assessment of the pros and cons affecting each stakeholder community (local and global).

Consider "discipline" as ways of knowing or practicing. Many people are not considered to have the "acceptable" credentials to participate in the problem-solving spaces. Transdisciplinary collaboration can increase the problem-solving capacity by widening the field of experience and skills. Transdisciplinary (TD) collaboration mixes "disciplines" together to solve problems (e.g., pairing an electrical engineer and a native person from the Amazon). This includes stakeholders not recognized by some as modern-day professionals. For example, although not recognized by all university-based professions as valid professionals, in regenerative design, Indigenous peoples are considered to be a source of useful knowledge regarding sustainability. Transdisciplinary collaboration also differs from other collaborative approaches (e.g., multidisciplinary, cross-disciplinary, and interdisciplinary). This emergent approach has the potential to unify branches of knowledge (e.g., technical, natural, social, and health sciences) to form something entirely new that the individual contributors could not create themselves.

To better understand the differences in disciplinary approaches, see Figure 3 below.

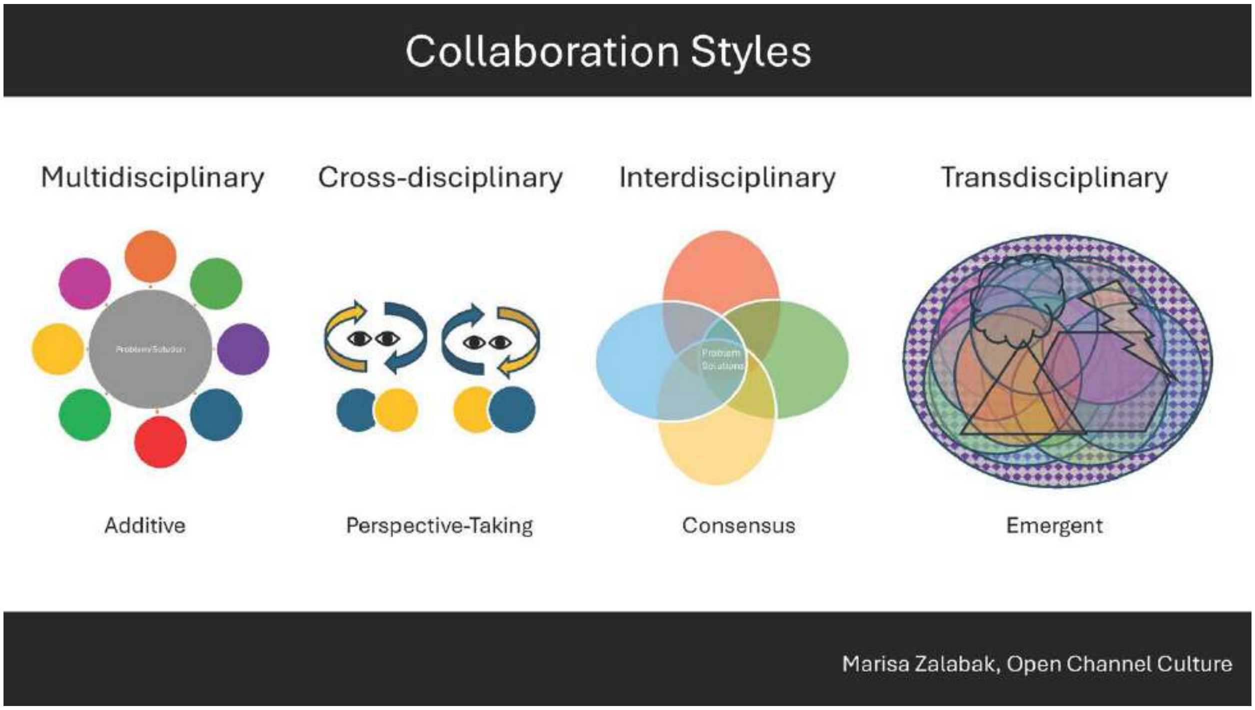

Figure 3. Emergence-Focused Collaboration
(Image: Marisa Zalabak)

Specific differences in disciplinary collaborative approaches are as follows:

- *Multidisciplinary* is additive, meaning that people from several different disciplines, domains, or groups remain within their individual boundaries (e.g., disciplines, specializations, and perspectives) and collaborate by adding ideas to the problem-solving space where the solution is determined by an assigned decision-maker.
- *Cross-disciplinary* is based in perspective taking, where empathy is used to view the problem-space from another discipline's perspective while individual boundaries still remain. For example, an aerospace engineer considers the point of view of a behavioral psychologist and the behavioral psychologist considers the point of view of the engineer when designing the safety features of a plane.
- *Interdisciplinary* is consensus-based, where two or more individual disciplinary boundaries are crossed, like a Venn diagram, identifying a consensus (i.e., all collaborators agree on the solution to the problem). This leads to the creation of a new level of integration—while still remaining within each member's or group's disciplinary framework. Interdisciplinary collaborations can lead to the creation of a new hybrid discipline (e.g., neuropsychology). For example, neuroscientists, psychologists, and medical doctors who have different methods to tackle a problem combine them to find a collectively agreed-upon solution.

- *Transdisciplinary* collaboration, referred to as *xenogenesis* (i.e., between, across, and beyond disciplines), transcends boundaries, unifying individual disciplines, branches of knowledge, and/or intellectual frameworks (e.g., technical, natural, social, and health sciences) to form an entirely new approach, unlike any of the contributing parts. It is a re-creative, emergent, regenerative approach. One key difference is the inclusion of all stakeholders (stakeholders often left excluded). Although transdisciplinary (TD) collaboration is often a messier and less predictable approach, some of the most innovative ideas and concepts emerge. The challenges of the nonconventional approach increase the need for regenerative processes during facilitation (e.g., stretch collaboration, psychological safety). This is an emergent process, and a single identified "field" or approach does not apply.

When using a TD collaboration approach, it is also important to consider social exclusion and the role it plays in limiting perspectives, knowledge, and experiences. Although the challenges facing our planet affect everyone, many people are not considered to have the "acceptable credentials" to participate in the problem-solving spaces. This applies as well to the ethical concerns with collaborations around designing, developing, and mobilizing technologies. With this in mind, TD collaboration can increase equity (as defined in the glossary) and problem-solving capacity by widening the field of experience and skill.

Transdisciplinary collaborations enable diverse collaborations to shine. As a booster for mobilizing innovation, these collaborations have the potential to:

- Grow psychological resilience and flexibility for navigating unknowns and adversity (e.g., tolerance for ambiguity, ability to express one's point of view while being aware that it is a limited perspective due to one's conditioning and unconscious biases).
- Reveal unexpected opportunities, risks, and leverage points in the collective field of effect.
- Create narratives that translate complex experiences into meaningful explanations and contributions while attracting and energizing others to join the learning journey.
- Increase experiential, educational opportunities through learning from and of others from different backgrounds, perspectives, and expertise (Lennon, Zalabak, & Dajani, 2020).

Recommendations

How we can facilitate effective transdisciplinary collaborations when collaborating in diverse groups seeking global solutions includes the following:

1. **Establish restorative circles practices.** Establish restorative circles practices, an Indigenous practice of deep listening, ensuring all voices are heard and honored, increasing equity, trust, and psychological safety needed to:
    a. **Create new pathways for solutions to emerge.**
    b. **Develop people's ability for navigating the unknown, an essential part of the transdisciplinary process (e.g., tolerance for ambiguity).**
    c. **Utilize and expand the practice of storytelling of circles by using platforms.** These circles can also be continued through diverse platforms (e.g., podcast and messaging apps), attracting and energizing others to join the journey by enabling storytellers to share experiences of doing meaningful work.

2. **Create collaborative agreements (social) that elevate and mobilize collective intelligence.** These agreements should be "living" documents, adapted and amended as needed throughout the collaboration to increase efficacy and meaning. This also serves to incorporate wisdom traditions and best practices for processing conflict constructively. This can be extended to include methodological and technical agreements and protocols. This document will:
    a. **Collect feedback for effective ongoing constructive collaboration.**
    b. **Help demystify the experience of working in a transdisciplinary environment for those who haven't experienced it.**
    c. **Use transdisciplinary collaborative agreements.** For an example, see Figure 4 for the agreement used by the Global Methodologies committee.

Figure 4. Community Agreements Example
(Image: Marisa Zalabak)

3. **Increase equity in the process** (e.g., language, gender, ethnicity, race, socioeconomic status, education, religion, and age). "Equity in the process" includes establishing processes for collecting and sharing information.
    a. **Apply multimodal and multi-perspective communication practices between all stakeholders.** This includes demystifying the language, concepts, and terminology used in technical professions when sharing information.
4. **Consider what is being measured.** Use of mixed methods (i.e., quantitative and qualitative combined; Schoonerboom & Johnson, 2017) with a translation of how the quantitative data relates to the complexity of human and planetary well-being. Technologies centered around care are modeled after humans; it is important to be aware of who and what is being measured and whose lens is used to process the data. One consideration is that technology is defined as separate from

humans, although humans apply human skills as tools in daily life. Increase education on the causes and effects of climate change. For example, adopt other multimodal forms of communication as tools for weaving human connection and understanding, cognitively aligning and enabling effective innovation (e.g., storytelling, visualizations).

a. **Create solid training models that can be adapted across cultures and backgrounds to reeducate and train a considerable percentage of humans on Earth toward a holistic lifestyle that includes care for all other creatures on the planet and turn things around** (e.g., regenerative design, life optimization).

5. **Create open and participatory platform solutions for collaboration.** Use AI and blockchain to create open and participatory platform solutions for transdisciplinary collaboration, unbiased collecting and sharing information, and tracking of issues and progress to better match resources with needs that have solid, positive planetary and financial impact. For example, using the World Intellectual Property Organization (WIPO) for intellectual property policy, services, information and cooperation.

Further resources

1. Binder, Claudia R. "Transdisciplinarity: Co-Creation of Knowledge for the Future." *RCC Perspectives*, no. 2 Minding the Gap: Working Across Disciplines in Environmental Studies (2014): 31–34.
2. Chandha, Saikiran. "Scientific Research Needs to Be More Transdisciplinary Than Ever." *Fast Company*, 19 Aug. 2022.
3. The DEAL Team. "What is the Doughnut?" Doughnut Economics Action Lab (DEAL). 15 July 2020.
4. Doughnut Economics Action Lab. "About Doughnut Economics."
5. Hill, Rosemary, Chrissy Grant, Melissa George, Catherine J. Robinson, Sue Jackson, and Nick Abel. "A Typology of Indigenous Engagement in Australian Environmental Management: Implications for Knowledge Integration and Social-Ecological System Sustainability." *Ecology and Society* 17, no. 1 (2020).
6. IEEE Standards Association. *IEEE P2890, Draft Recommended Practice for Provenance of Indigenous Peoples' Data*.
7. Kaiser, Matthias, and Peter Gluckman. "Looking at the Future of Transdisciplinary Research." *Center for Science Futures*, 2023.
8. Kim, Milena Kiatkoski, Michael M. Douglas, David Pannell, Samantha A. Setterfield, Rosemary Hill, Sarah Laborde, Laura Perrott, Jorge G. Álvarez-Romero et al. "When to Use Transdisciplinary Approaches for Environmental Research." *Frontiers in Environmental Science* 10 (9 May 2022).
9. Kuban, Adam. "Transdisciplinary Collaboration: An Introduction." National Association of Geoscience Teachers.
10. Marchant, Natalie. "Thinking Like Leonardo da Vinci Will Help Children Tackle Climate Change." World Economic Forum, *Behavioral Science*, 11 May 2021.
11. Mâsse, Louise C., Richard P. Moser, Daniel Stokols, Brandie K. Taylor, Stephen E. Marcus, Glen D. Morgan, Kara L. Hall, Robert T. Croyle, and William M. Trochim. "Measuring Collaboration and Transdisciplinary Integration in Team Science." *American Journal of Preventive Medicine* 35, no. 2S (Aug. 2008).

12. McPhee, Chris, Martin Bliemel, and Mieke van der Bijl-Brouwer. "Editorial: Transdisciplinary Innovation (August 2018)." *Technology Innovation Management (TIM) Review* 8, no. 8 (Aug. 2018): 3–6.
13. Pokojska, Justyna. "Competencies of the Future as a Transdisciplinary." *Proceedings of the 13th International Multi-Conference on Complexity, Informatics and Cybernetics* (IMCIC 2022).
14. Polman, Paul, and Andrew Winston. "The Net Positive Manifesto." *Harvard Business Review Magazine*, Sept.–Oct. 2021.
15. Project Drawdown (website).
16. Project Drawdown. "Climate Solutions 101."
17. Regenesis Group (website).
18. Root-Bernstein, Robert. "Correlation between Tools for Thinking; Arts, Crafts, and Design Avocations; and Scientific Achievement among STEMM Professionals." *Proceedings of the National Academy of Sciences of the United States of America* 116, no. 6 (Feb. 2019): 1910–1917.
19. Science and Nonduality. *Story Disruption & Morphogenesis, Charles Eisenstein*. YouTube video. 27 Nov. 2015.
20. Taylor Wesselink, Keisha. "Interdisciplinary and Transdisciplinary—Creating Maps for the Maze and Our Labyrinth." SHAPE-ID, 5 Oct. 2020.
21. Taylor Wesselink, Keisha, and Doireann Wallace. "System of Preconditions for Successful Arts, Humanities and Social Sciences Integration." *Zenodo*, 28 Jan. 2021.
22. "Tolerance of Ambiguity." *Science Direct, 2015.*
23. Tötzer, Tanja, Sabine Sedlacek, and Markus Knoflacher. "Designing the Future—A Reflection of a Transdisciplinary Case Study in Austria." *Futures* 43, no. 8 (2011): 840–852.
24. Zingale, Nicolas, Julieta Matos-Castaño, Abigail Poeske, and Anouk Geenen. "Transdisciplinarity and the Future: Conversations between Cleveland State University and University of Twente." Change Forward: Visions and Voices of Higher Education's Future 2021–2022. University Innovation Fellows, 28 Oct. 2022.

Issue 3: Technical barriers to achieving regenerative sustainability

Background

When proposing global methodologies for climate change mitigation, it is important to consider technical barriers to achieving intended solutions. *Technical barriers* can be geographic, scientific, and technological. These barriers can affect the design, development, production, and mobilization of individual mitigation strategies. When solving complex problems with technologies, collateral damage as in unintended and unanticipated consequences can emerge at every phase of the proposed solutions from inception to completion to end of life/use, for example:

- Materials and supply chains involved in battery-operated cars currently depend mostly on batteries created with lithium, while the noncircular disposal and replacement of batteries can result in negative impacts.
- The fossil fuels currently used to produce wind turbines may reduce the positive impacts of clean energy created by the turbines.
- Dam construction in the Northwest of the United States initially produced low-cost, high-value electricity but resulted in an expense to society by reducing the available food source produced by salmon fisheries (NPCC, "Dams").
- The recycling of plastics can result in microplastics in the atmosphere as well as other ways plastics have become embedded and integrated into natural ecosystems.
- Manufacture of single-use plastics, e.g. for potable liquids, result in the production of plastic debris polluting the oceans and dispersing throughout the environment (i.e., wicked problems) and the exposure to virtually forever chemicals contaminating the environment.

Technical barriers are complicated by a lack of continual real-time evaluation with protocols and metrics that effectively measure negative impacts on the well-being of entire socioeconomic systems (e.g., The Gross National Happiness (GNH) measure from Bhutan). Another contributor to technical ineffectiveness includes barriers to implementation. Implementation of solutions for transforming the planet to regenerative, sustainable ecosystems. Regenerative ecosystems are holistic and co-evolving. They focus on the wellbeing of the entire system (e.g., rainforests, "circular" communities, or the body of any living being, where the wellbeing of the whole system is reliant on the health of all its parts) (Elo et al., 2024). Regenerative businesses, societies and agriculture, essentially practice biomimicry, that is, mimic nature. These societal structures connect people to places, natural systems, and technologies. This is also often sabotaged by human barriers and social pressures (e.g., access to technology, lack of resources, energy sources, political conflicts, economic preferences for profit and gain). Although some barriers to mitigation can be effectively solved by technology, these approaches can conflict with current socioeconomic systems in place around the world (recording can be found at the link).

Global methodologies are still developing. No single methodology can address the entirety of diverse global societies, environments, and natural world issues. Many of these methodologies are originally proposed in silos—they have no clearly defined links to connect them. As methodologies develop, links that integrate objectives, strategies, targets, metrics, and impacts need to be refined.

As new technologies are discovered to improve climate change mitigation, it is essential to understand the potential impacts outside of the focus area. For example:

- In the shipping industry, there is movement to help ensure that the design of every ship must consider the entire life span of each component so that ships that are retired won't show up as trash in another part of the world, perpetuating the problem.
- The use of plants to replace biofuels may result in food shortages, poor food quality, or inflation.
- The communications technology created to provide more access and connectivity globally can end as electronic waste in landfills, damaging the planet.

Because of these potential negative impacts, we need to be mindful of existing gaps and barriers that inevitably occur whenever different technological concepts, languages, methods, and disciplines interact. As a consequence, some of these gaps prevent effective technical solutions from being globally applied. If a community cannot understand the technical concept and implications of a solution, they cannot apply it themselves or keep it running sustainably after implementation. For example, different climate change forecasting models (including formatting and data collection) do not always have shared languages and methods. They sometimes result in conflicting predictions when applied in diverse geographic locations.

In addition, unpredictable challenges can surface as technologies evolve without their long-term vetting (e.g., cost-benefit analysis or life-cycle effects), for example, cobalt used to mobilize electric vehicles resulting in disposal and mining issues or sulfur dioxide seeding to improve reflective qualities of the atmosphere and cool the planet resulting in acid rain. Careful vetting is also often limited by a lack of shared information following negative technical incidents (e.g., registry). Although the nature of vetting can require countless rounds of experimentation for improvement, it can provide the necessary guardrails to help prevent significant negative, unintended impacts. When well vetted in partnership with governmental support, like smart farming systems, technologies can improve efficiency and reduce resource consumption with fewer negative side effects.

Recommendations

1. **Link and integrate major global methodologies.** To address technical barriers that inhibit achieving a positive sustainable turnaround by 2030, major global methodologies should be linked and integrated through meaningful and practical objectives, strategies, targets, and metrics. Consider Malcolm Gladwell's description of the *tipping point:* the "magic moment when an idea, trend, or social behavior crosses a threshold, tips, and spreads like wildfire" (Gladwell, 2000).
2. **Incentivize collaboration between organizations.** Create a global communications campaign to incentivize outreach between organizations and entities for exchange and collaboration.
3. **Encourage compatibility /interoperability of technical standards.** Align the technical standards used around the globe and /or by global entities to proactively drive the integration of the various methodologies
4. **Create maps of methodologies.** Leverage AI technology to create maps of methodologies that identify the domain concepts and the relationships among them to harmonize them across domains and dimensions (as illustrated in a map included later in this chapter), including the following:

a. **The development of global maps of methodologies should consider that a methodology that works in one location does not always work well in another. Allow for context-specific, community-driven, and localized application of methodologies.**

b. **Utilize AI applications to match organizations and individuals and improve communication of shared goals, connecting the purpose of initiatives in alignment with the sustainable development goals** (e.g., SDG and ESG).

c. **Create maps or detailed registries of wicked problems discovered in vetting and deployment, including notable incidents in time to prevent future damage** (e.g., "test and invest", IEEE P7010™,).

d. **Create applications for wicked problem prediction and mitigation.**

5. **Encourage governments to deploy tools like incentives and reminders to encourage collaboration and cooperation among stakeholders.** Create incentives and systemic reminders (i.e., nudge theory and choice architecture, discussed by Richard H. Thaler) at the government level to encourage cooperation and collaboration between technical entities and stakeholders to achieve holistic innovations (e.g., organizations, institutions, agencies, businesses, nonprofits, communities, and individuals).

6. **Verify applicability of methodologies.** Provide some form of valuation/metric for each methodology that communicates the success of the methodology, and consider the following:

   a. **Create deterrents to avoid innovating for things that are not necessary.** For example, reduction in production may be a solution because it seems like societies continue to create products, run into issues they cause, then create rules and regulations to minimize those issues. Some societies keep doing this cycle after cycle, while no amount of knowledge and advancement has helped them find a sense of contentment and "enoughness." We have become an "issue-creating, issue-solving species" that can potentially never be satisfied.

Further resources

1. Achlim, Yasmina. "Environmental Impact of Salmon Farming." One Green Planet Earth.
2. Adams, Chris, Rym Baouendi, Tim Frick, Tom Greenwood, and Dryden Williams. "Estimating Digital Emissions." Sustainable Web Design. Updated 17 Apr. 2022.
3. "Application of Southern California Gas Company (U904G) for Authority to Establish a Memorandum Account for the Angeles Link Project." *Before the Public Utilities Commission of the State of California. Application 22-02.* Filed 17 Feb. 2022.[47]
4. B Corporation (website).
5. Boutros, Tristan. "The Ego: The Biggest Barrier to Success and Leadership." Process Excellence Network (PEX). 17 May 2015.
6. Carbon Trust. "Briefing: What Are Scope 3 Emissions?"
7. Brondizio, Eduardo, Sandra Díaz, Josef Settele, S. Díaz, and Hien T. Ngo, eds. *The Global Assessment Report on Biodiversity and Ecosystem Services.* Bonn, Germany: IPBES Secretariat, 2019.

[47] Green Hydrogen solution.

8. Chibvongodze, Danford T. "Ubuntu is Not Only about the Human! An Analysis of the Role of African Philosophy and Ethics in Environment Management." *Journal of Human Ecology* 53, no. 2 (2016): 157–166.
9. Climate Change AI. "AAAI 2022 Fall Symposium: The Role of AI in Responding to Climate Challenges."
10. Conspicuous Capitalism (website).
11. Davis, Shawna. "Having Chickens Reduces Your Food Waste, and There's Proof." dengarden, 30 Dec. 2022.
12. Donoff, Elizabeth. "Nobel Prize for the Discovery of the Blue LED." *Architect Magazine*, 6 Dec. 2016.
13. Earth Charter (website).
14. Elkington, John. *Green Swans: The Coming Boom in Regenerative Capitalism*. New York: Fast Company Press, 2020.
15. Etieyibo, Edwin. "Ubuntu and the Environment." In *The Palgrave Handbook of African Philosophy, edited by* Adeshina Afolayan and Toyin Falola. New York: Palgrave Macmillan, 2017.
16. Global Oneness Project. *Sawubona*. YouTube video. 8 Feb. 2007.
17. Government of Canada. "RETScreen Clean Energy Management Software." Natural Resources Canada; Maps, Tools, and Publications; Tools; Data Analysis Software Modelling Tools.
18. Hagens, Nate. *The Great Simplification: Film on Energy, Environment, and Our Future.* YouTube video, 19 May 2022.
19. Henfrey, Thomas. "Designing for Resilience: Permaculture as a Transdisciplinary Methodology in Applied Resilience Research." *Ecology & Society* 23, no. 2 (2018).
20. Hickel, Jason, Sam Fankhauser, and Kate Raworth. "How to Save the Planet: Degrowth vs Green Growth?" The Smith School, School of Geography and the Environment. Video recording. 2 Sep. 2022.
21. Hougaard, Rasmus, and Jacqueline Carter. "Ego is the Enemy of the Good." *Harvard Business Review*, 6 Nov. 2018.
22. "Investment Theme: Sustainability." S&P Dow Jones Indices.
23. Jacobson, Mark Z., Anna-Katharina von Krauland, Stephen J. Coughlin, Emily Dukas, Alexander J. H. Nelson, Frances C. Palmer, and Kylie R. Rasmussen. "Low-Cost Solutions to Global Warming, Air Pollution, and Energy Insecurity for 145 Countries." *Energy & Environmental Science* 15, no. 3343 (2022).
24. Kumar, Pushpam. "This Index Measures Progress and Sustainability Better Than GDP." Columbia Climate School, Climate Earth, and Society, State of the Planet, 9 Oct. 2018.
25. Lai, Charmaine, Subutai Ahmad, Donna Dubinsky, and Christy Maver. "AI Is Harming Our Planet: Addressing AI's Staggering Energy Cost." *Numenta* (blog), 24 May 2022.
26. Lewis, Barnaby. "How Smart Farming Is Changing the Future of Food." ISO News, 15 June 2022.
27. Liew, Robert. "Can Wind Power Become Truly Carbon Neutral?" Wood MacKenzie, 8 July 2021.
28. Lin, Janice. *Beyond Power: Opportunities and Challenges for Green Hydrogen.* Green Hydrogen Coalition, June 2020.

29. Lipták, Béla. "Hydrogen Is Key to Sustainable Green Energy." Control, 24 Jan. 2022.[48]
30. Mann, Paul. "Can Bringing Back Mammoths Help Stop Climate Change?" *Smithsonian Magazine*, 14 May 2018.
31. McDonough, William. "William McDonough Articulates Circular Carbon Economy Framework for the G20." William McDonough, 20 Mar. 2021.
32. Melanie Goodchild (website).
33. "Mining Landfills." *Mission 2016: The Future of Strategic Natural Resources*, MIT.edu.
34. National Academies of Sciences, Engineering, and Medicine. *Gaseous Carbon Waste Streams Utilization: Status and Research Needs.* Washington, DC: The National Academies Press, 2019.
35. Newcomb, Tim. "Scientists Are Reincarnating the Woolly Mammoth to Return in 4 Years." *Popular Mechanics*, 20 Jan. 2023.
36. Partnerism (website).
37. ProSocial World (website).
38. Purpose (website).
39. Regeneration (website). "Methodology."[49]
40. Resilience (website). "Daniel Christian Wahl."[50]
41. Maersk. Sustainability at Maersk, Our ESG Priorities. "Responsible Ship Recycling."
42. SYSTEMIQ. "Introducing the Global Commons Stewardship Framework." SYSTEMIQ Earth, 19 May 2022.
43. Terblanché-Greeff, Aida C. "Ubuntu and Environmental Ethics: The West Can Learn from Africa When Faced with Climate Change." In *African Environmental Ethics*. Chemhuru, M., ed. *The International Library of Environmental, Agricultural and Food Ethics* 29 (2019). Springer, Cham.
44. UN Department of Economic and Social Affairs. "The 17 Goals." Sustainable Development.
45. Weaver, John Fitzgerald. "LA Could Soon Be Home to the Nation's Largest Green Hydrogen Infrastructure System." *PV Magazine*, 17 Feb. 2022.[51]
46. "What is the Seventh Generation Principle?" *Indigenous Corporate Training Inc.* (blog). 30 May 2020.
47. World Climate Tech Summit (website).
48. Yeung, Peter. "The Toxic Effects of Electronic Waste in Accra, Ghana." Bloomberg CityLab, 29 May 2019.

[48] Green Hydrogen solution.
[49] Regenerative Methods/Models (Paul Hawken).
[50] Regenerative Methods/Models (Paul Hawken).
[51] Green Hydrogen solution.

Issue 4: Human barriers to achieving regenerative sustainability by 2030

Background

Since technological barriers are so often interwoven with human capacities to solve problems in diverse paradigms, advantages and disadvantages emerge together that must be considered. The complexity of human diversity—individual, collective, and social (e.g., socioeconomic, cultural, political, and geographic realities and experiences)—presents barriers for coordinated actions that lead to effective outcomes. While we face global challenges as humans living on the same planet, like climate change, the place in which we live influences how we can solve the problem. To better understand and apply appropriate interventions and mitigations it is essential to use methods and approaches that are capable of differentiating needs, causes and effects, for example, "location intelligence" (e.g., Life Map) and other methods that research the specific energy consumption in each location, the energy consumption resulting from natural systems, and the technologies used (e.g., AIS). In addition to the energy use, other factors like water use and product lifecycle must be considered.

A lack of social coherence also plays a big role in continuing destructive social behaviors, calling for applications for mitigating conflict and increasing peacemaking within, between, and across local and global boundaries. Conflicts fed by perceived threats to basic psychological human needs (safety, security, etc.) too often result in natural reactive behaviors (e.g., fight, flight, or freeze) driven by emotions (e.g., fear, anxiety, anger, sadness).

Political norms in varying countries also influence the ability to create change. In some countries, citizens have the power to create movements of change (e.g., a democracy), while in others the ruling party controls what can be done. In addition, political norms, cultural norms, socioeconomic structures, and psychological factors affect the ability to inspire people's minds to change (e.g., see Jared Diamond: Collapse). Positive change in behaviors and social practices require new mindsets that deeply engage all levels (e.g., individual, social, industrial, communal) accounting for the interconnectedness of all life and elements on Earth. As Bernard Shaw wrote, "Progress is impossible without change, and those who cannot change their minds cannot change anything" (Bernard, 2018). As described in this Chapter's Issue 1, *care* is of universal relevance. Despite all contextual and cultural differentiation, care is a golden, connective thread. A collection of effective methodologies is necessary to support cooperation and combined efforts to meet these challenges and realize the aspirations for planetary well-being.

As data-driven technologies scale and exploitative economic practices have grown unchecked, cultures of care (as described in our Issue 1), continue to be diminished. Prioritizing quantifiable outcomes over well-being (e.g., GDP vs GNH) can inevitably lead to a decline of cultures of care across public and private sectors, resulting in challenges to human and animal rights as well as the preservation of natural spaces. In addition, the proliferation of misinformation increases divisiveness that hinders changes in behavior.

Fortunately, some methodologies bridge Indigenous wisdom traditions, effective for thousands of years (e.g., Seven Generations and Ubuntu) to newer methodologies (e.g., conscious capitalism, Doughnut economics, and B Corp Certification). Currently, with a few expectations, most of these methodologies exist in silos and do not capitalize on the vast overlap, potential synergies, and possible symbiotic relationships. While the UN Sustainable Development Goals (SDGs) represent the biggest global attempt to bridge silos for sustainable, life-promoting policies today, there is still a lack of consensus that negatively affects meaningful action. For example, divides exist for many corporations and government entities. There are those who prefer to base their actions solely on environmental, social, and corporate governance (ESG) metrics versus the SDGs, preventing aligned actions. For example, most ESG metrics valued by business enterprises do not encompass the needs of the entire ecosystem (e.g., farmers, schools, not-for-profit services). In addition, methods that are currently recommended as roadmaps (e.g., SDGs) have evolved and will continue to evolve from their original forms. Consequently, no single framework or methodology will be sufficient.

Within the wider context of global knowledge (e.g., sociology, geography, and regional sciences) there are two distinguishable factors: individual and environmental. *Individual* relates to the personal experience of a human being within day-to-day parameters, while *environmental* relates to external events, which may affect wider groups, regions, and nations. The interaction between the individual and environmental spheres is where impact resides, raising the key performance indicators' (KPIs') every iteration, so that each methodology is more ambitious than the one before. This can be exemplified by the current European Green Deal, which targets much more ambitious goals as opposed to the plans in the prior programming periods. But there is little emphasis on the societal processes and behaviors that need to occur to translate these targets into concrete actions.

There are several layers of considerations, which impact the implementation of various frameworks and contexts. There is an initial local context (e.g., individual or environmental), the regional geographic context, and the global context. Each of these present a different space for implementation of green methodologies and technologies that may present a new wave of challenges. In addition, the temporal nature and regional context of methodological approaches are barriers for implementation, which include traditional geopolitical competitions that prevent countries from working as true global partners.

Other major barriers to achieving the goals of planetary well-being include human perceptions and biases based on personal locations, habits, cultures, beliefs, and educational backgrounds as well as political and social preferences. Although diversity is an advantage socially and biologically, aggressive differences and lack of consensus can result in little or no action. Despite often-cited climate change skepticism, the UN Peoples' Climate Vote demonstrated that a significant percentage of the world's population is concerned and shares the desire to live in a sustainable and responsible manner.

An additional hindrance is created by the financial concerns and incentives driven by old models for profitability. Even though a sustainable-oriented business may be created with the best intentions, in the end it is often taken over or merged into large profit-driven corporations (where many prioritize exponential growth models measured primarily by fiscal metrics in isolation, rather than including metrics for human and planetary well-being). Often this forces smaller, sustainable businesses into luxury niches that few people can afford (e.g., the merger of European chocolate companies). The lack of models or profit with purpose that fit within the constraints of sustainability (e.g., Doughnut Economy, Net Positive) also hinders progress.

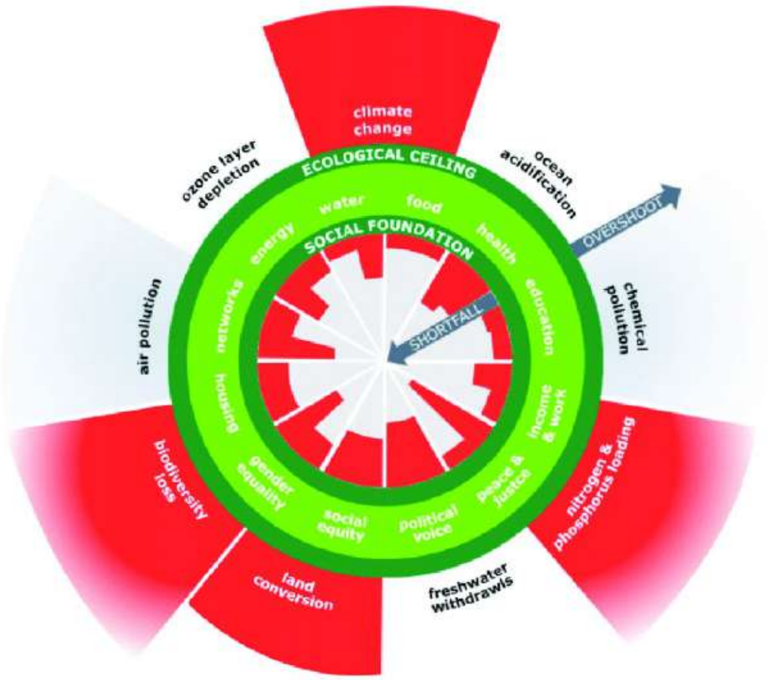

***Figure 5.* Doughnut Economics**
(Image: The Doughnut of social and planetary boundaries (Kate Raworth and Christain Guthier)

A barrier to change is individuals' mindsets, due to limitations of current mental models created by personal experiences and self-reinforcing habits learned over a lifetime and mental models and belief systems developed over time by life experience. This results in blind spots, making it difficult for individuals to see clearly and objectively—to say what they think, do what they say, and see what they do.

Conflicts occur individually, interpersonally, and socially given the reactions to threats created by climate change. Understanding basic human psychological needs (i.e., safety, security, belonging, respect, love, and self-actualization) is essential. Many reactions, although presented as opposition to taking action, are based in fear and sadness regarding the effects and potential consequences of the climate warming.

A fundamental shift in mindset is required to overcome these barriers. A shift is required to a more holistic approach, where sustainability is inherently valued, is a core expectation, and is measured, monitored, and designed accordingly, both for compliance and to drive sustainable innovation. In order to shift paradigms of entrenched mindsets, deeper levels and methods of learning are required to develop awareness of other belief systems and holistic thinking. These deeper insights can lead to seismic shifts of perception and effective consequential action.

Recommendations

To benefit from the establishment of technologically advanced and environmentally conscious societies, observe the following recommendations.

1. **Coordinate action via all existing and emerging sustainability-oriented methodologies.** What is urgently needed at this point in history is coordinated action via all existing sustainability-oriented methodologies alongside improving human factors that impact processes. Linking these

methodologies and technologies in a meaningful and pragmatic manner is paramount for reaching the tipping point for a positive turnaround (see mind maps discussed in Issue 5).

2. **Share information about process possible improvement widely.** When implementing processes, information about proposed improvement iterations should be made accessible to as many affected stakeholders as possible, reaching all levels in societies. Engagement at all levels to improve the impact of the various goals and innovations is paramount.
3. **Develop and share impact assessment reports.** To engage more people, impact assessment reports will be needed, differentiated by target, goals, and focus of impact. This includes the need for the impacts of current and proposed technologies.
4. **Incorporate sustainability and climate change related education widely.** Education in sustainability and climate change must be incorporated in general pre-K to 12 education and in every sector of society for all generations.
5. **Foster democratization.** Assign ownership of individual's data to the individuals. Democratization is needed in data-driven technologies to foster global creative societies (e.g., Society 5.0). To achieve this democratization, individuals' data should be made available to them as owner and access and use granted by them.
6. **Create methods to bridge communication gaps between diverse demographics.** Create methods to bridge differences and gaps in communication between diverse demographics (e.g., semantics) and provide access to conflict management and peacemaking.
7. **Urgently address climate change adaptation and mitigation.**
8. **Prevent misinformation.** Create systems and processes to address misinformation driven by personally and/or politically driven actors intending to mislead the general public about the realities of climate change.
9. **Address ecoanxiety.** Create programs/approaches to address ecoanxiety: locus of control (Krockow, 2023) and binary and nonbinary thinking including the following:
    a. **Incorporate a range of practices for constructive conflict mediation.** This includes Indigenous cultural and religious practices, as well as practices from social sciences that create opportunities for conflicts to result in a win–win outcome versus a temporary compromise. This includes empathetic listening, establishing a shared language for conceptual understanding, respect for individual, cultural, and religious values, and distinguishing between what is wanted and what is needed by all parties and the community involved. Some examples include Indigenous-based restorative circles, nonviolent communication, relational thinking, Indigenous wisdom traditions' "original ways of knowing" (Anishinaabe Gikendaasowin) (see Goodchild, 2021) and the United Nations General Assembly. One example of a technical augmentation is an app created to help users apply empathic, perspective-taking strategies in daily life to mediate conflicts constructively.
10. **Encourage changing mindsets.** A fundamental change in the mindset of individuals, communities, and nations is required in order to overcome their blind spots, to let nature work, and to reestablish and unleash the capacity for self-healing. The following is an example:
    a. Applying the Presencing Institute model, Theory U: Theory U has been utilized by the United Nations Development Coordination Office together with the Presencing Institute in 2021 to assist 14 countries in the adoption of the UN Sustainable Development Goals (SDGs) to advance the UN Agenda 2030. Theory U is used to counter illusive, unhealthy, ego-driven

social habits. In support of developing a heightened sense of systems thinking through complex systems, Theory U fosters collaboration and action learning by encouraging the creation of new prototypes that help to identify different levels of the emerging knowledge and understanding and how consequential action comes into being. This approach supports authentic change by:

i. Holding spaces for deep listening.
ii. Observing while suspending judgment.
iii. Sensing what is occurring with an "open mind, open heart, and open will."
iv. Increasing participants' ability for "presencing," the "capacity to connect to the deepest" sources of self and to access an inner place of stillness where inherent "knowing" is more able to surface.
v. Crystallizing and committing to a shared purpose.
vi. Prototyping, which involves "integration of thinking, feeling, and will in the context of practical applications and learning by doing."
vii. Coevolving as a group, convening the right sets of players to help them to co-sense and cocreate at the scale of the whole.

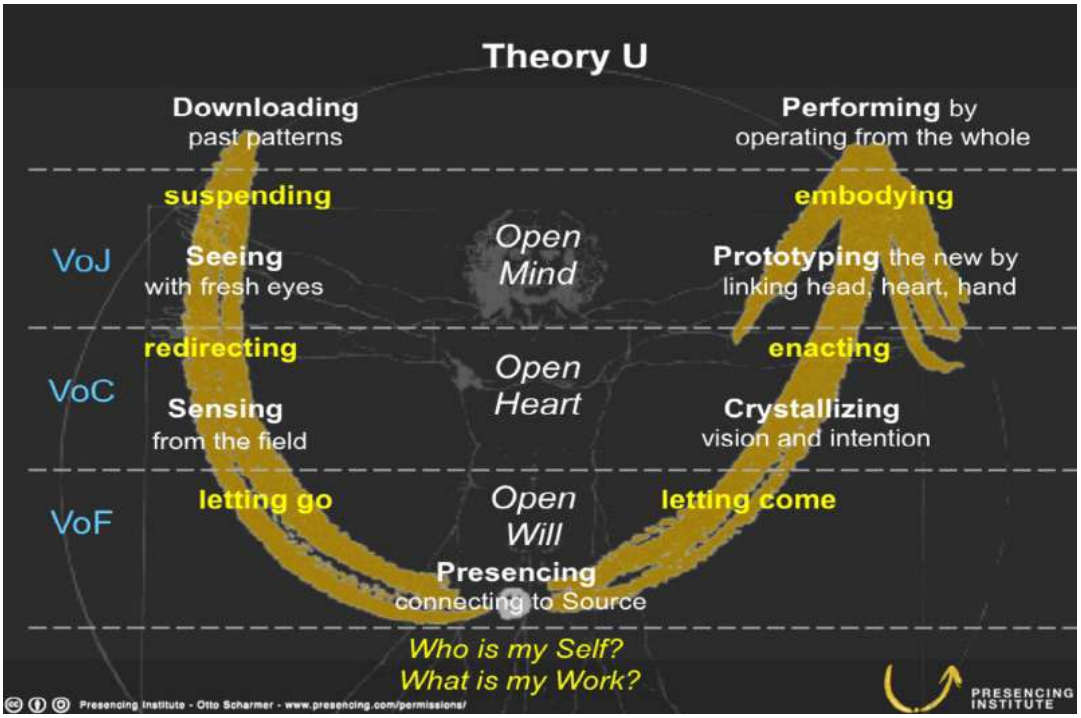

Figure 6. ***Theory U***
(Image: u-school for Transformation and the Presencing Institute)

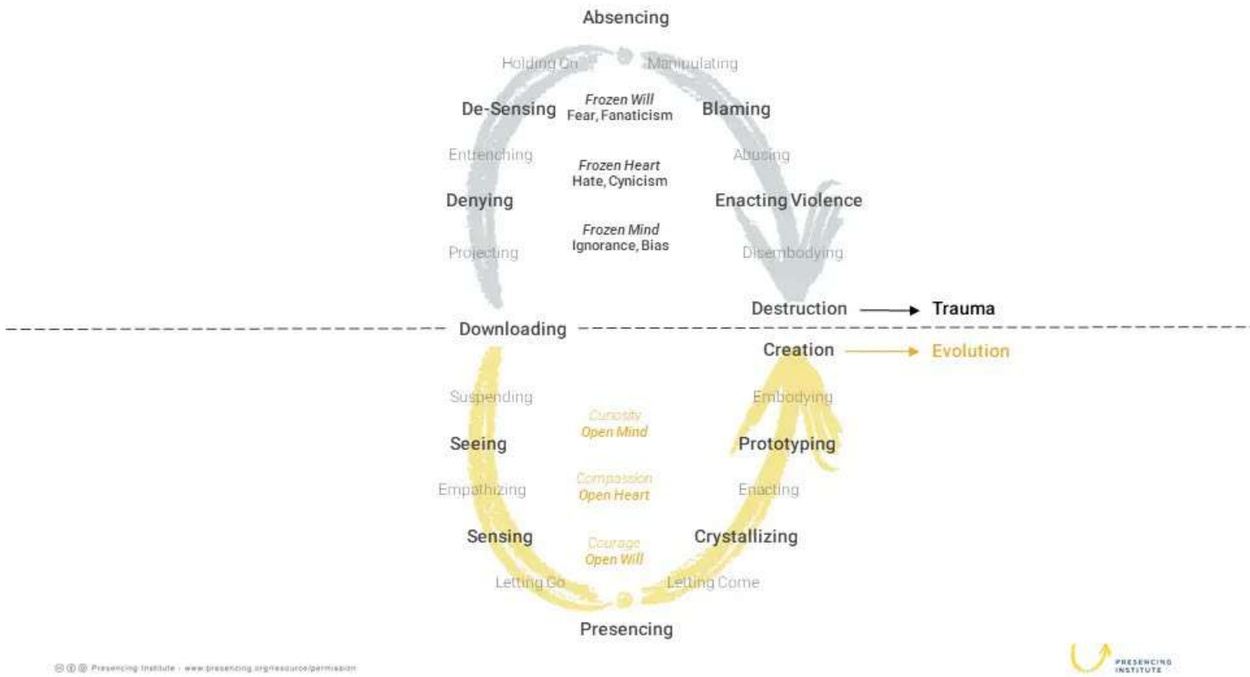

Figure 7. [*Theory U—Presencing and Sensing Process*]
[(Image: u-school for Transformation and the Presencing Institute)]

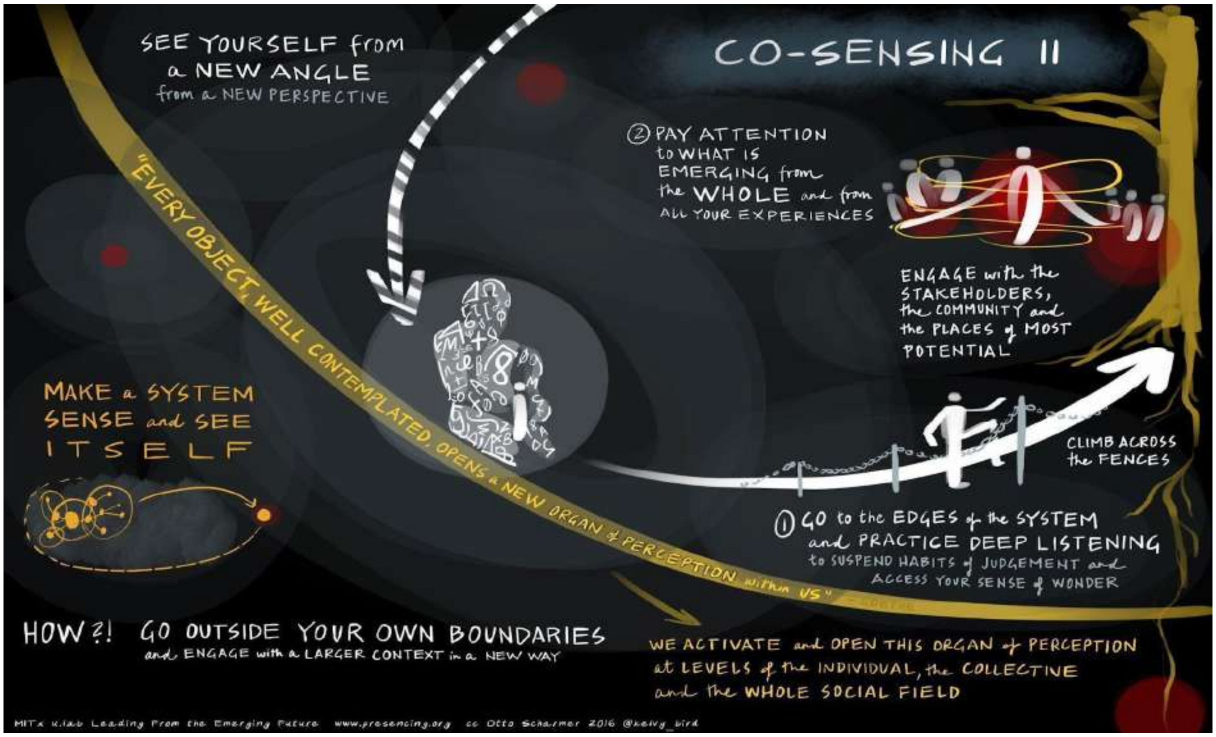

Figure 8. [*Theory U—Co-Sensing*]
[(Image: u-school for Transformation and the Presencing Institute)]

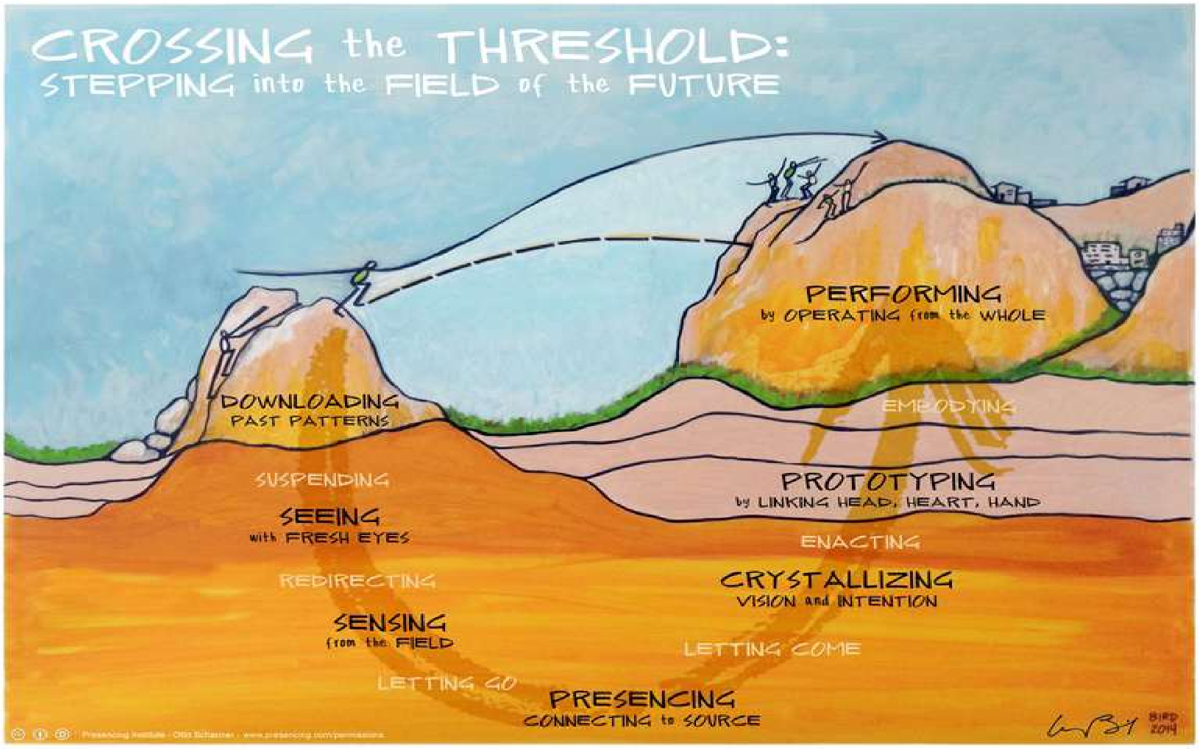

Figure 9. ***Theory U—Stepping into the Field of the Future***
(Image: u-school for Transformation and the Presencing Institute)

Further resources

1. Adhanom Ghebreyesus, Tedros. "Conflict, Climate Crisis and COVID: World Needs 'Peace for Health and Health for Peace'." World Health Organization, Commentaries, 7 Apr. 2022.
2. Bernier, Andrew. "Sustainability Storytelling is Not Just Telling Stories about Sustainability." In Reference Module in Earth Systems and Environmental Sciences, edited by M.I. Goldstein and D. A. DellaSala, 430–437. Encyclopedia of the World's Biomes 5, Elsevier (2020).
3. Buhaug, Halvard, Tor A. Benjaminsen, Elizabeth A. Gilmore, and Cullen S. Hendrix. "Climate-Driven Risks to Peace Over the 21st Century." *Climate Risk Management* 39, no. 100471 (2023).
4. Curiosity Stream. "Going Circular."
5. DePaul University. Asset-Based Community Development Institute (ABCD).
6. European Commission. "Business & Biodiversity." Energy, Climate Change, Environment, *Green Business*.
7. European Parliament. "EU Measures Against Climate Change." Topics, Climate and Environment, Climate Change., 7 Aug. 2018.
8. Goodchild, Melanie. "Relational Systems Thinking: The Dibaajimowin (Story) of Re-Theorizing 'Systems Thinking' and 'Complexity Science'." *Journal of Awareness-Based Systems Change* 2, no. 1 (2022).

9. Hentsch, Rachel. "SDG Leadership Labs: Supporting UN Country Teams to Achieve Agenda 2030." *Medium, Field of the Future* (blog), 10 Dec. 2021.
10. Krey, V., O. Masera, G. Blanford, T. Bruckner, R. Cooke, K. Fisher-Vanden, H. Haberl et al. "Annex II: Metrics & Methodology." In *Climate Change 2014: Mitigation of Climate Change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by O. R. Edenhofer, Y. Pichs-Madruga, E. Sokona, S. Farahani, K. Kadner, A. Seyboth, I. Adler et al.
11. Lazard, Olivia. *The Blind Spots of the Green Energy Transition.* TED Talks, TED Countdown New York Session 2022.
12. MDPI Sustainability. "Sustainable Education and Approaches." MDPI Sustainability.
13. Scharmer, C. Otto. *Theory U: Leading from the Future As It Emerges*. Oakland, CA: Berrett-Koehler Publishers, Kindle Edition, 2016: 29–114.
14. Schmitt, M. T., S. D. Neufeld, C. M. L. Mackay, and O. Dys-Steenbergen. "The Perils of Explaining Climate Inaction in Terms of Psychological Barriers." *Journal of Social Issues* 76 (2020): 123–135.
15. Ship Recycling Transparency Initiative. "Using Transparency to Drive Progress on Responsible Ship Recycling."
16. Swim, Janet, Susan Clayton, and George Howard. "Human Behavioral Contributions to Climate Change: Psychological and Contextual Drivers." *American Psychologist* 66, no. 4 (2011): 251–261.
17. u-school for Transformation by Presencing Institute. "SDG Leadership Labs: Supporting UN Country Teams to Achieve Agenda 2030." 9 Dec. 2021.
18. u-school for Transformation by Presencing Institute. "Theory U."
19. UN. Conflict and Climate (blog). United Nations, Climate Change. 12 July 2022.
20. UN, Security Council. "Climate Change 'Biggest Threat Modern Humans Have Ever Faced', World-Renowned Naturalist Tells Security Council, Calls for Greater Global Cooperation." Press release, 23 Feb. 2021.
21. Wahl, Daniel Christian. "Salutogenic Cities & Bioregional Regeneration (Part I of II)." Medium, *Age of Awareness*, 20 Mar. 2020.
22. Weder, Franzisca, Amornpan Tungarat, and Stella Lemke. "Sustainability as Cognitive "Friction": A Narrative Approach to Understand the Moral Dissonance of Sustainability and Harmonization Strategies." *Frontiers in Communication* 5 (Feb. 2020).
23. Werrell, Caitlin, and Francesco Femia. "Climate Change Raises Conflict Concerns." *The UNESCO Courier*, 2018-2, e-ISSN 2220-2293.
24. "What is 'Double Materiality' and Why Should You Consider It?" *Greenstone, A Cority Company* (blog), 25 Aug. 2021.
25. "What is the Seventh Generation Principle?" *Indigenous Corporate Training Inc.* (blog). Working Effectively with Indigenous Peoples, 30 May 2020.
26. The World Bank. "Social Dimensions of Climate Change."

Issue 5: Lack of linking and mapping

Background

Since technical and human barriers are linked, there is a difficulty in achieving consensus and resolving divergent priorities when selecting plans, policies, and actions to achieve the objectives for planetary well-being (e.g., reducing GHG emissions) and improving the well-being of a global population.

The participating stakeholder communities are expected to be large and very diverse. As a consequence, considerable resources and supporting methodological protocols and tools should be made available to facilitate obtaining consensus and consilience among stakeholders (e.g., among advocates, practitioners, and nontechnical people and cultures). This includes metrics that accurately reflect ongoing effectiveness.

In addition, with the lack of effective tools, the complexity of connections between social and technical aspects of interventions is often unclear and difficult to comprehend. The diversity of human and environmental factors—as well as the evolution of technological advancements—calls for effective tools (e.g., maps, libraries) that support visualization and comprehension. For example, tools are needed to fully understand the impacts of specific geographic regions and environments in designing effective towns and cities (such as critical regionalism).

Ongoing accumulation of this kind of knowledge is critical. For example, Project Drawdown[52], one of the most current successful approaches for climate change mitigation, has recently introduced a library of effective methods and solutions for a diverse global audience; they are encouraging others to contribute by proposing additional tools for sharing information.

Recommendations

1. **Use effective technological and non-technological solutions to achieve consensus.** The difficulty in achieving consensus and resolving conflict can be minimized through technological and non-technological solutions. Some proposals are stated in the following recommendations.
2. **Create mind maps for methodologies systems.** Create and expand a methodologies systems mind maps (for an example, see Figure 3 below) with updates of emerging methodologies (e.g., Project Drawdowns' Solutions Library[53] recently added to the Project Drawdown approach or Edward Darling's LifeMap with CODES Action Plan as discussed by David Jensen[54]).
3. **Create networks maps of global methodologies.** Improve and create networks map of global methodologies, including the methodologies used globally for specific branches and purposes that align to the overall purpose SDGs. Build in a process to reassess inputs and outputs, including human behaviors.

[52] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.
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4. **Map effective methods by focus area.** Identify and map effective applied methods that support the focus of each specialized focus area (e.g., cities and towns, villages, lakes, metrics).
5. **Provide clear inclusive communications.** Create appendices, glossaries, and indexes supporting clarity and communication to increase inclusion of diverse stakeholder groups with real-time updates.
6. **Include destination-specific information and approaches.** Include destination-specific approaches as the maps evolve with innovation and geographic changes. This is already an approach ingrained in the Horizon Europe framework—with its destinations and ground-up approach—which should be present within the implementation of private and public green strategies as well as the growth of green technologies, for example, destination-specific approaches like critical regionalism in architecture.

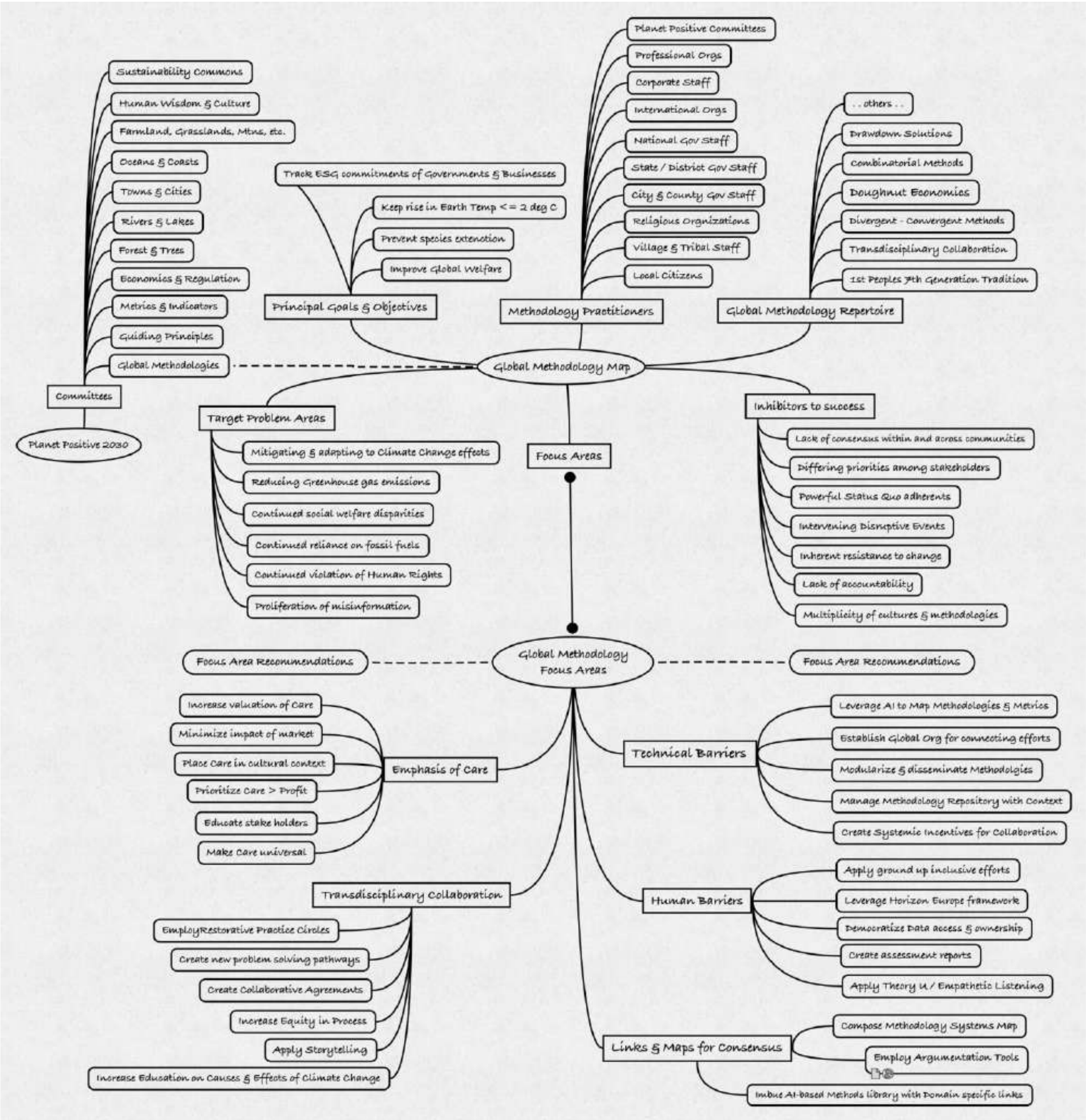

Figure 10. Methodologies Systems Mind-Mapping
(Image: Mike Houghtaling)

Further resources

1. Atkinson, Katie. “Value-Based Argumentation for Democratic Decision Support.” *Proceedings of the 2006 Conference on Computational Models of Argument: Proceedings of COMMA 2006.* Amsterdam: IOS Press, 25 May 2006: 47–58.

2. Conklin, Jeff. "Growing a Global Issue Base: An Issue-Based Approach to Policy Deliberation." *Directions and Implications of Advanced Computing: Conference on Online Deliberation*, DIAC-2008/OD2008.
3. Evoqua Water Technologies. "Sustainability Impact Map." Evoqua Water Technologies.
4. Gray, Erin, and Charlie Bloch. "INSIDER: Systems Mapping—A Vital Ingredient for Successful Partnerships." World Resources Institute, Technical Perspective, Finance, 17 Aug. 2020.
5. Green, Nancy L., Michael Branon, and Luke Roosje. "Argument Schemes and Visualization Software for Critical Thinking about International Politics." *Argument and Computation* 10, no. 10 (2018): 1–13.
6. International Trade Centre. "Sustainability Map."
7. ITC Sustainability Map (website).
8. Janjua, N. K., O. K. Hussain, F. K. Hussain, and E. Chang. "Philosophical and Logic-Based Argumentation-Driven Reasoning Approaches and their Realization on the WWW: A Survey." *The Computer Journal* 58, no. 9 (2014).
9. MIT Global System for Sustainable Development (GSSD). "Mapping Sustainability." Updated 27 Aug. 2020.
10. NASA and Columbia University, Socioeconomic Data and Applications Center (SEDAC). "Maps."
11. Romo, Adam. "Polygon Power: Putting Sustainability Systems on the Map." iseal, 18 Nov. 2020.
12. Reed, Chris, Katarzyna Budzynska, Rory Duthie, Mathilde Janier, Barbara Konat, John Lawrence, Alison Pease, et al. "The Argument Web: An Online Ecosystem of Tools, Systems, and Services for Argumentation." *Philosophy & Technology* 30, no. 2 (2017): 137–160 .
13. Wahl, Daniel Christian. "Salutogenic Cities & Bioregional Regeneration (Part I of II)." Medium, *Age of Awareness*, 20 Mar. 2020.

Case Studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. US Climate Change Dashboard

   US government dashboard application CMRA (Climate Mapping for Resilience and Adaptation) that integrates information from across the federal government to help people learn about climate-related hazards: CMRA home site.

   a. Case studies listed at CMRA site
   b. Open data at CMRA site.
   c. Southwest Sky Islands case sample
   d. Bracing for Heat case example

References

1. Bernard, Václav. "Remembering George Bernard Shaw with Ten of His Wittiest Quotes." Bernard's, News. 6 Aug. 2018.
2. Cilliers, Paul. *Complexity and Postmodernism: Understanding Complex Systems.* London and New York: Routledge, 1998.
3. Diamond, Jared. Collapse: How Societies Choose to Fail or Succeed. New York: Penguin, 2005.
4. Elo, Merja, Jonne Hytönen, Sanna Karkulehto, Teea Kortetmäki, Janne S. Kotiaho, Mikael Puurtinen, and Miikka Salo, eds. *Interdisciplinary Perspectives on Planetary Well-Being*. Oxon, England: Routledge, 2024.
5. Gladwell, Malcolm. The Tipping Point: How Little Things Can Make a Big Difference. New York: Little, Brown, 2000.
6. Goodchild, Melanie. *Gichi Gaakinoo'imaatiwin (Original Ways of Knowing)*. Vimeo video. Updated 2021.
7. IEEE Standards Association. *IEEE 7010™-2020, IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being*.
8. Jensen, David. "How Can You Support the Launch of the CODES Action Plan on 2 June at Stockholm +50." SparkBlue, 21 May 2022.
9. Krockow, Eva M. "What's Your Locus of Control—And Why Does It Matter?" *Psychology Today*, 24 April 2024.
10. Lennon, Michael, Marisa Zalabak, and Lubja Dajani. "Activating Collective Intelligence to Engineer Transdisciplinary Impacts." *2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (Oct. 2020): 2762–2769.
11. Lenton, Tim, and Bruno Latour. "Gaia 2.0: Could Humans Add Some Level of Self-Awareness to Earth's Self-Regulation?," *Science* 361, no. 6407 (14 Sept. 2018): 1066–1068.
12. MNC Editorial Team. "The First Faces of Manhattan." MessyNessyChic, 31 May 2021.
13. Northwest Power and Conservation Council (NPCC). "Dams: Impact on Salmon and Steelhead."
14. Project Drawdown. "Solutions Library."
15. Schoonerboom, Judith, and R. Burke Johnson. "How to Construct a Mixed Methods Research Design." *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 69, suppl. 2 (5 July 2017): 107–131.
16. Sydney Business Insights. "Richard H. Thaler on Nudges and Choice Architecture." *Sydney Business Insights* YouTube channel. 15 Oct. 2021.

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CHAPTER 5: FORESTS AND TREES

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FORESTS AND TREES

Committee Members

Committee Co-Chairs

- David Dao, Climate Tech Entrepreneur, Zurich, Switzerland
- Max Song, Climate Tech Entrepreneur, Digital Climate Policy Researcher, Board member, HKSAR

Committee Members / Contributors

- Lisa Revelli, Larkspur, California, United States
- Lucy Tong, Beijing, China
- Mihai Hrimiuc, Berlin, Germany
- Steven Fraser, Sanata Clara, California, United States
- Susanna Raj, Mountain View, California, United States
- Alana Leader, HKSAR

FORESTS AND TREES

Future Vision

It is 2030.

Our natural world is thriving thanks to humankind's sustainable stewardship. In less than a decade, the introduction of robust ecosystem policies, technological breakthroughs, and grass-roots movements have inspired whole generations and communities to protect and restore nature. Humanity was able to turn the tide on the tragedy of the commons—halting and reversing global deforestation, stopping species extinction, massive biodiversity loss, and the overall deterioration of nature.

After years of discussion, the global community decided on science-based regulations that addressed large market failures when it concerns nature conservation and created new models of economic prosperity based on regeneration and climate action.

The creation of robust carbon credits backed by integrity standards and scientific boards raised the level of quality of nature-based solutions. The introduction of a biodiversity index and payments for ecosystem services contributed to nature-based carbon sequestration projects that are biologically diverse, strengthening the overall health of ecosystems.

This not only removed policies that drove deforestation but also created a new and greener business model for local communities to actively reforest around the world and inspired large enterprises to double down on their zero-deforestation commitments.

Citizen-led grassroots movements played an important role. The global ecosystem restoration movement inspired communities around the world to restore and reconnect with nature. At the end of the decade, the movement fulfilled its ambitious goal of planting one trillion biodiverse trees, restoring valuable ecosystems, and preventing ecological tipping points. Large-scale syntropic farming models have been developed and successfully implemented, regenerating healthy agro-ecosystems.

By reconnecting with nature, civilization has rediscovered the vital importance of Indigenous wisdom and communities. There is reciprocity between humans and the natural world. Excessive extraction has been replaced by respect and responsibility for nature's gifts. The "Indigenous renaissance" enabled not only a newfound mutual respect between alternative worldviews but also allowed local communities to legally regain the ownership rights of their ancestral land. Under Indigenous leadership, rainforests are thriving with life and science and business are acquiring knowledge about novel medicines and forest products.

The demand for impact assessment, transparency, traceability, resilience, sustainability, and efficiency in these new markets now drives and supports technological innovation, and, in return, technology delivers. Global satellite data combined with advancements in artificial intelligence allow the transparent tracing and tracking of land-use change and conservation progress all around the world. Additionally, innovations in on-ground and aerial mapping technology empower local communities to map, understand, monitor, and provide better management of their project sites, even in traditionally inaccessible areas below the forest canopy.

Novel field-based sensors such as bioacoustics and environmental DNA collection allow data analysts to measure biodiversity and the richness of life in unprecedented ways to capture even the most concealed of species. Establishing mutual respect and affordable high-speed Internet access will empower local and

Indigenous communities to provide valuable information and feedback to decision-makers. They are crucial stakeholders when it comes to deciphering the collected data and providing sustainable, integrated, and resilient solutions.

Economically stable, corruption-free, and ecologically sustainable cryptocurrencies have now become mainstream in many parts of the world when it comes to carbon accounting—providing global and liquid financial access to communities while, at the same time, transparently linking supply chains and carbon credits and remuneration.

Digital citizenship has flourished in emerging economies, creating new paradigms of regenerative wealth creation, where physical natural resources are measured and then transformed into digital wealth. Stewards of nature have received livelihood payments from this pool of natural capital, and there is a vibrant ecotourism industry in space—mediated by virtual reality (VR)/augmented reality (AR)—that brings the value of participating in the immersive travel experiences filmed and captured in these remote regions. Destruction and exploitation of natural resources led to real-time digital penalties, as well as a decrease in community social standing through a social reputational system that became used for international travel and individual social banking.

Advances in legal courts led to the definition of personhood being applied more widely in forestry areas, where entire portions of the forest are considered to be legal persons now. Decentralized community-led conservation groups established closed boundaries that encapsulate large pieces of land and assigned the entire area of the forest to the "body" representing legal personhood.

The global rejuvenation of our natural world has come with immense benefits for all of humankind. People now enjoy reliable access to ecosystem services such as freshwater, flood protection, and clean air, resulting in increased health and happiness benefits. Cities, being immersed in dense urban forests, benefit from the protection from natural hazards such as cool shades during heatwaves. Ecological forestry and early detection of fire risks through technological monitoring have put an end to megafires. To the surprise of many scientists, many endangered species are reappearing in their natural habitat.

Issue 1: Deforestation and forest degradation are key drivers in the climate crisis

Background

Deforestation and land-use change account for 18% of global anthropogenic emissions and contribute to driving up atmospheric carbon levels (IPCC, 2019). Climate change increases the risk of forest fires, creating a vicious cycle for deforestation as well.

Land use is a key component, accounting for approximately 25% of total greenhouse gas (GHG) emissions (Dao et al., 2019). Since 2000, Earth has "lost 361 million hectares of forest cover, equivalent to the size of Europe" (Reiersen et al., 2024).

> *"If tropical deforestation would be a country, it would be the world's third largest emitter (after China and the US). Land use includes a wide range of critical issues, from deforestation and forest degradation to agriculture. The domain is particularly challenging, given that the world's growing population and rising standards of living exert an increasing pressure on food and consumer goods production, both of which may lead to conflicting objectives with climate change and biodiversity."* (Dao et al., 2019)

> *"Forests face increasing risk and frequency of wildfires, droughts, and extreme weather; forest ecosystems are under severe pressure."* (Stephens et al., 2018)

> *"To avoid planetary tipping points (Nobre et al., 2016) and maintain a stable and livable climate…" humankind "…urgently needs to reduce carbon emissions until 2030 and preserve essential ecosystems."* (IPCC, 2021)

> *"Forests and natural carbon sequestration are important climate change mitigation strategies with a biophysical mitigation potential of 5,380 metric tons of carbon dioxide (MtCO2) per year on average until 2050. Forestry is a large industrial sector, and the causes of deforestation are mostly economically driven."* (Nabuurs et al., 2007)

> *"There is thus a need for higher-quality carbon offsetting protocols and higher transparency and accountability of the 'measurement, reporting, and verification'(MRV) of these projects."* (Reiersen et al., 2024)

Recommendations

The technologies listed in the recommendations below offer a range of opportunities to better understand, manage, and protect forests and address the drivers of deforestation. By combining these technologies with effective conservation strategies, it is possible to achieve sustainable forest management and mitigate the impacts of climate change.

1. **Implement quality carbon offsetting protocols and higher transparency and accountability.** "High-quality carbon offsetting protocols and higher transparency and accountability of the MRV of natural carbon sequestration projects" (Dao et al., 2019) should be used as part of the climate change mitigation strategies.
2. **Monitor forests, deforestation, and land use.** Effectively utilize satellite mapping and real-time remote-sensing technologies for the detailed monitoring of forests and deforestation at a local and global scale. By analyzing satellite imagery, researchers and conservationists should track changes in forest cover and identify areas of deforestation in near real time. This technology should also be used to monitor other forest-related variables, such as carbon stocks, biodiversity, and land-use changes.

   Real-time remote-sensing technology enables conservationists to quickly respond to changes in forest cover and take appropriate action to address deforestation. For example, when deforestation is detected, authorities can use this technology to identify the parties responsible and take legal action to prevent further destruction.
3. **Create digital twins to better allow people to see and analyze the data.** Creating digital twins is a powerful tool for visualizing and analyzing data related to forests and deforestation. Digital twins are virtual models that replicate physical objects, systems, or processes. In the case of forests, digital twins can provide a three-dimensional (3D) model of the forest ecosystem, including information on the location, type, and density of trees, as well as other important variables such as soil composition, water availability, and wildlife populations.
4. Digital twins should be used by conservationists, policymakers, and other stakeholders to gain a better understanding of the complexities of forest ecosystems and the impact of deforestation. This technology should also be used to simulate the impact of different conservation strategies and identify the most effective interventions to address deforestation.
5. **Employ decentralized ledgers and on-chain representation to record data.** Decentralized ledgers and on-chain representation offer a new way of recording and managing data related to forests and deforestation. By using blockchain technology, data related to forest conservation can be stored in a decentralized and tamper-resistant way, allowing for greater transparency and accountability in the management of forest resources.
6. **Decentralized ledgers should be used to track forest products and the certification of sustainable forestry practices.** This technology enables stakeholders to trace the origin of forest products, verifying that they come from legal and sustainable sources.
7. **Create conversational AI natural language processing (NLP) speech partners representing trees and forests.** Creating conversational AI NLP speech partners representing trees and forests can help to raise awareness of the importance of forests and the impact of deforestation. These AI-powered assistants should be designed to provide information about the benefits of forests, the impact of deforestation, and ways in which individuals can help to protect forests.

The AI-powered speech partners should also be used to educate and engage with children, who are the future custodians of forests. This technology can be designed to use gamification and storytelling techniques to make learning about forests and deforestation fun and engaging.

8. **Support deployment of enhanced MRV of greenhouse gas (GHG) emissions using Internet of Things (IoT) technology.** Enhanced MRV using IoT technology can provide real-time data on forest resources, enabling conservationists and policymakers to make informed decisions about forest management. By using IoT sensors, it is possible to monitor forest carbon stocks, biodiversity, and other important variables in real-time.
9. **IoT technology should be used to monitor and prevent illegal logging and deforestation.** For example, sensors can be used to detect the sound of chainsaws or the movement of logging trucks, enabling authorities to quickly respond to unauthorized activity and help prevent further destruction.

Case studies

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1. Deforestation in the Amazon Rainforest

   The Amazon rainforest is the largest rainforest in the world and plays a critical role in regulating the global climate by absorbing carbon dioxide from the atmosphere. However, deforestation in the Amazon has been occurring at an alarming rate, with an estimated 17% of the forest area lost in the past 50 years. This deforestation is largely driven by cattle ranching, soybean farming, and logging and has led to significant carbon emissions, loss of biodiversity, and changes in regional weather patterns.

   One example of the impact of deforestation in the Amazon is the severe drought that occurred in 2005. Researchers found that the loss of vegetation due to deforestation reduced the amount of water released into the atmosphere through evapotranspiration, leading to a reduction in rainfall and an increase in temperature. This feedback loop resulted in a severe drought that affected millions of people and caused economic losses of over $3 billion (Saatchi et al., 2012).

2. Forest Degradation in Indonesia

   Indonesia is home to some of the world's most biodiverse forests, but the country has been experiencing rapid forest degradation due to illegal logging and conversion of forests for palm oil plantations. Forest degradation refers to the gradual decline in the quality of forest ecosystems, which can lead to a loss of biodiversity, carbon emissions, and changes in local climate patterns.

   In Indonesia, forest degradation has led to the loss of critical habitats for endangered species such as orangutans and tigers. Additionally, the conversion of forests for palm oil plantations has resulted in significant carbon emissions, as well as air and water pollution. The impact of forest degradation is not limited to Indonesia, as the country is a major exporter of palm oil and the demand for this commodity has contributed to deforestation and forest degradation in other countries as well (Riyou, 2016).

3. Deforestation in the Congo Basin

   The Congo Basin is the second-largest tropical forest in the world, and its forests play a crucial role in regulating the global climate by storing large amounts of carbon. However, deforestation in the region has been occurring at an alarming rate, with an estimated 4.3 million hectares lost between 2000 and 2014. The main drivers of deforestation in the Congo Basin are agriculture, logging, and mining.

   One example of the impact of deforestation in the Congo Basin is the loss of habitat for endangered species such as gorillas and elephants. Additionally, deforestation has led to soil erosion, reduced water quality, and changes in local climate patterns. The loss of forest cover also has significant implications for the livelihoods of local communities who rely on the forest for food, medicine, and other resources (Tchatchou, 2015).

Further resources

1. Canadell, J. G., and M. R. Raupach. “Managing Forests for Climate Change Mitigation.” *Science* 320 (2008): 1456–1457.
2. Carnicer, Jofre, Andres Alegria, Christos Giannakopoulos, Francesca Di Giuseppe, Anna Karali, Nikos Koutsias, Piero Lionello, et al. “Global Warming Is Shifting the Relationships between Fire Weather and Realized Fire-Induced CO_2 Emissions in Europe.” *Scientific Reports* 12 (June 2022).
3. Elbein, Saul. “How Climate Change Is Making Fires Worse.” *The Hill*, 24 June 2022.
4. Forzieri, Giovanni, Vasilis Dakos, Nate G. McDowell, Alkama Ramdane, and Alessandro Cescatti. “Emerging Signals of Declining Forest Resilience under Climate Change.” *Nature* 608 (July 2022).
5. Le Page, Michael. “Trees Are Dying at Increasing Rates in Forests across Europe.” *New Scientist*, 15 Nov. 2021.
6. Nobre, Carlos A., Gilvan Sampaio, Laura S. Borma, Juan Carlos Castilla-Rubio, José S. Silva, and Manoel Cardoso. “Land-Use and Climate Change Risks in the Amazon and the Need of a Novel Sustainable Development Paradigm.” *Proceedings of the National Academy of Sciences* 113, no. 39 (Sept. 2016).
7. Vaughan, Adam. “Amazon Rainforest Nears Tipping Point That May See It Become Savannah.” *New Scientist*, 7 Mar. 2022.
8. Vaughan, Adam. “Forests Are Becoming Less Resilient Because of Climate Change.” *New Scientist*, 13 July 2022.

Issue 2: There is no assignment of value for the existence of nature

Background

“Nature is essential for human existence and good quality of life. Most of nature’s contributions to people and their lives are not fully replaceable, and some are irreplaceable” (IPBES, 2019). The natural world is deteriorating at rates unparalleled in human history resulting in a currently ongoing sixth mass extinction.

Forests, especially tropical forests, provide habitats for 80% of land-based biodiversity.

> *“Harmful activities, including habitat destruction, poor farming practices, and pollution, have altered ecosystems significantly, driving many species past the point of recovery… Globally, there are an estimated one million at risk, with biodiversity declining at a faster rate than at any time in human history” (IPBES, 2019).*

“The climate crisis is exacerbating the issue. Many species simply cannot adapt to the scale and pace of changing temperatures” (Vallance, 2022). Furthermore, there is danger of a vicious cycle: biodiversity loss can reduce forest carbon storage and exacerbate climate change, which can, again, spur biodiversity loss. The concept of “nature-based solutions” was pioneered more than two decades ago by the International Union for Conservation of Nature (IUCN) but is now increasing in popularity.

Nature-based solutions (NBS) are “actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature” (IUCN). The 2019 United Nations (UN) Climate Action Summit convened by the UN Secretary-General brought great political attention to the power of NBS. In particular, “the NBS Coalition co-led by China and New Zealand launched the NBS for Climate Manifesto with the support of more than 70 governments and private sector, civil society, and international organizations” and outlining nearly 200 initiatives and best practices on NBS from around the world (UNEP, 2019).

Recommendations

1. **Grow recognition for the value of all ecosystems.** Expand beyond forestry to include grasslands and wetlands, which play vital roles for local and global environments. We should protect the existence of wetlands, grassland, and not blindly plant trees over wetlands and natural grasslands.
2. **View issues in a holistic manner.** Treat the climate and biodiversity crisis as twin crises that affect each other and interact to create complex problems and understand the self-feedback loop between the two crises.
3. **Advocate for restoring natural levels of biodiversity.** Support projects that restore a healthy diversity of native species in any location that should naturally support trees. Monocultures not only capture less carbon but also don’t support biodiversity and can even harm nearby ecosystems (ETHzürich, Crowther Lab).

4. **Encourage a forestry credit industry.** Help generate credibility from carbon credits from projects such as forest conservation, reforestation, and agroforestry, which are some of the most common types of nature-based solutions in the carbon market.
5. **Encourage government policies and funding for NBS.** Governments can be encouraged to recognize and promote the value of NBS by implementing policies that support the protection and restoration of natural habitats, including forests. This can include providing funding and incentives for companies and individuals who engage in sustainable forestry practices, as well as implementing regulations that limit deforestation and promote reforestation efforts. Governments can also incorporate NBS into their climate change strategies, highlighting the role that natural solutions can play in mitigating and adapting to the impacts of climate change.
6. **Collaborate with private sector companies.** Private sector companies can be incentivized to recognize and utilize NBS by partnering with conservation organizations and promoting sustainable forestry practices. Companies can be encouraged to adopt policies that promote sustainable sourcing of forest products and engage in reforestation and habitat restoration efforts. Public–private partnerships can also be established to support the development and implementation of NBS projects, providing funding and expertise to support conservation efforts.
7. **Promote education and awareness campaigns.** Education and awareness campaigns can be launched to promote the value of NBS and encourage individuals to engage in conservation efforts. This can include outreach to schools, community organizations, and other stakeholders, providing information on the importance of forests and the benefits of engaging in sustainable forestry practices. Campaigns can also highlight the economic benefits of NBS, such as the creation of jobs in the forestry and conservation sectors and the potential for sustainable tourism.
8. **Develop an open-source monitoring system:** Technologists can leverage their expertise in software and hardware development to create an open-source monitoring system for NBS projects. This system could include IoT sensors, drones, and other technologies to provide real-time data on forest health, carbon storage, and biodiversity. The system could be made available to conservation organizations and communities to support the development and monitoring of NBS projects.
9. **Use AI to predict forest fires:** Technologists can develop AI-powered algorithms to help predict and prevent forest fires. These algorithms could use data from remote sensing technologies, such as satellite imagery and weather data, to identify areas at risk of wildfires. The algorithms could also be used to identify potential fire suppression strategies, such as controlled burns, to prevent the spread of wildfires.
10. **Create virtual reality experiences to showcase NBS:** Technologists can develop virtual reality (VR) experiences that showcase the importance of NBS and the benefits of forest conservation. These experiences could be used in education and awareness campaigns to engage and educate individuals about the value of NBS. IEEE community members with expertise in VR technology could also contribute to the development.
11. **Designing blockchain-based solutions for forest management:** Technologists can design blockchain-based solutions to enable transparent and secure tracking of forest resources, including timber and non-timber forest products. The use of blockchain can provide a tamper-resistant record of forest products, enabling stakeholders to trace the origin of forest products and help verify they come from legal and sustainable sources.

Case studies

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1. Costa Rica's Payments for Environmental Services Program

   Costa Rica's payments for environmental services (PES) program (PAS in Spanish) is a nature-based solution that provides financial incentives to landowners who engage in conservation efforts. Under the program, landowners receive payments for preserving forests, protecting watersheds, and other conservation activities. The program has been highly successful, with over 1.2 million hectares of forest protected since its implementation in 1997.

   The PES program has had a significant impact on forest conservation in Costa Rica, helping to reduce deforestation rates from 4% in the 1980s to less than 1% in the early 2000s. Additionally, the program has provided economic benefits to rural communities, creating jobs in the forestry and conservation sectors and promoting sustainable tourism (UNFCCC, 2023).

2. China's Giant Panda Conservation Program

   China's giant panda conservation program is a nature-based solution that has helped to protect and restore critical habitat for the endangered giant panda. The program involves the restoration of degraded forests and the creation of wildlife corridors to connect isolated panda populations.

   The program has had a significant impact on the conservation of giant pandas, with the population increasing from just over 1,000 in the 1970s to over 1,800 today. Additionally, the program has promoted sustainable tourism, providing economic benefits to local communities (Hua Xia, 2023).

3. The US Great Lakes Restoration Initiative

   In the United States, the Great Lakes Restoration Initiative is a nature-based solution that aims to restore and protect the Great Lakes ecosystem, including its forests, wetlands, and coastal habitats. The program involves a range of activities, including the restoration of degraded wetlands, the control of invasive species, and the reduction of nutrient pollution.

   The program has had a significant impact on the Great Lakes ecosystem, helping to reduce the harmful algal blooms that have plagued the region in recent years. Additionally, the program has provided economic benefits to local communities, promoting tourism and creating jobs in the conservation and restoration sectors (NOAA Fisheries, 2024).

4. Brazil's Forest Code

   Brazil's Forest Code is a nature-based solution that regulates the use and protection of forests in the country. The code requires landowners to maintain a certain percentage of their land as forest and establishes protections for sensitive areas such as riverbanks and hilltops.

   The Forest Code has had a significant impact on forest conservation in Brazil, helping to reduce deforestation rates in the Amazon region. Additionally, the code has provided economic benefits to rural communities, promoting sustainable agriculture practices and creating jobs in the forestry and conservation sectors. However, enforcement of the code has been challenging, and there have been concerns about the impact of recent changes to the code that have weakened some of its protections (Chiavari & Leme Lopes, 2015).

Further resources

1. Ceballos, Gerardo, and Paul R. Ehrlich. "The Misunderstood Sixth Mass Extinction." *Science* 360, no. 6393 (June 2018): 1080–1081.
2. IPBES. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth et al. Bonn, Germany: IPBES Secretariat, 25 Nov. 2019.
3. IUCN (International Union for Conservation of Nature) (website).

Issue 3: The sudden death of forests from infectious diseases is a major concern in the management and conservation of forests worldwide

Background

Infectious diseases can impact various tree species, including both conifers and broad-leaved trees, and the severity of the disease can vary widely depending on the species and environmental conditions. Infectious diseases in forests can be caused by a variety of pathogens, including fungi, bacteria, viruses, and other microorganisms. These pathogens can be spread by various means, such as through soil, water, insects, or other vectors.

When a tree is infected with an infectious disease, it can cause a range of symptoms, including wilting, yellowing, defoliation, and dieback of branches or the entire tree. In severe cases, the disease can cause sudden death of the tree, leading to significant impacts on forest structure, biodiversity, and ecosystem functioning.

The impacts of sudden death of forests from infectious diseases can be particularly significant in managed forests, where trees may be planted in monocultures or in high-density stands, making them more vulnerable to disease outbreaks. In addition, climate change is exacerbating the problem, as changes in temperature and precipitation patterns can increase the spread and severity of infectious diseases.

Recommendations

1. **Support all measures to prevent damage to forests caused by disease and infestations.** Support all measures to prevent, manage, and control the sudden death of forests from infectious diseases. Such measures include forest monitoring, quarantine and sanitation measures, use of disease-resistant tree species, and the development of effective treatments and management strategies. It’s important to address this issue to protect forest ecosystems and the many ecological, economic, and social benefits they provide. Some specific measures are detailed in the following recommendations.
2. **Reduce unintended and intended transport of vegetative particles and soil.** Wash and disinfect shoes, tires, and anything that can transport vegetative particles and dirt.
3. **Use local firewood.** If using firewood, Don't move firewood—buy it where you burn it. Do not bring oak, fir, redwood, madrone, or tanoak outside of the area of origin unless they are certified to be free of *Phytophthora ramorum*. This would limit the spread of this pathogen (U.S. Department of Agriculture “Phytophthora Ramorum;” Schadel et al., 2020).
4. **Share information about Sudden Oak Death (SOD).** Spread the word about SOD, especially to those who engage in hiking, biking, and driving in and out of infected areas (NPS, “Sudden Oak Death”).
5. **Engage stakeholders and remember the importance of oaks**. In addition to being a part of our cultural heritage, they are a keystone species in our ecological communities. Whole ecosystems of plants, animals, and fungi are dependent on the survival of our oaks (NPS, “Sudden Oak Death”).

Case studies

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The state of California and the USDA (with the help of the Department of Homeland Security and the US Customs and Border Protection) are vigilant to limit the influx of infection vectors. Dutch elm disease, which affects species in the genera *Ulmus* and *Zelkova,* was a major challenge in northeastern North America (US/Canada) more than 40 years ago. Another pest is the spruce budworm.

1. Budworm

   "Budworm outbreaks can have significant economic impacts on the forestry *industry. As a result, the eastern spruce budworm is considered one of the most destructive forest pests in North America, and various methods of control are utilized. However, the species is also ecologically important, and several bird species are specialized on feeding on budworms during the breeding season."* (Schadel et al., 2020; Wikipedia, "Choristoneura fumiferana")

2. Asian Citrus Psyllid

   Citrus trees are also victims of Asian Citrus Psyllid (ACP), which can spread very fast from infected trees to healthy ones by the psyllid (USDA, 2024).

3. Dutch Elm Disease

   Dutch elm disease is caused by a fungus and affects elm trees. It was first identified in the Netherlands in the early 1900s and has since spread throughout Europe and North America. The disease is spread by bark beetles and can kill a tree within one to three years of infection. It has had a significant impact on elm tree populations, particularly in urban areas (Potter et al, 1966).

4. Chestnut Blight

   Chestnut blight is caused by a fungus and affects American chestnut trees. The disease was introduced to North America in the late 1800s and has since spread throughout the range of the American chestnut. The fungus infects the bark of the tree and can kill a tree within a few years of infection. The loss of American chestnut trees has had a significant impact on forest ecosystems and the many ecological, economic, and social benefits they provide (Rigling, 2018).

   Ash Dieback

5. Ash dieback is caused by a fungus and affects ash trees. The disease was first identified in Poland in the early 1990s and has since spread throughout Europe. The disease is spread by wind-borne spores and can cause significant damage to ash tree populations. In some areas, up to 90% of ash trees have been killed by the disease (Klesse et al., 2021).

Further resources

1. U.S. Code of Federal Regulations (CFR) 2022 § 301.92-2. *Restricted, Regulated, and Associated Articles; Lists of Proven Hosts and Associated Plant Taxa*. Title 7, Subtitle B, Chapter III, Part 301, Subpart X. Last amended May 2023.

Issue 4: Global reforestation potential has a large and cost-effective mitigation potential when done right

Background

“Forests and natural carbon sequestration are important climate change mitigation strategies with a biophysical mitigation potential of 5,380 MtCO2 per year on average until 2050” (IPCC, 2019), yet “forestry is a large industry and the causes of deforestation are mostly economically driven” (Steinweig, 2016), which means the future of our forests are currently dependent on exponential financial growth versus ecosystem health.

Forests are a critical part of the global carbon cycle, sequestering large amounts of carbon dioxide (CO_2) from the atmosphere through photosynthesis and storing it in biomass and soil. The global amount of carbon stored in forests is estimated to be approximately 638 billion metric tons, equivalent to around 2,340 billion MtCO2. The amount of carbon stored in forests varies depending on several factors, including the species of trees, their age and size, the location of the forests, and the management practices used. Tropical rainforests are some of the most carbon-dense forests, with an estimated 170 metric tons of carbon per hectare, while temperate and boreal forests typically store less carbon per hectare. “The causes of deforestation are mostly economically driven: expansion of commercial or subsistence agriculture, logging, fuelwood collection, or livestock grazing” (WWF, 2018).

On average, a mature tree can absorb around 22 kilograms of CO_2 per year, but this can vary widely depending on the tree species, size, age, and environmental conditions such as temperature, light, and water availability. Some studies have suggested that fast-growing tree species such as eucalyptus or hybrid poplar can absorb up to 48 kilograms of CO_2 per year per tree, while slower-growing species such as oak or pine may absorb less, around 15 kilograms of CO_2 per year. Generally, younger trees absorb more carbon than older trees, and trees in areas with higher rainfall and more sunlight tend to absorb more carbon than trees in drier areas (Collins, 2021).

The mitigation potential of reversing the deterioration of nature is large.

“Every year, the ocean absorbs about 30% of human-made carbon emissions, and terrestrial ecosystems absorb slightly less. The rest of our emissions enter the atmosphere. Over the years, this has caused the accumulation of approximately 300 Gt of excess carbon in the atmosphere.” One “study finds an additional 0.9 billion hectares of forests could capture approximately 205 Gt carbon,” that is, “two-thirds of the total human-made carbon emissions currently in the atmosphere” (Bastin et al., 2019).

“To counteract the economic incentives, payments for ecosystem services (Wunder, 2007) are increasingly provided (Donofrio et al., 2019) to forest-conserving or forest-restoring landowners by international stakeholders—for example, through the governmental UN-REDD program (Gibbs et al., 2007) or the commercial voluntary carbon market (Donofrio et al., 2019; Santamaria et al., 2020). Money from carbon offsets can provide vital financial support for projects seeking to protect and restore some of the most beautiful and threatened ecosystems around the world. Given that nature-based solutions can make a significant contribution to the climate mitigation needed to stabilize global heating, a functioning finance channel will be important for climate change progress, particularly for developing countries. However, so far only 2% of all global climate finance has been invested in nature-based solutions.

Recommendations

1. **Utilize UN Sustainable Development Goals (SDGs) and environmental, social, and corporate governance (ESG) metrics demonstrating "triple bottom line" metrics of success for society and business that prioritize planet and people before or in conjunction with profit to help ensure long-term health of our forests and those organizations that practice genuine sustainable business practices.**
2. **"To avoid catastrophic climate change, cut GHG emissions quickly and drastically, and reduce the excess GHG levels already in the atmosphere.** Achieving this will require many solutions. Restored trees will accumulate carbon slowly over the rest of this century and beyond. Like many climate change solutions, this is a long-term vision, which highlights the urgent need for action now" (ETHzürich. "Tree Restoration Potential, Q&A). Planting trees is not a silver bullet for climate change but can help. "Significant cuts to current emissions are still essential" and urgent (ETHzürich, "Tree Restoration Potential, Q&A.").
3. **Governments should implement policies that provide financial incentives for companies and individuals to invest in forest conservation and reforestation efforts.** This could include tax credits for reforestation projects, subsidies for sustainable forest management practices, and funding for research into new methods of carbon sequestration.
4. **Corporations should take a leadership role in promoting sustainable forest management practices and investing in reforestation efforts.** This should include setting targets for reducing deforestation in their supply chains, investing in sustainable agroforestry practices, and supporting conservation efforts through corporate social responsibility programs.
5. **Individuals should support reforestation efforts by donating to organizations that plant trees or support sustainable forest management practices.** They can also make changes in their own lives, such as reducing paper consumption or supporting sustainable forestry products.
6. **Policy makers must implement policies to promote sustainable land-use practices, such as incentivizing farmers to adopt agroforestry practices that integrate trees into agricultural landscapes.** This can increase carbon sequestration and biodiversity while also supporting rural livelihoods.
7. **Governments and corporations should work together to address the root causes of deforestation, such as the expansion of agricultural land and the demand for products like palm oil and soy.** This could include measures such as improving land-use planning, promoting sustainable agriculture, and supporting the development of alternative livelihoods for rural communities.

Case studies

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1. The REDD+ Program in Brazil

   The REDD+ program in Brazil has been successful in reducing deforestation rates in the Brazilian Amazon. According to a study by the Center for Global Development, the program led to a 70% reduction in deforestation in the Amazon between 2005 and 2012, which avoided the emission of approximately 1.2 billion tons of CO_2. The program also helped protect an estimated 60 million hectares of forest, which is equivalent to the size of France. (Fraser, 2023)

2. The Sustainable Agriculture and Forests Program in Indonesia

   The Sustainable Agriculture and Forests program in Indonesia has helped reduce deforestation rates while also providing economic opportunities for farmers and improving food security. According to a report by the World Resources Institute, the program has helped protect an estimated 5.5 million hectares of forest, which is equivalent to the size of Costa Rica. The program has also helped reduce greenhouse gas emissions by an estimated 0.4 billion tons of CO_2. (Global Waters, 2022)

3. The Forest Stewardship Council (FSC)

   The Forest Stewardship Council is an international organization that promotes sustainable forest management practices. According to a study by the University of Wisconsin-Madison, FSC-certified forests store an average of 6.7 metric tons of CO_2 per hectare per year, which is 37% more than noncertified forests. The study also found that FSC-certified forests have higher biodiversity and support local communities. (Forest Eco Certification)

4. The Green Belt Movement in Kenya

   The Green Belt Movement is a grassroots organization that promotes reforestation and community empowerment in Kenya. Since its founding in 1977, the organization has helped plant over 51 million trees and has provided economic opportunities to over 30,000 women through its tree-planting initiatives. According to a study by the University of Oxford, the trees planted by the Green Belt Movement have sequestered an estimated 2.5 million metric tons of CO_2, which is equivalent to taking more than 500,000 cars off the road for a year. (Green Belt Movement)

5. The Bonn Challenge

   The Bonn Challenge is a global effort to restore 150 million hectares of degraded and deforested land by 2020 and 350 million hectares by 2030. The initiative is led by the International Union for Conservation of Nature (IUCN) and the German government, and it has been endorsed by over 50 countries. According to a report by the IUCN, if the Bonn Challenge is successful, it could sequester up to 1.7 billion tons of CO_2 per year by 2030, which is equivalent to the annual emissions of India. (Caya, 2016)

Further resources

1. IPBES. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth et al. Bonn, Germany: IPBES Secretariat, 25 Nov. 2019.

Issue 5: Monitoring, verification, and reporting of nature-based solutions is capital- and labor-intensive

Background

> *"The certification process for forest carbon offsetting projects is capital- and labor-intensive, especially due to the high cost of manual" measurement and "monitoring), reporting, and verification (MRV) of the forest carbon stock."* (Reiersen et al., 2024)

> *"For the last 20 years, major conservation efforts have been underway to mitigate and safeguard against these losses. One of the global financing strategies is carbon offsets."* (Blaufelder et al, 2021)

> *"Initially, it started as the Clean Development Mechanism (CDM) under the Kyoto Protocol, allowing governments and business organizations from industrialized countries to invest in forestry in developing countries by buying carbon credits to offset industrialized emissions (FAO, 2020). Several other independent bodies have later developed official standards for verifying and certifying carbon offsetting projects, such as the Gold Standard (GS) and the Verified Carbon Standard (VERRA). The certification process for forest carbon offset projects is capital- and labor-intensive, especially due to the high cost of manual MRV" of the forest carbon stock."* (Reiersen et al., 2024)

According to a report by the Food and Agriculture Organization (FAO) and the United Nations Development Programme (UNDP), an estimated $80 billion to $100 billion per year is needed to halve deforestation rates by 2030 and restore degraded forests. This investment is needed to support activities such as strengthening forest governance, providing incentives for sustainable land use, and scaling up restoration efforts.

"The carbon offsetting market is rapidly increasing and expected to grow by a factor of 100 until 2050 due to high demand and available capital" (Blaufelder et al., 2021). However, the main obstacle is "the limited supply of offsetting projects as forest owners lack upfront capital and market access" (Kamukama, 2022; (Reiersen et al., 2024). "Current methods for…MRV of the landowner-provided forest ecosystem services are either based on 1) on-ground inspection, which is…expensive (US $20,000 to US $30,000)," can be "delayed (up to two years)," or be "corruptible, and biased" (Foss, 2013); 2) satellite-based data, which is lower-cost but may be limited to the binary verification of forest/no-forest cover (Hanan et al., 2020); or 3) drone-based data collection. Further, forests are complex ecosystems with multiple layers and components, including different tree species, understory vegetation, and soil microorganisms. Monitoring and reporting on these components is difficult, particularly if they are not directly visible or easily measurable (Reiersen et al., 2024).

Recommendations

1. **Invest in innovation of technology. Invest in technology innovation such as satellite monitoring, drone analysis, and automated on-ground data collection that allows for low-cost MRV. Develop new technologies for MRV:** The use of new technologies such as remote sensing and machine learning (ML) can help reduce the cost and time required for MRV. For example, light detection and ranging (lidar) technology can be used to measure the height and density of trees, which can be used to estimate carbon stock. ML algorithms can be used to analyze this data and provide accurate estimates of carbon sequestration.
2. **Carefully consider which technology addresses the goal(s) effectively.** Acknowledge that technology is not a silver bullet and seek to accelerate those applications that correctly address the barriers to scale in the use of technology for environmental good:
    a. **Increase data compatibility, making more geospatial and in situ data accessible for model training–effective use of ML is hindered by a lack of accessible data.**
    b. **Harness AI and ML to create new—and to scale existing (and promising)—granular climate models.**
    c. **Access computing resources for the purpose of training AI models, especially for developing countries.**
    d. **Develop technical expertise and skills to integrate data and computing resources, tools, and models to produce insights.**
    e. **Leverage domain expertise and management capabilities to turn AI-generated climate insights into policy-making decisions.**
3. **Build capacity.** Local communities need the technical skills and knowledge to effectively monitor and report on forest carbon stocks and emissions. Capacity-building programs can help to provide training and support for community members, including on the use of MRV technologies and data analysis.
4. **Provide local control.** Providing local communities with ownership and control over MRV technology can help to build trust and accountability. This can include developing community-led MRV systems and providing access to data and information on forest carbon stocks and emissions.
5. **Support collaboration.** Collaboration between local communities, governments, and the private sector can help to ensure that MRV systems are integrated into broader forest conservation and management strategies. This should include developing partnerships and alliances to share data and knowledge, as well as leveraging funding and technical support.
6. **Encourage collaboration among project developers.** Encouraging project developers to collaborate and share information on MRV can help reduce duplication of effort and facilitate the development of best practices. For example, the Forest Carbon Partnership Facility (FCPF) has established a knowledge-sharing platform to encourage collaboration among project developers and to share information on MRV best practices.
7. **Provide incentives.** Providing financial and nonfinancial incentives for local communities to participate in MRV can help to promote uptake and sustainability. This should include providing payments for verified emissions reductions or other benefits such as improved forest governance, biodiversity conservation, or livelihood opportunities.

8. **Implement standardized MRV protocols.** Developing standardized MRV protocols can help reduce the time and cost required for certification by streamlining the process and making it more transparent. For example, the Verified Carbon Standard (VCS) has developed a standardized methodology for measuring forest carbon stock and determining the additionality of forest carbon offsetting projects. Another example is work under development of IEEE P7802, Standard for Measurement and Verification of Reduction of Greenhouse Gases for Climate Action Projects and Solutions (IEEE SA, IEEE P7802).
9. **Provide financing and technical support.** Providing financing and technical support to project developers, particularly in developing countries, can help overcome barriers to entry and increase access to the resources needed for MRV. For example, the World Bank's BioCarbon Fund provides financing and technical assistance to support forest carbon offsetting projects in developing countries.

Case studies

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1. The Implementation of the Verified Carbon Standard (VCS) in the Rimba Raya Biodiversity Reserve Project in Indonesia

   The Rimba Raya Biodiversity Reserve project in Indonesia was the first REDD+ project to receive VCS certification. The project involves the conservation of more than 64,000 hectares of tropical forest, which has sequestered an estimated 20 million metric tons of CO_2. The use of standardized MRV protocols under the VCS certification process helped streamline the MRV process and reduce the cost of certification while also increasing the credibility and transparency of the project (InfiniteEARTH).
2. The Collaboration Among Project Developers in the Community-Based REDD+ Project in Nepal

   The Community-Based REDD+ project in Nepal is a community-led initiative that aims to conserve and restore forests while also providing economic opportunities to local communities. The project involves the collaboration of several community groups, nongovernmental organizations (NGOs), and government agencies who share information and resources on MRV best practices. This collaboration has helped reduce duplication of effort and facilitate the development of cost-effective MRV approaches (ANSAB, 2013).
3. The Provision of Financing and Technical Support in the BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)

   The BioCarbon Fund ISFL is a partnership between the World Bank and several donor countries, providing financing and technical assistance to support forest conservation and restoration in developing countries. The initiative has provided financing and technical support to several forest carbon offsetting projects, including in Brazil, Indonesia, and Ethiopia. This support has helped overcome barriers to entry and increase access to the resources needed for MRV (Initiative for Sustainable Forest Landscapes, "BioCarbon Fund")

4. The Provision of Policy Support in the California Compliance Offset Program

   The California Compliance Offset Program provides incentives for companies to invest in forest carbon offsetting projects, such as the Improved Forest Management project in the Sierra Nevada mountains. This project involves the sustainable management of more than 22,000 hectares of forest, sequestering an estimated 2 million metric tons of CO_2. The policy support provided by the California Air Resources Board has helped increase the demand for legitimate carbon offsetting projects while also creating a more favorable environment for investment in MRV technology and best practices (California Air Resource Board, "Compliance Offset Program").

Further resources

1. Brown, Sandra, and Louis R. Iverson. "Biomass Estimates for Tropical Forest." *World Resource Review* 4, no. 3 (1992): 366–383.

Issue 6: Nature-based carbon offsets currently lack trust and integrity standards, harming the world's climate

Background

Forest carbon offsets and methodologies are prone to errors and deliberate systematic over-accounting, undermining trust in offsets while providing large industries an opportunity to greenwash.

The forest protection carbon offsetting market is used by major airlines for claims of carbon-neutral flying and by major fossil fuel companies to showcase their climate ambition. However, it faces a significant credibility problem and there are warnings that the system may not be fit for purpose.

One of the main challenges with forest carbon offsets is the complexity of measuring and verifying the carbon benefits of these projects. Forests are dynamic ecosystems with multiple layers and components, making it difficult to accurately quantify carbon stocks and emissions. In addition, natural disturbances such as wildfires and pests can have a significant impact on forest carbon dynamics, making it challenging to attribute carbon benefits to specific conservation or restoration activities.

> *"Recent research investigations (Badgley et al., 2022) have shown that the current manual forest carbon stock practices systematically overestimate forestry carbon offsetting projects with up to 29% of the offsets analyzed, totaling up to 30 million tCO2e (metric tons of CO_2 equivalents) and worth approximately $410 million."*
> (Reiersen et al., 2024)

Overestimation can occur when project developers inflate the carbon benefits of their projects through practices such as double counting or using inaccurate baseline scenarios. This can lead to an overestimation of the carbon benefits of the project, which can undermine the effectiveness of the offset and erode trust in the integrity of the carbon market.

Recommendations

1. **Create trust through radical transparency**. **Open up methodologies, baselines, algorithms, and models transparently for independent audits to create trust.** Increasing transparency and accountability in the forest carbon offsetting process can help reduce the risk of errors and deliberate over-accounting. This should include requiring project developers to provide detailed documentation of their MRV processes, as well as establishing third-party verification of carbon stock estimates and project additionality.
2. **Implement a blockchain-based registry for forest carbon offsets.** It should be possible to reduce the risk of errors and deliberate over-accounting by providing a transparent and traceable system for monitoring and reporting on carbon benefits. This is expected to help increase trust in the integrity of forest carbon offsets and reduce the opportunity for large industries to engage in greenwashing by investing in low-quality offsets that do not deliver real emissions reductions.

3. **Create a tamper-proof record of project data, including project design, monitoring and verification data, and transaction records.** This can help to reduce the risk of fraud and improve the accuracy and credibility of forest carbon offsets.
4. **Invest in codesigning MRV systems with local communities.** This approach can help ensure that the technology is appropriate and effective for the local context. This process should include involving local stakeholders in the design of monitoring protocols, selecting appropriate technologies, and interpreting and communicating data.
5. **Strengthen verification protocols.** Strengthening verification protocols for forest carbon offsetting projects can help reduce the risk of errors and over-accounting. This should include requiring project developers to use standardized methodologies for MRV and establishing minimum requirements for third-party verification.
6. **Establish penalties for noncompliance.** Establishing penalties for noncompliance with forest carbon offsetting standards and protocols should help deter deliberate over-accounting and other forms of misconduct. This can include fines and sanctions for project developers found to be in violation of established standards and protocols.
7. **Establish clear standards and protocols for measurement and audit.** Establishing clear standards and protocols for measurement and audit can help prevent over-accounting by providing a consistent and transparent framework for carbon accounting. These standards and protocols should be based on best practices and should be subject to review and revision as necessary.
8. **Conduct frequent and random spot checks.** Conducting frequent and random spot checks of measurements and audits can help detect any over-accounting or other irregularities that may occur. These spot checks should be conducted by independent third-party auditors and should be a requirement for all forest carbon offsetting projects.
9. **Encourage disclosure and reporting of over-accounting.** Encouraging project developers and auditors to disclose any instances of over-accounting or other irregularities can help increase transparency and prevent future instances of misconduct. This can include requiring regular reporting of carbon accounting and making this information publicly available.

Case studies

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1. For Independent Third-Party Auditors

   The California Air Resources Board (CARB) Compliance Offset Protocol requires the use of independent third-party verifiers to help ensure the accuracy and reliability of forest carbon offsetting projects. The verifiers must be accredited by the American National Standards Institute (ANSI) and meet other qualification requirements. The use of independent third-party auditors helps prevent over-accounting by ensuring that carbon stock estimates are independently verified.

2. For Clear Standards and Protocols for Measurement and Audit

   The Forest Stewardship Council (FSC) has established clear standards and protocols for forest carbon offsetting, including requirements for MRV and third-party verification. These standards and protocols are based on best practices and are subject to regular review and revision. The use of clear standards and protocols helps prevent over-accounting by providing a consistent and transparent framework for carbon accounting.

3. For Frequent and Random Spot Checks

   The Verified Carbon Standard (VCS) requires project developers to conduct frequent and random spot checks of their MRV processes for accuracy and reliability of carbon stock estimates. The VCS also requires independent third-party verification of carbon stock estimates to confirm that these spot checks are conducted properly. The use of frequent and random spot checks helps prevent over-accounting by detecting any irregularities that may occur.

4. For Blockchain Technology

   HBAR Foundation, the foundation behind Hedera Hashgraph, has created the Guardian, a tool for recording digital MRV. The Guardian is an open source blockchain library to support registration for carbon offsetting. It is developing a platform that provides secure and transparent carbon accounting. The use of blockchain technology helps prevent over-accounting by providing a decentralized and transparent record of carbon transactions.

5. For Disclosure and Reporting of Over-Accounting

   The Rainforest Alliance, a nonprofit organization that works to promote sustainable forestry, requires project developers to disclose any instances of over-accounting or other irregularities as part of its certification process. This information is publicly available on the Rainforest Alliance website. The use of disclosure and reporting helps prevent over-accounting by increasing transparency and accountability.

Issue 7: Individual tree accounting is almost nonexistent, making various techniques such as selective logging and selection cutting difficult to execute, monitor, and verify

Background

Individual tree accounting refers to the practice of tracking the growth, mortality, and carbon sequestration of individual trees in a forest. This practice is important for understanding the overall carbon balance of the forest, as well as for informing forest management practices such as selective logging and selection cutting. However, individual tree accounting is often difficult to implement, particularly in large-scale forest management operations, due to the high cost and technical complexity of monitoring and measuring individual trees. No individual identification exists for trees to track their existence, so when trees are cut and hauled away, there is no way for law enforcement to record their loss. Trees do not have serial numbers.

As a result, many forest management practices, such as selective logging and selection cutting, are often carried out without accurate information on the carbon sequestration potential of individual trees. This can lead to suboptimal forest management decisions and can undermine efforts to promote sustainable forestry practices that balance economic, social, and environmental considerations. Additionally, the lack of individual tree accounting can make it difficult to accurately estimate the carbon sequestration potential of a forest, which can in turn affect the ability of forest carbon offsetting projects to generate credits.

Anecdotally, there is no specific accounting for how many trees are being lost and no legal process to account for losses even on privately owned land. On the other hand, cities like Mountain View, CA, tout their canopy coverage by promoting that the city has the best canopy foliage by counting the number of shrubs and young trees planted for every mature tree cut. Sometimes trees as old as 200 years are cut and replaced with three or four smaller shrubs that will take another 30 to 40 years to grow to just a few feet tall.

Recommendations

1. **Tag and track the history of individual trees.** There are high-end solutions like geospatial mapping that feeds into ML models to assess the number of trees. Aerial views of the past can be compared to those of the present. Most cities have extensive paper trails for every process, so the number of trees removed can be tracked by their process paperwork alone—all tallied on good old spreadsheets. It requires the public to demand transparency, and that is the issue: making the public care enough to demand transparency from their governments. Simple QR codes and geotagging have worked well in many countries to track trees. Tagging for existing trees and new ones planted should be more common.
2. **Develop more advanced and sophisticated monitoring techniques that can track the carbon stored in individual trees within a forest ecosystem.** This can and should include using remote sensing technologies such as lidar to map the structure and composition of the forest, as well as developing ground-based monitoring techniques that can track the growth and health of individual trees over time.

3. **Develop genetic barcoding.** Develop and implement genetic barcoding techniques for individual trees in a forest. This can involve using DNA sequencing to create a unique genetic barcode for each tree, which can be used to track its growth, mortality, and carbon sequestration over time. The genetic barcodes can be linked to other data on the tree, such as its size, location, and age, as well as data on the surrounding environment, such as soil type and moisture levels.
4. **Use genetic barcoding.** By using genetic barcoding, forest managers can accurately track the carbon sequestration potential of individual trees, allowing for more precise forest management decisions. This can include selectively harvesting trees based on their carbon sequestration potential or planting new trees with specific genetic traits that promote carbon sequestration. Additionally, genetic barcoding can provide important data for forest carbon offsetting projects, which require accurate measurements of carbon stock.
5. **Deploy and utilize sensor-equipped tree robot.** Develop and implement tree-climbing robots equipped with lidar and other sensors to map out the structure of individual trees before cutting. These robots can be programmed to climb trees and collect data on their size, shape, and biomass, as well as to identify potential hazards such as weak or dead branches. The lidar and other sensors can provide high-resolution 3D scans of the tree's structure, allowing for accurate and detailed measurements of individual branches and foliage.
6. **Utilize the data collected by the tree-climbing robots to inform forest management decisions, such as the selective removal of specific branches or trees.** This can help reduce the risk of accidental damage to surrounding trees or to the environment, while also ensuring that the most valuable timber is harvested. Additionally, the data collected by the robots can be used to improve forest carbon stock estimates, which can be used to generate carbon credits for forest carbon offsetting projects.
7. **Consider deploying block chain technology to safe-guard and share data.** Blockchain technology has a key advantage due to its ability to provide a tamper-resistant and decentralized system for storing and sharing data. This can be particularly useful for tracking changes in forest ecosystems, as it can provide a transparent and verifiable record of individual tree growth, carbon sequestration, and other key metrics.

Case studies

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1. Tree-Climbing Robots

   The startup Treebot[55], based in Switzerland, has developed a tree-climbing robot equipped with sensors and cameras that can climb trees up to 70 meters tall. The robot can collect data on the tree's structure, including its size, shape, and biomass, as well as identifying potential hazards such as weak or dead branches.

[55]This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

2. Genetic Barcoding for Trees

   Researchers at the University of British Columbia, Canada, have developed a genetic barcode for individual trees, allowing them to track the carbon sequestration potential of each tree over time. The genetic barcodes can be used to inform forest management decisions, such as selectively harvesting trees with high carbon sequestration potential.

3. Remote Sensing Technologies

   The Global Ecosystem Dynamics Investigation (GEDI) satellite from the National Aeronautics and Space Administration (NASA) uses lidar technology to provide detailed information on the structure and biomass of individual trees in forests around the world. This data can be used to inform forest management decisions and improve forest carbon stock estimates.

4. Drones for Aerial Surveys

   The startup DroneSeed[56], based in Seattle, WA, uses drones equipped with lidar and multispectral cameras to map out forest ecosystems and identify areas that require reforestation. The drones can also plant new trees using a precision planting system.

5. Mobile Apps for Data Collection

   The Rainforest Connection[57], a nonprofit organization that works to prevent illegal deforestation, has developed a mobile app that uses ML to detect sounds of illegal logging activities in real time. The app also collects data on forest biodiversity, helping to inform forest management decisions.

6. Satellite Mapping

   Earth observation with machine learning-based methods plays a crucial role in environmental and climate sciences. Being able to continuously monitor and report changes is an important tool for decision-makers to address urgent challenges in climate change mitigation and adaptation, especially for forestry where land-use change is one of the key factors to understand. Earth observation data is stored in the petabyte scales. Public institutional data such as the European Space Agency's Sentinel-1 synthetic aperture radar data and Sentinel-2 optical images produce four petabytes of data. Private providers such as Maxar have reportedly stored more than 110 petabytes in its image library since 2000, adding up to 80 terabytes of satellite data per day. Leveraging this data, researchers have developed global maps on tree cover loss and gains (Hansen et al., 2011), reforestation potential (Bastin et al., 2019), and biodiversity richness (Jetz et al., 2012).

7. Digital Twins

   Creating digital replicas that mirror the existence and dynamics of physical objects, processes, assets, or arrangements is known as the creation of *digital t*wins. Using advances in satellite, aerial, and on-ground sensing technologies, realistic records of land cover, forest type, biomass, and canopy height can be created. The ever-growing spatiotemporal data records are used to improve the accuracy of digital twins, namely climate and land surface models, such that it can forecast the state and health of forests. Forest digital twins could be advanced toward mapping ecosystem health, carbon content, and biodiversity or the rapid exploration of climate policy impacts, visualizing future scenarios. Advances in digital twins have historically been applied extensively in architecture, BEAM modeling, and simulation design. For the sake of the IEEE Planet Positive 2030 application, focusing on data

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curation, collection, sensing, mapping, and simulating challenging forest landscapes and the interior canopy of rainforests is proposed.

8. Decentralized Ledgers and On-Chain Representation

   Decentralized ledger technology as a whole is oriented towards the use of an open and public decentralized ledger to create a permanent record keeping of account. This is for the sake of economic support, as well as representation of digital environmental attributes such as carbon removal credits and hectares of land preservation.

9. AI NLP Speech Partners

   Drawing from the existing advancements in artificial intelligence for natural language processing (NLP), there are opportunities to make an AI chatbot that can persuasively and humanely interact with external audiences, bringing an emphatic "voice" and "character" to an otherwise amorphous concept of trees and hectares. Key tools and advances in AI can be used to represent and design at scale a mass market-facing awareness-building tool, for example, by allowing the AI to actively engage with conversations on social media platforms.

Further resources

1. Nix, Steve. "3 Ways Your Trees Can Be Stolen." ThoughtCo. Last updated 13 Aug. 2019.
2. Njambi, Rose. "Tackling Deforestation in India: Why You Need Satellite Data." UP42, 20 Sept. 2021.
3. Noack, Mark. "Is Mountain View Losing Its Trees? New City Data Still Leaves Question Up in the Air." *Mountain View Voice,* 1 July 2018.
4. Vyawahare, Malavika. "Tree-Planting Programs Turn to Tech Solutions to Track Effectiveness." *Mongabay*, 22 Nov. 2019.
5. Yao, Ling, Tang Liu, Jun Qin, Ning Lu, and Chengdu Zhou. "Tree Counting with High Spatial-Resolution Satellite Imagery Based on Deep Neural Networks." *Ecological Indicators* 125 (June 2021).

Issue 8: Despite the social media-driven push for corporate engagement on tree planting, numerous organizations have advocated that the process of tree and forestry protection is much more effective than that of virgin tree planting

Background

The key debate is between the merits of reforestation and the merits of preserving what we have available. Some simple analysis by EcoCart[58] shows:

- "Trees can take up to 10 years before they start absorbing more carbon dioxide than they emit."
- "Planting new trees requires more work."
- Planting new trees is expensive.
- Reforestation projects can be less sustainable, as it is uncertain whether "the newly planted forests will be capable of supporting animal, insect, and plant ecosystems as current forests actively do."

Recommendations

1. **Protect and save existing forests first**. Advocates from the World Wildlife Fund (WWF) acknowledge: "Planting trees is good. Saving existing forests is better. Protecting people and nature is best" (Stevenson, 2020).

   The mathematics behind forestry protection is much better than reforestation.

2. **Support thoughtful mass tree planting in addition to protecting existing forests.** Mass tree planting initiatives are a possibility but also require thoughtful planning and execution. Planting the wrong trees in the wrong place may reduce biodiversity, speed up extinctions, and reduce resiliency of ecosystems (Einhorn, 2022).

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Case studies

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1. GainForest[59]

   "GainForest is an open platform that empowers sustainable conservation efforts by unifying 1) accessible and automated monitoring, 2) auditable and decentralized payments, and 3) stakeholder engagement and user-focused token incentives into one system...Tracing the impact of a donor's individual donation is difficult, making it hard for them to develop a sense of ownership. GainForest NFTrees make payments to conservation organizations more tangible. They are unique digital assets that track the ownership of virtual sites of a conservation or restoration project using blockchain technology. Virtual sites correspond to a predefined land area within the project with possibly multiple plants." (GainForest Primer)

2. NFTree Tokens

   "NFTree tokens include unique artwork from local communities and Indigenous artists for each project. Each token links to a unique" monitoring "website…that provides geospatial and ecological information of the corresponding site, displaying recent drone and satellite data, current and potential tree cover," the existing "species of flora…and how much carbon is currently stored or could potentially be stored if the ecosystem was intact. The group of corresponding plants within an NFTree can change during its lifetime due to survival rates and active restoration efforts. NFTree holders can follow recent updates and progress on their respective conservation areas through the NFTree profile website," dynamic artwork, and data airdrops. "Investments raised from NFTrees are first parked in a decentralized fund. Payments are automatically released to conservation organizations after achieving specific milestones during the verifiable 'Proof-of-Care'" stage, which consists of automated digital MRV. (GainForest Primer)

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[59] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

References

1. ANSAB. "Community-Based REDD+ Pilot Program in Nepal: Incentive for Climate Change Mitigation and Forest Conservation Measures." 21 March 2013.
2. Badgley, Grayson, Jeremy Freeman, Joseph J. Hamman, Barbara Haya, Anna T. Trugman, William R. L. Anderegg, and Danny Cullenward. "Systematic Over-Crediting in California's Forest Carbon Offsets Program." *Global Change Biology* 28, no. 4 (Feb. 2022).
3. Bastin, Jean-Francois, Yelena Finegold, Claude Garcia, Danilo Mollicone, Marcelo Rezende, Devin Routh, Constantin M. Zohner, et al. "The Global Tree Restoration Potential." *Science* 365, no. 6448 (July 2019): 76–79.
4. Blaufelder, Christopher, Cindy Levy, Peter Mannion, and Dickon Pinner. "A Blueprint for Scaling Voluntary Carbon Markets to Meet the Climate Challenge." McKinsey Sustainability, 29 Jan. 2021.
5. Brock, R.C., A. Arnell, W. Simonson et al. "Implementing Brazil's Forest Code: A Vital Contribution to Securing Forests and Conserving Biodiversity." *Biodiversity and Conservation* 30 (2021) 1621–1635.
6. California Air Resource Board. "Compliance Offset Program."
7. Canadell, J. G., and M. R. Raupach. "Managing Forests for Climate Change Mitigation." *Science* 320 (2008): 1456–1457.
8. Caya, Sandra. "Bonn Challenge Approaches Target to Restore 150 Million Hectares of Degraded Land." IUCN, 2016.
9. Chiavari, Joana and Cristina Leme Lopes. *Policy Brief---Brazil's New Forest Code, Part I: How to Navigate the Complexity*. Climate Policy Initiative, 2015.
10. Collins, Paul. "How Much CO2 Does a Tree Absorb?" Climate Consulting by Selectra, 2021.
11. Dao, David, Catherine Cang, Clement Fung, M. Zhang, Nick Pawlowski, R. Gonzales, Nick Beglinger, and Ce Zhang. "GainForest: Scaling Climate Finance for Forest Conservation using Interpretable Machine Learning on Satellite Imagery." International Conference on Machine Learning 2019.
12. Einhorn, Catrin. "Tree Planting is Blooming. Here's How That Could Help, or Harm, the Planet." *New York Times*, 14 Mar. 2022. Last updated 21 Mar. 2022.
13. Ehrlich, Gabriel, Donald Grimes, Michael McWilliams et al. "Socioeconomic Impacts of the Great Lakes Restoration Initiative." University of Michigan Research Seminar in Quantitative Economics. 30 Sept. 2018.
14. ETHzürich. The Crowther Lab (website).
15. ETHzürich. "Tree Restoration Potential, Q&A." The Crowther Lab.
16. Fearnside, Phillip. "Deforestation of the Brazilian Amazon." Oxford Research Encyclopedia of Environmental Science. 26 Sept. 2017.
17. Forest Eco Certification. "FSC Certification."
18. Foss, Mark. "The Challenge of Certifying Forest Ecosystem Services." *Forest News*, 2013.
19. Fraser, Barbara. "Following the REDD+ Money." CIFOR Forest News, 2023.
20. Global Waters. *Indonesian Forest and Climate Support Project (IFACS)*. 2022.
21. Green Belt Movement (website).

22. Hanan, Niall P., and Julius Y. Anchang. "Satellites Could Soon Map Every Tree on Earth." *Nature* 587 (2020).

23. Hua Xia, ed. "Update: China Establishes National Giant Panda Conservation, Research Center." Xinhua, 17 Nov. 2023.

24. Initiative for Sustainable Forest Landscapes. "BioCarbon Fund." World Bank.

25. IEEE Standards Association. *IEEE P7802, IEEE Draft Standard for Measurement and Verification of Reduction of Greenhouse Gases for Climate Action Projects and Solutions.*

26. IPCC, 2019. *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Edited by P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, et al. In press.

27. IPCC. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds. Cambridge and New York: Cambridge University Press, 2021.

28. Jetz, Walter, Jana McPherson, and Robert Guralnick. "Integrating Biodiversity Distribution Knowledge: Toward a Global Map of Life." *Trends in Ecology & Evolution* 27 (2012): 151–9.

29. Kamukama, Marvin K. D. *Trees for Global Benefit Uganda: A Case Study on the Failures of Carbon Offsetting*. 2022.

30. Klesse, Stefan, Meinrad Abegg, Sven E. Hopf, Martin M. Gossner, Andreas Rigling, and Valentin Queloz. "Spread and Severity of Ash Dieback in Switzerland–Tree Characteristics and Landscape Features Explain Varying Mortality Probability." *Frontiers in Forrest and Global Change* 4 (Mar. 2021).

31. Krantzberg, Gail, Irena F. Creed, Kathryn B. Friedman, Katrina L. Laurent, John A. Jackson, Joel Brammeier, and Donald Scavia. "Community Engagement is Critical to Achieve a "Thriving and Prosperous" Future for the Great Lakes–St. Lawrence River Basin." *Journal of Great Lakes Research* (2014).

32. Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, and X. Zhang. *Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer. Cambridge and New York: Cambridge University Press, 2007.

33. National Park Service (NPS). "Sudden Oak Death." Point Reyes, National Seashore, California.

34. NOAA Fisheries. Great Lakes Habitat Restoration (website). Last updated 10 Sept. 2024.

35. Potter, Clive, Tom Harwood, Jon Knight, and Isobel Tomlinson. "Learning from History, Predicting the Future: The UK Dutch Elm Disease Outbreak in Relation to Contemporary Tree Disease Threats." *Philosophical Transactions of the Royal Society B: Biological Sciences* 366, no. 1573 (July 2011): 1966–74.

36. Powell, William A., Andres E. Newhouse, and Vernon Coffey. "Developing Blight-Tolerant American Chestnut Trees." *Cold Spring Harbor Perspectives in Biology* 11, no. 7 (July 2019).

37. Reiersen, Gyri, David Dao, Björn Lütjens, Konstantin Klemmer, Kenza Amara, Attila Steinegger, Ce Zhang, and Xiaoxiang Zhu. "ReforesTree: A Dataset for Estimating Tropical Forest Carbon Stock with Deep Learning and Aerial Imagery." arXiv.org, 6 Mar. 2024.
38. Rigling, D., and S. Prospero. "Cryphonectria Parasitica—The Causal Agent of Chestnut Blight: Invasion History, Population Biology and Disease Control." *Mol Plant Pathol 19*, no. 1 (Jan. 2018): 7–20.
39. Riyou Tsujino, Takakazu Yumoto, Shumpei Kitamura, Ibrahim Djamaluddin, Dedy Darnaedi. "History of Forest Loss and Degradation in Indonesia." *Land Use Policy* 57 (2016): 335–347.
40. Saatchi, Sassan, Salvi Asefi-Najafabady, Yadvinder Malhi, Luiz E. O. C. Aragão, Liana O. Anderson, Ranga B. Myneni, and Ramakrishna Nemani. "Persistent Effects of a Severe Drought on Amazonian Forest Canopy."*PNAS* 110, no. 2 (24 Dec. 2012).
41. Sánchez-Azofeifa, G. A., A. Pfaff, J. A. Robalino, and J. P. Boomhower. "Costa Rica's Payment for Environmental Services Program: Intention, Implementation, and Impact." *Conservation Biology* 21, no. 5 (Oct. 2007) 1165–73.
42. Santamaria, Simona, David Dao, Björn Lütjens, and Ce Zhang. "TrueBranch: Metric Learning-based Verification of Forest Conservation Projects." Arxiv.org, 21 Apr. 2020.
43. Schadel, B. R., and W. Wesela. "APHIS List of Regulated Hosts and Plants Proven or Associated with Phytophthora Ramorum." *Pacific Northwest Pest Management Handbooks*. July 2020.
44. Steinweg, Tim, Barbara Kuepper, and Gabriedl Thoumi. *Economic Drivers of Deforestation: Sectors Exposed to Sustainability and Financial Risks*. Chain Reaction Research, Aug. 2016.
45. Stephens, Scott, Brandon Collins, Christopher Fettig, Mark Finney, Chad Hoffman, Eric Knapp, Malcolm North, Hugh Safford, and Rebecca Wayman. (2018). "Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire." *BioScience* 68, no. 2 (Feb. 2018): 77–88.
46. Stevenson, Martha. "Sustainability Works." World Wildlife Fund, Transforming Business. 28 Apr. 2020.
47. Swaisgood, R. R., F. Wei, D. E. Wildt, A. J. Kouba, and Z. Zhang. "Giant Panda Conservation Science: How Far We Have Come." *Biology Letters* 6, no. 2 (23 Apr. 2010):143–145.
48. Tchatchou, B., D. J. Sonwa, S. Ifo, and A. M. Tiani. Deforestation and Forest Degradation in the Congo Basin: State of Knowledge, Current Causes and Perspectives: Occasional Paper 144. Bogor, Indonesia: CIFOR, 2015.
49. UN Climate Change, UNFCCC. "Payments for Environmental Services Program: Costa Rica." Climate Action, 2023 UN Global Climate Actions Awards.
50. UN Environment Programme (UNEP). *The Nature-Based Solutions for Climate Manifesto: Developed for the UN Climate Action Summit 2019*. 14 Aug. 2019.
51. U.S. Department of Agriculture (USDA). "Citrus Greening and Asian Citrus Psyllid." Plant Pests and Diseases, Citrus Diseases.
52. U.S. Department of Agriculture (USDA). "Phytophthora Ramorum." Animal and Plant Health Inspection Services.
53. Vallance, Patrick. "We've Overexploited the Planet, Now We Need to Change if We're to Survive." *The Guardian*, 8 Jul. 2022.

54. Van Noordwijk, Meine, Berla Laimonas, Minh Ha Hoang, Grace Villamor, and Thomas Yatich. "Principles for Fairness and Efficiency in Enhancing Environmental Services in Asia: Payments, Compensation, or Co-Investment?" *Ecology and Society* 15, no. 4 (2010).

55. World Wildlife Fund (WWF). "What are the Biggest Drivers of Tropical Deforestation?" WWF Magazine, 2018.

56. Wunder, Sven et al. "Payments for Environmental Services and the Poor: Concepts and Preliminary Evidence." *Environment and Development Economics* 10, no. 3 (2005).

57. Zhisong Yang, Xiaodong Gu, Yonggang Nie, Feng Huang, Yan Huang, Qiang Dai, Yibo Hu, Yi Yang, Xiao Zhou, Hemin Zhang, Xuyu Yang, and Fuwen Wei. "Reintroduction of the Giant Panda into the Wild: A Good Start Suggests a Bright Future." *Biological Conservation* 217 (2018): 181–186.

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CHAPTER 6: RIVERS AND LAKES

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RIVERS AND LAKES

Committee Members

Committee Co-Chairs

- Angshuman Kaushik, Assam, India
- Guy Hochstetler, Greenville, SC, United States
- Chuck Metz Jr., Knoxville, TN, United States

Committee Members / Contributing Authors

- George Assalley, Lisle, IL, United States
- Guy Hochstetler, Greenville, SC, United States
- Angshuman Kaushikv, Assam, India
- Enock Ole Kiminta, Nairobi, Kenya
- Jonathan Kurniawan, Sydney, Australia/Jakarta, Indonesia
- Chuck Metz Jr., Knoxville, TN, United States
- Shannon Mullen O'Keefe, Omaha, NE, United States

RIVERS AND LAKES

Future Vision

It is 2030.

Key technology developments, policy implementations, and perhaps most difficult of all, the focus of humans have together resulted in the regeneration of the ecosystems of the world's rivers and lakes. Inspired to address the many problems brought about by an exploding population engaged in unsustainable environmental practices, people chose to come together. They chose to imagine what was possible, and as a result, achieved the victories in these areas that all experience today.

Access to clean potable water has been democratized across cultural and economic divides. Water-use rights and access to water have expanded even as water waste has dramatically dropped.

The world's commercial agriculture businesses have diversified. Crops include more regionally appropriate "less thirsty" crops, decreasing the demand for agricultural irrigation, as well as diminishing the runoff from pesticides, fertilizers, and other nutrient pollutants into neighboring rivers and lakes. The need for flow diversion via dams and other artificial means has also decreased. In response, freshwater ecosystems have rebounded with an increasing number of healthy plant and animal species.

Pollution from Earth's manufacturing facilities and urban infrastructure is significantly reduced. New technologies, bolstered by educational and media efforts, have addressed physical, chemical, and biological pollutants at their source, bringing back a biological diversity not seen in generations. The world's urban areas have made significant progress in integrating natural ecosystems into their urban developments. Parks, woodlands, rivers, and lakes have an expanded natural presence within their boundaries, helping to reduce the effects of climate change.

Human influences on water's temperature and flow direction affected the natural water and land interaction in the past, disrupting its chemical makeup, affecting the diversity of flora and fauna, of which, and this is the ironic and salient point, humans are included. Many humans viewed themselves as occupants, settlers, even conquerors of this planet, using its resources to fulfill their needs and desires. This attitude shifted when more of Earth's people recognized that all are Indigenous planet Earth members, reliant on its rich diversity of species to survive. They began to realize that as much as species depend on a healthy habitat for their survival, habitats rely on each other too. And as people knew the importance of their cardiovascular health, they also began to recognize the sacred importance of Earth's lungs and heart and made better efforts to understand it for their own good. People all around the world recognized they needed to become a responsible species.

This shift was inspired by science and the realization that the Earth's "wetlands store about five times more CO_2 than forests and as much as 500 times more than oceans" (Duke University, 2022). The shift represented a significant turning point for humans as they began to consider nature as something to care for (rather than to dominate). Before this, over centuries, humans drained wetlands, treating them as obstructions or undesirable swamps and attempting to claim as much inhabitable land as possible for agriculture and settlement purposes. Renowned novelist and journalist, Annie Proulx elegantly reflected on this with respect to the early settlement of North America:

> *The original occupants of the continent knew the rivers and swamps, the bogs and lakes, as they knew the terrain and one another. But for most English settlers and European newcomers' nature consisted of passive and inanimate substances and situations waiting*

> *to be used to human advantage. **Preservation and care of nature were not what they had come for**.* (Proulx, 2022)

Regarding the North American continent, for example, over the decades in the short history of its settlement by non-Indigenous people, according to the U.S. Environmental Protection Agency (EPA), there were approximately 220 million acres of wetlands in the area comprising the continental United States in the 1600s, and by 2009, roughly half of that was gone (U.S. EPA, "Wetlands;" Dahl & Allord, 1997). This is not isolated to the North American continent. A United Nations (UN) report cited a source revealing even more stunning data: Worldwide "some 85 percent of wetlands present in 1700, were lost by 2000, many drained to make way for development, farming or other 'productive' uses." While evidence suggests the rate of losing wetlands is slowing, we lost 1% of the world's wetlands by 2023; however, "the good news is, people now know how to restore these wetlands at a scale that was never before possible and in a way that both stops the release of carbon dioxide and re-establishes the wetland's carbon dioxide storing capacity" Dahl & Allord, 1997; Duke University, 2022; NSW Government, 2019).

It was with this knowledge, and in the spirit of pioneer conservationist Rachel Carson, that collectively, Earth's riverbanks and lakes now enjoy regeneration.

Today, in 2030, our water planet predictably spins on its axis propelling winds in opposite directions above and below its equator, driving surface and deep ocean currents affecting temperature changes across this azure and tawny sphere. Evaporation occurs. Clouds form. Storms develop. Rain falls. Watershed commences, and water's journey back to the sea begins. Like blood vessels, rivers and lakes work with the ocean and the atmosphere to pump water around the globe. It's the Earth's cardiovascular system: life imitating life (Baratto, 2020). Along its way, water runoff enlivens and enriches ecosystems on a mass scale beginning in the Lilliputian world of a phytotelmata, ending in an estuary that slow dances with its ocean partner to the tune of the tides. In between, millions of species of flora and fauna, including humans, now live symbiotically and sustainably with our planet, surviving and thriving in habitats naturally created in an amalgam of water and land, adapting to temperature and gravity forces compelling water along its way.

Introduction

Human population growth and its impacts on the Earth's river and lake ecosystems are considered. The scope, "Rivers and Lakes," references the Earth's freshwater systems, including rivers, streams, creeks, wetlands, and groundwater. The impacts of urbanization, commercial farming and manufacturing, resulting pollution types, and the overall impacts occasioned by climate change are explored.

Issue 1: Water access rights are becoming increasingly complex, especially with transboundary waters

Background

Waterways naturally and unforgivingly flow across geopolitical borders. Historically, around the globe, most species evolved near a reliable clean source of water. Times have changed such that water may no longer be reliable, and what water there is may be beyond the control of a given society or species. Typically, the upstream societies or human legal policy arrangements retain water access to the potentially disastrous detriment of all others. Where there is little water upstream, there may be none downstream, or where there may be plenty of water upstream, the controlling societies may use most of it to establish, sustain, and grow their economies that may be ruinous to downstream needs. Conversely, a controlling community may redirect an overflow of water to avert a local disaster only to convey the disaster to downstream communities.

Water access rights are centuries old. Colonization activities empowered governments to control access for whatever purpose they prioritized (Mwanza, 2018). Today, water access control, from a global perspective, ranges from full public access to government regulated to private access. Each of these approaches is nuanced; for example, private access may be further restricted by either riparian or prior appropriation access rights (NALC, "Water Law"). Then there is the consideration of groundwater versus surface water. It's complicated (NALC, "Water Law").

Humans control access to many clean water sources through legal arrangements impacting numerous species, not just humans.

The core challenge, then, is how do we equitably share fresh water, the lifeblood of this planet among all its inhabitants? This challenge is a policy one. The future of transboundary waters largely depends on the collective efforts and cooperation among countries sharing these water resources. Securing the future of transboundary waters requires a cooperative, inclusive, and long-term approach (Wouters, 2013). In 2010, the UN adopted resolution 64/292 recognizing the human right to water and sanitation, rallying the international community to action, especially in support of developing nations (UNDESA, "Water for Life"). As of 2020, one in four people on this globe still did not have access to safe drinking water (Ritchie & Roser, 2021).

Recommendations

1. **Build on the water usage knowledge of Indigenous peoples and other societies.** Consult Indigenous peoples regarding their knowledge of water usage that may have been passed along, and societies that have taken steps to rectify and improve equitable water access for all. In addition, consider the guidance in the UN report, "The Human Rights to Water and Sanitation in Practice" (UNECE, 2019).
2. **Mission local organizations with championing clean water access and protection.** Such organizations should be contextually aware and aligned around key water regions. Organizations should be linked within and across nations to improve decision-making, goal-setting, and knowledge sharing.

3. **Practice international cooperation.** Strengthening collaboration and dialogue among countries sharing transboundary waters will be vital. This cooperation could involve the establishment or enhancement of international agreements, joint commissions, or other mechanisms for effective management and conflict resolution (UN 2023 Water Conference).
4. **Integrate water resources management.** Adopting integrated approaches to water resources management can help improve the equitable and sustainable use of transboundary waters. This approach involves considering the needs of various sectors, such as agriculture, industry, and ecosystems, while balancing social, economic, and environmental objectives (Wouters, 2013).
5. **Continue efforts to improve approaches to agriculture that make more efficient use of water while minimizing pollutants**. This effort is vital considering that agriculture uses globally 70% of freshwater (freshwater withdrawals) and contributes toward polluting the freshwater through nutrient pollution (UN FAO, 2011).
6. **Use modeling tools to aid in decision-making.** Explore the use of "serious gaming" modeling tools to help engage stakeholders in decision-making exercises (Wikipedia, "Serious Game;" Angarita et al., 2016).
7. **Explore the concept of location specific water standards**. Explore clean water standards targeted at, and appropriate for, specific communities, encompassing the native species of the region. Local context is important.
8. **Develop a water-forecasting process.** Devise a weather-forecasting approach that better evaluates water impact to aid communities/states in better forecasting long-term water availability and its capacity to support community viability as populations grow. For example, the use of satellite and thermal technology could evolve to aid "in both monitoring and measuring both surface and groundwater extractions, and consumptive use" (Wheeler, 2021).

Case studies

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1. Serious Gaming as a Tool to Model and Communicate Considerations for Water Resource Management

   Serious games, such as "SimBasin,"[60] may hold promise in helping communities improve their approach to water management within given water basins. With SimBasin, "the engine allows to easily create a simulated multiplayer basin management game using WEAP water resources modeling software (SEI, 1992–2015), to facilitate the communication of the complex, long term and wide range relationships between hydrologic, climate, and human systems present in river basins, and enable dialogue between policy-makers and scientists" (Angarita et al., 2016). The game was used in Columbia, applicable to the Magdalena-Cauca River Basin (Craven et al., 2017). It was also tried in Thailand for the Upper Nan River Basin (Gunathilake, 2020).

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2. Water Scarcity and Agriculture

   The Food and Agriculture Organization (FAO) of the UN has engaged in a program titled, “Coping with Water Scarcity—the Role of Agriculture,” based on its framework for agriculture and food security (UN FAO, 2012). The program focused on Egypt, Jordan, and Lebanon. The FAO indicates their program is having success per a separate 2020 evaluation of the project in Lebanon:

   > *FAO projects made positive impacts on their beneficiaries, in terms of enhanced capacity, higher productivity and increased income. The impact was greater when the interventions addressed institutional, policy and cross-sectoral issues as in the case of forest management, statistics and vocational training projects.* (UN FAO, 2020)

Further resources

1. Guest Blogger for the Internationalist. “Navigating Rough Waters: The Limitations of International Watercourse Governance.” *The Internationalist* and *International Institutions and Global Governance Program* (blog), *Council on Foreign Relations*, 2 Sept. 2020.
2. “Nebraska and Colorado Face Off Over Water.” *AP News*, 18 May 2022.
3. NPR Staff. “Water Wars: Who Controls The Flow?” *NPR All Things Considered*, 15 June 2013.
4. Meshel, Tamar, and Moin A. Yahya. “International Water Law and Fresh Water Dispute Resolution: A Cosean Perspective.” *University of Colorado Law Review* 92, no. 2 (18 Mar. 2021).
5. “Potential Problems with Cross-Border Water Issues: The U.S. and Canada in the 21st Century.” In *Canada and the New American Empire*. University of Victory, CA: Center for Global Studies and CBC News World.
6. Singh, Shashwat. “The American Southwest’s Water Crisis, and Why Canada May Have the Solution.” *Glimpse from the Globe.* 10 Jan. 2022.

Issue 2: Humans treat water as an endless resource that causes unnecessary waste

Background

To those living in the developed world, water can seem limitless, just a turn of a knob away. This easy and ready water access in some societies triggers wasteful habits, which could run the gamut, from letting water run in a sink while brushing teeth or washing dishes, to the obsession of watering residential grass in pursuit of idyllic green lawns. The problem extends beyond individual household waste. Water overuse and waste happen in agricultural, commercial, and industrial settings too. Where it is plentiful and inexpensive, there will be a tendency toward neglectful water spillage and runoff. Even where water is scarce, in less developed countries, water rights owners or those with means to pay for the water may feel entitled to water use as if it is a limitless resource. Notably, the challenge may have more to do with developing and implementing workable policies and regulations that incentivize sustainable usage. An example is the 1980 Groundwater Management Code in Arizona.

It is projected that even as “the U.S. water supply decreases, demand is set to increase.” Specifically, “On average, each American uses 80 to 100 gallons of water every day, with the nation’s estimated total daily usage topping 345 billion gallons—enough to sink the state of Rhode Island under a foot of water” (Heggie, 2020). As the population increases, water stress will increase accordingly. Progress is happening with simple technological creations such as effective household greywater capture systems that might affect greater impact with broader adoption (Heggie, 2020; Gelt, 1993; Boano et al., 2020).

Recommendations

1. **Support maintenance of old infrastructure, such as leaky pipes.** Old fixtures should be replaced with new, efficient ones, and installation of water-efficient fixtures and appliances should be incentivized (U.S. EPA, “Statistics and Facts”).
2. **Encourage use of water-efficient technologies** (Federal Energy Management Program, “Water-Efficient Technology Opportunities”). Ongoing innovation in this area is needed; therefore, promoting imaginative study, experimentation, and entrepreneurship may help to continue to raise the bar. For example, where appropriate, advocate for more use of greywater technology to capture and reuse household water from laundry, bath, and kitchen usage to be applied toward nonedible landscape vegetation (Gelt, 1993; Boano et al, 2020).
3. **Form new water use habits**. Inclusive campaigns could help people from all generations, backgrounds, and roles to reverse the power of old habits (e.g., such as learning to run dishwashers only when full). With an eye to the future, especially focus on building new habits with children (U.S. EPA, “Water Sense for Kids”). Leaders and influential managers should be empowered to use water conservation means in commercial buildings (U.S. EPA, “Commercial Buildings”). The role cultural values play should also be considered, while inspiring new values for beauty. One option would be to encourage the use of plants that conserve water rather than growing grass lawns. Outdoor water use should be limited (Karlamangla, 2021).

4. **Examine the potential for using water markets to help determine a fair price for water that encompasses all stakeholders** (Wheeler et al., 2017; Young, 2021). Water markets, like any market, can help manage scarce resource usage by assigning appropriate value to it. Be mindful, however, that capital markets are human centric. Today's water markets may trend more toward agricultural benefits, weighing the water value against crop value. To benefit all of society, such markets should continue to broaden their participation to encompass all water users, attributing a fairness factor that considers the importance of the water to each stakeholder, beyond just humans, balancing seasonal, environmental, economic, and safety factors, to name a few (Ritcher, 2016). New technologically applied ideas may be of help to further promote/market/educate, increase accessibility, and assure equitable and inclusive participation among all stakeholders, including nonhumans (corporate, policy, community).

Case studies

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1. Water Management in San Diego County, USA.

   San Diego County, California, has actively managed its water resources for many years. Its leaders were especially motivated to rectify their water situation during a drought period in the 1990s. Their approach incorporates a combination of water rights access, appropriate pricing, infrastructure (aquifers, stopping leaks, and desalination plants), and educating their constituents, including both industry and households about common-sense water conservancy practices. Today, when other California residents need to make major adjustments to reduce water consumption, San Diego County inhabitants are less impacted given they have already been conditioned for water scarcity (Naishadham, 2022).

2. Balancing the Use of Water Through Water Trading Markets—Australia

   Water trading markets in Australia have exhibited reasonable success as a means to balance the use of water as a scarce resource among competing parties. The market approaches vary by the water rights being traded (e.g., access entitlement, allocation, irrigation, and delivery). The markets accommodate both economic and climate demands (Australian Government, DCCEEW; Hughes, 2021).

Further resources

1. Dalin, Carole, Yoshihide Wada, Thomas Kastner, and Michael J. Puma. "Groundwater Depletion Embedded in International Food Trade." *Nature* 543 (Mar. 2017).
2. "Excessive Water Use." City of Show Low, Arizona.
3. James, Barry. "Overuse Leading to Food Shortages, Study Warns: Less Water, and Less to Eat. *New York Times*, 18 Oct. 2002.
4. Karlamangla, Soumya. "Here's Where California Really Uses Its Water." *New York Times*, 10 Dec. 2021.

5. Pawlukiewicz, Amy. "“7 Ways to Ensure Your Water is Always Hot." *Angi*, 17 Oct. 2022.
6. Sengupta, Somini. "City Living, With Less Water." *New York Times*, 29 Apr. 2022.
7. United Nations (UN). *Groundwater: Making the Invisible Visible*. Paris: UN Educational, Scientific and Cultural Organization (UNESCO) World Water Assessment Programme (WWAP), 2022.
8. U.S. Environmental Protection Agency (EPA). "Statistics and Facts: Why Save Water?" WaterSense. Last updated 24 April 2023.
9. Water Science School. "Total Water Use in the United States." USGS, U.S. Department of the Interior. 8 June 2018.[61]
10. Water Science School. "Trends in Water Usage in the United States, 1950 to 2015." USGS, U.S. Department of the Interior. 18 June 2018.

[61] "Thermoelectric power and irrigation remained the two largest uses of water (in the USA) in 2015, and total withdrawals decreased for thermoelectric power but increased for irrigation."

Issue 3: Community overexpansion can overtax water resources, whereas the scaling effect, while seemingly efficient from a financial sense, may have the unexpected impact of overtaxing available water resources

Background

As populations grow in various countries, the pressure for already scarce water resources increases accordingly. The surrounding infrastructure on which people rely to sustain themselves in various regions needs to scale to meet the demand of ballooning populations. Notably, "according to the World Health Organization (WHO), between 50 and 100 liters of water per person per day are needed to ensure that most basic needs are met, and few health concerns arise" (UN Water Decade Programme). Community planners should accommodate such a fundamental requirement. Compounding this basic infrastructure demand in water-stressed regions is the competition for water among a community's flora and fauna, human residents, and businesses, including agriculture and electricity production where that applies. The aggregate of all water-consuming parties amplifies the potential for disaster in such areas (Derla, 2016).

Recommendations

1. **Develop more detailed planning tools. Build and use better planning models that incorporate a richer set of variables inclusive of the surrounding species, the stakeholders.** For example, the use of "serious gaming" modeling tools should be explored to help engage stakeholders in decision-making exercises (Wikipedia, "Serious Game;" Angarita et al., 2016).
2. **Consult stakeholders extensively about the impact of proposed community growth on water availability**. **Consult local Indigenous communities, as well as local research universities and nongovernment organizations (NGOs), to advise on environmental impacts.** Those impacts should reflect not just that of human projects on the environment, but rather the converse, the impact of a potentially damaged environment on the community. Also, the UN should be partnered with, using the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to devise methods for the public, businesses, and local governments to understand and apply its guidance (Brondizio at al., 2019).
3. **Build an extensive knowledge base on water scarcity and its causes as well as potential flooding.** Leverage, on a global scale, the UN and other nations to identify regions of increasing water scarcity, breaking down that scarcity by its cause at local situational levels: natural, water diversion, pollution, industrial/commercial usage, and so on (all the issues listed in this chapter). Then the effect can be modeled as human-controlled water scarcity culprits are scaled down (Wada et al., 2016).
4. **Communicate to the public about water consumption by industry. Educate the general population on the effect of scaling, as well as on how to balance water needs with enterprise.** Bigger is not necessarily better.

Case studies

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1. River of Life Project—Kuala Lumpur

   Kuala Lumpur invested more than $1 billion via its "River of Life" project to clean and revive its Klang River with the intent to balance the area's natural resources with economic development. The city has been transformed by these changes:

   > *Restoring river habitat and ecological processes not only enhanced the quality of the human experience, it also added resilience to local economies.* (Schneider, 2018)

2. Smart Growth—New Jersey, USA

   Evidence shows that "smart growth," applying environmental conservation principles, can increase property values within communities that apply them. Conservation Tools Org discusses these principles and successful use cases in its paper, "Economic Benefits of Smart Growth and Costs of Sprawl":

   > *This impact assessment compares two possible growth plans for New Jersey, one in which growth is managed according to the State Development and Redevelopment Plan, and one in which it continues according to historical trends.* (WeConservePA, 2012)

Issue 4: City infrastructure detracts from healthy river and lake ecosystems

Background

Cities have a "profound relationship" with rivers and lakes. Infrastructure development "affects both the quantity and quality of water by changing the natural flow of stormwater runoff in a watershed. When rain hits impervious surfaces such as roofs, streets, and parking lots, it flows off in large quantities, carrying pollutants it picks up from the surfaces. The runoff's increased quantity and speed erode stream channels and destabilize [sic] their banks, while pollutants harm plants and wildlife in rivers, streams and bays" (U.S. EPA, "Smart Growth and Water"). But it is not only the functional aspects of city infrastructure that matter to rivers and lakes. Now, rivers and lakes also serve as sources of pride for cities and their urban dwellers as leaders invest to build infrastructure that enhances the beauty of the waterfront and that invites people to use these bodies of water for recreational purposes. "A good waterfront development considers diversity, community engagement, safety and security, environment and sustainability" (Hussein, 2014).

Our opportunity is to invest in city infrastructure that enables rather than detracts from healthy river and lake ecosystems by minimizing barriers, elevating natural systems, and advocating for sustainable practices.

Recommendations

1. **Consider the ecosystem needs of rivers and lakes, not only to maintain their functionality and their beauty but also to help improve the health and safety of urban dwellers**. To do this, building an infrastructure to support sustainable rivers and lakes and to minimize human-made pollution is essential.
2. **Implement "green Infrastructure" within and around cities.** Such infrastructure includes technologies that manage storm water safely, effectively, and sustainably using "natural infrastructure" and "techniques that protect, restore, and replicate natural systems." It might also mean "[r]estor[ing] floodplains, and preserv[ing] wetland forests through conservation programs." These programs might include things such as energy efficiency, water access, and green walks along the waterfront (Hussein, 2014).
3. **Create more "public greenspaces" in cities.** "Urban greenspaces" help reduce air, water, and noise pollution, and they may offset greenhouse gas emissions through CO_2 absorption. As it relates to the health of river and lake ecosystems, "Urban greenery also provides storm water attenuation, thereby acting as a measure for flood mitigation" (Lee et al., 2015).
4. **Consider initiatives to create and protect healthy watersheds** (U.S. EPA, "Initiatives to Create and Protect Healthy Watersheds"). This consideration should be an integral part of a holistic infrastructure planning process. Organizations such as the EPA partner with local states to encourage "holistic protection of aquatic ecosystems" (U.S. EPA, "Initiatives to Create and Protect Healthy Watersheds") This alliance results in joint efforts to employ such things as monitoring and assessment approaches, goal development, transparent communication with the public, and strategic habitat protection partnerships (U.S. EPA, "Initiatives to Create and Protect Healthy

Watersheds"). When used as part of a coherent strategic planning process, all of these may inform how best to approach modifications to city infrastructure or future planning for such infrastructure.

5. **Retrofit/renovate industrial riverfront infrastructure for long-term sustainable use.** Retrofit out-of-date industrial riverfront properties, while including plans for the future use of the space by keeping in mind not only the human desire for "live, work, play" (Tierney, 2013) but also the ecosystem's needs. The ecosystem itself, the river, should play an equally important role as the human stakeholders in the planning process.

Case studies

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1. Huangpu River Development—Shanghai

   Shanghai is experiencing a renaissance devised through development along the Huangpu River with the river as the centerpiece:

   > *The urban regeneration of the Huangpu riverfronts plays a key role with no less than 120 kilometers of waterfront transformation intended to eliminate polluting industries, create a continuous open public space, to make new ecological connections, to reuse industrial heritage, and to add new landmarks. More than 50 kilometers of new waterfronts have been already implemented.* (den Hartog, 2021)

2. Sabarmati Riverfront Redevelopment—Ahmedabad, India

   In Ahmedabad (India),

   > *"the closure of mills along the Sabarmati Riverfront caused unemployed laborers to form large informal settlements along the riverbed, creating unsafe and unclean living areas and reducing the flood management capacity…In response, the city created a development corporation to reclaim 200 hectares of riverfront land on both sides and paid the project costs through the sale of 14.5 percent of the reclaimed land, while the rest of the riverfront was transformed into public parks and laborers resettled through a national program*. (World Bank, 2016)

3. Riverfront Project—Omaha, Nebraska, USA

   In Omaha, Nebraska, "The Riverfront" project "became the first in Nebraska to earn an "Envision" award for sustainability," with a "Platinum sustainability rating." The project transformed downtown Omaha along the Missouri River by connecting three parks near the city's downtown core.

   > ***Preserving undeveloped land and remediating a brownfield.*** *To preserve undeveloped land, one hundred percent of the project has been located on previously developed areas. The Lewis and Clark Landing, representing approximately 41% of the site, is located on a brownfield site where a lead smelting and refinery company operated for decades. A response action to install a geosynthetic clay liner was started in the late 1990s to cap the contaminated soils and was fully completed in 2016.* ("Omaha, Nebraska's Riverfront Revitalization Project," 2021)

Further resources

1. Bell, Lauren. "The 7 Most Sustainable Cities in the World." Rate It Green, Green Building & Design. 21 Sept. 2018.
2. Denchak, Melissa. "Green Infrastructure: How to Manage Water in a Sustainable Way." NRDC, 25 July 2023.
3. Gidigbi Jenkins, Stephanie, Rob Moore, Becky Hammer, Erik D. Olson, Luke Tonachel, Khalil Shahyd, Douglass Sims, et al. "Invest in 21st Century Infrastructure." NRDC.
4. Lubell, Sam. "7 Cities Transforming their Rivers from Blights to Beauties**."** *Wired*, 4 Aug. 2016.
5. Phong, L. H. "The Relationship Between Rivers and Cities: Influences of Urbanization on the Riverine Zones: A Case Study of Red River Zones in Hanoi, Vietnam." *WIT Transactions on Ecology and The Environment* 193 (2015).
6. *Rivers and Lakes in European Cities.* EEA Report, no. 26/2016. Copenhagen, Denmark: European Environment Agency, 2016.
7. Sedlak, David. "How Development of America's Water Infrastructure Has Lurched Through History." *Pew*, 3 Mar. 2019.
8. U.S. Environmental Protection Agency (EPA). "Why Urban Waters?" Urban Waters Partnership. Last updated 10 June 2022.

Issue 5: Excess fertilizer, pesticide, and animal waste pollute water sources and increase the chances for toxic harmful algal blooms (HABs)

Background

Humanity has been applying fertilizer and pesticide to crops for ages. There is a limit, however, to how much of it the waterways can filter before it impacts us and our surrounding environment (University of Oxford, 2013; PennState Extension, 2022). A U.S. EPA "assessment found that 48% of water quality impairment in American surface waters is attributable to agriculture" (Nosowitz, 2021). This problem isn't just an agriculture challenge, but also a household cultural problem. In the United States, household lawns may be the largest crop. "Lawns comprise over 150 000 km^2 of land in the US, an area larger than that of any irrigated crop" (Groffman et al., 2016) As a result, people are overfertilizing. In lakes and ponds, the result is increasing algal blooms. Here are some quotes from a few different sources:

> *"Using lots of fertilizer wouldn't necessarily be a bad thing if all of it was used by the crops. Unfortunately, most of it isn't."* (Ritchie, Roser, & Rosado, 2022)
>
> ***"[L]ess than half of the nitrogen we apply to our crops is actually taken up by them. The rest is excess that leaks into the natural environment."*** (Lassaletta et al., 2014)
>
> *"Nutrient pollution is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, **causing excessive growth of algae.**"* (NOAA, 2023)

Apart from occurring naturally, toxic algal blooms can be caused by the flow of nutrients like nitrogen and phosphorus into the lake ecosystem. These nutrients may originate from fertilizers used in agriculture and through household use of chemicals and so forth.

HABs "occur when colonies of algae—simple plants that live in the sea and freshwater—grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal" (NOAA, 2016).

Costs to the economy include healthcare costs for affected human beings, as well as to tourism and to mitigate the damage. There is also a cost to marine life (Florida Dept. of Health, "Harmful Algae Blooms"). Effective sustainable farming practices are evolving. They balance the objectives of a healthy environment and economic profitability with social and economic equity (UC SAREP, 2021).

Recommendations

1. **Consider natural, native solutions to let nature repair nature.** For example, it's been known for many years that some native grasses, such as switchgrass, serve as filters. "Grassy riparian buffers, either alone or in a forested buffer system, trap or transform sediments and plant nutrients before they enter streams. Native grasses might also be used in contour filter strips that can retain 50–70% of nutrients, pathogens, and sediment" (Schnabel, 1999).

2. **Reduce the use of pesticides and chemical fertilizer in crop production.** Use regenerative farming (University of Missouri Center for Regenerative Agriculture) or, at minimum, crop rotation. These practices can reintroduce natural nutrients from a crop back into the soil for future crop benefit. This approach can also reduce the need for fertilizers and pesticides. Research has already made progress in identifying food crops that require less fertilizer.

3. **Use financial incentives or disincentives to avert the overuse of fertilizers**. For example, continued evolving and popularizing the use of water quality trading (WQT) is needed. Much like voluntary carbon markets (VCMs) use greenhouse gas (GHG) offsets traded among carbon producers to achieve lower carbon output to meet policy goals, WQT enables waterway nutrient polluters to achieve something similar. Its advantage is in attracting private capital market investment toward infrastructure required to clean the water. It brings together key stakeholders (e.g., government, nongovernment, agriculture, private industry, and capital markets) to achieve water quality policy goals such as the 1972 Clean Water Act in the United States (Chesapeake Bay Foundation, "Water Quality Trading;" U.S. EPA, "Water Quality Trading").

4. **Continue to develop, evolve, and deploy sustainable agriculture practices**. "Growers may use methods to promote soil health, minimize water use, and lower pollution levels on the farm" (UC SAREP, 2021).

5. **Improve the efficiency of fertilizer application.** Use new advances in science, both in analyzing the results of applications (e.g., plant sap analysis; Barrera, 2021) and in exploring the viability of using super-absorbent polymer (SAP) technology:

   > *Besides improving water use efficiency of soil, SAPs are also used for controlled release of fertilizers. It is reported that about 40–70% of nitrogen (N) and about 80–90% of phosphorus (P) in conventional fertilizers cannot be absorbed by crops due to their high solubility in water and high diffusivity to the surrounding environment.* (Chang et al., 2021)

6. ***Encourage minimizing "manicured" lawns.*** Promote ways to encourage a natural residential lawn and disrupt the pursuit of an unnatural manicured lawn that requires more chemical treatment—potentially significant irrigation—to maintain it. Growing native species encourages and supports a healthy habitat for surrounding indigenous flora and fauna. For households unwilling to switch to a natural lawn, suggestions to mow at taller heights that "can reduce pest problems, such as weeds, insects, and diseases" (Clear Choices Clean Water, Indiana, "Fertilizer and Water") are useful. Landscaping services should be mindful of and better educated about over fertilizing and should provide more natural means of pest control.

7. **Implement sustainable algae management practices.** These practices and viable technologies include increasing the level of oxygen in lake water through technologies like aeration, educating and encouraging households to reduce the use of detergent, algae control using ultrasonic waves, judicious use of aquatic herbicides, and the potential use of nanobubble technology (Temesgen, 2017). These tactical approaches should be advertised to the community as clearly temporary and requiring pairing with more natural strategic solutions. Such tactics should avoid leaving the community with the sense that temporary remediation solves the underlying problem to the point where they lose interest.

8. **Monitor water and communicate water quality in real time**.

Case studies

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1. Remediation of the Pleasant Valley Branch of the Pecatonica River, Wisconsin, USA

   The Pleasant Valley Branch of the Pecatonica River in Wisconsin managed to reduce sediment and chemical runoff by proactively engaging stakeholders to rally around a solution. That solution included government agencies, NGOs, and farmers (voluntarily) applying a SNAP PLUS program (Soil Nutrient Application Planner) to identify "hot spots" and assess appropriate remediation. They managed to reduce the phosphorus pollution by 40%, which improved the health of the fish and other species reliant on the river as their habitat; it also dramatically reduced the algae growth in downstream waters. Thus, they incorporated a sustainable management model by introducing an automated sampler mechanism along the river (Into the Outdoors, 2017; Environmental Trading Network).

2. Building the Future of Freshwater Protection

   Lake George Association—The Jefferson Project: Building the Future of Freshwater Protection.

3. Impacts of climate change on coastal blooms

   The National Centers for Coastal Ocean Science (NCCOS) are working to monitor and address the impacts of climate change on coastal blooms: Monitoring and Event Response (MERHAB).

4. Algal Blooms—Root Causes

   Moleaer's nanobubble technology is used for various purposes, including for treating the root cause of algal blooms.

Further resources

1. Calderon, Ignacio. "Climate Change Is Intensifying the Effects of Fertilizer Runoff." *Modern Farmer,* 22 Dec. 2021.
2. Cox, Paul Alan, David A. Davis, Deborah C. Mash, James S. Metcalf, and Sandra Anne Banack. "Dietary Exposure to an Environmental Toxin Triggers Neurofibrillary Tangles and Amyloid Deposits in the Brain." *Proceedings of The Royal Society B* 283, no. 1823, (Jan. 2016).
3. Elliot, Josh K. "Woman's Puppy Playdate Ends with 3 Dogs Dead from Toxic Algae." *Global News*, 12 Aug. 2019.
4. Johnson, Ashanti, and Melanie Harrison. "The Increasing Problem of Nutrient Runoff on the Coast." *American Scientist* 103, no. 2 (March–April 2015): 98.
5. Kirkpatrick, Barbara, Richard Pierce, Yung Sung Cheng, Michael S. Henry, Patricia Blum, Shannon Osborn, Katie Nierenberg et al. "Inland Transport of Aerosolized Florida Red Tide Toxins." *Harmful Algae* 9, no. 2 (Feb. 2010).

6. Marohn, Kirsti. "Wet Spring, Warm Temps in Minnesota Could Spur Toxic Algae Blooms." *MPR News*, 18 June 2022.
7. Mays, Chris, Vivi Vajda, and Stephen McLoughlin. "Toxic Slime Contributed to Earth's Worst Mass Extinction—And It's Making a Comeback." *Scientific American*, 1 July 2022.
8. National Institutes of Environmental Health Sciences (NIEHS). "Algal Blooms." NIH. Last updated 8 Sep. 2021.
9. OECD Data. "Meat Consumption."
10. Poore, J., and T. Nemecek. "Reducing Food's Environmental Impacts through Producers and Consumers." *Science* 360, no. 6392 (June 2018): 987–982.
11. "Preventing Runoff into The Mississippi River." *USDA* YouTube channel. Aug. 2011.Safe Drinking Water Foundation. "Pesticides and Water Pollution."
12. Ritchie, Hannah, and Max Roser. "Clean Water." OurWorldInData.org, Sept. 2019. Last updated June 2021.
13. Schaefer, Adam M., Luke Yrastorza, Nicole Stockley, Kathi Harvey, Nancy Harris, Robert Grady, James Sullivan et al. "Exposure to Microcystin among Coastal Residents during a Cyanobacteria Bloom in Florida." *ScienceDirect*, 5 Feb. 2020.
14. Schlossberg, Tatiana. "Fertilizers, a Boon to Agriculture, Pose Growing Threat to U.S Waterways." *New York Times*, 27 July 2017.
15. U.S. Environmental Protection Agency (EPA). "Climate Change and Harmful Algal Blooms." Nutrient Pollution. Last updated 15 Dec. 2022.
16. U.S. Environmental Protection Agency (EPA). "Harmful Algal Blooms." Nutrient Pollution. Last updated 25 Aug. 2022.
17. U.S. Environmental Protection Agency (EPA). "The Sources and Solutions: Agriculture." Nutrient Pollution. Last updated 28 Oct. 2022.
18. U.S. Department of Agriculture (USDA). Farm Service Agency, US Department of Agriculture. "Feed Grains and Oilseeds Analysis."
19. Wempen, Kristi. "Are You Getting Too Much Protein?" *Speaking of Health,* Mayo Clinic Health System, 29 Apr. 2022.
20. "When it Comes to Protein, How Much is Too much?" *Harvard Health Publishing*, Harvard Medical School, 30 Mar. 2020.

Issue 6: Water flow diversions disrupt critical ecosystems

Background

The human need for energy, irrigation, transportation, household, and industrial products often alters the natural flow of rivers and streams through construction and deforestation. Modification of the natural environment has a detrimental impact on rivers and lakes by either increasing or impeding the natural flow of water, by increasing pollutants in the water, and/or by disrupting the natural processes of interconnected ecosystems.

The land area through which water naturally flows is called a *watershed*. Any human modification to the watershed interrupts the natural flow of water, including modifications humans make every day such as construction ranging from dams and irrigation channels to buildings and dwellings to roadways and parking lots. Disturbing the watershed by building structures such as parking lots can dramatically increase rainwater runoff, resulting in increased volumes of water, which results in flooding and erosion. Construction is not the only culprit, though. Other uses of the land, such as harvesting materials like lumber, impact the natural flow of water. When the natural flow of water is interrupted, the receptacles of the water, such as streams, rivers, and lakes, are impacted. When trees are removed for human use, the natural process they play in our ecosystem is disrupted too. For example, trees facilitate the natural rivers in the sky. They do this by absorbing and then releasing water into the atmosphere that travels "hundreds or even thousands of miles away," feeding rivers and lakes across the world. Other impacts can range from increases in water flow, where barriers are reduced, which results in flooding and erosion, to the polluting of water as pollutants are collected during flow. When humans introduce barriers within the natural watershed, as water flows, it can pick up contaminants and pollutants, which impact rivers and lakes downstream.

The fact that people have made choices over centuries to alter natural water flows without understanding their impact on other species also affects humans in the long run. For example, one study finds a correlation of human disease increases with the 20th-century construction of two large dams in Egypt (Derr, 2021). Regarding dams, numerous articles and studies provide evidence of their disrupting nature, but it is prudent to ask whether dams could be used in other ways that benefit other species as well as humans. Alternative sources of energy are needed to relieve dependency on fossil fuel, and dams provide such a choice. Of course, there are trade-offs. Each action by any species on Earth affects others, sometimes negatively. It's a dance! And like a "dance," troupes must work in unison to achieve harmony.

Recommendations

1. **Examine the appropriate timing of dam water releases to balance the needs of multiple stakeholders** (Chen, 2018). The impact of dam creation on the habitat of the native species that are important to maintaining the sustenance of the surroundings should be considered.
2. **Employ more permeable construction materials for infrastructure to minimize water flow impact.** For example, studies have trialed the use of permeable pavement for roadways or walkways that has the potential for improving water flow disruption (USGS, 2019).

3. **Effectively use AI to assess the life cycle of a dam—from design to end-of-use.** Use artificial intelligence based on trusted data models to aid in assessing the motivations and the impact of building a dam, even its removal. Alternative approaches may reveal themselves.
4. **Take a systems approach including the need for irrigation, potential types of crops when assessing the need for an irrigation dam.** Determine, when the motivation for a dam is for irrigation, whether more appropriate crops could grow in a region that would lower or minimize the demand for water from the irrigation channels. An example is in Arizona where local alfalfa farmers are looking at substituting their usual non-native alfalfa with a native plant, guayule, that has uses in the latex market.

Case studies

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1. Dam Removal—Selune River, France

   France has been making concerted efforts to reduce the river flow diversions of its dams by scientifically researching and applying approaches. A major dam was removed from the Selune River with acknowledged success:

   > *"The way the river has been reborn is such an important message, a message of hope," says Roussel. "Just when you think that everything is going wrong with the environment, sometimes you can get a sign, a concrete example of nature reclaiming its territory. And I think that's really comforting."* (Dekimpe, 2022)

2. Dam Modification to Support Atlantic Salmon Population—Poutes Dam, France

   Another dam, the Poutes Dam was retained but lowered by nearly two thirds with modifications to both its operational structure and schedule to provide a migration path for the declining Atlantic salmon population. This project is still in progress but with encouraging results so far (Dekimpe, 2022).

3. Dolphin Population Decline in the Ganges River—Assam, India

   In Assam, a state in India, the Xihu (river dolphin) population is in serious decline in the Ganges River, which is partly attributable to dams that restrict the dolphins' movements. Being at the top of the food chain, these dolphins help maintain the health of the rivers they inhabit. Any indication of their population decline is a sign of an unhealthy river (Swinton & Gomez, 2009; Guha, 2022).

4. Environmental Flows—Human and Environmental Water Needs Study, USA

   A 2017 study from the *University of Washington School of Aquatic and Fishery Sciences*) provides some hope of a possible positive compromise addressing this problem, "Designing flows to resolve human and environmental water needs in a dam-regulated river":

   > *One of the most promising approaches to **integrating human uses into the larger scope of ecological sustainability** is the concept of environmental flows, or the provision of water within rivers to support positive ecological outcomes while maintaining the water needs of human society.* (Chen & Olden, 2017)

5. Large Dam Study

   Another promising example of compromise is described in this *Scientific American* article, "We Can Make Large Dams More Friendly to the Environment," which provides some hope of a possible positive compromise addressing this problem (Chen, 2018).

Further resources

1. Fountain, Henry. "Deforestation Remains High, Despite International Pledges." *New York Times*, 28 Apr. 2022.
2. Fountain, Henry. "Tropical Forest Destruction Accelerated in 2020." *New York Times,* 31 Mar. 2021. Updated 2 Nov. 2021.
3. Lovgren, Stefan. "Rivers and Lakes are the Most Degraded Ecosystems in the World." *National Geographic Environment*, 1 Mar. 2021.
4. Pearce, Fred. "Rivers in the Sky How Deforestation is Affecting Global Water Cycles." *YaleEnvironment 360,* Yale School of the Environment, 24 July 2018.

Issue 7: Growing water-intensive crops in arid zones accelerates water scarcity

Background

The agriculture industry is incentivized to grow crops that provide the greatest yield for their investment and available resources. In some cases, the crops require more water than the local ecosystem is natively capable of providing.

Thirsty crops: It's an economic problem:

> *"When growers are producing things, they think in terms of what income can you generate per unit of water, so a crop that doesn't use as much water per acre, might not generate much income."* ~George Frisvold, Researcher, Univ of Arizona Dept of Agricultural and Resource Economics. (Mysofski, 2022)

For example, the United States produces almonds largely in California and Arizona, two water-stressed areas. Almonds natively grow in the Mediterranean region, and they do require a great deal of water. This crop, therefore, may no longer be practical from a water usage perspective. The issue becomes more complicated when intricate dependencies are unveiled about crops grown at scale to fulfill the demands of the entire vertical food industry from farm to wholesale to industrial to commercial to consumer.

This 2016 article in the Austin American-Statesman (updated in 2018), "5 Reasons Farmers Grow Thirsty Crops in Dry Climates," reveals a great deal about the problematic relationship specifically in the United States between agriculture and water. Here are some key snippets:

> *"**Corn's production value is higher than that of soy or wheat**, making it an attractive choice for farmers to plant. But corn also demands more water."*
>
> *"**Most of the corn grown in America goes to fatten up livestock**. It's also **used in starch, corn oil, beverage and industrial alcohol, sweeteners such as corn syrup, and fuel ethanol**.*
>
> *"**Irrigated land is worth more** than non-irrigated land in low-rainfall regions."*
>
> *"Farmers have a choice: **Fully irrigate or risk losing** the lease to a neighbor who's willing to do so."*
>
> *"Farmers who want to cut irrigation to conserve water only qualify for **dryland insurance policies that don't compensate** them nearly **as much** as an irrigated policy."*
>
> *"**Farmers** often purchase the equipment using **loans**. **To pay down the debt**, they **need to keep up production**, which usually **means irrigating**."* (Wise, 2018)

Recommendations

1. **Educate and incentivize the agricultural industry regarding growing native crops** (i.e., farmers need to avoid planting water-thirsty crops in water-stressed regions). For example, an Arizona alfalfa and cotton farmer is learning to grow and develop a market for guayule (pronounced "why-YOU-lee"), a desert shrub plant that provides a natural rubber useful for latex and other similar products (USDA, 2009; Allhands, 2021).
2. **Educate the public on the water stress impact of their product choices.** For example, consider developing a reliable measure of water intensity. Then the water intensity information could be added to food product labels.
3. **Educatevize and incentivize the public to consider locally sourced foods as well as a variety of protein sources.** Incentivize the public to look more at the advantages of locally sourced foods, where possible, as well as at alternative sources of protein to aid in rebalancing the demand across protein choices. The cattle and dairy industry, however, should be supported through this transition, that is, in fairness to their business investment, both their financial and sweat equity. Support for this industry during this transition can help bolster greater support and avoid blowback that could undermine such efforts. One way to improve incentivization is to use tokens layered on blockchain technology to open access to a broader population that wishes to participate in affecting such changes (Guo, 2022).
4. **Consider crop selection for a particular location a "systems" problem.** Develop ways to educate societies on how to improve the valuing of water and other environmental resources when analyzing the costs/benefit of growing a crop in a particular area/land—in addition to weather, time to market and so on. The intent is to improve the decision-making of crop selection with more accurate and inclusive resource cost and benefit information.
5. **Pair advanced moisture sensors with AI to improve water management system options**.[62]
6. **Minimize the water requirements for irrigation.** Consider alternative forms of irrigation, such as drip irrigation to improve the water efficiency in plant growth, especially when paired with native crops (Smith & Freemark, 2016).

Case studies

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1. Crop Water Intensity and Natively Resilient Crops

   Extensive evidence exists that farmers are aware of the issue of crop water intensity and are taking measures to address it. They are looking at farming crops natively resilient to the local climate extremes, and they are seeking a market for them. Farmers then become market-makers as opposed to merely growing crops in the most cost-effective manner to meet existing world consumer demand:

[62] Evja provides solar-powered agriculture water management system. See https://www.evja.eu/#features.

Some farmers are also starting to grow crops based not on what faraway foreign consumers already demand, but raising animals and crops which thrive on increasingly arid lands, and then create a demand for those commodities abroad. (Elbein, 2021)

Accelerating such activity requires more financial help that supports farmers in this pivot. Programs such as the Environmental Quality Incentives Program (EQUIP) aim to do just that with participation from the National Resource Conservation Stewardship (NRCS). Also, the United States has passed recent legislation to further encourage and support such endeavors by way of bill S.1251, the Growing Climate Solutions Act. (U.S. Senate Bill S.1251)

2. Water Reclamation from Wastewater—Israel

   Being an arid nation with a growing population, Israel has improved water reclamation from wastewater to upward of 85% and has learned to employ drip irrigation to enrich its agriculture (Smith & Freemark, 2016).

Further resources

1. Bunch, Kevin. "Using Satellites to Measure How Thirsty Crops are in the St. Mary-Milk Rivers Region." International Joint Commission. *Shared Waters: Water Matters*, 16 Nov. 2020.[63]
2. Oletic, Dinko, and Vedran Bilas. "How Thirsty the Crops Are: Emerging Instrumentation for Plant-Based Field Measurement of Water Stress." *IEEE Instrumentation & Measurement* 23, no. 2, Apr. 2020.
3. Qazi, Moin. "Water Crisis: Thirsty Crops Drain India Dry." *QRIUS*, 18 Mar. 2018.[64]

[63] Reveals the important awareness of thirsty crops in resolving cross-border water sharing between Canada and the United States.
[64] Discusses water problems in India's agriculture.

Issue 8: Physical trash / plastics pollute freshwater ecosystems and play a significant role in ecosystem degradation and destruction

Background

A steady stream of physical trash ends up in rivers and lakes. A significant amount is generated by people's processes in disposing of end-use materials in their homes, such as plastic, cardboard, paper, building materials, abandoned items, and illegally dumped items.

Single-use plastics are a particularly toxic form of trash pollution. Unlike cardboard, paper, and many metals, their biodegradability has a particularly long lifespan. Additionally, they are often physically harmful to plants, animals, and humans.

The continuing single-use economy exacerbates the problem (Plastic Action Centre, "Here's Where the World's Plastic Will End Up, by 2050).

Regional, cultural, and economic differences complicate the issue further, leading to the need for a multifaceted approach.

Recommendations

1. **Transition from single-use resource economies to sustainable, regenerative, and circular economies appropriate for areas of differing physical, cultural, and economic development.** Tactics for such a transition should be tailored to the specific physical, cultural, and economic context of each area and be based on strategies developed around education, local partnerships, policies, regulations and incentives, and research and development of technological solutions.
2. **Educate populations globally and locally through primary, highly visible private, government, and media channels to change the principle worldview of societies.**
3. **Develop and improve waste disposal technologies that have a more modest, minimal, impact on the air, land, and water environments.**

Case studies

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1. Ganga River Water Quality—India

   Three start-ups are taking different approaches to improving and protecting India's Ganga River water quality. One uses autonomous robot, or ro-boat, technology to monitor and clean the river surface waters. Another focuses on the capture and repurposing of the flower pollution contributed by the historical religious floating floral arrangements. Still another monitors the river bed pipeline using ultrasound to alert whenever oil leaks are detected (Pal, 2017).

2. Cross Border Waterway Contamination—Balkan

   Balkan nations try yet struggle to coordinate the prevention of trash from entering shared waters. Often trash landfills are inappropriately located next to waterways, compounding the problem (CBS News, 2021).

3. Menhaden Return to the Coast of New Jersey, USA

   Humpback whales and one of their food sources, Menhaden, have returned to the shores of New Jersey, a reflection of prior long-term policy-driven efforts to clean the waterways feeding the US coastal areas:

   > *"There is still a lot of ongoing research to determine why they're here, but certainly we're seeing the long-term benefits of action taken in the 1970s like the Clean Water Act and the Marine Mammal Protection Act," said Brown, a Rutgers doctoral candidate and head researcher for the advocacy group Gotham Whale.* (Fallon, 2022)

Further resources

1. American Rivers. "National River Cleanup."
2. Antony, Anu. "What Are Some of the Latest Waste-to-Energy Technologies Available?" PreScouter, Oct. 2017.
3. Chesapeake Bay Foundation."14 Things You Can Do to Clean Up Your Rivers, Streams, and the Chesapeake Bay."
4. Gergel, Igor. "Waste to Energy Technologies: Overview." Waste To Energy International, 19 May 2021.
5. Gray, Brian, Jennifer Harder, and Karrigan Bork. "Implementing Ecosystem-Based Management." *Duke Environmental Law & Policy Forum* 31 (2021).
6. National Ocean and Atmospheric Administration (NOAA), Damage Assessment, Remediation, and Restoration Program (DARP). "Restoring Rivers to Reverse Impacts from Pollution." 3 May 2021.
7. River Cleanup (website).

8. The Rivers Trust. "Cleaning Up Rivers."
9. SENSA Networks.**"**5 Technologies That Are Making Waste Disposal More Efficient." *SENSA Networks* (blog). 6 Nov. 2018.
10. U.S. Department of Energy (DoE). "Waste-to-Energy." Department of Energy, Office of Energy Efficiency & Renewable Energy.
11. U.S. Environmental Protection Agency (EPA). "Learn About Aquatic Trash." Trash-Free Waters. Last updated 31 Oct. 2022.
12. U.S. Environmental Protection Agency (EPA). "Sustaining Healthy Freshwater Ecosystems." Watershed Academy. Last updated 7 Mar. 2023.
13. Water Detective. "How Can a River Clean Itself?"
14. Water Encyclopedia. "Pollution of Lakes and Streams."
15. Natural Resources Defense Council (NRDC). "Water Pollution: Everything You Need to Know." 11 Jan. 2023.

Issue 9: Chemical and hazardous waste adversely affects river and lake ecosystems

Background

Hazardous waste from commercial and private sources adversely affects the world's river and lake ecosystems, leading to ecosystem degradation and destruction, loss of biodiversity, and increasing human food and water insecurity.

The U.S. EPA characterizes hazardous waste threats according to four broad categories: ignitability, corrosivity, reactivity, and toxicity (U.S. EPA, "Defining Hazardous Waste).

> ***Ignitable waste*** *can catch fire spontaneously or burn easily. Examples include charcoal lighter fluid, gasoline, kerosene, and nail polish remover.* ***Corrosive wastes*** *can cause a chemical action that eats away materials or living tissue. Battery acid is an example.* ***Reactive waste*** *can react with air, water, or other substances to cause rapid heating or explosions. Acids that heat up rapidly and spatter when mixed with water are examples.* ***Toxic wastes*** *can cause illness or death. Some such wastes are more dangerous than others. Exposure to a small concentration of a highly toxic chemical may cause symptoms of poisoning. Pesticides, cleaning products, paints, photographic supplies, and many art supplies are examples. (NASD, "Disposal of Hazardous Household Waste)*

Waste with these characteristics is introduced into Earth's river and lake ecosystems from both commercial and private sources.

Commercial sources include manufacturing across a wide range of industries; mining activities (Ecowatch, 2012); commercial agriculture; and construction. Introduction of their hazardous waste byproducts into rivers and lakes results from inadequate disposal technology, water runoff, groundwater (Desjardins, 2015), acid rain, and illegal dumping.

Residential sources consist of the products consumers buy. Hazardous residue from these products enters rivers and lakes through runoff, groundwater, and illegal dumping (Denchak, 2023).

Management of hazardous wastes includes management at the source, disposal technologies, cleanup technologies, and infrastructure developments.

Recommendations

1. **Increase communication about hazardous waste disposal.** Increase education around, and public exposure to, messaging regarding the environmental hazards of pouring oils, antifreeze, paint, solvents, cleaners, preservatives, and prescription drugs down household and storm drains.
2. **Treat the hazardous waste problem at the source.** The treatment at the source approach is the most efficient means of dealing with hazardous waste. This approach includes employing disposal technologies, public education, and engagement.

3. **Improve and/or replace traditional disposal technologies such as landfills, incineration, and chemical treatment.** Further technologies must be developed, such as bioremediation, encapsulation, plasma arc technologies, thermal desorption, ion exchange, and electrochemical remediation.
4. **Design groundwater and freshwater "friendly" infrastructure.** Examples are inert permeable paving systems that manage surface runoff by allowing rainwater to be introduced into groundwater. Roads, driveways, sidewalks, and other urban infrastructure can be developed that allow for more direct introduction of rainwater into the ground and groundwater. Current concrete production has a high carbon footprint cost. Asphalt paving is fossil oil and gas resource intensive. Both additionally channel various forms of pollution into freshwater ecosystems (Venditti, 2022).

Case studies

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1. Microbubble Technology to Clean Up Pollution in Water Bodies

   A way has been found to clean up polluted lakes using a microbubble solution that attracts viruses and bacteria ("A Man from Peru, Bright Side).

2. Transport of Contaminants in Groundwater—Case Study Collection

   "Case Studies in Groundwater Contaminant Fate and Transport" is a collection of case studies that focuses on "natural processes that control the fate and transport of contaminants in groundwater rather than on active remediation methods." (Bekins, 2018)

3. Waste in Lake Malawi, Malawi

   A paper, "The impacts of waste dumping in Lake Malawi," reveals "the challenges and dangers that occur due to waste dumping globally and how individuals, water species, and even the water itself are affected." This paper is about an important lake in the African nation, the Republic of Malawi. It considers local context, sharing "what the local inhabitants are saying about this issue, and their recommendations for improving the condition of the lake." (Tsuro, 2021)

4. Cleanup of the Lower Duwamish River, Seattle, Washington, USA

   The National Oceanic and Atmospheric Administration (NOAA) runs a Damage Assessment, Remediation, and Restoration Program (DARRP) wherein they publicly share documented activity of projects. In this example, "Lower Duwamish River," DARRP information is being shared about the progress in the cleanup of the Lower Duwamish River in Seattle, Washington, USA (NOAA, "Hazardous Waste").

Further resources

1. Dutzik, Tony, Piper Crowell, and John Rumpler. *Wasting Our Waterways: Toxic Industrial Pollution and the Unfulfilled Promise of the Clean Water Act.* Environment America Research & Policy Center, Fall 2009.
2. Leitch, Carmen. "How Microbes Can Help Clean a Toxic River." LabRoots, 23 Aug. 2020.
3. NOAA. "Hazardous Waste." Damage Assessment, Remediation, and Restoration Program (DARP).
4. UN Environment Programme (UNEP). "A Framework for Freshwater Ecosystem Management." 29 Nov. 2017.

Issue 10: Raw human sewage pollution causes degradation of river and lake ecosystems

Background

While land and water can naturally treat sewage, everything has a capacity. Where humans have concentrated in growing population areas, if no separate sewage treatment mechanisms are in place, then the nearby natural waterways are likely polluted with human sewage.

Sewage from outdated treatment plants and growing populations pollutes rivers and lakes worldwide (American Rivers, "How Sewage Pollution Ends Up in Rivers"). Medicines, household cleaners, biologic waste, and a host of other pollutants make their way into water supplies, damaging ecosystems and threatening public health. Changing or conflicting policies exacerbate the problem (Flavelle, 2020). Climate change only worsens the problem (Kruzman, 2022).

Recommendations

1. **Provide extensive education around all aspects of sewage to raise public awareness** (SAS, "Get Learning").
2. **Rebuild infrastructure in light of local climate change parameters/forecasts such that the infrastructure is resilient.**
3. **Effectively deploy filtration and other sewage/wastewater treatment technologies as appropriate to the location.** Deploy and further develop advanced filtration technologies such as membrane bioreactors, moving bed biofilm reactors, integrated fixed-film activated sludge, granulated activated carbon, and oxonation.

Case studies

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1. Marine Conservation—UK

   Grassroots UK organization, Surfers Against Sewage (SAS), is an education program that not only teaches sustainable practices but also provides teach-the-teacher workshops (SAS, "Get Learning"). From a handful of activists to a nationwide movement, over the last 30 years, Surfers Against Sewage has grown into one of the UK's most successful marine conservation and campaigning charities.

2. "Stop, Don't Flush That" Campaign by the Water Environment Foundation (Water Environment Foundation, 2013)

   WEF members work to solve the non-dispersibles problem. Perpetrators mucking up the system are known as "non-dispersibles," which currently means anything other than human waste and toilet paper that is flushed down the toilet.

Further resources

1. Denchak, Melissa. "Water Pollution: Everything You Need to Know." NRDC, 11 Jan. 2023.
2. Gawel, Antonia. "4 Key Steps Towards a Circular Economy." World Economic Forum, 14 Feb. 2019.
3. Parker, Halle. "Most of Louisiana's Waterways Are Polluted. Biggest Reasons? Fertilizer and Sewage." New Orleans Public Radio (WWNO), 6 Apr. 2022.
4. Preidt, Robert. "How Your Medicines Make Their Way into Rivers, Lakes and Bays." *U.S. News & World Report*, 23 Aug. 2021.
5. The Rivers Trust. "Raw Sewage in Our Rivers."
6. Seametrics. "15 Interesting Facts About Water Pollution That You Should Know."
7. State of Green. "10 Examples of Circular Economy Solutions." 21 July 2017.
8. Ullah Bhat, Sami, and Umara Qayoom. "Implications of Sewage Discharge on Freshwater Ecosystems." In *Sewage*, edited by Tao Zhang. IntechOpen, 2022.
9. UN Water. "Water Quality and Wastewater."
10. U.S. Environmental Protection Agency (EPA). "What is a Circular Economy?" Circular Economy. Last updated 29 Sep. 2022.

Issue 11: Invasive species threaten freshwater ecosystems

Background

Invasive species are “non-native (or alien) to the ecosystem under consideration and … introduce causes or are likely to cause economic or environmental harm or harm to human health” (USDA NISIC, “What Are Invasive Species?).” Freshwater ecosystems are being threatened by invasive species because of the climate changing and human introduction of non-native species. These invasive species in some cases thrive due to being introduced into an ecosystem with no predators along with a substantial source of accessible food allowing them to prosper and outcompete other species.

With warmer temperatures in rivers and lakes, the native species are shifting and migrating to cooler environments, and they are being replaced by invasive species that can better adapt to the warmer water. These invasive species pose serious challenges to the entire ecosystem. Furthermore, the native species that cannot move to tolerable areas face possible extinction.

Recommendations

1. **Create strategies to prevent the introduction of invasive species.** “Once invasive species become established and spread, it can be extraordinarily difficult and costly to control or eradicate them” (NWF, “Combatting Invasive Species”) To curtail the spread of invasive species, preventive measures should be deployed such as:
   a) Enforcing strict boat cleaning rules at boat ramps and docks preventing species from transferring from one body of water to another
   b) Educating fisherman on releasing live bait into bodies of waters
   c) “Creat[ing] monitoring systems for detecting new infestations (NWF, “Combatting Invasive Species”)”
2. **Use scientifically defensible methods to identify freshwater aquatic species at high risk of becoming invasive species.**The focus should be specifically on the ‘import processes’ and those who import fish or plant species for home aquarium use. Policies and methods are needed to prevent accidental introduction of such species into river and lake ecosystems (Nature Conservancy, “Great Lakes Aquatic Invasive Species).Another focus area is the accidental transport of aquatic species in ships’ ballast water as well as on the hulls of ships.
3. **Focus preventative measures on waterway connections**. “The places where waterways connect are vulnerable to the movement of aquatic invasive species. Both natural and artificial connections pose a risk for the transmission of such species.“ By focusing on these connections, we can protect them and stop the two-way movement of aquatic and invasive species” (Nature Conservancy, “Great Lakes Aquatic Invasive Species).

4. **Employ mitigation and removal strategies for invasive species in freshwater bodies when preventative strategies are not effective.** Some strategies are:
    a) Moving rapidly to remove newly detected invasive species (Nature Conservancy, "Great Lakes Aquatic Invasive Species).
    b) Encouraging mitigation strategies like the hunting/harvesting of non-native species
5. **Promote public education campaigns about the problem of invasive species and engage the public to help**. Campaigns like "Don't Move a Mussel" should be considered. Such a campaign includes "general information and outreach materials to increase awareness of invasive species issues" (USDA, "Public Awareness Campaigns"). In addition to using billboards, technology should be employed to help through online and social media campaigns.
6. **Consider using remote-sensing technologies (from an airplane or drone) to determine the potential effects and locations of invasive species** (Lake George Association, "Invasive Species").
7. **Take care when introducing new species into freshwater ecosystems while trying to control non-native species growth.**

Case studies

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1. Invasive Species Management

    "Understanding population-level responses to removal and immigration rates are essential aspects of invasive species management." (Weber et al., 2016)

2. Invasive Phragmites on Beaver Island in Lake Michigan

    Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands. A report from the Michigan Natural Features Inventory demonstrates success of early detection and subsequent removal in minimizing the impact of the invasive phragmites on Beaver Island in Lake Michigan. (Higman et al., 2019)

Further resources

1. Greenfield, Patrick. "How to Rewind a Country: The Story of Argentina." *The Guardian*, 24 June 2023.
2. U.S. Department of the Interior. "Invasive Species Finding Solutions to Stop Their Spread." *U.S. Department of the Interior* (blog). 21 Feb. 2021.
3. University of Minnesota Extension. "Keeping Shoreland Lakes Free of Invasive Species. Water, Lakes and Wetlands, Shoreland Properties. Reviewed 2018.
4. Owens, Brian. "AI Technology Could be Used to Monitor Invaders in the Great Lakes." Great Lakes Now, 24 May 2022.
5. Sackett, Heather. "Declining Levels at Lake Powell Increase Risk to Humpback Chub Downstream." *Aspen Journalism*, 13 June 2022.

Issue 12: Engineering education lacks sufficient ecological literacy content

Background

Universities train engineers into specialties, be it chemical, civil, electrical, mechanical, software, or other areas of expertise. All are grounded largely in mathematics, physics and other sciences. Gaps in ecoliteracy knowledge contribute to human mistakes, unintended and unanticipated consequences, based on designing and implementing narrowly scoped engineering solutions that address misunderstood problems (Schultz-Bergin, 2021). The participating engineers from the spectrum of engineering disciplines, as well as the stakeholders involved across an expanse of project sizes, mega-industrial to residential, could improve their understanding of local environmental trade-offs by having engineers and stakeholder participants better trained on Earth's natural system behavior.

> *Human technologies developed over the past several hundred years have tended to be extractive, leaving the biosphere increasingly degraded as they have expanded. Imagine technology that is instead designed to function as an integral part of the Earth's living systems. (Institute for Regenerative Design and Innovation)*

Recommendations

1. **Encourage schools of engineering to modify their curricula to incorporate ecoliteracy as foundational throughout their courses.**
2. **Educate children on ecoliteracy.** Continue to build and deliver more early education for children in elementary, middle, and high schools that ground them in understanding and appreciating how humans both integrate in and influence their surrounding environment.
3. **Engage business in ecoliteracy education.** Encourage local businesses to not just donate funds to local environmental NGOs but also to encourage, engage, and incentivize their employees to donate their time toward such efforts.

Case studies

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1. Hands-on Education at Riverside Intermediate School, Fishers, Indiana, USA

   An effective way to improve planet stewardship is by local community “hands-on” education. Educators need more community involvement. The Riverside Intermediate School in Fishers, Indiana, a part of the Hamilton Southeast (HSE) school district, uses its proximity to nature to help students better interact with it. HSE succeeds by engaging the community to support raising goats and chickens on the school property, so the children, as well as community residents, gain appreciation for these farm animals. (Muljat, 2023)

2. Centre for Regenerative Design & Engineering for a Net Positive World, Bath, UK

   University of Bath in England has a Centre for Regenerative Design & Engineering for a Net Positive World. “We offer global research leadership in regenerative design and engineering, co-evolving solutions with societal, cultural, ecological, and economic co-benefits.” (University of Bath Center for Regenerative Design & Engineering for a New Positive World.)

Further resources

1. Lent, Jeremy. “Something Far More Deeply Interfused.” In *That Patterning Instinct*. Prometheus, 2017.

   This new understanding of nature as a self-organized, self-regenerating system extends, like a fractal, from a single cell to the global system of life on Earth. The conventional view of nature as a machine has encouraged many in our culture to view the Earth as a material resource with no intrinsic value, available to be exploited purely for humanity’s needs. (Lent, “Is Nature A Machine—Or a Self-Governing Fractal System?”)

2. Water Education Foundation. *WOW! The Wonders of Wetlands: An Educator’s Guide*. The Watercourse.

3. Southeastern Environmental Education Alliance (SEEA). “Landscape Analysis.”

Issue 13: Freshwater ecosystems face multiple challenges

Background

The future of freshwater biodiversity is a topic of great concern and importance. As human activities continue to impact our environment, freshwater ecosystems face a multitude of challenges that threaten their biodiversity (Su et al., 2021). Some key factors affecting freshwater biodiversity include habitat loss and degradation, pollution, climate change, overexploitation of resources, and the introduction of invasive species. These factors not only lead to the decline in species populations but also disrupt the delicate balance of freshwater ecosystems (Dodds, Perkin, and Gerken, 2013).

Recommendations

1. **Conserve and restore habitats.** Efforts should be focused on protecting and restoring critical habitats, such as wetlands, rivers, lakes, and streams. By preserving these habitats, we can provide safe havens for a diverse range of species. Management can help improve the equitable and sustainable use of transboundary waters. This approach involves considering the needs of various sectors, such as agriculture, industry, and ecosystems, while balancing social, economic, and environmental objectives (Meli et al., 2014).
2. **Adopt sustainable practices in water management.** This crucial need includes reducing pollution from industries and agricultural activities, implementing efficient irrigation systems, and promoting responsible water consumption (Eros, Hermoso, and Langhans).
3. **Prevent the introduction and spread of invasive species in freshwater ecosystems.** Effective monitoring and control programs can help prevent the negative impacts of invasive species on native biodiversity (Neumann, 2020).
4. **Develop and implement strategies to help freshwater ecosystems adapt to climate change.** This approach may involve creating protected areas, implementing habitat restoration projects, and promoting water conservation (Combes, 2003).
5. **Promote and support collaboration among governments, organizations, scientists, and local communities.** This cooperation is essential to the success of conservation efforts.
6. **Increase awareness and education about the importance of freshwater biodiversity.** This effort can also help drive positive change, including reducing the chances of conflict and violence among people over scarce resources.[65]

[65] Largest river and wetland restoration initiative in history launched at UN Water Conference, March 2023, UN Environment Programme.

Case studies

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1. River Danube Restoration, Romania

   Restoration of a portion of the Danube River in Romania. Efforts continue to reconnect the Garla Mare marshland to the Danube, restoring the natural river floodplains by removing dykes. The expectation is improved biodiversity such as migratory birds, better flood control, and improved freshwater quality. (WWF, 2010)

2. Cross-border Collaboration in Water Management—Eastern Africa

   Collaboration among countries and organizations in Eastern Africa, especially inclusive of input from women, are improving water conditions. There is increased awareness and education on the importance of hygiene, trees, and animal management on the creation and maintenance of clean freshwater, and the impact on the surrounding flora and fauna. (Indakwa & Wamba, 2021)

3. Recovery from Freshwater Biodiversity Loss

   "Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan." (Tickner et al., 2020)

4. Freshwater Biodiversity in the Western Ghats, India

   "The status and distribution of freshwater biodiversity in the Western Ghats, India." (Molur et al., 2011)

Further resources

1. Albert, James S., Georgia Destouni, Scott M. Duke-Sylvester, Anne E. Magurran, Thierry Oberdorff, Roberto E. Reis, Kirk O. Winemiller et al. "Scientists' Warning to Humanity on the Freshwater Biodiversity Crisis." *Ambio* 50, no. 1 (2021): 85–94.
2. Dudgeon, David, Angela H. Arthington, Mark O. Gessner, Zen-Ichiro Kawabata, Duncan J. Knowler, Christian Leveque, Robert J. Naiman, Anne-Helene Prieur-Richard, Doris Soto, Melanie L. J. Stiassny, and Caroline A. Sullivan. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." *Biological Reviews* 81 (2006): 163–182.

References

1. "A Man From Peru Has Found an Ingenious Way to Clean Lakes, and It's a Breakthrough the Earth Was Crying For." Bright Side, 30 Mar. 2019.
2. Albert, James S., Georgia Destouni, Scott M. Duke-Sylvester, Anne E. Magurran, Thierry Oberdorff, Roberto E. Reis, Kirk O. Winemiller et al. "Scientists' Warning to Humanity on the Freshwater Biodiversity Crisis." *Ambio* 50, no. 1 (2021): 85–94.
3. Allhands, Joanna. "Pinal Farmers are Facing Water Shortages. Shouldn't They Be Growing Less Thirsty Crops?" *AZCentral*, 6 June 2021.
4. American Rivers. "How Sewage Pollution Ends Up in Rivers."
5. Angarita, H., J. Craven, F. Caggiano, and G. Corzo. "SimBasin: A Serious Gaming Framework for Integrated and Cooperative Decision-Making in Water Management." *American Geophysical Union*, Fall Meeting 2016 (Dec. 2016).
6. Australian Government Department of Climate Change, Energy, Environment and Water (DCCEEW). "Australian Water Markets."
7. Baratto, Romullo. "Global Watersheds and Waterways Captured in Vibrant Colorized Maps." Translated by Nicolás Valencia. *Arch Daily*, 9 June 2020.
8. Barrera, Lauren. "Reducing Fertilizer, Boosting Yields with Sap Analysis." No-Till Farmer, 31 Dec. 2021.
9. Bekins, Barbara. "Case Studies in Groundwater Contaminant Fate and Transport." *Oxford Bibliographies*, 26 April 2018.
10. Boano, Fulvio, Alice Caruso, Elisa Costamagna, Luca Ridolfi, Silvia Fiore, Francesca Demichelis, Ana Galvão et al. "A Review of Nature-Based Solutions for Greywater Treatment: Applications, Hydraulic Design, and Environmental Benefits." *Science of the Total Environment* 711 (Apr. 2020).
11. Brondizio, Eduardo, Sandra Díaz, Josef Settele, and Hien T. Ngo, eds. *The Global Assessment Report on Biodiversity and Ecosystem Services.* Bonn, Germany: IPBES Secretariat, 2019.
12. CBS News. "Lake of Garbage: Every Winter Pollution is Swept from Overflowing Landfills into Balkan Waterways." 26 Jan. 2021.
13. Chang, Liangyu, Liju Xu, Yaohu Liu, and Dong Qiu. "Superabsorbent Polymers Used for Agricultural Water Retention." *Polymer Testing* 94 (Feb. 2021).
14. Chen, William. "We Can Make Large Dams More Friendly to the Environment." *Scientific American*, Apr. 2018.
15. Chen, William, and Julia Olden. "Designing Flows to Resolve Human and Environmental Water Needs in a Dam-Regulated River." *Nature Communications* 8 (Dec. 2017).
16. Chesapeake Bay Foundation. "Water Quality Trading."
17. Clear Choices Clean Water, Indiana. "Fertilizer and Water."
18. Combes, Stacey. "Protecting Freshwater Ecosystems in the Face of Global Climate Change." World Wildlife Fund, Jan. 2003.

19. Craven, Joanne, Hector Angarita, G. A. Corzo Perez, and Daniel Vasquez. "Development and Testing of a River Basin Management Simulation Game for Integrated Management of the Magdalena-Cauca River Basin." *Environmental Modelling & Software* 90 (Apr. 2017).
20. Dahl, Thomas E., and Gregory J. Allord. "History of Wetlands in the Conterminous United States." *United States Geological Survey Water Supply Paper* 2425, U.S. Geological Survey, National Water Summary on Wetland Resources. 1997.
21. Dekimpe, Valérie. "Dam Busters: Tearing Down Concrete Walls to Save Atlantic Salmon." *France24,* 15 Apr. 2022.
22. den Hartog, Harry. "Shanghai's Regenerated Industrial Waterfronts: Urban Lab for Sustainability Transitions?" *Urban Planning* 6, no. 3 (Feb. 2021).
23. Denchak, Melissa. "Water Pollution: Everything You Need to Know." NRDC, 11 Jan. 2023.
24. Derla, Katherine. "4 Billion People Face Water Shortage: Rising Populations, Agriculture Drive Water Demand." *Tech Times*, 15 Feb. 2016.
25. Derr, Jennifer. "The Dammed Body: Thinking Historically about Water Security & Public Health." *Daedalus, Journal of the American Academy of Arts & Sciences* 150, no. 4 (Fall 2021).
26. Desjardins, Jeff. "NASA Satellites Show Disturbing Trends in Water Supply." *Visual Capitalist,* 22 June 2015.
27. Dodds, Walter K., Joshua S. Perkin, and Joseph E. Gerken. "Human Impact on Freshwater Ecosystem Services: A Global Perspective." *Environmental Science & Technology*, no. 47 (2013): 9061–9068.
28. Dudgeon, David, Angela H. Arthington, Mark O. Gessner, Zen-Ichiro Kawabata, Duncan J. Knowler, Christian Leveque, Robert J. Naiman, Anne-Helene Prieur-Richard, Doris Soto, Melanie L. J. Stiassny, and Caroline A. Sullivan. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." *Biological Reviews* 81 (2006): 163–182.
29. Duke University, Nicholas School of the Environment. "Land-Building Marsh Plants Are Champions of Carbon Capture." 5 May 2022.
30. Ecowatch. "Rivers, Lakes, and Oceans Poisoned with 180 Million Tons of Mine Waste Every Year." Deep Green Resistance News Service, 28 Feb. 2012.
31. Elbein, Saul. "As Climate-Driven Drought Slams Farms in U.S. West, Water Solutions Loom." Mongabay, 17 Dec. 2021.
32. The Environmental Trading Network. "Organizations and Tools."
33. Eros, Tibor, Virgilio Hermoso, and Simone Langhans. "Leading the Path Toward Sustainable Freshwater Management: Reconciling Challenges and Opportunities in Historical, Hybrid, and Novel Ecosystem Types." WIRES Water Wiley (June 2022).
34. Evja (website).
35. Fallon, Scott. "Humpback Whales Continue Surprising Resurgence off NJ Shores." NorthJersey.com, 19 July 2022.
36. Federal Energy Management Program. "Water-Efficient Technology Opportunities." Energy.gov. Accessed Aug. 2022.
37. Flavelle, Christopher. "E.P.A. Is Letting Cities Dump More Raw Sewage into Rivers for Years to Come." *New York Times*, 24 Jan. 2020.

38. Florida Department of Health. "Harmful Algae Blooms—Economic Impacts."
39. Foote, Natasha. "How to Plant, Grow, and Care for Almond Trees." *Gardener's Path*, 25 Mar. 2023.
40. Gelt, Joe. "Home Use of Greywater, Rainwater Conserves Water—and May Save Money." Tucson, AZ: University of Arizona Water Resource Research Center, 1993.
41. Guha, Nabarun. "Gangetic River Dolphins in Assam Decline in the Wake of Anthropogenic Pressures." Mongabay, 24 Aug. 2022.
42. Groffman, Peter M., J. Morgan Grove, Colin Polsky, Neil D. Bettez, Jennifer L. Morse, Jeannine Cavender-Bares, Sharon J Hall et al. "Satisfaction, Water and Fertilizer Use in the American Residential Macrosystem." *Environmental Research Letters* 11, no. 3 (Feb. 2016).
43. Gunathilake, Miyuru, Yasasna Amaratunga, Anushka Perea, Chamaka Karunanayake, Anura Gunathilake, and Upaka Rathnayake. "Statistical Evaluation and Hydrologic Simulation Capacity of Different Satellite-Based Precipitation Products (SbPPs) in the Upper Nan River Basin, Northern Thailand." *Journal of Hydrology: Regional Studies* 32 (Dec. 2020).
44. Guo, Joy. "How Can Blockchain Open Access to Carbon Markets?" World Economic Forum, 28 July 2022.
45. Heggie, Jon. "Why is America Running Out of Water?" *National Geographic Science,* 12 Aug. 2020.
46. Higman, P. J., H. D. Enander, D. A. Hyde, P. J. Badra, and K. M. Korroch. *Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands*. Michigan Natural Features Inventory, Michigan State University, MNFI Report Number 2019-19, 2019.
47. Hughes, Neal. "Water Markets Are Not Perfect, But Vital to the Future of the Murray-Darling Basin." *The Conversation*, Mar. 2021.
48. Hussein, R. M. R. "Sustainable Urban Waterfronts Using Sustainable Assessment Rating System." World Academy of Science, Engineering and Technology, *International Journal of Architectural and Environmental Engineering* 8, no. 4 (2014).
49. Indakwa, Edward, and Elizabeth Wamba. "Voices for Wetlands and Water: Case Studies on Water Resources Management and WASH in Kenya." Wetlands Organization, 2021.
50. Institute for Regenerative Design and Innovation (website).
51. Into the Outdoors. "A Water Pollution Solution—A Case Study in Success." *Into the Outdoors* YouTube channel. Aug. 2021.
52. Kruzman, Diana. "Cities Are Investing Billions in New Sewage Systems. They're Already Obsolete." *Grist,* 8 Mar. 2022.
53. Lake George Association. "Invasive Species are Challenging our Water Quality and Landscape."
54. Lassaletta, Luis, Gilles Billen, Bruna Grizzetti, Juliette Anglade, and Josette Garnier. "50 Year Trends in Nitrogen Use Efficiency of World Cropping Systems: The Relationship between Yield and Nitrogen Input to Cropland." *Environmental Research Letters* 9, no. 10 (Oct. 2014).
55. Lee, Andrew Chee Keng, Hannah C. Jordan, and Jason Horsely. "Value of Urban Green Spaces in Promoting Healthy Living and Wellbeing: Prospects for Planning." *Risk Management and Healthcare Policy* 8 (Aug. 2015).
56. Lent, Jeremy. "Is Nature A Machine—Or A Self-Organized Fractal System?" Jeremy Lent.com.

57. Karlamangla, Soumya. "Here's Where California Really Uses Its Water." *New York Times,* 10 Dec. 2021.

58. McBride, B. B., C. A. Brewer, A. R. Berkowitz, and W. T. Borrie. "Environmental Literacy, Ecological Literacy, Ecoliteracy: What Do We Mean and How Did We Get Here?" *Ecological Society of America (ESA) Journal*, 31 May 2013.

59. Meli, Paula, José María Rey Benayas, Patricia Balvanera, and Miguel Martínez Ramos. "Restoration Enhances Wetland Biodiversity and Ecosystem Service Supply, but Results Are Context-Dependent: A Meta-Analysis." *PLoS ONE* 9, no. 4 (Apr. 2014).

60. Molur, S., K. G. Smith, B. A. Daniel, and W. R. T. Darwall, compilers. *The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India.* Cambridge, UK, and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation, 2011.

61. Muljat, Marissa. "Riverside Intermediate: Agriculture, Engineering, & Environment." *This is Fishers*, Summer 2023.

62. Mwanza, Kevin. "African Countries Should 'Decolonize' Water, Recognize Customary Rights: Report." *Reuters*, Oct. 2018.

63. Myscofski, Megan. "Not Here for Some Agrarian Fantasy." *Arizona Public Media*, 25 July 2022. Last updated 1 Aug. 2022.

64. Naishadham, Suman. "How San Diego Secured Its Water Supply, at a Cost." AP News, 29 May 2022.

65. National Ag Safety Database (NASD). "Disposal of Hazardous Household Waste." Clemson University Cooperative Extension Service.

66. National Agricultural Law Center (NALC). "Water Law: An Overview."

67. National Wildlife Federation (NWF). "Combatting Invasive Species."

68. The Nature Conservancy. "Great Lakes Aquatic Invasive Species."

69. Neumann, Nadja. "14 Recommendations for the Protection of Freshwater Biodiversity Beyond 2020." Press release. Liebniz Institute of Freshwater Ecology and Inland Fisheries, Oct 2020.

70. NOAA. "Lower Duwamish River." Damage Assessment, Remediation, and Restoration Program. Last updated Jan. 2023.

71. NOAA. "What is Nutrient Pollution?" National Ocean Service. Last updated 20 Jan. 2023.

72. NOAA. "What is Harmful Algal Bloom?" Last updated 27 Apr. 2016.

73. Nosowitz, Dan. "Study: There Are Ways to Dramatically Reduce Agricultural Water Pollution." Modern Farmer, 4 Aug. 2021.

74. NSW Government. "Gayini Nimmie-Caira Project." Water in New South Wales, NSW Dept of Planning and Environment within Australia. Project completed 2019.

75. "Omaha, Nebraska's Riverfront Revitalization Project on a Brownfield Wins International Sustainable Infrastructure Award." *Revitalization, The Journal of Urban, Rural and Environmental Resilience* 159, 15 Nov. 2021.

76. Pal, Sanchari. "How Three Startups Are Using Innovative Methods to Clean and Restore River Ganga." The Better India, 12 Jan. 2017.

77. Parkinson, Giles. "France's Troubled Nuclear Fleet a Bigger Problem for Europe Than Russia Gas." *Renew Economy*, 5 Aug. 2022.

78. Plastic Action Centre. “Here’s Where the World’s Plastic Waste Will End Up, by 2050.”
79. Proulx. Annie. “Swamps Can Protect Against Climate Change, If We Only Let Them.” *The New Yorker*, 27 June 2022.
80. Ritcher, Brian. *Water Share: Using Water Markets and Impact Investment to Drive Sustainability*. Washington, DC: The Nature Conservancy, 2016.
81. Ritchie, Hannah, and Max Roser. “Clean Water.” OurWorldInData.org, Sept. 2019. Last updated June 2021.
82. Ritchie, Hannah, Max Roser, and Pablo Rosado. "Fertilizers." OurWorldInData.org, 2022.
83. Schnabel, Ronald. “Improving Water Quality Using Native Grasses.” USDA Agricultural Research Service, Nov. 1999.
84. Schneider, Keith. “A River Restored Breathes New Life into Kuala Lumpur.” Mongabay, Aug. 2018.
85. Schultz-Bergin, Marcus. “The Primacy of the Public: Ethical Design for Technical Professionals, Chapter 6: Engineering & the Environment.” Cleveland State University, 1 May, 2021.
86. “A Short History of Pest Management.” PennState Extension. Updated 30 June 2022.
87. Smith, Stephen, and Samara Freemark. “Thirsty Planet—Israel: Using Technology, Engineering to Cut Reliance on Galilee.” *APM Reports* (American Public Media), 12 May 2016.
88. Stockholm Environment Institute (website).
89. Su, Guohuan, Maxime Logez, Jun Xu, Shengli Tao, Sebastien Villeger, and Sebastien Brosse. “Human Impacts on Global Freshwater Fish Biodiversity.” *Science* 371, no. 6531 (19 Feb. 2021): 835–838.
90. Surfers Against Sewage (SAS). “Get Learning.”
91. Swinton, Jonathan, and Whitney Gomez. “Platanista Gangetica, Ganges River Dolphin; Susu.” Animal Diversity Web, 2009.
92. Temesgen, Tatek, Thi Thuy Bui, Moonyoung Han, Teschung-il Kim, and Hyunju Park, “Micro and Nanobubble Technologies as a New Horizon for Water-Treatment Techniques: A Review.” *Advances in Colloid and Interface Science* 246 (Aug. 2017).
93. Tickner, David, Jeffrey J. Opperman, Robin Abell, Mike Acreman, Angela H. Arthington, Stuart E. Bunn, Steven J. Cooke et al. “Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan.” *BioScience* 70, no. 4 (Apr. 2020): 330–342.
94. Tierney, John. “Wasted Waterfronts Why Cities Struggle to Build Along Rivers.” *The Atlantic*, Oct. 2013.
95. Tsuro, Lewis. “The Impacts of Waste Dumping in Lake Malawi.” *ResearchGate*, 7 May 2021.
96. UC Sustainable Agriculture Research and Education Program (UC SAREP). "What is Sustainable Agriculture?" UC Agriculture and Natural Resources. Last updated 3 Aug. 2021.
97. UN Department of Economic and Social Affairs (UNDESA). “International Decade for Action ‘Water for Life’ 2005–2015.”
98. UN Environment Programme (UNEP). “Largest River and Wetland Restoration Initiative in History Launched at UN Water Conference.” Press release. Mar. 2023.
99. UN Food and Agriculture Organization (FAO). Coping with Water Scarcity. Rome: FAO, 2012.

100. UN Food and Agriculture Organization (FAO). Evaluation of FAO'S Country Programme in Lebanon, 2016–2019. Rome: FAO, 2020.

101. UN Food and Agriculture Organization (FAO). *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW): Managing Systems at Risk*. Oxford and New York: FAO by Earthscan, 2011.

102. UN Economic Commission for Europe (UNECE). *The Human Rights to Water and Sanitation in Practice*. Publication E.20.II.E.12. 2019.

103. UN Meetings Coverage and Press Releases. "Transboundary Water Management Cooperation Crucial for Sustainable Development, Peace, Security, Speakers Stress at Conference's Fourth Interactive Dialogue." UN 2023 Water Conference: Mar. 2023.

104. UN Water Decade Programme on Advocacy and Communication and Water Supply and Sanitation Collaborative Council. *The Human Right to Water and Sanitation*. Media brief.

105. University of Bath Center for Regenerative Design & Engineering for a Net Positive World (website).

106. University of Missouri Center for Regenerative Agriculture (website).

107. University of Oxford. "Manure Used by Europe's First Farmers 8,000 Years Ago." *ScienceDaily*, 16 July 2013.

108. U.S. Department of Agriculture (USDA). "Guayule Go Native With This Promising Biofuel—and Biomedical—Crop." Agricultural Research, Feb. 2009.

109. U.S. Department of Agriculture (USDA). "Public Awareness Campaigns." Invasive Species Resources.

110. U.S. Department of Agriculture (USDA) National Invasive Species Information Center (NISIC). "What Are Invasive Species?" About Invasive Species.

111. U.S. Environmental Protection Agency (EPA). "Commercial Buildings." WaterFacts, WaterSense. Accessed June 2022.

112. U.S. Environmental Protection Agency (EPA). "Defining Hazardous Waste: Listed, Characteristic and Mixed Radiological Wastes." Hazardous Waste.

113. U.S. Environmental Protection Agency (EPA). "Initiatives to Create and Protect Healthy Watersheds." Healthy Watersheds Protection.

114. U.S. Environmental Protection Agency (EPA). "Smart Growth and Water." Smart Growth. Last updated 28 June 2022.

115. U.S. Environmental Protection Agency (EPA). "Statistics and Facts: Why Save Water?" WaterSense. Last updated 24 April 2023.

116. U.S. Environmental Protection Agency (EPA). "Water Sense for Kids." WaterFacts, WaterSense. Accessed Mar. 2022.

117. U.S. Environmental Protection Agency (EPA). "Water Quality Trading." National Pollutant Discharge Elimination Systems (NPDES). Last updated 14 Dec. 2022.

118. U.S. Environmental Protection Agency (EPA). "Wetlands—Status and Trends." Water, Our Water, Wetlands.

119. U.S. Geological Survey (USGS). "Evaluating the Potential Benefits of Permeable Pavement on the Quantity and Quality of Stormwater Runoff." Upper Midwest Water Science Center. Mar. 2019.

120. U.S. Senate Bill S.1251. Growing Climate Solutions Act.

121. U.S. Water Alliance (website).

122. Vanek Smith, Stacey. "The Twisty Logic Of The Drought: Grow Thirsty Crops To Dig Deeper Wells." *NPR All Things Considered*, 6 Aug. 2015.

123. Venditti, Bruno. "The Road to Decarbonization: How Asphalt is Affecting the Planet." *Visual Capitalist*, 13 May 2022.

124. Wada, Y., M. Flörke, N. Hanasaki, S. Eisner, G. Fischer, S. Tramberend, Y. Satoh, M. T. H. van Vliet, P. Yillia, C. Ringler, P. Burek, and D. Wiberg. "Modeling Global Water Use for the 21st Century: The Water Futures and Solutions (WFaS) Initiative and Its Approaches." *Geoscientific Model Development* 9 (2016): 175–222.

125. Water Environment Foundation (WEF). "Stop, Don't Flush That." WEF Highlights, 12 June 2013.

126. Weber, M. J., M. J. Hennen, M. L. Brown, D. O. Lucchesi, and T. R. S. Sauver. "Compensatory Response of Invasive Common Carp Cyprinus carpio to Harvest, Fisheries Research." 10 Mar. 2016.

127. WeConservePA. "Economic Benefits of Smart Growth and Costs of Sprawl." Apr. 2012.

128. Wheeler, Sarah Ann. "Assessing Water Markets around the World." Global Water Forum, Nov. 2021.

129. Wheeler, Sarah Ann, Adam Loch, Lin Crase, Mike Young, and R. Quentin Grafton. "Developing a Water Market Readiness Assessment Framework." *Journal of Hydrology* 552 (Sept. 2017): 807–820.

130. Wikipedia, s. v. "Serious Game."

131. Wise, Lindsay. "5 Reasons Farmers Grow Thirsty Crops in Dry Climates." *Austin American-Statesman*, 23 Sept. 2016. Last updated 25 Sept. 2018.

132. The World Bank. "How Eight Cities Succeeded in Rejuvenating Their Urban Land." Press release. 13 July 2016.

133. World Wildlife Fund (WWF). Gârla Mare: New Perspectives for the Danube River Floodplain Resilience and Livelihoods. Fact sheet, Sept. 2010.

134. Wouters, Patricia. "International Law—Facilitating Transboundary Water Cooperation." *Global Water Partnership Technical Committee, TEC Background Papers* 17 (2013).

135. Young, Richael. "Trading Water, Saving Water." *PERC*. 19 July 2021.

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CHAPTER 7: TOWNS AND CITIES

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Committee Members

Committee Co-Chairs

- Luís C. Lamb, Porto Alegre, RS, Brazil, and Cambridge, MA, United States
- Joel Myers, Italy

Committee Members

- Arsalan Abtahi, CA, United States
- Peace Bello, Lagos, Nigeria
- Stephanie Camarena, Melbourne, Australia
- Felipe Castro Quiles, Washington, DC, United States
- Rochelle Cherenfant, NY, United States
- Jon Coleman, MI, United States
- Thomas Coughlin, CA, United States
- Drury Crawley, Washington, DC, United States
- Susan Dickey, CA, United States
- Jeff Felice, GA, United States
- Didem Gurdur Broo, Stockholm, Sweden
- Dimitrios Kalogeropoulos, London, United Kingdom
- Stanislav Kirdey, CA, United States
- Kashyap Kompella, Bengaluru, India
- Eleni Mangina, Dublin, Ireland
- Monika Manolova, Sofia, Bulgaria
- Khaled Mokhtar, Cairo, Egypt
- Sunny Narayanan, FL, United States
- Sanjana Paul, MA, United States
- Emma Ruttkamp-Bloem, Pretoria, South Africa
- Sadasivan Shankar, CA, United States
- Vladimir Stankovic, Glasgow, United Kingdom
- John Zelek, Waterloo, Canada

TOWNS AND CITIES

Future Vision

It is 2030.

Cities have been transformed into "positive innovation ecosystems," in which each actor in the ecosystem makes a positive contribution to regenerative sustainability and human well-being. The 21st century marked the transition from the industrial to the digital era; from industrial productivity to sustainability focus; from human competition to cooperation. Human knowledge and its expression in technologies are available to accelerate the positive change we now witness.

We live under society 6.0 (Žižek, Šarotar, and Potočnik, 2021; Harayama, 2017), where human-centric design, urban planning (The 15-Minute City), environmental sustainability concepts, and other technological systems and solutions coexist to provide a more equitable organization of resources within our world. Humans are involved at every stage, both design and implementation—improving/transforming buildings, structures, maps, and infrastructures that shelter, organize, and provide for the needs of humanity. While using and benefiting from these resources and services, they are also responsible for fairness, equity, care and maintenance, and continuity of best practices.

Water and energy are more efficiently used, and we have reached sustainable food distribution worldwide. Our climate change and sustainability efforts have led to a new economic, technological, and human perception of values and collective ethical behavior.

Digital technologies [including artificial intelligence (AI), Internet of Things (IoT), and extended reality (XR)] have enabled intelligent cities, and open education systems have transformed them into equitable hubs of innovation and advancement.

Public health and education, green mobility, and sustainable growth are now shared commodities, accessible to most of the world's population. Fresh air and clean water are available in most cities on planet Earth, notably in the developing world, which is flourishing as the new economic systems and models recognize the value of renewal based on a circular economy and respect for human rights.

Sustainability is now affordable for everyone.

Introduction

Towns and cities are the physical spaces where public policies are affected, and human actions impact our planet. Current literature points out that innovation ecosystems are the proper organization to harness positive actions that improve human life and foster sustainable development (Budden & Murray, 2022), stemming from the implementation of innovation in the urban space that prioritizes attention to the responsible and sustainable use of technologies to protect and improve life on our planet. These innovative systems should be implemented to help leverage clean energy solutions, reimagine the legacy fossil-fuel urban infrastructure, redesign urban space mobility, manage food and waste, and maintain access to fresh air and clean water.

Communities share in the responsibility of working toward a net-positive future; therefore, fostering sustainable and regenerative communities and promoting community solidarity and social responsibility are also key priorities. A broad array of suggestions is included to spark the readers' imaginations since the best way to move forward will vary in each community.

Issue 1: Need for harnessing positive innovation ecosystems

Background

The coordinated actions of government, academia, entrepreneurs, and social agents can transform cities and towns into so-called “positive innovation ecosystems.” The infrastructure of smart cities has been described as “a unique collaborative ecosystem in which citizens, prosumers, industries, universities and research centers may develop innovative products, services, and solutions” (Appioa, 2019). To this, in the spirit of the IEEE Planet Positive 2030 Initiative, we add the obligation of each actor not only to avoid further harm to the Earth’s system but also to regenerate the land, air, and water, that is, the ecosystem, and improve the well-being of living creatures in our urban spaces.

Action is needed now to create these innovative urban spaces as most of the world’s population will live in the cities and towns of the developing world in the 21st century. By 2050, more than 70% of the world’s population will live in cities (UNDP, “Goal 11”). Most of this human density will be concentrated in developing countries with limited financial resources. Positive innovation must build on existing skills and strengths, and it must find ways to rebuild and renew.

Even in more affluent countries, economic and regulatory obstacles must be addressed to avoid excluding individuals with lower incomes from the benefits of innovation. For example, state and federal tax incentives may allow affluent families to install rooftop solar panels with payback from energy savings in a short period, but these incentives do not help those with lower incomes (Borland, 2022).

The need for positive innovation ecosystems is a unique opportunity and perhaps the ultimate target for leaving a multigenerational legacy to the planet. The 21st century marks the transition from the industrial to the digital era—from productivity to sustainability, from competition to cooperation. Such bipolarities—a concept from the past—ideally must cede their place to diverse innovation that benefits the population in cities and towns worldwide. As information flows freely, at lower and lower costs, knowledge will be available to accelerate positive change in ways unprecedented until now but, more importantly, until now not properly imagined or projected into the future.

The power of technology can be leveraged to impact the planet positively. AI, IoT, and computing technologies are key to optimizing the use of renewable energy and to reducing Carbon Dioxide (CO_2) emissions by streamlining and redirecting resources in a more efficient fashion. Social concerns within the planning and execution phases of a transition toward positive innovation systems can be alleviated by the integration of an ethical approach to social issues and the inclusion of all groups represented within cities.

Within the realm of digital advancement and future economies, new businesses and organizations based on human-centered innovation driven by the common good should continue to evolve. Existing organizations should also begin to act in the public interest instead of supporting reliance on fossil fuels (Zero Cool, 2019), heavy industries, and solutions that cause more damage to the planet. Support from governments and funding agencies should go toward business entities, operating within the city scope, which target public-interest innovation rather than targeting only profit and monetary value.

Positive innovation ecosystems integrate the diversity of knowledge via multiple stakeholders (government and nongovernment organizations, i.e., community leadership and organizations, academia, investors, corporations, and social entrepreneurs; Budden & Murray, 2022) that share common values. Cities must seek to build innovation ecosystems in which coordinated and collaborative action drives toward a sustainable present and increasingly positive future.

Some examples[66] of actors in positive innovation ecosystems are as follows:

- Citizen groups are actively engaged to support the return to net zero (The Nature Conservancy, "Our Goals for 2030").
- Reuse-and-reduce groups, which advocate for local circular economy waste control (ISWA), including e-waste (U.S. EPA, "International Cooperation"), can collaborate with manufacturers to support the decrease of waste in the production cycle.
- Groups that sponsor nature education programs (SCA, 2023; NWF, "Kids and Nature Programs") for children can collaborate with groups working on protecting and regenerating green space in and near towns and cities (Gøtzsche Lange & Rodriguez, 2021).
- Neighbors working together in urban agriculture (Dellesky, 2015) can collaborate with food waste reclamation groups (Singapore's Zero Waste Master Plan, "Food Waste") to increase food security (Mercado, 2021). More information on food waste and a list of food groups working on food loss and waste reduction can be accessed here.
- Clean air monitoring groups can chart the overall emission reduction progress and collaborate with city officials to make sure all neighborhoods have clean air (Air Now, "List of Partners").
- Housing groups can collaborate with companies that improve heating and cooling systems in existing buildings and provide energy-efficient housing for all (Habitat for Humanity, "Housing and Climate Change").

Cities and towns are the home of all aspects of human life and of all our technologies: water supply, energy, transportation, health, education, and all other public services and private activities. The need for changing the supply and adding sustainability to the value system of all these technologies significantly affects the way we live on a frail yet resilient planet.

Recommendations

1. **Apply and deploy technology for the benefit of the urban environment and humankind.** The approach should always respect the diversity and rights of the people's historic and harmonic connections to their land and environment and treat cities as an interlinked landscape of human, environmental and technology ecosystems.
2. **Find ways to prioritize the "planet positive" use of our knowledge and technologies.** Consider that all technology may be dual (or even multimodal). Thus, planet-centric actions shall be the vectors that accelerate innovation and sustainable change in developed and developing countries and, more importantly, in the cities that invite most of us to live in them.
3. **Define an agenda, a strategy, and actions for positive innovation ecosystems**. Drawing inspiration from the literature on innovation ecosystems (Murray & Stern, 2022) and sustainable economics, positive innovative ecosystems extend the underlying idea of innovation ecosystems to respond to the challenges of building ethically aligned, sustainable, cooperative, diverse, equal, inclusive cities and metropolitan areas where socioeconomic development is truly focused on constructing and

[66] 66 This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

preserving the planet and biodiversity, and raising sustainable living standards, especially in the developing world.

4. **Change the innovation culture to drive a positive innovation ecosystem agenda.** This innovation culture should be reflected in all types of project and activities: from simply building the most immediately effective business or political models to promoting positive innovation ecosystems, in which we all seek to preserve, recover, and leverage our accumulated, distributed scientific knowledge and resulting technologies (e.g., AI, clean energies, block chain, new materials, and sustainable supply chain optimization). Structural changes in incentives and regulations must be made to make sure all societal groups participate in the benefit for the planet and future generations.
5. **Include societal values in the design of positive innovation ecosystems.** Design and implement ecosystems that take into consideration moral, cultural, and ethical values, many of which, it is expected, can be universally accepted, and, at the same time, respect individual cultures and peoples.

Issue 2: Lack of access to affordable clean energy

Background

Cities need to provide affordable and easy-to-access emission-free energy while deploying sustainable smart monitoring systems to enable real-time monitoring of emissions to track our progress. Cities and towns should also use smart energy systems and IoT to help protect vulnerable populations from power outages (St. John, 2022) and provide them with heating and cooling as appropriate.

Access to clean energy in our towns and cities remains a challenge faced by cities and towns in both the developed (Pollin, 2022) and the developing world. Technologies allowing for smart monitoring systems (Ramirez-Moreno et al., 2021) are crucial to providing solutions, and their equitable application across countries and continents is fundamental to the well-being of the planet. The affordability of wind and solar power plants, compared with fossil fuel plants, makes them an easy choice for power grid expansion in many jurisdictions (Baker, 2022).

Cities and towns should aim for a planet where the use of energy, such as in buildings, transportation, and manufacturing, is emission-free, that is, so called carbon neutral. The progression to electrification and potentially other emission-free energy use, i.e. hydrogen, requires changing our current energy supply and management system, including eliminating wasted energy.

Cities should strive to be healthy environments for all their citizens. Currently, heat waves and other extreme weather events, often combined with power outages make it difficult for cities to protect citizens and ecosystems. Some metropolitan areas in the world have already begun to hire heat response and mitigation officers (Loomis, 2021), as well as climate change officers (Mayor of London/London Assembly, “Our Fight Against Climate Change”), to tackle the existing mitigation and adaptation issues within the energy sector.

Recommendations

1. **Plan, build, and rebuild healthy cities.** Aspects of healthy cities include active transportation, clean air, clean water, safe food, minimal criminal activities, effective garbage and waste disposal, and sustainable use of clean energy sources.
    a. **Plan and build carbon-neutral heating/cooling of buildings, as well as sustainable designs, and retrofit with passive environmental control** (Liu et al., 2023).
    b. **Encourage and incentivize the adoption of heat pump adoption to save energy** (Malinowski et al., 2022).
    c. **Enable the use of electric vehicles.** Support smart charging (Burger et al., 2022) and advanced energy storage (Kamiya et al., *Energy Storage*) technologies that are needed to help ensure a widespread use of electric vehicles (EVs) (Dumiak, 2022) and to possibly harness the energy storage capacity of parked EVs (Delaney, 2022), that is, use parked EVs as part of a grid energy storage system, in addition to appropriate network planning to balance renewable energy supply and demand.

2. **Provide affordable and easy-to-access emission-free energy in cities and towns.**
3. **Reduce overall energy consumption and transition to net-zero energy supply for cities and towns.** Aim for efficient use of energy—to reduce energy use—and for all use of energy, such as in buildings, transportation, and manufacturing, to be free of emissions (carbon neutral).
    a. **Provide consumers with access to energy consumption data. Include deploying sustainable smart monitoring systems to enable (near) real-time monitoring of energy consumption and of emissions to track our progress.** An example platform of customer access to electricity (gas and water) consumption data is "Green Button® Data[67]. It is in use in some parts of Canada and the USA.
    b. **Create incentives in urban areas to drive change in the current behavior of most citizens in developed and developing nations toward the use of energy from clean, renewable energy sources** (Crow et al., 2021).
    c. **Emphasize in the global North the need to reduce excess energy use while focusing especially on sustainability** (Hickel & Slamersak, 2022).
4. **Provide transnational funding of research and development in clean energy solutions.** The outcomes of the funded projects (e.g., development in batteries and materials) should provide clean energy solutions within cities and towns worldwide; for example, for community centers and communities within cities.
5. **Prioritize government funding schemes in developing nations for research and development of renewable and low-carbon energies, harnessing the potential of clean energy sources**.
6. **Develop innovative new and/or improved energy storage solutions.** Efficient and cost-effective electricity storage solutions are needed for storage of inexpensive solar and wind power, like the "water battery" in Switzerland (Cuthbertson, 2022).
7. **Use smart energy systems and IoT to protect vulnerable populations from power outages** (St. John, 2022).
8. **Protect vulnerable (city) populations from extreme weather**.
    a. Strive to provide healthy environments for all the citizens in cities and towns to address health threats caused by heat waves, other extreme weather events, and/or power outages.
9. **Provide populations with heating and cooling**.
10. **Keep promises made.** The rich countries historically responsible for climate change (Evans, 2021) should keep the promises they made at COP15 to fund climate adaptation and mitigation worldwide (Lindwall, 2022).
11. **Improve the policies, organization, planning, and infrastructure related to energy sourcing, power generation, management and distribution, and electrification in developing countries (although developed nations face similar challenges;** EC, "2050 Long-Term Strategy").
12. **Focus on key technologies.** The technologies should include heat pumps (Matson & Potter, 2022), refrigeration, micro grids, community solar (Takemura, 2022), grid-enhancing technologies (Mendel, Einberger, and Siegner, 2022), energy storage, and demand-side management (Sisson, 2022).

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[67] [67] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

13. **Focus on key policies.** These key policies should include racial/gender/disability justice, and economic incentives to first help make the cost of living more affordable, and then address the concept of cost of living overall [e.g., for necessities like food and shelter in a planet positive world (Chisholm Legacy Project, "Policies for the People")].

Issue 3: Unsustainable use of legacy fossil-fuel urban transportation and infrastructure

Background

Towns and cities inherit urban spaces from the legacy of the fossil-fuel industrial era that are unsustainable. “Estimates suggest that cities are responsible for 75 percent of global CO_2 emissions, with transport and buildings being among the largest contributors,” according to UNEP (UNEP, “Cities & Climate Change”). CO_2 equivalent emissions must come down to net zero to avoid further climate warming far beyond the pre-industrial temperature levels safe for agriculture and Earth’s ecosystems (McKinsey, 2020). As noted by The Royal Society, “If emissions of CO_2 stopped altogether, it would take many thousands of years for atmospheric CO_2 to return to ‘pre-industrial’ levels” (The Royal Society, “Climate Change”). Meeting the climate crisis, therefore, requires bringing people together to take action, drive change, and to care about each other and all life on the planet, as discussed in the Global Methodologies chapter of this document, especially in the cities where most people live (Global Methodologies, Issue 1).

In towns and cities worldwide, citizens can join together to rebuild and refurbish their urban spaces into sustainable communities that provide a good life for all people. As the cost of environmental disasters due to climate change becomes more obvious (NOAA, 2023), finances for redesigning megacities from the ground up become more feasible with government participation (NLC, 2023). Energy-efficient housing, including both heating and cooling systems, well-designed parks and green infrastructures that connect humanity with nature and aid in preserving biodiversity, and improved transportation with shorter commute times have immediate benefits and cost savings for citizens, as well as long-term benefits for resolving the climate crisis.

The construction and operation of buildings account for a significant share of greenhouse gas (GHG) emissions. New construction for expanding urban areas could increase this share of GHG emissions. According to Natural Resources Canada, for example, “commercial and institutional buildings account for approximately one eighth of the energy used in Canada” (Natural Resources Canada, 2015). Building heating systems are estimated to emit 2.5 billion metric tons of CO_2 (out of a global total of 40 billion) from fossil-fuel boilers; global cement and steel production combined account for approximately 6 billion metric tons of CO_2 (Krishnan, 2020, p.76).

Other estimates show “mobility” as accounting for ~60% of an estimated 12 billion metric tons of global CO_2 emissions due to petroleum in 2019, out of more than 42 billion metric tons from all sources (McKinsey, 2020, p. 9). To minimize travel emissions, commuter suburbs could be designed close to jobs and work hubs. With remote work opportunities enabled by advances in computer networks, the historical conflict between low-density housing and short commutes may be somewhat alleviated (Jacobs, 1961). What makes sense depends on the housing density and existing transit infrastructure. In low-density communities, ‘van on demand microtransit’ may be the solution (Shared Use Mobility Center, 2023). In Los Angeles, where packed buses come every two minutes, it’s bus lanes (LA Times Editorial Board, 2023) and trying to shift to electric buses (Brisco, 2023).

It remains a challenge to preserve conservation areas with natural habitats, green ecosystems services, and organic agriculture within the urban and peri-urban landscape, but it can be considered essential for human well-being. Public transit systems could even help with integration with nature by planting trees at bus shelters to mitigate the effects of climate change heat waves (Brasueli, 2021) and helping transit riders get to parks and natural areas (Johnson, 2021).

The existing opportunities for reducing GHG emissions vary widely from community to community depending on transportation, logistics, communications, and legacy infrastructure. Removing or not introducing high-pollution motor vehicles is essential. In any case, cities must still tackle improving the quality of life for all citizens. A mixture of electrical vehicles (including trucks and scooters, as well as passenger vehicles), bikes, trains, big and little buses can be combined with urban planning so that the megacities of the future allow people to find jobs near their homes (Going Green, 2020) or within short commutes with sustainable transport. Changes to all aspects of urban life—business centers, residential zoning, industrial redesign and logistics, provision of goods and services, street safety—as well as efficient transportation powered with renewable energy are required to experience the benefits of the "15 minute city" (Luscher, 2021).

Recommendations

1. **Redesign legacy transport and logistics infrastructures wherever possible to limit both CO_2 emissions and commuting times.** Providing essential healthcare, shopping and jobs within a short commute to all neighborhoods should be a cornerstone of urban planning.
2. **Consider innovative means of transportation and "last mile" solutions.** Such solutions will be informed by research results on emission free vehicle technology such as automated electric vehicle research for both commuting (Folsom, 2021) and goods delivery (Sindi & Woodman, 2020).
3. **Offer energy-efficient common infrastructures.** Such infrastructures should support networks, security, desks, and other needs available for locals to use as their working spaces. These infrastructure solutions can increase the possibility of reducing carbon footprint by working from home or from nearby common office spaces (Tao et al., 2023).
4. **Incentivize public transport, powered by renewable energy, to be affordable. Affordability** would increase its use (News in Germany, 2022). The public sector can leverage multimodal integration like Mobility on Demand (MOD) in the United States or Mobility as a Service (MAAS) in Europe, or new mobility combinations based on innovations around the world (Shaheen & Cohen, 2021). Public transit should be designed and implemented to reduce the need for a private car for everyone, not just those who can bike or walk to trains and buses. Furthermore, ride/taxi services should be available, especially for older persons, those with disabilities, and those with small children.
5. **Implement "green" innovations in the sphere of building retrofitting, construction, operation, and heating and cooling.** These innovations should replace conventional technologies which produce a large share of GHG emissions. The use of heat pumps, district heating, and biomass boilers for heating, as well as of innovative building methods like carbon-sucking concrete (Pless et al., "Integrating Energy Efficiency"; Clancy, 2021), should be considered and implemented, alongside smart grid and network solutions, which significantly reduce GHG emissions.
6. **Install smart energy grids and utility systems that are efficient and reliable, as well as based on renewable clean energy sources within cities**.
7. **Implement circular economy solutions.** Reduce use of waste disposal and treatment systems that are a source of methane, N_2O and other emissions in favor of circular economy solutions and reuse technologies.
8. **Adapt infrastructure to climate change impacts such as sea-level rise and extreme weather.** Offer housing alternatives that are safe and less vulnerable to climate change consequences to urban populations who are vulnerable to sea-level rise and extreme weather events—drought, floods, wildfires, hurricanes, and tornadoes.

9. **Retrofit housing into carbon-positive places.** Insulation and design should cater to an energy consumption reduced to a strict minimum.
10. **Decentralize renewable energy generation in cities to local districts/suburbs**.
11. **Encourage wide spread of emissions-free transportation.** Implement smart charging and advanced energy storage to facilitate wider spread of EVs and /or implement infrastructure to support hydrogen powered vehicles and /or other vehicles solutions.
12. **Reduce noise pollution from vehicles.** Fund research and development to find ways to significantly reduce noise pollution from vehicles (e.g., planes, cars, and buses; Meininger, 2022), such as the study of electric planes and vehicle systems that require further technological advancements.

Issue 4: Lack of clean air and potable water

Background

Cities and towns should provide fresh air and clean water to their populations for sustainable human health and well-being. This challenge must be solved while coping with the extreme weather events caused by global warming, like more frequent and damaging floods (Andreoni, 2022; Flavelle et al., 2022) and wildfires (Flannigan et al., 2000), which threaten our existing water treatment and air quality infrastructure.

“Air pollution is the greatest environmental threat to public health globally and accounts for an estimated 7 million premature deaths every year. Air pollution and climate change are closely linked as all major pollutants have an impact on the climate and most share common sources with greenhouse gasses,” according to the UN Environment Programme (UNEP, 2022). “Clean water and sanitation” is UN Sustainable Development Goal 6 (UNDP, “Goal 6”), which states: “Safe and affordable drinking water for all by 2030 requires we invest in adequate infrastructure, provide sanitation facilities, and encourage hygiene. Protecting and restoring water-related ecosystems is essential” (UNDP, “Goal 6”). The sustainable use of natural resources could help cities prevent a scenario in which people are deprived of clean air and have limited or no access to clean water. Cities are already making their own climate action plans in support of the Paris agreement for clean air (C40 Cities, 2022).

Sustainable urban life depends on an effective health care system. Potable water and clean air are the key to improving public health. They depend on clean public and private transportation systems, a secure water supply, and energy efficiency. Watersheds should be redesigned and rebuilt to help with water recapture for local aquifers and availability, maybe even by restoring natural systems like beaver colonies (Goldfarb, 2018).

To create a healthier world, where future generations are more self-reliant and have the capacity to achieve the goals of a fair living standard, we need to focus on the conservation of natural resources and on aiding those facing economic challenges with guidance on reversing environmental degradation.

The idea of being deprived of fresh air or drinking water should be a thing of the past. What should exist is a world with freedom and empathy, where every life and life form is valued, and every human being has the capacity to choose life over death. Therefore, environmental scarcity and air pollution should be our starting points. Actions should be implemented to immediately address air quality in urban areas by addressing cars, trucks, and buses—one of the largest sources of bad air quality in urban areas globally is traffic-related air pollution—while recognizing that air quality can be affected by wildfires or industrial pollution, including pollution produced thousands of miles away.

Urban ecosystems need to value nature (Masood, 2022) and truly appreciate what nature means for humanity and how it shapes and has shaped, structured, and conditioned human life. The people of the modern world should effectively reconnect with nature. Scarcity of resources within the cities should not stretch to the point of clean air and water, and those should be affordable to all human beings to prevent diseases and to increase the quality of human life. The quality of human existence within urban areas should be addressed, especially within districts that suffer consistent water shortages and within housing areas with unhealthy air conditions.

Recommendations

1. **Implement technological and nature solutions to increase the ability to retain water in the soil and prevent flooding in cities** (Climate-ADAPT, 2023). To do so, wider collaboration between actors from the rural and urban spheres will be needed, due to the capacity of agriculture and forest ecosystems to alleviate the environmental pressures on cities from both flash floods and droughts.
2. **Consider the water supply to cities and the water quality within all urban districts as fundamental human rights, regardless of purchase power and capacity.**
3. **Clean up air pollution**.
4. **Reduce particulate pollution from tires.** These particulates pose a serious health risk in cities.
5. **Provide fresh air and clean water to urban populations for sustainable human health and well-being.** The provision of clean water and air should be a consistent element of all planning and zoning policies that compete for space within the urban areas with consistent methodological assessments for the impact of new developments.
6. **Teach responsibility for clean water, environment, and air.** Teaching should reach all age groups, especially from a young age, with consideration to water waste and transport efficiency so that precious resources are available for all city dwellers.
7. **Redesign and rebuild watersheds.** This will help with water recapture for local aquifers and availability.
8. **Use extensive (inexpensive) air quality monitoring at the local government level to track problems and create policies** (Oladini, 2022).

Issue 5: Need for ensuring reliable access to food, improving food distribution, and decreasing food waste

Background

In the 21st century, the agriculture industry produces enough food to avoid hunger in the cities and towns of every country (Borens et al., 2022). However, we have been unable to solve hunger in developing nations and underdeveloped regions of developed nations (Kavi et al., 2019) due to distribution inefficiencies and income inequality, which results in food waste (Food Cycle Science Corporation, "A Complete Overview"). Moreover, the transport of food and agricultural processes, such as manure management, liming and urea application, rice cultivation, and burning crop residue, result in emissions of carbon dioxide, methane, and other GHGs. Meeting the climate crisis sustainably requires solving the hunger problem while reducing GHG emissions due to agricultural production. Food systems must be made resilient to water shortage, drought, heat waves, and other consequences of climate change, as well as to political conflict and income inequality (Simpkins, 2022).

Urban agriculture can reduce the pressure on land use and agricultural production outside of cities while improving the quality of life for everyone in urban areas.

Citizen-led initiatives are already developing to help with urban food production and to prevent food waste. Grassroots efforts[68] like provide job training and food for the needy, using donated food that would otherwise go to waste. Urban gardens can decrease carbon in the atmosphere while establishing a movement for significant vegetable production similar to the victory gardens[69] planted in the United States during World War II (Green America, "Climate Victory Gardens").

At the municipal rather than the individual level, community fridges should be provided where low-income and homeless community members can pick up excess food, e.g., from grocery stores. Municipal composting services should be provided in every city, with compost collection bins in every public building and at every large business. Food waste breaking down in landfills emits a considerable percentage of GHGs, whereas composting prevents this negative impact and instead provides nutritious soil for use in gardens (U.S. EPA, "Composting Food Waste").

Community groups that sponsor nature education clubs and gardens (City of Oakland, "Oakland Community Gardening Program") for children, protect and regenerate green space in and near towns and cities and are critical to sustainable, local food production. Neighbors working together in community gardens alongside food waste reclamation groups could contribute to eliminating hunger within urban and peri-urban areas.

[68] An example of such grassroot efforts, among many, is Food Shift. This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

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Recommendations

1. **Produce and consume food locally where feasible**. Moving farm production closer to cities will reduce CO_2 emissions from food transportation and logistics (ARUP, "Cities Must Help Produce More Food"). Implement urban farming. Urban agriculture could contribute to better quality of food consumed within cities while reducing waste and GHG emissions. These approaches increase the resilience of the food supply chain, create deeper connections between producers and consumers of food in cities and towns, improve logistics and transportation, and reduce CO_2 emissions.
2. **Work to reduce food waste from production through transportation and retail.** The European Union is already implementing waste reduction strategies within its Farm to Fork strategy (EC, "Farm to Fork Strategy"), but a global movement must take place within cities that prioritizes waste reduction in the food sector.
3. **Engage many, if not all stakeholders, within urban areas to reduce waste and to support networks for the management of food consumption and waste in a more sustainable fashion.** The UN SDGs Goal 2 (UN, "Goal 2") prioritizes the end of world hunger, but that will be impossible to achieve without the concerted efforts of all actors within urban areas, including local governments, service businesses, and local communities.
4. **Manage urban sprawl resulting in the expansion of cities that consume agricultural areas to preserve peri-urban greenbelts and areas.** Although the current growth of cities is mostly reasonable, the post–COVID-19 ability of workers to perform the same tasks remotely and the implementation of four-day workweeks within some countries (Joly & Hurst, 2023) support the transition to an urban system under less pressure to grow in geographical areas.
5. **Support research on technological advances for sustainable food production and on consumer acceptance of sustainable foods.** This should include, for example, sustainable protein production (WBC for Sustainable Development, "Sustainable Protein"). Healthy food ecosystems should be targeted and expanded on within consumer-based industries, which should be further incentivized to reduce waste.

Issue 6: Need for fostering sustainable and regenerative communities

Background

Sedentary, exclusive, and extractive city models prevent integrated ecosystems in which humans, animals, all other lifeforms, and machines coexist harmoniously in nature.

Sustainable development on a global scale is possible through the multilevel and interdisciplinary efforts of many people. Although projects dedicated to building smart cities have expanded exponentially in the past few years, people still live in places with fragmented infrastructures, poor value accounting, low-quality services, and artificial barriers between people and their basic needs.

By 2030, human urban settlements should be transformed into inclusive, sustainable, and regenerative model cities in which humans, animals, and machines coexist harmoniously. Regenerating forests (Nargi, 2019) and creating wildlife corridors (Barkham, 2022) can help to reconnect children and adults with nature and to motivate further social change.

Traditional competitive mechanisms that have produced great so-called advancements within societies have produced negative side effects that prevent the resolution of some of society's greatest problems. Greed and corruption, and the lack of incentive mechanisms to promote a sustainable social architecture, work against the establishment of an equitable world that prioritizes environmental sustainability. For example, monopolist pricing structures and artificial scarcity mechanisms can cause unnecessary search and competition despite existing technologies for production and sufficient capacity to share resources and the economic production output. To resolve the issue for future societies, improvements in public education are needed to provide care for all children and promote shared responsibility and shared abundance for all citizens.

According to European Commission Report on The Future of Cities in Europe:

> *Urban segregation is the unequal distribution of different social groups in the urban space, based mainly on occupation, income, and education, as well as on gender and ethnicity. The quality of life and number of healthy life years differ among these groups, too (EC, The Future of Cities, 2019, p. 67, Sect. 9.1).*
>
> *Socio-spatial segregation is not negative per se, since it can entail a high sense of local identity and cultural and social capital within a community (Bolt et al., 1998).*
>
> *However, it can have a detrimental effect on cities' social stability and augment social fragmentation* (EC, The Future of Cities, 2019, p. 67, Sect. 9.1).

Urban societies, while continuing to support the multitude of cultures and freedom to live without censure from neighbors that have traditionally been the strength of cities, need to find a way for each community to support the well-being of all other citizens. Joining together to solve the climate crisis may help us find that way.

Recommendations

1. **Design cities based on a sustainable and inclusive social architecture.** Zoning should be based on sustainable development stages. Modern architecture has the capacity to reflect the needs and wishes of the current citizen while maintaining the individuality and style of the region. A future cityscape should be a co-creation between all citizens, regardless of their social and economic standing.
2. **Include gender and age considerations when remaking infrastructure and transportation to adapt to climate change** (Patterson, 2021). This should foster a more inclusive city experience for both young families and older persons.
3. **Avoid urban segregation.** Urban segregation results in unequal outcomes for different groups in areas such as climate-resilient housing, air quality, and education. Instead, solutions of equal value should be provided for people in all districts and all economic conditions.
4. **Promote peace, compassion, altruism, and justice through collaboration of urban communication networks.** Show zero tolerance toward supremacy, violence, inequity, colonialism, expansionism, and oppressive behavior. Cities should strive to establish platforms for the voices of environmental justice groups, such as West Harlem Environmental Action and Deep South Center for Environmental Justice[70].
5. **Adapt social media to stimulate and support "local" face-to-face connectivity.** Examples of what this can look like are groups flourishing on social media (Herrera, 2022) and mutual aid projects (Fischer-Benitez, 2020).[71]
6. **Bring people together in towns and cities, whether by meeting up at the central mail drop, at the public library, or at a community event.** Metropolitan areas should come together not only in times of need but also in everyday interactions to allow citizens to feel a part of something that they nourish but that also nourishes their experience. Initiatives like repair cafes (Streams, 2023) and the fair trade movement (Deg, 2021) allow individuals to contribute to the reorganization of a circular economy while getting to know their neighbors and taking care of their household needs.
7. **Transform education of engineers and other professionals so that environmental stewardship and regenerative sustainability become core tenets of professional responsibility.** One example of such a curriculum for engineers is *The Engineering for One Planet Framework* (Anderson & Cooper, 2022). Another is the curriculum framework being developed by the Southern African Regional Universities Association (SARUA) for a master's degree in Climate Change and Sustainable Development (Ruwoko, 2023).

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Issue 7: Need for curbing the growth of energy consumption by computing and communications application technologies

Background

AI and data-driven solutions can introduce efficiency in heating, cooling, and industrial processes. And since electronic devices use energy, global communities need to assure that expanded use of computers and computer networks is supported by power from renewable energy sources and is subject to cost–benefit analysis in terms of energy and e-waste costs, as well as monetary costs.

The current explosion in AI-based solutions for "everything" is a result of the convergence of greatly increased computing hardware power with graphics processing units in cloud data centers; massive amounts of data from networks of websites, cell phones, and IoT sensors; and advancement in the techniques of machine learning (ML) based on game playing and linguistics research. The insight that neural networks can be used for ML anywhere so that the desired result can be formulated as a winning outcome has resulted in remarkable successes, like the recent result in finding faster ways to do matrix multiply (which is the core of computer implementation of neural networks; Heaven, 2022).

A key component of building sustainable cities and towns is technological diversification based on three main major building blocks: open platforms, machine intelligence, and diversified, reusable resources, all of which can make recommendations in these areas. There are resources available, for example at the intersection of climate change and ML[72].

However, data center energy consumption amounts to 1% to 1.5% of worldwide final electricity demand (excluding cryptocurrency mining; IEA, 2022). Due to strong efficiency improvements, this has been a consistent percentage since at least 2010 despite large increases in volumes. Data transmission networks consume another 1% to 1.5% of global electricity use (2022 data). Another statistic states that the telecommunications industry accounts for 2% to 3% of global total energy use (Thompson, 2023). On the other hand, the information and communications technology (ICT) sector is estimated to have consumed about 4% of global electricity consumption in 2020; that includes ICT network operations, data center operation, and the operation of user devices (Malmodin et al., 2023). Future generations of telecommunications such as 5G and 6G networks can be up to 90% energy efficient in terms of data transmitted/energy consumed, but they will also depend on AI techniques for these advances (Nokia, "AVA").

As AI systems, for the benefit of cities, evolve, changes in the amount of data collected will occur due to IoT (such as connected sensors for city infrastructure and industrial, agricultural, and consumer applications). Training and inference of large AI/ML models that could drive data center energy consumption (including processing at the network edge) and telecommunications network usage to much higher levels in a few years' time unless new computer/network/storage/memory architectures are introduced. Based on the increasing energy demands for computing and its applications and the ubiquitous use of digitalization, the

[72] An example is Climate Change AI, a global initiative to catalyze impactful work at the intersection of climate change and ML.
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trajectory of computing appears unsustainable from both energy and materials perspectives (Jaumotte et al., 2023; U.S. DoE, 2022; SRC, 2020; Shankar & Reuther, 2022).

Many helpful tools in managing complex cities and industries will arise from data-fueled technologies, but not all problems can be solved via data aggregation. We need conscientious monitoring of the kind of training data used and how outcomes are evaluated to create a sustainable data ecosystem of value to humanity.

Open-source systems harnessing machine intelligence can help humans improve resource efficiency. But we should remain mindful of the waste from our electronic and computation systems (e-waste). Setting up towns and cities to manage e-waste and other industrial waste carefully is the key to a sustainable future. See the GOSH Manifesto (GOSH, 2016) for ideas on how to open these resources.

Human knowledge should be transferable and accessible. Open-sourced information and knowledge will help this world to be a better place (Dosemagen, “Writing”). Having open backend platforms that communities can use, and reuse, is a core concept of sustainable advancement. Building on this knowledge is a dream that open-source platforms can achieve. The speed of the technological transformation experienced today should be reflected within the cities of tomorrow, where telecommunications and advanced digitalization systems and sustainable planning should function in cohesion.

Recommendations

1. **Evaluate the benefits and costs of AI solutions using ML.** Consider both, how well the training outcomes match truly desirable results and the expense of the computation resources.
2. **Consider energy efficiency as a crucial factor when identifying innovations in computer design.** One example of identifying innovation pathways includes the Energy Efficiency Scaling for 2 Decades (EES2) initiative of the U.S. Department of Energy, setting up a collaborative ecosystem for the national laboratories, industrial partners, academia, and international agencies to work for a bi-decadal plan to reduce energy use in computing (Office of Energy Efficiency & Renewable Energy, 2022; SLAC, “DOE EES2 Pledge”).
3. **Reduce data center energy consumption.** Develop and deploy energy saving innovations to cool the data center such as better separation of hot and cool air and liquid cooling of hot components. Innovate to reduce data movement, to move to photonic from current-driven communication, and to change from volatile to nonvolatile memory. Furthermore, data center management should be made energy effective, by optimizing how software applications and data are hosted to minimize resource usage (Verdecchia et al., 2022). Using direct current (DC) power in data centers versus the customary alternating current (AC) power could become another option to reduce energy consumption.
4. **Consider decentralizing computation to the edge.** This approach can decrease energy use and be powered by waste energy systems (Flower, 2022). This is especially important for computations on data that originate at the edge, as in the emerging field of telehealth. Digital health interventions, including the use of telehealth augmented by AI, support an increasingly broad range of improvement goals for prevention and treatment that require new techniques to contain the explosion of data (Kalogeropoulos & Barach, 2023).

5. **Encourage the development of open-source software frameworks to standardize the way new technologies can be used with various vendor equipment and systems. Efforts** (Parker, Dosemagen, & Schuett, 2022) should be supported to involve everyone in creating solutions. A very interesting initiative is regional cloud infrastructures that are sustainable, compliant with European Union stringent privacy laws, and built on the principles of open-source collaboration (Aknostic, 2023).
6. **Support data-driven solutions based on energy use and central processing unit conservative systems, combining resources across cities to help ensure that data are processed more efficiently**.

Issue 8: Lack of livable shared urban spaces for work–life balance and a well–being economy

Background

Urban ecosystems must leverage the technologies of smart cities (U.S. DoT, 2021) and a circular economy (Stahel, 2016) in practice to provide more livable shared spaces, prioritizing community and mental health. One concept is the "Wellbeing Economy" (Wellbeing Economy Alliance).

The current ecosystem of urban landscapes being measured by economic criteria does not take into consideration the flourishing of human relationships, creativity, and happiness within the urban areas. The capacity for citizens to enjoy art, tourism, and culture is present in planning within large metropolitan areas but is often sidelined by industrial growth.

By 2030, humanity is expected to have evolved to a society 6.0, where AI and environmental sustainability concepts coexist to provide a more equitable organization of resources within the world. This may hold only for some areas on the planet by 2030.

The implementation of AI-driven networks and solutions can remove some pressure from the workforce and introduce an equitable urban space, prioritizing well-being and health over momentary economic gains. With the capacity of technology to transform the labor market and numerous industry segments, and with the implementation of robotics within the service industry and autonomous vehicles populating the streets, the urban economy will also need to evolve to integrate a new understanding of value.

Advanced digital technologies will be important for the planning and redesigning of urban space, with the main goal of transforming cities into enjoyable urban spaces (Speck, 2018), where work, food and services are reachable within a 20-minute walk or cycling radius or paired with carbon-neutral public transport. As a main living space for most of humanity, the urban area will need to integrate within itself additional value-driven systems that improve on the human experience and provide for a healthier, happier society.

Rather than focusing on establishing an environment for investment and sustaining traditional economic segments, cities must adopt a more advanced approach to integrate the values of well-being, nature-based restoration, and rejuvenation that closely align not only with a more sustainable future but also with the values of an advanced technological society that will be present after the wider adoption of AI systems.

Recommendations

1. **Provide more livable shared spaces, prioritizing community and mental health**.
2. **Employ technologies as appropriate to grow the availability of livable shared spaces.** Offer more livable shared spaces through technologies that enable smart cities and circular economies, prioritizing community and mental health, green mobility, smart utility systems, knowledge and ethics, and sustainable societal growth over monetary benefits.
3. **Foster knowledge sharing on the introduction of technologically sound and environmentally** conscious concepts**.** Focus on widely communicating (on easily accessible digital platforms) the introduction of technologically sound and environmentally conscious terms such as *green AI* (Schwartz et al., 2020), *knowledge city*, and *smart utilities* to promote synced comprehension between wider groups of stakeholders and the actualization of society 6.0.
4. **Encourage the practice of ethical AI.** Use the practice of ethical AI within urban areas to support the positive impact of these systems on improved efficiency and to remedy negative side effects that may occur from the misuse of AI in certain areas such as law enforcement and hiring. The U.S National Institute of Standards and Technology (NIST) has released an AI Risk Management Framework to assist in this effort.
5. **Communicate information, knowledge, and shared planning about urban environmental problems, standards, and solutions widely between the various stakeholders.** This includes sharing information, data, plans, and knowledge between different levels of government, nongovernmental organizations, and the public, as well as between people in different parts of the world, creating smart communities within the smart cities.
6. **Incentivize and promote creativity within the urban space as much as industrial investment.** As most of the world's population will be spending more than 80% of their lives within urban areas, the human experience of these areas should be one of enjoyment and balance beyond the rush.
7. **Evolve the metrics by which the advancement of an urban society is measured.** As technologies (including but not limited to AI) continue to evolve, the metrics by which the advancement of an urban society is measured should also evolve to potentially include measurements for well-being, creativity, and presence. Within a technologically advanced city system, sustainability and human well-being should not be targets to be achieved but a concurrent condition of the environment.
8. **Adapt education systems within urban areas to include the further and more comprehensive understanding of a city as an ecosystem.** A city is understood as an ecosystem of interlinked technologies, social groups, and economic segments, where the definitions and standards for sustainability, health, and happiness within society are shared and solidified to bring forth an actual post-AI society.

Further resources

1. NIST. "AI Risk Management Framework". Information Technology Laboratory.

References

2. The 15-Minute City (website).
3. AirNow. "List of Partners."
4. Aknostic. "Regional Clouds in Europe: Embracing Sustainability and Open-Source Innovation." 11 Dec. 2023.
5. Andreoni, Manuela. "Why Pakistan Was Hit So Hard." New York Times Climate Forward Newsletter, 30 Aug. 2022.
6. Appioa, Francesco Paolo, Marcos Limab, and Sotirios Paroutis. "Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges." *Technological Forecasting and Social Change* 142 (May 2019): 1–14.
7. Baker, David R. "Renewable Power Costs Rise, Just Not as Much as Fossil Fuels." *Bloomberg News*, 30 June 2022.
8. Borland, J. O. "Reverse Energy Injustice On Molokai Island To The Underserved Communities With 100% Energy From The Sun (Light & Heat) For Energy Cost Savings Equity." 2022 IEEE 49th Photovoltaics Specialists Conference (PVSC), Philadelphia, PA, USA, 2022: 0127–0130.
9. Bolt G., J. Burgers J., and R. Van Kempen R. "On the Social Significance of Spatial Location: Spatial Segregation and Social Inclusion. *Netherlands Journal of Housing and the Built Environment* 13, no. 1 (1998): 83-95.
10. Brasueli, J. "As Heat Waves Become More Common, Bus Shelters Are Needed to Keep Transit Riders Onboard." *Planetizen,* 30 Aug. 2021
11. Brisco, Tony. "Boiling Point: Which Cities Are Taking Charge as California Shifts to Electric Buses?" *Los Angeles Times,* 12 July 2023.
12. Budden, Philip and Fiona Murray. "Strategically Engaging with Innovation Ecosystems." *MIT Sloan Management Review*, 20 July 2022.
13. Burger, Jaap, Julia Hildermeier, Andreas Jahn, and Jan Rosenow. *The Time is Now: Smart Charging of Electric Vehicles*. Regulatory Assistance Project: Apr. 2022.
14. C40 Cities. "Clean Air Accelerator." Feb. 2022.
15. The Chisholm Legacy Project. "Policies for the People."
16. Clancy, Heather. "Carbon-Sucking Concrete is Capturing Attention and Funding." GreenBiz, 6 May 2021.
17. Climate Change AI (website).
18. Climate-ADAPT. "Improved Water Retention Capacity in the Agricultural Landscape." Database, Adaptation Options, 7 June 2016, updated 9 Mar. 2023.
19. Crow, Daniel, Insa Handschuch, Gabriel Saive, and Leonie Staas. "Behaviour Change: Strategies and Case Studies for Reaching Net-Zero by 2050," EnergyPost, 8 Nov. 2021.
20. Cuthbertson, Anthony. "€2 Billion Underground 'Water Battery' Turns on in Switzerland." *Independent*, 5 July 2022.
21. Delaney, Kevin. "Harnessing the Power of Parked EVs." *Cisco Newsroom*, 27 June 2022.

22. Dellesky, Carrie. "The City Dwellers Who Are Growing Food in India, China And Brazil." Rozenberg Quarterly, March 2015.

23. Dosemagen, Shannon. "Writing" (website).

24. Dumiak, Michael. "This Dutch City is Road-Testing Vehicle-to Grid Tech." *IEEE Spectrum*, 27 June 2022.

25. European Commission (EC). "2050 Long-Term Strategy." Climate Action, EU Action, Climate Strategies and Targets.

26. European Commission (EC). *The Future of Cities*. Joint Research Centre. Luxembourg: Publications Office of the European Union, 2019.

27. Evans, Simon. "Analysis: Which Countries Are Historically Responsible for Climate Change?" 5 Oct. 2021.

28. Flavelle, Christopher, Rick Rojas, Jim Tankersley, and Jack Healy. "Mississippi Crisis Highlights Climate Threat to Drinking Water Nationwide." *New York Times.* 1 Sept. 2022, updated 4 Sept. 2022.

29. Flannigan, M. D., B. J. Stocks, and B. M. Wotton. "Climate Change and Forest Fires," *The Science of the Total Environment* 262 (2000): 221–229.

30. Flower, David. "How Machine Learning and Edge Computing Power Sustainability." *Forbes Innovation.* 18 March 18, 2022.

31. Folsom, T. "Improved Bus Service on TenTimes Less Energy." 5th EAI International Conference on Intelligent Transport Systems (Lisbon, Portugal). Nov. 2021.

32. Gathering for Open Science Hardware (GOSH). "GOSH Manifesto." 2016.

33. Going Green. "What is the Most Sustainable City in the World?" Going Green YouTube video.

34. Goldfarb, Ben. *Eager: The Surprising, Secret Life of Beavers and Why They Matter.* White River Junction, VT and London, UK: Chelsea Green Publishing, 2018.

35. Gøtzsche Lange, I., and C. Neysa Rodriquez. "Urban Green Spaces: Combining Goals for Sustainability and Placemaking." *Europe Now,* 11 May 2021.

36. Habitat for Humanity. "Housing and Climate Change: Habitat for Humanity International's Position."

37. Harayama, Yuko. "Society 5.0: Aiming for a New Human-Centered Society: Japan's Science and Technology Policies for Addressing Global Social Challenges." *Hitachi Review* 66, no. 6: 558–559.

38. Heaven, Will Douglas. "DeepMind's Game-Playing AI Just Beat 50-Year-Old Record in Computer Science." *MIT Technology Review, 5* Oct. 2022.

39. Hickel, Jason, Sam Fankhauser, and Kate Raworth. "How to Save the Planet: Degrowth vs Green Growth?" The Smith School, School of Geography and the Environment. Video recording. 2 Sept. 2022.

40. IEA. *Data Centres and Data Transmission Networks*. Paris: IEA, Sept. 2022.

41. International Solid Waste Association (ISWA) (website).

42. Jacobs, Jane. *The Death and Life of Great American Cities*. New York: Random House, 1961.

43. Jaumotte, Florence, Myrto Oikonomou, Carlo Pizzinelli, and Marina M. Tavares. "How Pandemic Accelerated Digital Transformation in Advanced Economies." *IMF Blog,* 21 March 2023.

44. Johnson, Emma. "All Aboard for Nature: Improving Outdoor Access Through Public Transportation." EESI (Environmental and Energy Study Institute), 29 July 2021.

45. Kalogeropoulos, Dimitrios, and Paul Barach. "The Role of Telehealth in Enabling Sustainable Innovation and Circular Economies in Health." *Telehealth and Medicine Today 8, no 1* (2023).

46. Kamiya, G. et al. *Energy Storage.* IEA Technical Report.

47. Krishnan, Mekala, Hamid Samandari, Jonathan Woetzel, Sven Smit, Daniel Pacthod, Dickon Pinner, Tomas Nauclér, Humayun Tai, Annabel Farr, Weige Wu, Danielle Imperato. *The Net Zero Transition: What It Would Cost, What It Could Bring.* McKinsey Global Institute, Jan. 2020.

48. Lindwall, Courtney. "Rich, Polluting Nations Still Owe the Developing World." NRDC Explainer, 22 Jan. 2022.

49. Liu, Chenfei et. al. "A Review of Building Energy Retrofit Measures, Passive Design Strategies and Building Regulation for the Low Carbon Development of Existing Dwellings in the Hot Summer–Cold Winter Region of China." *Energies,* 2023, 16(10), 4115.

50. Loomis, Brandon. "Phoenix Names a Heat Officer, with a Goal of Easing the Risk of Rising Temperatures." *Arizona Republic*, 7 Oct. 2021.

51. The Los Angeles Times Editorial Board. "Finally, a Bus-Lane Building Boom in Los Angeles." *Los Angeles Times,* 219 Oct. 2023.

52. Luscher, D. "Introducing the 15-Minute City Project." 16 June 2021.

53. Malinowski, Matt, Max Dupuy, David Farnsworth, and Dara Torre. *Combating High Fuel Prices with Hybrid Heating: The Case for Swapping Air Conditioners for Heat Pumps.* CLASP (Cooperative Labeling and Appliance Standards Program), 2022.

54. Malmodin, Jens, Nina Lövehagen, Pernilla Bergmark, and Dag Lundén. *ICT Sector Electricity Consumption and Greenhouse Gas Emissions—2020 Outcome*. 20 April 2023.

55. Masood, Ehsan. "More Than Dollars: Mega-Review Finds 50 Ways to Value Nature." *Nature, 15* July 2022.

56. Matson, John, and Chris Potter. "Clean Energy 101: Heat Pumps." RMI (Rocky Mountain Institute), Buildings, July 2022.

57. Mayor of London/London Assembly. "Our Fight Against Climate Change." Programmes and Strategies, Environment and Climate Change.

58. Meininger, Kathleen. "Community Noise Lab Studies Urban Pollution, Environmental Injustice." *The Brown Daily Herald*, 25 Feb. 2022.

59. Mendell, Russell, Mathias Einberger, and Katie Siegner. "FERC Could Slash Inflation and Double Renewables with These Grid Upgrades." RMI (Rocky Mountain Institute), Electricity, 7 July 2022.

60. Mercado, Luz. "The Role of Community Gardens During the COVID-19 Pandemic." Columbia University Mailman School of Public Health News, 25 Feb. 2021.

61. Murray, Fiona, and Scott Stern, "Accelerating Innovation-Driven Entrepreneurial Ecosystems," in *Innovation and Public Policy,* National Bureau of Economic Research Conference Report, Austan Goolsbee and Benjamin F. Jones, eds. Chicago, IL: University of Chicago Press, 2022.

62. Nargi, Lela. "The Miyawaki Method: A Better Way to Build Forests." *JSTOR Daily*, 24 July 2019.

63. National League of Cities. "Ready to Rebuild Initiative 2023."

64. National Wildlife Federation (NWF). "Kids and Nature Programs."

65. Natural Resources Canada. *Major Energy Retrofit Guidelines for Commercial and Institutional Buildings: Office Buildings*. 2015.

66. The Nature Conservancy. “Our Goals for 2030: Build Healthy Cities.”

67. News in Germany. “Less Traffic Jams with a 9-Euro Ticket. Analysis of TomTom Data. Economy.” July 2022.

68. NOAA. “U.S. Billion-Dollar Weather and Climate Disasters.” National Centers for Environmental Information (NCEI), 2023.

69. Nokia. “AVA—Energy Efficiency: For Cost-Efficient and Sustainable Networks.” Network Solutions, BSS/OSS, AVA-Energy Efficiency.

70. Office of Energy Efficiency & Renewable Energy. “Department of Energy Announces Pledges from 21 Organizations to Increase the Energy Efficiency of Semiconductors and Bolster American Manufacturing.” 21 Sept. 2022.

71. Oladini, Dolly. “4 Ways Cities Are Using Low-Cost Sensors to Improve Air Quality.” Clear Air Fund Blog, 21 June 2022.

72. Parker, Alison, Shannon Dosemagen, and Ashley Schuett. “Low-Cost and Open Tools for Environmental Decision-Making.” *The Wilson Center* (blog), 5 April 2022.

73. Pless, Shanti, Stacey Rothgeb, Ankur Podderm, and Noah Klammer. *Integrating Energy Efficiency into the Permanent Modular Construction Industry.* NREL Buildings Integration Research.

74. Pollin, Robert. “Nationalize the U.S. Fossil Fuel Industry to Save the Planet.” *The American Prospect*, 8 April 2022.

75. Ramirez-Moreno, Mauricio A. et al. “Sensors for Sustainable Smart Cities: A Review.” *Applied Sciences* 11, no. 17 (Aug. 2021).

76. The Royal Society. "Climate Change: Evidence and Causes, Question 20."

77. Schwartz, Roy, Jesse Dodge, Noah A. Smith, Oren Etzioni. “Green AI.” Communications of the ACM. 13 Aug. 2020.

78. Semiconductor Research Corporation (SRC). “The Decadal Plan for Semiconductors: A Pivotal Roadmap Outlining Research Priorities.” Insights & Initiatives. Oct. 2020.

79. Shaheen, S., and Cohen, A. “Mobility on Demand (MOD) and Mobility as a Service (MaaS): Similarities, Differences, and Potential Implications for Transportation in the Developing World.” In *Mobility and Development: Innovations, Policies and Practices*. World Bank Group, Transport. Fall 2021.

80. Shankar, S., and A. Reuther. “Trends in Energy Estimates for Computing in AI/Machine Learning Accelerators, Supercomputers, and Compute-Intensive Applications.” In *Proceedings of the 2022 IEEE High Performance Extreme Computing Conference (HPEC),* Waltham, MA, USA, 19–23 Sept. 2022. IEEE: Piscataway, NJ, USA, 2022: 1–8.

81. Shared-Use Mobility Center (SUMC). “Take a RIDE with Me: Highlighting the Adoption of Citywide Microtransit in Wilson, NC.” Resource Library. 17 Apr. 2023.

82. Sindi, S. and R. Woodman. “Autonomous Goods Vehicles for Last-mile Delivery: Evaluation of Impact and Barriers.” *2020 IEEE 23rd International Conference on Intelligent Transportation Systems*, Rhodes, Greece. 20 Sept. 2020.

83. Singapore’s Zero Waste Master Plan. “Food Waste: What are others doing?”

84. Sisson, Patrick. "The Future of Urban Housing is Energy Efficient Refrigerators." *MIT Technology Review,* 23 Feb. 2022.

85. SLAC National Accelerator Laboratory. "DOE EES2 Pledge." DOE, Energy Efficient Computing.

86. Speck, Jeff. Walkable City Rules: 101 Steps to Making Better Places. Washington, DC: Island Press, 2018.

87. St. John, Jeff. "A Grassroots Coalition Turns to Solar and Batteries to Help New Orleans Cope with Disasters." *Canary Media*, 11 July 2022.

88. Stahel, Walter R. "The Circular Economy." *Nature* 531 (Mar. 2016): 435–438.

89. Student Conservation Association (SCA). "Urban Green." 2023.

90. Takemura, Alison F. "What is Community Solar? And How Can You Sign Up?" *Canary Media*, 8 July 2022.

91. Tao, Y., L. Yang, S. Jaffe, and F. You. "Climate Mitigation Potentials of Teleworking Are Sensitive to Changes in Lifestyle and Workplace Rather Than ICT Usage." *Proceedings of the National Academy of Sciences (PNAS)* 120, no. 39 (18 Sept. 2023).

92. Thompson, Phil. "Telcos Need to Cut Energy Consumption, and They Can Start with Lab Equipment." *Vanilla Plus,* 24 Feb. 2023.

93. UN Development Programme (UNDP). "Goal 6: Clean Water and Sanitation." The SDGs in Action.

94. UN Development Programme (UNDP). "Goal 11: Sustainable Cities and Communities." The SDGs in Action.

95. UN Environment Programme (UNEP). "Cities and Climate Change." Resource Efficiency, What We Do, Cities.

96. UN Environment Programme (UNEP). "Goal 6: Clean Water and Sanitation." UNEP and the Sustainable Development Goals, Why Do the Sustainable Goals Matter?

97. UN Environment Programme (UNEP). "Pollution Action Note: Data You Need to Know." UNEP, Air, Pollution Action Note, 7 Sep. 2021, updated 30 Aug. 2022.

98. U.S. Department of Energy (DoE). "Semiconductor Supply Chain Deep Dive Assessment." 24 Feb. 2022.

99. U.S. Department of Transportation (DoT). *Putting People First: Smart Cities and Communities*. Federal Highway Administration. 9 June 2021.

100. U.S. Environmental Protection Agency (EPA). "International E-Waste Management Network (IEMN)." International Cooperation.

101. Verdecchia, Roberto, Patricia Lago, and Carol de Vries. "The Future of Sustainable Digital Infrastructures: A Landscape of Solutions, Adoption Factors, Impediments, Open Problems, and Scenarios." *Sustainable Computing Informatics and Systems* 35 (2022).

102. Wellbeing Economy Alliance (website).

103. žižek, Simona Šarotar, Matjaž Mulej, and Amna Potočnik. "The Sustainable Socially Responsible Society: Well-Being Society 6.0." *Sustainability* 13, no. 16 (Aug. 2021): 9186.

104. Zero Cool [pseud.] "Oil is the New Data." *Nature,* no. 9 (7 Dec. 2019).

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CHAPTER 8: OCEAN AND COASTS

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OCEAN AND COASTS

Committee Members

Committee Co-Chairs

- Christopher Whitt, Halifax, Nova Scotia, Canada
- Julia Keeping, St. John's, Newfoundland & Labrador, Canada
- Laura Meyer, Hamburg, Germany

Committee Members / Contributors

- Abhijit Mukherjee, Kharagpur, West Bengal, India
- Amy Deeb, Dartmouth, Nova Scotia, Canada
- Ananya Sen Gupta, Iowa City, IA, United States
- Brandy Armstrong, Kiln, MS, United States
- Felipe Castro Quiles, FL, United States
- John Eldon
- Jorge Barbosa
- Mehdi Rahmati, Cleveland, OH, United States
- Rajesh Nair, Sgonico, Trieste, Italy
- Nidhi Varshney, Chennai, India
- Peter Wallace, Houston, TX, United States

OCEAN AND COASTS

The ocean plays a crucial role in the achievement of the Sustainable Development Goals and the livelihoods of billions of people. We urgently need to change how we interact with it.

United Nations Secretary General António Guterres[73]

Future Vision

It is 2030.

It has been an incredible decade. The fact that the ocean produces half of the world's oxygen has evolved from obscure science trivia to common knowledge. The world has been educated about the ocean's influence on people and their influence on the ocean, inspiring grassroots groups of citizen scientists to organize globally, collecting data on ocean and coastal change, resilience, diversity, population, and economy. Society has met the 30 × 30 (30% of the ocean protected by 2030) goal. A definitive map of the ocean floor is complete.

Circular economy practices have moved from an emerging field to a central principle in both the private and the public sectors. Broad investments in process improvements and waste stream mining have resulted in 100% reuse and recycling of plastic, and nearly every jurisdiction has eliminated the use of single-use disposable plastic items. Where goods cannot be produced locally or nationally, they are transported via green shipping. Wind-, wave-, and current-driven renewable energy projects along the coastline now produce and buffer a substantial fraction of the electricity to power society day and night without relying on carbon-based fuels.

Ocean and coastal-based carbon dioxide (CO_2) removal strategies have been proven and are being built on a scale that will soon be able to remove carbon dioxide at rates comparable to the residual carbon output from human activities. There is now a clear economic and technological path to removing the human contribution to the rate of change in the Earth's climate.

Coastal desalination plants powered by salinity gradient energy technology (Kempener & Neumann, 2014) provide abundant clean water and clean energy to areas where freshwater is scarce. Sustainable aquaculture provides an important food source for global populations. Coastal communities are aware of and exposed to only a reasonable level of flood risk through sustainable defenses, nature-based solutions, and managed realignment. The residual risk is managed by robust advanced early warning systems in place and democratized globally.

As impressive as these technological achievements are, what is most meaningful to the average person is that the ocean is visibly healthier. Their favorite beaches no longer have garbage washed up from off the shore. Ocean economies are booming as biodiversity has rebounded, leading to increases in everything from whale watching to recreational fishing. Protected coastal wetlands and mangrove forests both make coastal communities safer and provide beautiful recreational spaces.

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[73] António Guterres, "Foreword" in *The Second World Ocean Report*, vol 1. (New York: United Nations, 2021).

Events and trends from the early 2010s precipitated a profound change in maritime shipping that has long reaching positive consequences. The Fukushima nuclear disaster (2011) caused early retirements of many nuclear power plants in favor of natural gas over coal and other forms of power generation, igniting concern about energy security. The COVID-19 pandemic upended supply webs and society in general for nearly two years from 2020 through 2021, causing concern about supply web security. The invasion of Ukraine in 2022 interrupted supply webs again, bringing more concerns on how to assure geopolitical stability. These events began pushing forward a new consensus on economic, energy, food, and geopolitical security that effectively began a seismic shift in new supply webs and trade patterns. The growing importance of climate change became a permanent priority as well.

Shipping is a graphic example of the change: As of 2030, we are seeing the first generation of truly advanced ships that have zero emissions, more efficient trade patterns, and a new breed of ship operators either working as part of or considered to be a high-value, critical piece of organizations that use ships instead of low-cost, minimum compliance subcontractors.

Simply stated, society cares about the ocean and interacts in an ocean economy like never before.

Issue 1: Imminent threat of sea-level rise to coastal communities

Background

As it stands, sea-level rise is a major threat to coastal communities in terms of increased economic losses, coastal erosion, and destruction to ecosystems such as wetlands and mangroves. Immediate mitigation is necessary to protect coastal communities and regenerate coastal ecosystems due to accelerating sea-level rise.

Since 1880, the sea level has risen by 0.21 m to 0.24 m, and the rate of sea-level rise is accelerating. Even with reduced greenhouse gas (GHG) emissions, coastal communities face an additional global mean sea-level rise (GMSLR) of between 0.28 m and 0.62 m (above 1995–2014 levels) by 2100. In future scenarios, not assuming significant GHG reductions, GMSLR of 0.44 m to 1.01 m by 2100 is likely (IPCC, 2021). Irrespective of the GHG pathway, the sea level will continue to rise well beyond 2100 by at least another 1 m to 2 m, possibly more, due to inertia already in the climate system. The main drivers of sea-level rise are thermal expansion of seawater due to excess heat being absorbed into and heating the ocean and increasing seawater mass from melting glaciers and ice sheets.

The high population and industrial facility densities near the coast, with around 680 million people less than 10 m above sea level, are forecasted to increase to more than 1 billion people by 2050 (IPCC, 2019). Rising sea levels are threatening lives, infrastructure, and water supplies. Higher sea levels allow storm surge and high tides to travel further inshore and result in increased high-tide flooding of coastal communities. Sea-level rise threatens the habitability and existence of small island nations, which are currently home to 65 million people (UN Office of the High Representative for the Least Developed Countries, "About Small Island States"). Ecosystems protecting the shoreline in many areas cannot evolve and migrate due to the impacts of humans, so the rate of erosion of these ecosystems increases as sea levels rise.

Sea-level rise is effectively changing the ecosystems of the coastline, including flora and fauna. Existing ecosystems, such as barrier islands, are evolving slower than the sea-level rise is occurring, meaning storm events are routinely exposing coastal areas to conditions outside of the normal realm of experience. Human activity affects the ability of the ecosystem to accommodate storm events and changes the evolution mechanisms. Subsidence of marshes and accelerated erosion are examples of changes precipitated by human activity.

Communities will require storm protection, coastal impact assessments/response plans, and better ways to measure direct local impact of climate change. The modeling and prediction of climate change is needed to determine coastal communities' vulnerability to storm surge, increasingly common flood inundation, saltwater intrusion, and natural disasters. Considering just extreme sea-level rise at the coast, rare once-in-a-century events are projected to occur at least once a year in many locations by 2050 in all future GHG scenarios. Perhaps much of the real damage goes unmeasured in the areas where less technology is available for monitoring and measurement. Sharing knowledge is important, especially for developing countries that may be disproportionately affected by climate change—both its acute hazards and its long-term effects.

The modeling and technical data are especially important to identify the sovereignty of each coastal state over its sovereignty area. The maritime boundaries are set "from the baseline, which is the low-water line along the coast as marked on large-scale charts officially recognized by the coastal state" (UNCLOS, "Outer Limit of the Territorial Sea"). Since the United Nations Convention on the Law of the Sea (UNCLOS) treaty "does not explicitly provide that the maritime boundaries shall shift with a change in baselines, it can be said that UNCLOS does not decidedly exclude the possibility of states resorting to either of the two approaches" (Goyal & Gupta, 2020): (1) to fix the baseline or (2) to shift it according to the rising sea level. Therefore, constant ongoing measurements are needed to determine how far the baseline has shifted (Arcanjo, 2019).

Recommendations

1. **Support the equitable distribution and deployment of low-cost, easy-to-use monitoring equipment and satellite data products to track sea-level rise and coastal erosion, providing early warning indicators and data for early warning systems.**
2. **Make available customized global and regional operational flood modeling and early warning systems to help protect life and infrastructure, including to some small nations and other countries that may not have such capability.**
3. **Maintain and provide access to critical long-term data sets of sea-level rises, such as from tide gauge networks [e.g., Global Sea Level Observing System (GLOSS)] and satellite altimetry missions, to detect trends and identify as early as possible any accelerations in sea-level rise, storm surges, and tides.**
4. **Carry out definitive mapping of the global seafloor, which is necessary for accurate modeling.**
5. **Model sea-level rise, storm surge dynamics, and erosion locally and globally.** This modeling will aid in developing smart maps to inform the placement and protection of critical infrastructure or the relocation, ecosystem-based adaptation, and planned shoreline retreat of coastal communities to help reduce or prevent loss.
6. **Focus adaptations on local drivers of exposure and vulnerability, dependent on regional sediment sources and budgets.**
7. **Restore and protect bio-coastal restoration in addition to or in place of infrastructure protection.** Restoration should target key coastal ecosystems, such as mangroves, saltmarshes, sandy beaches, and vegetated dunes. These ecosystems provide important services, such as habitat for diverse biota and coastal protection. Wherever possible, beneficial space should be made or protected for these natural ecosystems to migrate inland with sea-level rise.
8. **Build innovative financing models for ecosystem restoration**. New blended financing structures should be explored that increase funding available for ecosystem conservation and engage private- and public-sector players.

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. CoastSnap—A Global Citizen Science Project to Capture Changing Coastlines

   "CoastSnap is a global citizen science project to capture our changing coastlines. No matter where you are in the world, if you have a smartphone and an interest in the coast,

we welcome you to participate! CoastSnap relies on repeat photos at the same location to track how the coast is changing over time due to processes such as storms, rising sea levels, human activities and other factors. Using a specialised technique known as photogrammetry, CoastSnap turns your photos into valuable coastal data that is used by coastal scientists to understand and forecast how coastlines might change in the coming decades…"

2. Land Change Assessment, Monitoring, and Prediction Using Landsat

   "LCMAP Monitoring uses all available Landsat observations to perform nationwide characterization of change in land cover and condition annually. Validation provides a measure of map accuracy for use in evaluating the appropriateness of a map for a specific application. LCMAP collects reference data that is used to perform a validation analysis, and all datasets are available…."

3. Environment | Mangroves for the Future—Investing in Coastal Ecosystems

   "All coastal ecosystems such as mangroves, coral reefs and seagrass beds are under threat from climate-change and variability; however, the long-term survival and functioning of key ecosystems is crucial for the communities depending on ecosystem services such as provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., flood, storm and erosion control; prevention of salt water intrusion), and habitat (e.g., breeding, spawning and nursery habitat for commercial valuable fish species)…."

4. National Oceanic and Atmospheric Administration's Sea Level Rise viewer and NASA's Sea Level Change Portal

Further resources

1. Oppenheimer, Michael, Bruce C. Glavovic, Jochen Hinkel, Roderik van de Wal, Alexandre K. Magnan, Amro Abd-Elgawad, Rongshuo Cai, et al. "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities." Chp. 4 in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Edited by Hans-O Pörtner et al. Cambridge and New York: Cambridge University Press, 2019.
2. Seabed 2030. The Nippon Foundation-GEBCO Seabed 2030 Project.[74]
3. Sweet, William V., Benjamin D. Hamlington, Robert E. Kopp, Christopher P. Weaver, Patrick L. Barnard, David Bekaert, William Brooks et al. *2022 Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines.* NOAA Technical Report NOS 01. Silver Spring, MD: NOAA, National Ocean Service, Feb. 2022.

[74] "Our mission is to inspire ocean mapping and deliver a complete seabed map for the benefit of people and the planet." The Nippon Foundation and General Bathymetry Chart of the Ocean (GEBCO) website at https://seabed2030.org/our-mission/.

Issue 2: Warming and acidification of the ocean

Background

It will be nearly impossible for society to reach our sustainable development goals (SDGs) without a healthy ocean, and the largest threat to the ocean is the absorption of excess heat and atmospheric CO_2.

The ocean has until now been the largest climate buffer, absorbing 90% of excess heat and 25% of excess CO_2 (WMO, 2021). As a result, the physical, chemical, and biological processes in the ocean have been broadly affected, which in turn has adversely affected many ocean ecosystems and ocean health. In particular, ocean acidification is directly linked to absorption of atmospheric GHGs such as CO_2.

Are the strata of heat in the ocean understood? Climate is a heat engine. Heat is most abundant at the equator, and the rest of the climate system is designed to remove heat from the equator. The system has three parts: land, water, and atmosphere; the ocean is 72%. The high heat capacity of the ocean has (until now) smoothed the variations in heat input/output. This ocean heat uptake comes at a cost, including the thermal expansion of ocean water and the resulting sea-level rise and intensification of storms.

The warming of the ocean and the warming of the atmosphere affect ocean circulation, and likewise, the altered ocean circulations affect the weather in complicated and dynamic feedback loops: The fear is that these dynamics may become unstable and potentially irreversible.

If the rate of ocean acidification is not slowed or mitigated in its effects, there is a risk of significant impacts to biodiversity, especially in coral reefs and shellfish, but there is also a significant knowledge gap about the fuller impacts of acidification. Increased ocean heat combined with nutrient discharge (in this chapter, this topic is discussed in the issue covering pollutants) also reduces the capacity of the ocean to hold oxygen. Declining oxygen contributes to a loss of biodiversity and shifting species distributions; it also threatens to disrupt the ocean's food provisioning services. These changes make effective management of ocean resources extremely difficult.

Recommendations

1. **Act with urgency.** Develop and implement policy advancements in research, technology, and economics to make the circular economy the reality. Urgent action is required to stem the most detrimental changes in ocean warming and acidification in responsible ways, and to shape long-term behaviors in technology and practices that emphasize the circular economy.
2. **Urgently and vastly increase ocean and ocean systems observations to inform both technology development and management policy.** A solid understanding of any system is needed to design good technologies for it. With the ocean, not only is there a poor understanding of the baseline, but also because of human-induced climate change, the baseline is moving while different societies each try to measure, understand, and responsibly manage the vast ocean resources. This complex, interconnected problem calls for revolutionary increases in ocean observations.
3. **Invest in research and development.** A major increase in public, private and philanthropic science investments is needed to carry out the following:
    a. Basic research and development, including everything from scientific measurements of the carbon cycle to improving the understanding of how the ocean acts as a buffer to the

climate system, to physical measurements to support safety and energy transformation (bathymetry, currents, weather, hazards), to biological assessments to inform good management from both civil society and government policy.

b. Significant technology development in sensors, platforms, and autonomous vehicles. The UN Decade of Ocean Science for Sustainable Development 2021-2030 was launched with the goal of "The Science We Need for the Ocean We Want." Achieving the goals of the ocean decade will require significant technology development in parallel with coordination of public, private, and philanthropic science funding.

c. Early-stage design, engineering, and qualification to reach a Technology Readiness Level (TLR) 6 to encourage and produce promising technologies and practices that reduce global warming and effectively extract CO_2 from the atmosphere and dissolve CO_2 in effluent streams into the ocean.

4. **Structure investment with a longer-term return period to support maturing the above-mentioned technologies.** For these promising technologies and practices, scaling from demonstration and qualification is a task that can require significant efforts characterized by excellent project management, project delivery, advanced manufacturing processes, and use of sophisticated quality systems to adopt new practices. Therefore, investments with return periods longer than currently acceptable limits for many industries will likely be required, which means policy to encourage capital practices to change may need to be changed as well.
5. **Advance policy and regulation in areas such as forcing reduction or elimination of single-use plastics and general advancements to directly sponsor or encourage basic research, applied research, and scaling to promising technologies and better practices.**
6. **Restore coastal (tidal marshes, wetlands, and mangroves) and ocean (seagrass meadows and kelp forests)**. This regeneration could substantially contribute to carbon sequestration.
7. **Consider, investigate, and evaluate marine carbon dioxide removal (mCDR) technology. As** it stands, slowing anthropogenic CO_2 release will not meet 1.5 °C targets. Marine carbon dioxide removal technology may provide a path to limit net-carbon emissions. The ocean could potentially provide up to 20% of global carbon sequestration. To responsibly evaluate mCDR technologies relative to the economic and ecological costs of other carbon solutions, societies need to understand the costs and ecological impacts of various carbon dioxide removal (CDR) approaches to have the information at the time it is needed for the massive investments that may be required in carbon solutions.

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. The OSPAR 2017 Intermediate Assessment and the OSPAR 2023 Quality Status Report 2023 confirms acidification in the northeast Atlantic Ocean. OSPAR, 2023.

   "Climate Change Thematic Assessment." In: *OSPAR, 2023: Quality Status Report 2023*. OSPAR Commission, London. Available at:
2. The UN Intergovernmental Panel on Climate Change (IPCC) and its latest status report.

Further resources

1. Aliaga, Bernardo, Ward Appeltans, Rick Bailey, Julian Barbiere, Mathieu Belbeoch, Aileen Bohan, Elisabetta Bonotto et al. Edited by Henrik Enevoldsen, Kirsten Isensee, and Ikroh Yoon. *State of the Ocean Report 2022*. Paris: UN Educational, Scientific and Cultural (UNESCO) Intergovernmental Oceanographic Commission, 2022.
2. *Blueprint for Ocean Climate Action: Recommendations for the Ocean Policy Committee*. June 2022.[75]
3. Global Ocean Acidification Observing Network (GOA-ON) (website).
4. OASIS. Observing Air-Sea Interaction Strategy.[76]
5. Ocean Frontier Institute. North Atlantic Carbon Observatory.[77]
6. Ocean Visions. Ocean-Based Carbon Dioxide Removal Road Maps.
7. United Nations (UN). *The 2nd World Ocean Assessment: World Ocean Assessment II*. 2 vols. New York: United Nations, 2021.

[75] The Blueprint recommendations are backed by 93 organizations, ranging from environmental groups, ocean advocates, think tanks, and aquariums, to outdoor recreation brands, who came together to develop these comprehensive recommendations. The recommendations focus on 12 key policy areas identified by ocean experts to improve sustainability, resilience, conservation, equity, and justice and demonstrate the broad solutions offered by the ocean.

[76] Better understanding of the air–sea exchanges in important climate cycles.

[77] Observing carbon uptake within major ocean basins.

Issue 3: Impacts of unsustainable ocean-based food production

Background

Wide-scale changes in the methods, regulation, and social awareness of ocean-based food production are necessary to improve equity and food security and to help prevent the destruction of marine habitats.

Fisheries and aquaculture provide food and livelihoods for billions of people, while being a threat to marine biodiversity through both direct fishing impacts combined with bycatch and habitat destruction (Maxwell et al., 2016; O'Hara et al., 2021).

Approximately 60% of fish stocks are currently harvested at the maximally sustainable level; 33% are harvested beyond sustainable levels (UN FAO, 2022).

The 2017 annual value of fisheries was estimated at US$127 billion; the World Bank also estimated that US$88 billion of net loss occurred due to impacts of overfishing (UN, 2021). In addition, illegal, unregulated, and unreported (IUU) fisheries threaten the livelihoods of small-scale fisheries, which primarily support local food consumption and are vital to food security, particularly in developing states.

Challenges to sustainable ocean food production are many, including difficulty in identifying and tracking IUU fisheries, harmful subsidies, lack of political will to address the problem, and lack of transparency and control against transnational criminal networks.

In addition to the obvious economic, social, and food security impacts, unsustainable, and particularly IUU, fisheries are likely to present greater risk to the environment due to destructive fishing practices and improper waste management.

Recommendations

1. **Use large-scale ocean observations to prioritize areas and species for most urgent action.**
2. **Implement a comprehensive global approach to fisheries management through understanding of habitats and food chains and monitoring of fishing stocks.**
3. **Provide for widespread use and availability of modified fishing gear that reduces impacts to seafloor beds, minimizes bycatch, and biodegrades.**
4. **Employ remote-sensing and monitoring technologies to enable enforcement of existing regulations and inform the creation of new regulations.**
5. **Provide for traceability throughout the sea-food supply system.** Digital "traceability in the food supply chain can be defined as the ability to track and follow food production at all stages of production, processing, and distribution" (Center for Food Safety and Applied Nutrition, "Tracking and Tracing of Food"). "Traceability along the seafood supply chain is necessary to combat IUU fishing and achieve healthy fisheries and aquaculture." Consumers can also make informed decisions on how and where their seafood is being harvested or cultivated.

6. **Coordinate policy and regulation, i.e., the rapid adoption and implementation of Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) requirements that certify the sustainable harvest and farming of seafood** (MSC, 2019).

Case study

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Farhan et al. Calculation Model of Economic Losses Due to Illegal Fishing Activities in Indonesian Territorial Waters. 2018.

Further resources

1. European Commission. "Illegal Fishing." Sustainable Fisheries, Rules.
2. UN Food and Agriculture Organization (FAO). *International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing*. Rome: UN FAO, 2001.
3. Global Dialogue on Seafood Traceability (website).
4. Naibaho, Nicolaus. *Strengthening the Role of Ports in Combating Illegal, Unreported and Unregulated Fishing in Indonesia.* New York: Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs, United Nations, 2017.

Issue 4: Destruction of important biodiverse and climate-resilient habitats

Background

Changes are needed in development and resource extraction to reduce or prevent destruction of key habitats such as seagrass meadows, kelp forests, tidal marshes, and mangroves, causing a loss of marine biodiversity, coastal erosion, flooding, and ocean warming.

From seagrass meadows to kelp forests to tidal marshes and mangroves to deep sea ecosystems, our ocean and coasts provide key habitats for a multitude of plants, animals, and other organisms all over the world. Biodiverse environments are more resilient to climate fluctuations; therefore, the protection and restoration of these areas is crucial to maintaining a livable planet. These important habitats are being damaged by resource extraction, coastal urbanization, pollution, introduction of invasive species, storm surges, and sea-level rise.

The loss of biodiversity in the ocean is causing major reductions in available fishery stock, affecting livelihoods and increasing food insecurity globally.

These habitats also play an important role in ocean–atmosphere interaction. Seagrass meadows and kelp forests capture significant amounts of carbon dioxide absorbed by the ocean each year. The continued loss of seagrass meadows and kelp forests will further increase atmospheric levels of GHGs.

The destruction of tidal marshes and mangroves is destabilizing coastlines by increasing erosion and flooding, causing governments and coastal communities millions of dollars a year.

Deep sea ecosystems are poorly understood yet could be threatened by increased fishing and future deep-sea mining.

There has been a rapid increase in the establishment of marine conservation areas (MCAs) globally. However, the lack of ecological monitoring and enforcement has called into question the effectiveness of many of these areas in meeting conservation goals.

Recommendations

1. **Balance manufactured, that is, human-made structures, against using natural approaches to resilience.**
2. **Implement more marine protected areas (MPAs) and marine conservation areas (MCAs), including robust monitoring programs and adaptive management practices, that meet the 30 × 30 goals (30% of the ocean protected by 2030) and that include key habitats and prioritize biodiversity.** Take localized impacts on stakeholders into consideration, especially in the case of “no take” zones where all fishing activities are prohibited. This approach would also include the development of an open-access database allowing for MPA/MCA managers, researchers, and stakeholders to access and share best practices and *any* data (from oceanographic to economic and everything in between relating to these areas).

3. **Establish sophisticated monitoring and noninvasive technology (moorings, buoys, eDNA, underwater remote-operated vehicles, autonomous underwater vehicles, and sensors) to better understand the overall dynamics and detect changes in the ocean's ecosystems**. Understanding the ecology and processes of these habitats will provide valuable information on their integral importance and further inform evidence-based decision-making for management needs.
4. **Use machine-learning technology to process and synthesize monitoring data.** These analyses should enable adjustments to conservation goals and faster implementation of direct action.
5. **Implement widespread use and accessibility of mechanical restoration technologies, such as seeding buoys and vessels designed to mechanically plant seagrass and kelp seedlings**.
6. **Establish living seawalls with 3D-printed structures.** Designed to mimic naturally occurring substrates, these seawalls allow for a variety of invertebrates, fish, and seaweeds to live or grow on them, while protecting coastlines from storm surges and erosion.

Case studies

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1. Living Seawalls

   "Sydney Harbour has shown that after 1-2 years Living Seawalls already support at least 36% more species than plain, unmodified seawalls, with as many as 85 species of invertebrates, seaweeds and fish living and growing on the panels."

2. Monitoring of Marine-Protected Areas

   "eDNA as a metabarcoding tool for monitoring marine protected areas" (Gold et al., 2021).

Issue 5: Urgency of preventing coral reef bleaching and die-offs

Background

Without intervention, increases in coral reef bleaching and die-offs will continue, which will threaten large ecosystems that provide many services, from food security to ecotourism.

More than half a billion people depend on coral reefs for resources and protection. Coral reefs protect coastlines from storms and erosion and provide economic opportunities and ecosystem services. They also remove large amounts of carbon annually from the ocean.

Coral reefs are threatened by pollution, harmful fishing practices, and climate change impacts such as increased ocean temperatures and acidification.

Many of these threats can stress reef ecosystems, leading to bleaching and possible death. Bleaching is when stressed corals may expel the symbiotic algae—their main food source—living within them, thus, putting the coral at risk of dying. Many coral bleaching or mass mortality events have occurred over time; however, the largest recent one was the 2014 to 2017 global coral bleaching event, in which warm waters affected approximately 70% of coral reefs worldwide (Scott & Lindsey, 2018).

Recommendations

1. **Consider bioengineering of heat-resistant corals.**
2. **Convert the more than 10,000 (**Masterson, 2024) **offshore oil and gas rigs into living substrates or artificial reefs as fossil fuels are phased out**. Beware, however: Some believe this process will provide oil conglomerates a loophole to dump unwanted debris as a cost-saving measure.

Further resources

1. Blue Latitudes. "Rigs-to-Reefs."
2. International Coral Reef Initiative. "Coral Reef Restoration Guidelines."

Issue 6: Ocean pollution due to offshore extraction and processing of fossil fuels, and the difficulties associated with attributing damage to specific polluters

Background

The exploration and processing of raw hydrocarbons, along with the spills of raw hydrocarbons, petroleum products, and their related compounds, and everyday use of petroleum products has led to widespread and persistent pollution of the marine environment. Continued exploration for, extracting, processing, and using petroleum products demands a substantial change in engineering and behaviors to help reduce or eliminate controlled releases and uncontrolled releases of hydrocarbons into the ocean.

Petroleum pollution of the marine environment is well known and has been documented for decades. The most visible impact is that of oil spills[78,79]. One key issue making fingerprinting of oil spills intractable, even major ones, is the potential prevalence of natural oil seeps within the same region. These seeps make it challenging to detect small or early leakage of oil spills and to hold petroleum companies accountable for the long-term effects of major oil spills. Furthermore, a related issue is the difficulty of assessing effective long-term remediation for petroleum and petroleum-derived products in the ocean.

Recommendations

1. **Build a road map for ocean energy transition: all the technical, economic, and human issues related to decommissioning existing offshore infrastructure, building new infrastructure, and meeting society needs for energy while reducing CO2 emissions and other environmental impacts**.
2. **Encourage knowledge exchange and collaboration between existing offshore oil and gas practitioners and newer offshore wind developers**. Existing petroleum-sector knowledge could accelerate development, and infrastructure may be repurposed for clean energy solutions. All current functional platforms should be required to develop plans to modify their existing offshore infrastructure and operation toward sustainable energy alternatives—wind, wave, solar—within the next 20 years.
3. **Study marine pollution in the context of the environmental interaction of potentially hundreds of hydrocarbons that make up the complex mixture of petroleum** (different for different sources of petroleum.
4. **Assess effective remediation strategies for ocean pollution due to petroleum and related products like oil spills or slow leaks** (e.g., oil booms, skimmers, and sorbents). Bioremediation should also be of interest (i.e., using algae and bacteria to break down oils).

[78] For example: DeepWater Horizon-BP Gulf of Mexico Oil Spill, 10 Apr. 2010. https://www.epa.gov/enforcement/deepwater-horizon-bp-gulf-mexico-oil-spill.

[79] For example: Exxon-Valdez Oil Spill-Prince William Sound, Alaska, 24 Mar. 1989. https://darrp.noaa.gov/oil-spills/exxon-valdez.

5. **Consider limiting the development and construction of new offshore petroleum extraction platforms to reduce petroleum reliance across society.**
6. **Require all extraction/processing platforms to monitor the natural hydrocarbons in their region so that spills can be detected and mitigated early.**
7. **Require platforms to contribute to a regional management fund that can use tools such as satellite monitoring and tracking to trace the sources of natural hydrocarbons and of spills from other sources to improve accountability.**
8. **Investment should be made in ocean-based renewable energy systems using energy from wind, waves, currents, and geothermal, ion exchange, and the sun**.

Case studies

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1. Satellite oil spill detection and case study

   Sea Empress was grounded near the town of Milford Haven, Wales, on 15 Feb. 1996.

Further resources

1. Agarwal, Mayur. "10 Methods for Oil Spill Cleanup at Sea." Marine Insight, Marine Environment. 30 Apr. 2021.
2. Illuminem (website).
3. Leporini, Mariella, Barbara Marchetti, Francesco Corvaro, and Fabio Polonara. "Reconversion of Offshore Oil and Gas Platforms into Renewable Energy Sites Production: Assessment of Different Scenarios." *Renewable Energy* 135 (May 2019).
4. Löw, Fabian, Klaus Stieglitz, and Olga Diemar. "Terrestrial Oil Spill Mapping Using Satellite Earth Observation and Machine Learning: A Case Study in South Sudan." *Journal of Environmental Management* 298 (Nov. 2021).
5. Rajendran, Sankaran, Fadhil N. Sadooni, Hamad Al-Saad Al-Kuwari, Anisimov Oleg, Himanshu Govil, Sobhi Nasir, and Ponnumony Vethamony. "Monitoring Oil Spill in Norilsk, Russia Using Satellite Data." *Scientific Reports* 11, no. 3817 (Feb. 2021).

Issue 7: Influx of excess nutrients is polluting the ocean environment

Background

Food security, biodiversity, and the safe management of coastal and ocean ecosystems cannot be maintained without better monitoring and more effective control of pollutants: Nitrates and phosphates cause eutrophication, fish die-offs, and ecosystem changes and may increase harmful algal blooms (HABs) in coastal waters.

The presence of pollution in the ocean, particularly in the form of nitrates and phosphates, is becoming ubiquitous, with significant effects on marine life and human health. The complete picture of pollutants is complex, and there are not sufficient data available to fully characterize all sources and effects, but there are well-established major causes. These causes include agricultural runoff, impacts of inefficient aquaculture practices, effluent discharges from urban and industrial areas, and the modification of natural river flows, which disrupts sediment transfer processes.

Pollutants cause a change in the ratio of important nutrients and temporarily stimulate plant growth, causing or exacerbating localized "*dead zones* where" decaying "organic matter consumes oxygen faster than" is exchanged with "the oxygen-rich" sea "surface" (UNESCO, *State of the Ocean Report 2022*). These hypoxic conditions directly affect commercial fish stocks, alter food webs, and may be a major contributor to habitat and biodiversity loss (see issues elsewhere in this chapter on coral reefs, seagrass meadows, and coastal wetlands).

The changes in nutrient ratios due to human activities may also contribute to the sudden, rapid growth of certain phytoplankton species—known as HABs—which present health risks to food chains, commercial fisheries, and humans, as well as related economic effects.

Recommendations

1. **Develop and widely adopt low-cost technology for real-time monitoring of temperatures, nutrients, pollutants, and suspended sediment in all waterways**. The fit-for-purpose ocean observation system is a cross-cutting theme. For this issue specifically, monitoring of pollution outflows from rivers and cities is essential, including submarine groundwater discharge.
2. **Support and deploy direct measurements of water movement and its chemical composition** (for example, with gliders equipped with dissolved CO_2 and nitrous oxide sensors). The resulting data are necessary to validate detailed computer models, which can then help predict hazards and conduct what-if testing of various technical or policy mechanisms. These measurements should result in a wide range of actions, from changing regulations on farming and aquaculture practices to timing the operation of dams and spillways, to minimize harmful effects on ocean chemistry.
3. **Improve remote-sensing methods to help monitor and provide timely warnings to mitigate the immediate effects of HABs.** Improvements could be new sensors on new satellites but more likely will include improved machine learning algorithms to automate the processing and analysis of existing—near real-time—remote-sensing data.

4. **Work toward a long-term healthy ocean solution that would see the establishment of more regenerative agriculture practices and better urban wastewater management, including biofiltration systems and blue-green roof technology for storm water runoff.**
5. **Develop and implement corrective measures that protect the ocean mirroring those linked to land—this also impacts seafood production.** Sodium tripolyphosphate (STPP) is used in laundry detergents and on farmed shrimp and fish to retain water to add weight (not banned in most places). STPP contains phosphate and can cause eutrophication and algae bloom if wastewater merges into water bodies without the right treatment.
6. **Encourage citizen scientists to provide cost-effective water quality data on temporal and spatial scales that would otherwise not be possible**.

Case studies

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1. Use of Biochar to remove toxins from different harmful algal blooms

   "Biochar May Help Fight Against Harmful Algal Blooms"
2. Nanobubble ozone technology (NBOT) to control cyanobacteria and their toxins
3. Case studies of biofiltration systems from the Minnesota storm water manual
4. Blue-Green Roof technology
5. The development of smartphone applications (Apps), which can be used by citizen scientists to cost-effectively measure and record surface reflectance, water color, and water quality parameters
6. Environmental Protection Agency Participatory Science Water Projects

Further resources

1. Aliaga, Bernardo, Ward Appeltans, Rick Bailey, Julian Barbiere, Mathieu Belbeoch, Aileen Bohan, Elisabetta Bonotto, et al. Edited by Henrik Enevoldsen, Kirsten Isensee, and Ikroh Yoon. *State of the Ocean Report 2022*. Paris: UN Educational, Scientific and Cultural (UNESCO) Intergovernmental Oceanographic Commission, 2022.
2. Busker, Tim, Hans de Moel, Toon Haer, Maurice Schmeits, Bart van den Hurk, Kira Myers, Dirk Gijsbert Cirkel, et al. "Blue-Green Roofs with Forecast-Based Operation to Reduce the Impact of Weather Extremes." *Journal of Environmental Management* 301 (Jan. 2022).
3. Metcalfe, Anya N., Theodore Kennedy, Gabriella A. Mendez, and Jeffrey D. Muehlbauer. "Applied Citizen Science in Freshwater Research." *Wiley Interdisciplinary Reviews (WIREs): Water* 9, no. 2 (Jan. 2022).

4. San Llorente Capdevila, Anna, Ainur Kokimova, Saunak Sinha Ray, Tamara Avellán, Jiwon Kim, and Sabrina Kirschke. "Success Factors for Citizen Science Projects in Water Quality Monitoring." *Science of the Total Environment* 728 (Aug. 2020).
5. United Nations. *Groundwater: Making the Invisible Visible*. Paris: UN Educational, Scientific and Cultural Organization (UNESCO) World Water Assessment Programme (WWAP), 2022.
6. Yang, Feikai, Dafang Fu, Chris Zevenbergen, and Eldon R. Rene. "A Comprehensive Review on the Long-Term Performance of Stormwater Biofiltration Systems (SBS): Operational Challenges and Future Directions." *Journal of Environmental Management* 302, pt. A (Jan. 2022).

Issue 8: Unsustainable marine transportation industry operations

Background

The shipping industry is already on the edge of two major and simultaneous revolutions: *nature of trade* and *nature of shipping*. The nature of trade is where major gains can be made as trade is rearranged in terms of "what is carried" and "where it is carried" to reduce the total amount of shipping and use inherently more efficient ship types. For instance, the transport of feed stocks or materials for additive manufacturing is easier to carry than finished goods. Port facilities and access, driven by the nature of trade, will directly influence the effects of erosion and other coastal access issues. The nature of trade is a distinctly external set of characteristics that drives the shape of shipping.

The nature of shipping is about the mechanics of shipping in terms of ship propulsion types and operations, operating structure of shipping, construction, and repair of ships. It is a distinctly internal set of characteristics to shipping itself. Step changes can be made in zero/low-emissions powering and noise and vibration abatement.

Commercial shipping, for the purposes of this discussion, can be divided into "international" shipping between countries and "local" shipping within a single country. International shipping is effectively governed for safety and environment through the International Maritime Organization (IMO), a UN body that produces codes such as MARPOL or SOLAS that are endorsed and enforced by the maritime flags and ports. One distinct characterization of the IMO is that its codes are uniformly adopted worldwide without consideration of such groups as "developing nation" status or other fragmentations. Local shipping is effectively governed solely by the locality of the vessel, although many localities adopt general IMO codes in part or full. Commercial shipping represents an opportunity or major problem depending on one's viewpoint. Both international and local shipping issues provide two of the best opportunities for general decarbonization and industry leadership.

Commercial shipping is an ancient endeavor and has evolved to move "90% of everything" around the world. It accounts for around 3% of the world's GHG emissions (Figueres, 2020), making it approximately the fifth largest emitter if it were a country and, if left unchecked, will grow to around 16% of the world's emissions by 2030.[80] Commercial shipping is tightly integrated into the world's economies and is a key enabler in the creation and sustainability of supply webs and geopolitical stability that span the world. Shipping, while much more efficient compared to other modes of transport such as road, rail, pipeline, or airborne, should also be part of the overall solution of tackling climate change.

Shipping is also a major contributor to human-made subsea noise and vibration and local erosion/coastal changes in the way of harbors or channels where vessels are active.

Shipping is characterized by long-lived assets with asset lives ranging from 20 to 50 years, causing changes to occur over a period of time. Ships are acquired and operated based on having a full life with minimal retrofit for any type of regulation. Hence, there is a strong lobbying effort from the established operators to delay or minimize the effect of potential new regulations.

80 Projections for the future of CO_2 in shipping under different policies are found at: Bryan Comer, "Choose Wisely: IMO's Carbon Intensity Target Could Be the Difference between Rising or Falling Shipping Emissions This Decade," *The International Council on Clean Transportation (ICCT)* (blog), 18 May 2021.

IMO regulations are the primary policy driver for shipping, related merchant marine, and many naval requirements. Policy in the form of IMO regulations, while slow in formulation and full implementation, are thorough. One example is the phasing out of single hull tankers following the 1989 *Exxon Valdez* spill in Alaskan waters. The United States adopted OPA 90 in 1990, making the United States the first country to adopt double hull requirements followed by the IMO in 1992. Single hull tankers were fully phased out in 2015 in general worldwide trade with several intermediate steps. Profound change can happen even though it takes time, and it can be messy, especially in the earlier stages. The inherently slow and measured process of IMO work further limits the extent of what may be drafted and adopted by IMO; that said, IMO requirements, once established, are sticky and force change because it is the primary policy driver of the shipping industry.

Recommendations

1. **Implement step changes toward in zero/low-emissions powering for "local' and "international" shipping.** Commercial shipping represents an impactful opportunity for decarbonization of marine transportation.
2. **Reduce unnecessary transportation.**
3. **Optimize the use of shipping vessels and routes.**
4. **Work with the IMO to develop regulations for more sustainable shipping.**
5. **Support abatement of human-made sub-sea noise and vibration caused by shipping**.

Issue 9: Path to decarbonization for new and existing ships is unclear

Background

Ships are a significant source of GHGs, and gaps in scalable technology and enforceable policy make the pathways to reach zero emissions ambiguous.

Fuel used in commercial shipping results in the emission of harmful pollutants, including CO_2, nitrogen oxide (NOx), sulfur oxide (SOx), particulate matter (PM), and unburned hydrocarbons.

There is an ongoing effort to regulate marine pollutants, most notably led by the IMO's Convention for the Prevention of Pollution from Ships (MARPOL). However, these efforts are incremental and long because of the nature of regulations developed by consensus followed by ratification and implementation. Vessels that do not trade internationally are not subject to IMO/MARPOL; hence, the local regulations may be stronger or weaker than the IMO.

Individual nation-states can, and occasionally, adopt higher standards, but the jurisdiction is limited to vessels working within the waterways of the nation-state.

Fuel used in commercial shipping results in the emission of harmful pollutants, including GHGs (like CO_2, NOx, SOx, and PM). Studies are ongoing to measure the emissions levels and their impacts for many of these areas. For instance, 3% of global GHGs (Figueres, 2020) are attributed to shipping, and emissions are expected to rise by 16% by 2030 (Comer, 2021) if there are no changes made.

There is an ongoing effort to regulate marine pollutants, most notably led by the IMO's Convention for the Prevention of Pollution from Ships (MARPOL). However, these efforts fall short due to issues such as variations in regulations in different flag and port states, the high cost of refitting the large proportion of older vessels to meet modern standards, limited availability of truly clean energy solutions, and challenges in measuring and tracking the impact of any operational or equipment adaptations at an appropriate scale. The inherently slow and measured process of IMO work further limits the extent of what may be drafted and adopted by the IMO.

Recommendations

1. **The cost of emissions from the operation of vessels (and their embodied energy) should be higher than the cost of clean technologies.** This effort should be supported both through regulation (tracking of emissions and levying of fines) and by subsidizing technology development and adoption (policy, corporate).
2. **Support research and scaling of transformative technologies of ships' propulsion systems.** Although incremental improvements like liquid natural gas (LNG) fuels can be considered in the short term, transformative technologies will be needed, including propulsion innovation (e.g., hydrogen fuel, wind assist, and long-duration electric) and route optimization (e.g., data analytics, weather forecasting, and autonomous navigation).

3. **Consolidate localized studies, initiatives, and oversight to capture global trends and expectations in shipping.** International bodies should work and cooperate to provide a consistent regulatory environment (interoperable regulations between jurisdictions) across borders to help prevent local regulations (e.g., speed limits, green corridors, emissions limits, and clean fuel standards) from being bypassed as a ship transits from one regulatory regime to another. The industry should not force one region to bear the brunt of emissions as others enforce higher standards.
4. **Measurement of impact of a ship's operations on a smaller and more frequent scale should be enabled so that change (negative or positive) can be recognized and timely adjustments can be made.** This measurement can include emissions monitoring in ports that every ship can use to establish its baseline levels without additional cost.
5. **Build mechanisms to publicize *wins* and critique *losses* so that reputational factors (with respect to a vessel or a shipping company) further drive reduced emissions.** These mechanisms can include expanding programs that recommend, verify, track, and publicize metrics and industry members who meet them.
6. **Educate and inform the public about the embodied energy of goods.** Customers should be allowed to choose the right shipping option for their needs. This choice might include the option of slower shipping in exchange for reduced carbon footprint.

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Voluntary certification programs
    a. Green Marine (North America)

       *"The Green Marine program demonstrates year after year its ability to encourage its participants to go beyond regulatory requirements." (*Green Marine, "Certification, Results")

    b. First Movers Coalition (Global):

       "The FMC is a coalition of companies using their purchasing power to create early markets for innovative clean technologies across eight hard to abate sectors. These in-scope sectors are responsible for 30% of global emissions–a proportion expected to rise to over 50% by mid-century without urgent progress on clean technology innovation." (World Economic Forum, "First Movers Coalition")

2. Marine protected areas

    a. Mongabay—MPA Impact Review (US-based non-profit)

    "To find out if marine protected areas achieve their environmental and socioeconomic goals, we read 42 scientific studies and talked to seven experts. Overall, marine protected areas do appear to help marine animals recover within their boundaries. But a lot more rigorous research is needed. The effects of marine protected areas on socioeconomic outcomes and fisheries are less clear." (Dasgupta, 2018)

    b. PEW—The Case for MPAs (Charitable trust)

    "In 2016, members of the International Union for Conservation of Nature, a global authority on the status of the natural world, adopted a motion recommending that nations protect 30 percent of their waters from all extractive activities by 2030. Safeguarding ocean space in marine protected areas (MPAs) has been proved to help conserve marine life and associated habitats. Creation of MPAs can improve ocean health and provide multiple benefits to the people whose lives and traditions are linked to these waters." (Pew Charitable Trusts, "The Case for Marine Protected Areas")

    c. WWF Effects of MPAs (World-wide conservation organization)

    "WWF scientists collaborate on a geographically expansive, long-term study to quantify the impacts of marine protected areas on both people and nature." (Morgan, 2016)

3. Future fuels and propulsion

    a. Lloyd's Register—Zero-carbon fuel readiness monitor (Marine classification society)

    "Zero-emissions solutions have so far only been deployed in niche applications, solutions for large scale ocean shipping are not yet established." (Lloyd's Register, "Zero-Carbon Fuel Monitor")

    b. International Transport Forum—Market Forces Driving Decarbonisation (Intergovernmental organization)

    "This chapter spells out the drivers and barriers of decarbonisation and the conditions under which it could be achieved. One of these conditions is strong financial incentives, such as carbon pricing. The chapter concludes with implications for regulation." (Kirstein, Halim, & Merk, 2018)

c. Bureau Veritas—Challenges and Impact of Adopting Wind Propulsion (Marine classification society)

> *"In addition to turning to low- and zero-carbon fuels, many owners are researching alternative propulsion methods as a way to limit their impact. Among developing options, wind-assisted propulsion is considered a strong contender for achieving significant emissions reduction. As a free, clean energy source available worldwide, wind can power ships renewably through the use of sails – both advancing the shipping industry and returning it to its roots. However, much of the technology needed to support wind-assisted propulsion systems is still in the early stages of development. While a handful of pilot projects are underway, several environmental, technical, design and financial challenges remain before widespread adoption of wind-assisted systems is possible."* (Bureau Veritas, "Powering Marine Decarbonization")

Further resources

1. Comer, Bryan. "Choose Wisely: IMO's Carbon Intensity Target Could be the Difference Between Rising or Falling Shipping Emissions this Decade." *The International Council on Clean Transportation (ICCT)* (blog), 18 May 2021.
2. Hussain, Iftikar, Haiyan Wang, Muhammad Safdar, Quoc Bang Ho, Tina D. Wemegah, and Saima Noor. "Estimation of Shipping Emissions in Developing Country: A Case Study of Mohammad Bin Qasim Port, Pakistan." *International Journal of Environmental Research and Public Health* 19, no. 19 (Sept. 2022).
3. Kadwa, Farheen. "How Canada's Shipping Industry Can Reduce its Climate Change Impacts." WWF-Canada, 24 Nov. 2021.
4. Moldanová, Jana, Ida-Maja Hassellov, Volker Matthias, Erik Fridell, Jukka-PekkaJalkanen, Erik Ytreberg, Markus Quante et al. "Framework for the Environmental Impact Assessment of Operational Shipping." *Ambio* 51 (July 2022): 754–769.
5. Pavlenko, Nikita, Bryan Comer, Yuanrong Zhou, Nigel Clark, and Dan Rutherford*. The Climate Implications of Using LNG as a Marine Fuel.* Working Paper 2020-02. International Council on Clean Transportation (ICCT), Jan.2020.
6. Reinsch, William Alan, and Will O'Neill. "Hydrogen: The Key to Decarbonizing the Global Shipping Industry?" Center for Strategic and International Studies (CSIS), 13 Apr. 2021.

Issue 10: Increased noise from ships is destroying underwater habitats

Background

Increasing demands for fast shipping and tourism to remote habitats is causing a larger number of ships to operate along established shipping routes, as well as into areas where ships did not previously transit frequently. Aquatic species, and especially marine mammals, are sensitive to the underwater noise generated by these ships, causing them to change their behaviors or abandon critical habitats to avoid shipping traffic.

Ships are powered by large engines and driven by large propulsors, which results in significant vibration of the structure and results in both airborne and underwater noise and vibration resulting from mechanical and hydrodynamic phenomena. Barnacles and other biofouling on ships are another source of underwater noise. Underwater ambient noise levels have doubled each decade since the 1970s, and reductions are unlikely to be achieved by 2030 when the next generation of ships start being delivered. Studies are ongoing to measure the emissions levels and their impacts for many of these areas.

Due to the discomfort and harm caused to humans on noisy vessels, as well as onshore, there are standards in place to control airborne noise and structural vibration in crew areas. However, underwater noise does not have the same controls in place. Currently, there are actively mandated noise and vibration abatement programs, including design practices and specific technologies that have existed for many decades and have been routinely applied in various vessel types (naval, oceanographic, cruise, etc.) However, our ocean and coasts remain extremely noisy places for marine life.

Recommendations

1. **Fund the research needed to determine what noise levels are harmful in key shipping locations.** This research should include determining what species are present in locations, what their hearing thresholds are, and whether a limit on specific and/or total shipping activity is needed.
    a. Consolidate local studies and Indigenous knowledge and encourage industry leaders to collaborate in the work to build expertise among decision makers for the need to control underwater noise levels.
2. **Employ insights resulting from underwater noise studies and stakeholder cooperation (policy, academia, corporate, industry associations, Indigenous and other local stakeholders) to generate underwater noise emissions standards for individual vessels, as well as soundscape standards for shipping lanes, ports and harbors, and critical habitats.**
3. **Put noise management plans in place for all existing vessels that identifies their noise levels under different operating conditions and provides the vessel operators with guidance on what operating conditions are appropriate in areas where they may interact with noise-sensitive species.**
4. **Design new vessels to meet incoming underwater noise standards and follow a noise management plan once they become operational.** This effort should be supported both through regulation (tracking of emissions and levying of fines) and by subsidizing technology development and adoption (policy, corporate).

5. **Develop and implement the use of improved nontoxic antifouling coatings.**
6. **Measure the impact of underwater noise reduction approaches more frequently so that change (negative or positive) can be recognized and timely adjustments can be made.** This measurement can include noise monitoring in ports that every ship can use to establish its baseline levels without additional cost. There should also be mechanisms to publicize *wins* and critique *losses* so that reputational factors further drive reduced emissions (policy, industry associations).
7. **Support research in transformative technologies, including cavitation reduction, active and passive noise control in structures and spaces, antifouling coatings, and maintenance protocols** (policy, academia, corporate).

Case studies

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1. Marine protected areas (see Issue 9 of this chapter)
2. URN target setting and mitigation measures
    a. BC Ferries—URN Mitigation Study (Passenger Ferry Industry)

    "Key learnings for other vessel operators considering the implementation of underwater radiated noise targets: Obtain baseline measurements of your fleet to determine where your starting point is before setting underwater noise reduction goals; Make design decisions in consideration of the larger system. Underwater radiated noise is a function of many complex interactions within a vessel, and as such, it is important to design the propeller and propulsion systems in concert with the hull design to account for functional requirements; Engage an underwater radiated noise expert to assess design impacts and conduct trade-off analysis. Make expertise available for working closely with the selected shipyard throughout the detailed design and build process; Anticipate conflicting requirements as a part of the design optimization process. For BC Ferries, for example, meeting underwater radiated noise reduction requirements while achieving improved energy efficiency is a balancing act that requires careful consideration." (Peterson, 2021)
3. Incentive programs
    a. Port of Metro Vancouver—EcoAction Program (Port Authority)

    "Through the port authority's EcoAction Program, shipping companies can qualify for up to 75% off their harbor dues fees by taking voluntary measures to reduce their environmental impact, such as by using renewable energy to reduce air emissions, installing propeller technologies that reduce underwater noise, or obtaining third-party environmental designations." (Port of Vancouver, "EcoAction Program")

b. Santa Barbara Channel—Speed reduction incentive program (National Marine Sanctuary and Port)

"Commercial shipping is the dominant source of low-frequency noise in the ocean. It has been shown that the noise radiated by an individual vessel depends upon the vessel's speed. This study quantified the reduction in source levels (SLs) and sound exposure levels (SELs) for ships participating in two variations of a vessel speed reduction (VSR) program. SLs and SELs of individual ships participating in the program between 2014 and 2017 were statistically lower than non-participating ships ($p < 0.001$). In the 2018 fleet-based program, there were statistical differences between the SLs and SELs of fleets that participated with varying degrees of cooperation. Significant reductions in SL and SEL relied on cooperation of 25% or more in slowing vessel speed. This analysis highlights how slowing vessel speed to 10 knots or less is an effective method in reducing underwater noise emitted from commercial ships." (ZoBell et al, 2021)

4. Impact of noise on aquatic species

a. Measuring Impact on Cetaceans (Canadian Conservation)

"This report presents an analysis of high-risk areas in Canadian waters where shipping activity poses an elevated threat to cetaceans, and it is founded in in-depth interviews and a literature review of four working groups developing mitigation measures to manage impacts of shipping on cetaceans in the country. … Based on these case studies, we summarize best practices and draw the following recommendations: 1. Where possible, separate ships from cetaceans by modifying routes or designing vessel exclusion zones in high-risk areas. 2.Where it is not possible, apply speed restrictions in known sensitive cetacean habitats, such as feeding aggregation or nursing areas. 3.Evaluate the co-benefit of speed restrictions for cetacean conservation and for the environment in general to better quantify benefits versus costs. 4.Consider all endangered, threatened and protected species when designing mitigation measures. 5.Apply best practices to create an effective and collaborative structure to coordinate communication between relevant stakeholders, and base management decisions on the best available knowledge (scientific, local and Indigenous). 6.In areas where place-based measures are not enough, encourage certification or port-led incentive schemes and the development of quantifiable noise-reduction targets and/or noise thresholds to regulate shipping." (Dalili, Ushio, and Cosandey-Godin, 2020)

b. Managing Noise Impacts—Context and Monitoring Approach (US-based Ocean Noise Strategy Roadmap)

"This case study provides a place-based context for examining recommendations …expanded focus and attention to NOAA-managed and acoustically sensitive fishes and invertebrate species, …. extended use of existing authorities to address noise impacts to acoustic habitats for sensitive fish and invertebrate species, and … prioritized development of NOAA-maintained long-term passive acoustic monitoring capacity." (Gedamke, Harrison, & Hatch, 2021)

Further resources

1. Middel, Helen, and Francesca Verones. "Making Marine Noise Pollution Impacts Heard: The Case of Cetaceans in the North Sea within Life Cycle Impact Assessment." *Sustainability* 9, no. 1138 (June 2017).
2. Moldanová, Jana, Ida-Maja Hassellov, Volker Matthias, Erik Fridell, Jukka-PekkaJalkanen, Erik Ytreberg, Markus Quante et al. "Framework for the Environmental Impact Assessment of Operational Shipping." *Ambio* 51 (July 2022): 754–769.
3. Richardson, W. John, Charles R. Greene, Jr., Charles I. Malme, and Denis H. Thomson. *Marine Mammals and Noise*. Academic Press, 1995.

Issue 11: Waste streams and emissions from ships in the ocean are difficult to trace

Background

Ships generate many waste streams that have traditionally been dumped into the ocean with limited traceability. This has changed over many decades and addresses treatment of overboard waste streams and retaining waste until discharge at a receiving terminal. But lingering issues remain, such as antifouling coatings, ballast water, and transfer of invasive species.

In addition to emissions from fuel, commercial shipping and other vessels emit other harmful pollutants in many forms, including bilge water, scrubber water, and ballast water; wastewater and food; metals from bio- and antifouling coatings; and invasive species. These waste products can result in algae blooms, damage habitats by releasing cleaning products or metals that can poison key parts of ecosystems and/or introduce new species into locations where they have no natural predators, causing them to dominate over local species. These pollutants are particularly challenging as damage occurs quickly and traceability is impossible due to the vast spatial dimensions, the multitude of pollutants, and the traffic volume.

Recommendations

1. **Develop regulations for controlling emissions, including mechanisms for levying fines, when needed.** These regulations should apply to vessels throughout their routes to help prevent the storage of waste to be dumped in areas with fewer regulations (policy, industry associations).
2. **Provide funding for the development and adoption of new technologies for reducing the volume of waste, cleaning or processing waste waters onboard the vessel, and supporting the handling of waste in ports.** Funding is also needed for research into transformative technologies to mitigate invasive species in ballast tacks, and nonleaching antifouling coatings (policy, academia, industry associations).
3. **Support the development of meaningful metrics for these waste emissions and mechanisms for tracing their sources when dumped illegally**.
4. **Introduce transparency programs that publicize companies who do and do not act in good faith so that reputational factors further drive compliance** (academia, policy).
5. **Address technology gaps.** Develop and implement solutions with respect to:
    a. Anti-invasive species in ballast tanks
    b. Safe antifouling coatings
    c. Monitoring equipment and software (for consistent reporting)
6. **Conduct better monitoring of large areas for dumping** (e.g., satellite oil dumping detection).

Case studies

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1. Marine protected areas (see Issue 9 of this chapter)
2. Invasive species
    a. Lake Tahoe—Multi-jurisdictional Coordination (US-based conservation)

    "Biological invasions are increasing in frequency and the need to mitigate or control their effects is a major challenge to natural resource managers. Failure to control invasive species has been attributed to inadequate policies, resources or scientific knowledge. Often, natural resource managers with limited funds are tasked with the development of an invasive species control program without access to key decision-support information such as whether or not an invasive species will cause damage, and what the extent of that damage may be. Once damages are realized, knowing where to allocate resources and target control efforts is not straightforward. Here we present the history of invasive species policy development and management in a large, multi-jurisdictional and multi-use aquatic ecosystem. We present a science-based decision-support tool for on-the-ground aquatic invasive species (AIS) control to support the development of a sustainable control program. Lastly, we provide a set of recommendations for managers desiring to make an AIS control implementation plan based upon our development of novel invasive species research, policy and management in Lake Tahoe (USA). We find that a sustainable invasive species control program is possible when science, coordination and outreach are integrated." (Wittmann et al., 2015)
3. Cruise ships
    a. Cruising Tourism Environmental Impacts (Marine tourism Dubrovnik, Croatia)

    "Cruise tourism is new economic, social and environmental phenomena with potential serious impacts on the three pillars of sustainability. This paper will look into the environmental impacts in order to disclose potential hazards in port of Dubrovnik. Subsequently, existing mechanisms to deal with the hazards will be analyzed to determine their effectiveness to mitigate the impacts. This process will use direct pollution costs calculations to enable cost benefit analysis. Other impact analysis will be conducted in form of environmental (pollution) foot printing that compare environmental loads of cruise tourist vs. local inhabitant. The two (cost benefit analysis and environmental foot printing) analysis will provide information on general aspects of cruise tourism carrying capacity and its current direction of development. Finally, the discussion will point to key pollution management issues, possible solutions to some of the pollution aspects, and stress other direct ecological threats." (Carić, 2011)

b. Cruise Ships Wastewater Pollution (Marine tourism Adriatic Sea):

"The global growth of cruise tourism has brought increasing concern for the pollution of the marine environment. Marine pollution from sanitary wastewater is a problem especially pronounced on large cruise ships where the number of people on board may exceed 8,000. To evaluate future marine pollution in any selected period of time it is necessary to know the movement of ships in the Adriatic Sea. This paper presents the problem of marine pollution by sanitary wastewater from cruise ships, wastewater treatment technology and a model of cruise ship traffic in the Adriatic Sea considering MARPOL Annex IV areas of limited wastewater discharge. Using the model, it is possible to know in advance the routes of the cruisers and retention time in certain geographic areas. The data obtained by this model can be used as input parameters for evaluation model of wastewater pollution or for evaluation of other types of pollution from cruise ships." (Perić, 2016)

c. Cruise Ship Waste Generation and Management (Marine tourism in Aegean Sea)

"In a medium-sized cruise ship, 140808 m3 of all types of waste is produced annually. A high amount of the waste volume (90 %) is legally discharged at sea. Minor quantities are disposed to port reception facilities (8 %) or incinerated (2 %). The waste management infrastructure at land in the Caribbean area is poor. Management of ship generated waste is a prerequisite for sustainable cruising." (Kotrikla, 2021)

Further resources

1. Green Marine. *Green Marine Environmental Program: Performance Indicators for Ship Owners 2022*. Green Marine Management Corporation, 2022.
2. Moldanová, Jana, Ida-Maja Hassellov, Volker Matthias, Erik Fridell, Jukka-PekkaJalkanen, Erik Ytreberg, Markus Quante et al. "Framework for the Environmental Impact Assessment of Operational Shipping." *Ambio* 51 (July 2022): 754–769.
3. Kalnina, Renate, Ieva Demjanenko, Kristaps Smilgainis, Kristaps Lukins, Arnis Bankovics, and Reinis Drunka. "Microplastics in Ship Sewage and Solutions to Limit Their Spread: A Case Study." *Water* 14, no. 22 (Nov. 2022): 3701.

Issue 12: Ubiquitous presence of micro- and macro-plastics in the ocean

Background

One of the biggest issues within ocean conservation is plastic pollution. It directly threatens marine life, affecting biodiversity and human health. According to the UN Environment Programme (UNEP), 8 million tons of plastic waste end up in the ocean every year and this could double by the year 2025 if drastic action is not taken (Torkington, 2011). Plastic is floating in rivers. Plastic can even be caught and collected out on the ocean. But there is more than just visible plastic waste. There is macro- and micro-plastic. Macro-plastics are objects visible to our eyes. Microplastics, however, are particles smaller than 5 mm (NOAA, “What Are Microplastics?”). They come either from clothing fibers or are a result of larger plastic items breaking down. These tiny particles are floating throughout the ocean and are even found in the ocean´s tiniest creatures, like plankton.

Plastic makes up 80% of marine debris and is caused by mismanaged plastics. One source is land based, typically from areas with poor waste management without a recycling system (TONTOTON). Single-use plastic items make up half of all plastics produced annually and likely form the largest part of the plastic pollution problem. The largest pollution coming from marine sources are from fisheries (ghost-gear), aquaculture, and nautical activities (UNESCO, 2021). A recent study in the Great Garbage Patch shows that around 80% of plastic waste originates from fishing activities (Egger, 2022).

Marine plastic debris is a direct threat to animal health and, therefore, impacts biodiversity, food safety and quality, human health, and coastal tourism. Plastic waste also contributes to climate change through the potential release of carbon dioxide when incinerated.

It can be difficult for an Individual to understand the full impact of their decisions on the ocean/environment. Considering the complete lifecycle of a product can also help measure the benefits of changes that might appear too expensive without a full understanding of the cost of the status quo: the financial, environmental impact, disposal impact etc, and other costs. This approach should be captured in two ways: by making companies responsible for the full lifecycle cost of products/materials they produce and profit from, and by making consumers aware of the impact of their use of products.

Recommendations

1. **Overhaul the use of plastics and management of waste to reduce the prevalence of macro- and micro-marine plastics, which directly threaten marine life, affecting biodiversity and human health**.
2. **Control urban waste to prevent plastic waste from entering bodies of water, including the ocean.** Urban waste management is a key issue for preventing plastic waste reaching the ocean carried by river systems and through direct coastal runoff to be carried to the ocean.
3. **Investigate the potential of bacteria for plastic waste treatment.** Plastic-eating bacteria may be able to decrease the microplastic waste (Cornwall, 2021).

4. **Prioritize waste management in municipalities and invest in regulations to support proper waste collection and disposal**.
5. **Model pollution drifting to determine where to focus both mitigation and cleanup efforts.** Modeling will help in understanding the impacts of plastics on human health and planetary health.
6. **Monitor fishing gear to prevent the loss of equipment and save costs and fuel while searching for it.**
7. **Carry out lifecycle analyses (LCAs) for plastics-based products and services, including their potential impact on the ocean**.
8. **Make consumers aware of the impact of the use of their products, as well as encourage them to participate in appropriate reuse/recycling programs at the end of use of their items.**
9. **Encourage and support collaboration and cooperation between countries.** Countries should join forces. Currently, too many different organizations promote ocean literacy. There should be a way to combine and interchange the knowledge of new and improved technologies as well as processes and data in an efficient, transparent and reliable manner. This should lead to faster adoption of more environmentally beneficial technologies and protocols.
10. **Further develop biodegradable fishing lines/gear (Bland, 2023).**
11. **Update policy and regulation in a timely and effective manner as newer more environmentally friendly technology becomes available** (e.g., biodegradable fishing gear and effective environmentally safe antifouling paint).
12. **Investigate the impact of microplastics.** A better understanding of the impact of microplastics is needed, especially related to the food chain (human health vs. planetary health).
13. **Consider a global treaty banning plastics or other measures that will ultimately stop** (non-biodegradable) **plastic waste from entering the ocean**.
14. **Research into alternative plastics should be encouraged** (e.g., biodegradable “plastic” solutions such as **this one** made from seaweed; see Canadian Plastics, “This Non-Toxic Biodegradable Plastic Film Is Based on Seaweed”).
15. **Intercept, collect, and remove plastic pollution in runoff, ditches, streams, and rivers, preferably using low-cost, low-tech solutions.**
16. **Develop, implement, and enforce common standards and regulations for recycling, collection, treatment, and composting of end-of-use plastics across communities, states, and countries**. In addition, data collection methodologies (like block chain) need to be developed to report on these activities: plastic waste reduction, recycling rates and other waste reduction measures. Moreover, producers should assume/share responsibility for supporting effective end-of-use material handling programs.

Case studies

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1. The Great Bubble Barrier

   "Bubble Barriers capture plastic in waterways with bubbles. We create a bubble curtain by pumping air through a perforated tube on the bottom of the waterway. The bubble curtain creates an upward current which directs plastic to the surface. By placing the Bubble Barrier diagonally across the river, the natural flow of the water will push the plastic waste to the side and into the catchment system.

   The catchment system is designed to work in harmony with the bubble curtain to collect and retain plastics. Following collection, it will be removed for processing and reuse.…

   The Bubble Barrier comprises three main components: the bubble curtain, the compressor, and the catchment system. The three components are designed to work together to create the optimum solution for each location." (The Great Bubble Barrier website)

2. Plastic Fischer

   Installing a boom system in rivers can be up to 300 times more cost-effective than fishing plastic out of the ocean.

3. Lonely Whale

   Lonely Whale has trained thousands of young leaders across dozens of countries and engaged tens of thousands more through the OH-WAKE Media Network at ohwake.org.

4. NextWave

   This organization focuses on considering plastic no longer as waste, but a valuable raw material for the circular economy. "Keeping plastics in the economy and out of THE ocean."

5. Global Plastic Innovation Network

   An innovative network to crowdsource innovations of high potential innovators to tackle plastic pollution.

6. Mi Terro

   Sustainable and durable bio-based materials for packaging, textiles, contact lenses, and other applications. Using biomaterials that can be returned to nature after used, reducing harm to the environment.

Further resources

1. Alliance to End Plastic Waste (website).
2. *Blueprint for Ocean Climate Action: Recommendations for the Ocean Policy Committee.* June 2022.
3. Global Plastic Action Partnership (GPAP) (website).[81]
4. Incubation Network (website).[82]
5. Ocean Literacy (website).

[81] GPAP is a multi- stakeholder platform dedicated to translating commitments to reduce plastic pollution and waste into concrete action.
[82] The Incubation Network sources, supports, and scales innovative solutions that tackle plastic pollution.

Issue 13: Management and the lack of global ocean data

Background

Most, if not all, solutions to key ocean issues are hindered by an enormous gap between the available data and the data needed to support management, evidence-driven policy, and responsible economic and technology development. High-quality data collection is essential to making effective and efficient marine operations easier, as well as to predicting ocean related hazards through modeling (Canada's Ocean Supercluster, "Port Integration").

Data have always been essential, especially for evidence-based decision-making. Data on sound, weather and GHG monitoring, salinity, current, and temperature can show the impact of climate change on the ocean (NESDIS). The most important issue regarding ocean data is to find a balanced way to collect and share data (HUB Ocean, "Data Catalog"). Thus, even if data get collected, there has to be a way to translate it into a common language so that every sector (science, technology, industry, policy) has access and can make use of the data. With increased levels of technology-based approaches to addressing sustainability challenges, there is an even greater need for data. For example, machine learning algorithms highly depend on high-quality ground-truth data to use to design the algorithms. Remote-sensing (aerial and satellite) data of the sea surface, combined with complex ocean models, have provided large improvements in understanding of ocean systems over the past few decades. Still, the fact that electromagnetic waves (light, radio, etc.) do not penetrate water well has left the interior of the ocean vastly undersampled. Remote sensing of ocean properties, from bathymetry to physical properties, to chemical and biological cycles, depends on local sampling methods. Even advanced autonomous systems rely on physically coming to the surface to communicate. All methods of underwater communication are extremely slow, short range, or both. Even above the ocean, there is no parallel to the vast sampling of the atmosphere over land.

As a result, large parts of the climate and ocean system depend on modeling based on sparse data.

Recommendations

1. **Urgently narrow the data gap about the ocean.**
2. **Prioritize the collection of relevant ocean data points.**
3. **Use open-source data repositories, or if need be, create a common language for data sharing, for example, the IEEE Data Port.**
4. **Train scientists in how to collect and mine relevant and useful marine data.**
5. **Build machine learning models to recognize potential solutions and unseen problems.**
6. **Design causal learning models.**
7. **Invest in computational capabilities and make these resources more accessible.**

Case studies

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1. "The World Meteorological Organization (WMO) Executive Council has endorsed plans for a new Global Greenhouse Gas Monitoring Infrastructure to fill critical information gaps and support action to reduce heat-trapping gasses, which are fueling temperature increases." (UNEP, "Spotlight on Climate Action")
2. The Ocean Data Platform—HUB Ocean: Data: An open collaborative tool that unlocks and aggregates ocean data to encourage scientific collaboration, industry transparency, and layered analysis.
3. Port Integration and Enhancement of Data Project—Canada's Ocean Supercluster: Shows the importance of data through artificial intelligence to support economic growth both as an ocean transport hub and as a software hub.
4. Ellipsis Earth Ltd: To detect patterns of litter behavior through detailed monitoring and the ability to identify more than 47 types of litter. This technology identifies trends, measures impact, and targets critical hotspots. It can help to demonstrate direct success or failure of solutions by allowing for more efficient spending with less wasted time and money and eliminating greenwashing.

Further resources

1. Aliaga, Bernardo, Ward Appeltans, Rick Bailey, Julian Barbiere, Mathieu Belbeoch, Aileen Bohan, Elisabetta Bonotto, et al. Edited by Henrik Enevoldsen, Kirsten Isensee, and Ikroh Yoon. *State of the Ocean Report 2022*. Paris: UN Educational, Scientific and Cultural (UNESCO) Intergovernmental Oceanographic Commission, 2022.
2. Fugro. "Ocean Science Initiatives."
3. HUB Ocean (website).
4. MarineBio. "Marine Conservation."
5. National Ocean Service. "Ocean Facts: Our World Ocean."
6. National Centers for Environmental Information. "World Ocean Database." NOAA.
7. Ocean Frontier Institute. "Ocean Data & Technology."
8. Ocean Insight (website).
9. Schmidt Ocean Institute. "Data Management."
10. Seabed 2030. The Nippon Foundation-GEBCO Seabed 2030 Project.[83]
11. Valentine, Katie. "NOAA Collects a Lot of Data on the Ocean. Here Are 4 Ways We Use It." *NOAA Research News.* 8 June 2020.

[83] Seabed 2030 is working to create partnerships with industry and gain contributions of privately held data. Also note there is a new Ocean Decade committee for data coordination with industry.

12. "WMO Executive Council Endorses Global Greenhouse Gas Monitoring Plan." World Meteorological Organization, 6 Mar. 2023.
13. Woods Hole Oceanographic Institution. "Data & Repositories."

References

1. Arcanjo, Marcus. "Has Climate Change Rendered the Concept of Sovereignty Obsolete?" Washington, DC: Climate Institute, Jan. 2019.
2. Bland, Alastair. "Biodegradable Fishing Gear Isn't Good Enough." *Hakai Magazine*, 14 Sept. 2023.
3. Bureau Veritas. "Powering Marine Decarbonization with Wind-Assisted Propulsion." Marine & Offshore.
4. Canada's Ocean Supercluster. "Port Integration and Enhancement of Data Project."
5. Canadian Plastics. "This Non-Toxic Biodegradable Plastic Film Is Based on Seaweed." 1 Feb. 2021.
6. Carić, Hrvoje. "Cruising Tourism Environmental Impacts: Case Study of Dubrovnik, Croatia." *Journal of Coastal Research*, no. 61 (Oct. 2011): 104–13.
7. Center for Food Safety and Applied Nutrition. "Tracking and Tracing of Food." US Food and Drug Administration. Accessed 11 May 2023.
8. Comer, Bryan. "Choose Wisely: IMO's Carbon Intensity Target Could Be the Difference Between Rising or Falling Shipping Emissions This Decade." *The International Council on Clean Transportation (ICCT)* (blog). 18 May 2021.
9. Cornwall, Warren. "The Plastic Eaters: Bacterial Enzymes Can Digest Some Plastic Waste. Scientists Warn to Harness Them for Recycling." *ScienceAdviser,* 1 Jul. 2021.
10. Dalili, Nadia, Miako Ushio, and Aurelie Cosandey-Godin. "Mitigating Shipping Impacts on Cetaceans in Canada: Lessons Learned and Best Practices." WWF-Canada, Dec. 2020.
11. Dasgupta, Shreya. "The Ups and Downs of Marine Protected Areas: Examining the Evidence." Mongabay, 25 Jan. 2018.
12. Egger, Matthias. "The Other Source: Where Does Plastic in the Great Pacific Garbage Patch Come from?" The Ocean Cleanup, 1 Sept. 2022.
13. Farhan, Aulia Riza, R. Bambang Aditya, Dendi Mahabror, Romy Ardianto, and Kalu Nicolaus Naibaho. *Calculation Model of Economic Losses Due to Illegal Fishing Activities in Indonesian Territorial Waters.* Indonesia Marine Fellows Program Report, 2018.
14. Figueres, José María. "Here's How We Can Reduce Shipping Industry Emissions." World Economic Forum, 23 Oct. 2020.
15. Gedamke, J., J. Harrison, and L. Hatch. "Ocean Noise Strategy Roadmap." NOAA, 2021.
16. Gold, Zachary, Joshua Sprague, David Kushner, Erick Zerecero Marin, and Paul Barber. "eDNA Metabarcoding s a Biomonitoring Tool for Marine Protected Areas." *PLoS ONE* 16, no. 2 (Feb. 2021).
17. Goyal, Tanishk, and Dhruv Gupta. "Sea Level Rise and Its Implications in International Law." OpinioJuris, 9 Apr. 2020.
18. Green Marine. "Certification, Results." Accessed 12 Mar. 2023.
19. Guterres, António. "Foreword." In *The Second World Ocean Assessment, Vol. 1*. New York: United Nations, 2021.
20. HUB Ocean. "Data Catalog."
21. IPCC. "Summary for Policymakers." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. V.

Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds. Cambridge and New York: Cambridge University Press, 2021.

22. IPCC. "Summary for Policymakers." In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer, eds. Cambridge and New York: Cambridge University Press, 2019.
23. Kempener, Rudd, and Frank Neumann. "Salinity Gradient Energy: Technology Brief." *IRENA Ocean Energy Technology Brief* 2 (June 2014).
24. Kirstein, Lucie, Ronald Halim, and Olaf Merk. *Decarbonising Maritime Transport: Pathways to Zero-Carbon Shipping by 2035*. Paris: The International Transport Forum, 2018.
25. Kotrikla, Anna Maria, Alexandros Zavantias, and Maria Kaloupi. "Waste Generation and Management Onboard a Cruise Ship: A Case Study." *Ocean & Coastal Management* 212 (Oct. 2021).
26. Lindsey, Rebecca. "Climate Change: Global Sea Level." NOAA, Climate.gov. 19 Apr. 2022.
27. Living Seawalls (website).
28. Lloyd's Register. "Zero-Carbon Fuel Monitor: Findings." Maritime Decarbonisation Hub.
29. Marine Stewardship Council (MSC). *Get Certified: Your Guide to MSC and ASC Chain of Custody Certification Process.* 2019.
30. Masterson, Victoria. "What to Do with Ageing Oil and Gas Platforms—And Why It Matters." World Economic Forum, Energy Transition, 2 Apr. 2024.
31. Maxwell, Sean L., Richard A. Fuller, Thomas M. Brooks, and James E. Watson. "Biodiversity: The Ravages of Guns, Nets and Bulldozers." *Nature* 536, no. 7615 (2016).
32. Morgan, James. "Effects of Marine Protected Areas." *World Wildlife*, Fall 2016.
33. National Environmental Satellite Data and Information Service (NESDIS), NOAA (website).
34. NOAA. "What Are Microplastics?" Facts.
35. O'Hara, Casey C., Melanie Frazier, and Benjamin S. Halpern. "At-Risk Marine Biodiversity Faces Extensive, Expanding, and Intensifying Human Impacts." *Science* 372, no. 6537 (2021): 84–87.
36. Perić, T., P. Komadina, and N. Račić. "Wastewater Pollution from Cruise Ships in the Adriatic Sea." *Promet* 28, no. 4 (2016): 425–33.
37. Peterson, Greg, Chanwoo Bae, and Derek White. "A BC Ferries Case Study: Lessons Learned In Setting." MarineLink, 27 Apr. 2021.
38. The Pew Charitable Trusts. "The Case for Marine Protected Areas: A Way to Safeguard Biodiversity, Bolster Fisheries, and Protect Ocean Habitat."
39. Port of Vancouver, Vancouver Fraser Port Authority. "EcoAction Program." Climate Action at the Port of Vancouver.
40. Scott, Michon, and Rebecca Lindsey. "Unprecedented 3 Years of Global Coral Bleaching: 2014–2017." NOAA, Climate.gov. 1 Aug. 2018.
41. TONTOTON (website).

42. Torkington, Simon. "These Innovations Are Pulling Plastic Pollution Out of Rivers to Stop It Reaching Our Ocean. Here's How." World Economic Forum, Feb. 2011.
43. UN. "Trends in the Physical and Chemical State of the Ocean." Carlos Garcia-Soto, Levke Caesar, Anny Cazenave, Lijing Cheng, Alicia Cheripka, Paul Durack, Karen Evans, David Halpern et al., contributors. Chp. 15 in *The 2nd World Ocean Assessment: World Ocean Assessment II*, vol. II. New York: United Nations, 2021.
44. UN Convention on the Law of the Sea (UNCLOS). "Outer Limit of the Territorial Sea." Art. 4.
45. UN Educational, Scientific and Cultural Organization (UNESCO). *State of the Ocean Report 2022: Pilot Edition*. IOC, Technical Series, 173. ICO/2022/TS/173. 2022.
46. UN Educational, Scientific and Cultural Organization (UNESCO). *UN Decade of Ocean Science for Sustainable Development, ECO Special Issue*. 2021: 15.
47. UN Environment Programme (UNEP). "Spotlight on Climate Action." News.
48. UN Food and Agriculture Organization (FAO). "The Status of Fishery Resources." The State of World Fisheries and Aquaculture 2022, Part 1, World Review. 2022.
49. UN Office of the High Representative for the Least Developed Countries. "About Small Island States." Landlocked Developing Countries and Small Island Developing States.
50. Wittmann, Marion E., Sudeep Chandra, Kim Boyd, and Christopher L. Jerde. "Implementing Invasive Species Control: A Case Study of Multi-Jurisdictional Coordination at Lake Tahoe, USA." *Management of Biological Invasions* 6, no. 4 (Oct. 2015): 319–328.
51. World Economic Forum. "First Movers Coalition." Accessed 12 Mar. 2023.
52. World Meteorological Organization (WMO). "The State of Greenhouse Gases in the Atmosphere Based on Global Observations Through 2020." *WMO Greenhouse Gas Bulletin*, no. 17 (Oct. 2021).
53. ZoBell, Vanessa M., Kaitlin E. Frasier, Jessica A. Morten, Sean P. Hastings, Lindsey E. Peavey Reeves, Sean M. Wiggins, and John A. Hildebrand. "Underwater Noise Mitigation in the Santa Barbara Channel through Incentive-Based Vessel Speed Reduction." *Scientific Reports* 11, no. 18391 (Sept. 2021).

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CHAPTER 9: FARMLANDS AND GRASSLANDS, MOUNTAINS AND PEATLANDS

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FARMLANDS AND GRASSLANDS, MOUNTAINS AND PEATLANDS

Committee Members

Committee Co-Chairs:

- Elliot David, Miami, FL, United States
- Colleen Kirtland, Santa Ana, CA, United States
- Dr Stéphanie Camaréna, Melbourne, Australia

Committee Members:

- Cyrus Hodes, Miami, FL, United States
- Ran Liu, Palo Alto, CA, United States
- Norman Mugisha, Rwanda

While he is not on our committee, members would like to extend a special thanks to Steven Nitah, chief of the ŁútsëlK'é Dene First Nation, for providing a compass of the heart.

FARMLANDS AND GRASSLANDS, MOUNTAINS AND PEATLANDS

"We are one with nature. We are not above it or separate from it."

—Steven Nitah, chief of ŁútsëlK'é Dene First Nation

Future Vision

It is 2030.

Society has recognized and continues to recognize that the need to bring all humans together to care for the lands required immediate collective action/requires ongoing action. As U.S. environmentalist Paul Hawken said, "The first rule of sustainability is to align with natural forces, or at least not try to defy them."[84]

With support from the public, businesses, and governments, now in 2030, one-third of all farms have transitioned to regenerative agriculture practices. Societies no longer seek to exploit land for short-term profit but rather to better understand their role as healers of the land. Forests are recognized as life-sustaining ecosystems. Rather than cutting forests down, communities harvest only what the product/what they need. As a result, a significant boost in biodiversity has been measured across farmlands, forests, and the adjoining grasslands. People enjoy safe and tasty food grown in healthy, naturally regenerated soil. Soil carbon sequestration and the reduction of greenhouse gas (GHG) emissions have increased the overall value of the farms that made the transition. Furthermore, these farms have also reduced the costs of fuel and fertilizers, which have impacted the rest of the agricultural sector in the past decades. In 2030, ties have been established between the communities and land stewards, creating relationships that are co-caring versus transactional.

[84] Quote shared by Paul Hawken at a Real Organics Project online event on 22 April 2022.

Introduction

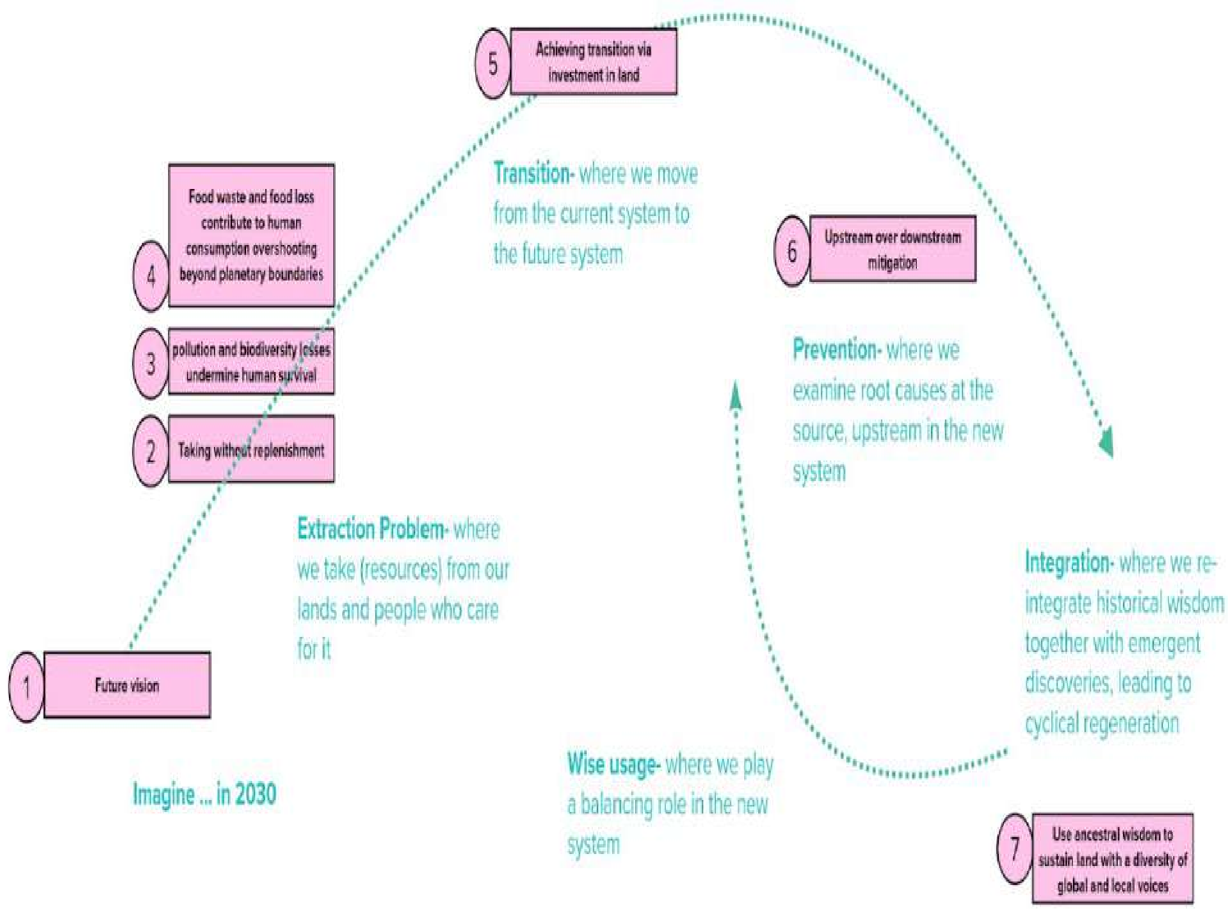

Figure 1: Structure of the Chapter in a Visual Format to Describe the Need for Integration and Reflection

Issue 1: Extraction—Taking without replenishment

Background

Changes in land use—deforestation, land clearing, mining, and depletion of freshwater resources—are a major driver of climate change and are often unsustainable. Plantation models persist in industrialized agriculture, leading to human labor exploitation (Gregor, 1962).

A high degree of correlation exists between resource aggregation into the hands of a few (consolidation of land and water rights) and human exploitation in terms of migrant wage labor, which has a direct impact on community health and economy, as follows (Hayes & Olmstead, 1984):

- Energy production relies on exploitation of resources that has left some areas inhabitable. Renewable energy production can have similar impacts on the environment (Sonter et al., 2020).
- Progress to safeguard key biodiversity areas has stalled during the last five years and without combined efforts in sustainable production, consumption and land use measures and the protection of key biodiversity areas, the loss of species will not turn around before 2050 (Whiting, 2022; Bingham et al., 2021).
- Invasive alien species have negatively affected native biodiversity, human health, and have cost the global economy billions of dollars annually (Rai & Singh, 2020).
- "Between 2015 and 2020, the rate of deforestation was estimated at 10 million hectares per year, down from 16 million hectares per year in the 1990s. The area of primary forest worldwide has decreased by over 80 million hectares since 1990" (UN FAO & UNEP, 2020).
- Climate and ecosystem change has been accelerated by unsustainable practices and has contributed to the increased prevalence and intensity of extreme weather events—such as droughts and floods—and of damaging invasive species—such as locusts—all of which are devastating to land stewards and farmers.
- An economically overdeveloped society has created unnecessary needs driving overconsumption. Gross domestic product (GDP) measures economic growth, which does not capture the complexity of the extractive models on which many societies have been based.
- The complexities behind intangible services have not been sufficiently questioned and, therefore, have not been resolved (e.g., software and cost on the environment).

Recommendations

1. **Set targets for soil carbon sequestration**:
    a. **Scale up and implement sustainable soil carbon sequestration practices** (Amelung et al., 2020)
    b. **Work toward valuation of natural capital** (EU, "Natural Capital Accounting")

2. **Support healthy and sustainable diets** (Willet et al., 2019):
    a. **Reduce meat consumption and land clearing and deforestation linked to grazing**
3. **Manage farms as systems**:
    a. **Establish nitrogen and phosphate cycles as a system rather than within the boundaries of the farm only**
4. **Lift the pressure of protein demand from animal raising**:
    a. **Promote alternative proteins such as cultivated, plant-based, and fermented protein**
    b. **Encourage protein diversity for health and nutritional balance**
    c. **Liberate freshwater reservoir and arable pasture land for regenerative agricultural development**
5. **Support technologies that provide alternatives to traditional farming products in restoration of biodiversity**:
    a. **Replace animal leathers and wooden products with novel materials (e.g., fermentation-derived materials)**
    b. **Support research and development of cultivated meat in replacement of traditional animal meat**
6. **Reduce the need for resources in the design phase of products to reduce or eliminate the need for extraction of resources**:
    a. **Design for durability (e.g., long-lasting items)**
    b. **Design as a circular system (e.g., zero waste of resources and use materials in the loop)**
    c. **Design for modularity (easy to reuse or recycle parts)**
    d. **Design with interoperability (reduce the need to upgrade equipment or to have "proprietary" parts)**
    e. **Use low-tech materials**
    f. **Think "fixable and repairable" (including adopting behavior around maintaining rather than replacing)**
    g. **Design services or product-service systems rather than products**
7. **Optimize the extraction processes:**
    a. **Prepare graduating and practicing engineers to be knowledgeable about and understand the critical issues faced by land-based ecosystems—these issues are key drivers of the climate crisis.**
    b. **Decrease energy usage, and promote the usage of renewable energy.**
    c. **Look to additive manufacturing as a default process.**
    d. **Mine the waste streams (decades have been spent throwing away valuable materials that took energy and resources to mine and process).**

8. **Support behavioral change to reduce the need for resources**:
    a. **Maintain rather than replace.**
    b. **Be responsible owners and have respect for what individuals own or what people share.**
    c. **Consume less.**
    d. **Encourage a sharing economy.**
    e. **Avoid tragedy of the commons.**
    f. **Change advertisement guidelines to encourage sustainable lifestyle (e.g., fashion, energy, sharing, and repairing).**

Further resources

1. Nishitani, Makiko, Martina Boese, and Helen Lee. "The Production of Precariousness and the Racialisation of Pacific Islanders in an Australian Horticultural Region." *Journal of Ethnic and Migration Studies* (Feb. 2023).
2. O'Connell, Daniel J., and Scott J. Peters. *In the Struggle: Scholars and the Fight Against Industrial Agribusiness in California.* New York: New Village Press, 2021.
3. Shamoon, Ahmad, Abid Haleem, Shashi Bahl, Mohd Javaid, Sonu Bala Garg, Rakesh Chandmal Sharma, and Jatinder Garg. "Environmental Impact of Energy Production and Extraction of Materials—A Review." *Materials Today: Proceedings* 57, pt. 2 (2022): 936–941.
4. Sun, Zhongxiao, Paul Behrens, Arnold Tukker, Martin Bruckner, and Laura Scherer. "Global Human Consumption Threatens Key Biodiversity Areas." *Environmental Science & Technology* 56 (May 2022): 9003–9014.

Issue 2: Extraction—Pollution and biodiversity losses undermine human survival

Background

Pollution, including from farming, reduces yields and food safety. Extraction from the land can leave dead zones, undermining current and future generations' ability to thrive. Climate change, population, and land use have profound impacts on the security of the global food supply chain (Molotoks et al., 2020; IPCC, 2019).

Farmlands (Boeraeve et al., 2020) and grasslands (Sun et al., 2022) are vital ecosystems. They supply food, fiber, and fodder and host countless organisms. However, degrading soil and vegetation, and excess agrochemicals and other pollutants deplete their vitality (Tilman, 1999; FoodPrint, "Food and the Environment").

Intensification of farmland is increasing. "Small farms (i.e., less than 2 ha) account for 84% of all farms worldwide; they operate on about 12 percent of all agricultural land but produce roughly 35% of the world's food" (UN FAO, *The State of the World's Forests 2022*, p. 78). "The largest 1% of farms (those larger than 50 ha) in the world operate more than 70% of the world's farmland" (Lowder, Sanchez, & Bertini, 2021).

Grasslands are one of the most widespread of all major vegetation types in the world. They occur in environments conducive to the growth of this plant cover but not that of taller plants (Smith, 2020). Ongoing degradation and the capacity to support biodiversity, ecosystem services, and human well-being place them under severe threat (Bardgett et al., 2021).

Policy decisions are often not anchored in research and may disregard long-term consequences for the environment, biodiversity, and people. Short-term goals were sometimes not questioned until it was too late to avoid negative impacts:

- Agricultural practices contribute to aquatic dead zones (Bailey et al., 2020) and negatively affect soil bacterial communities (Hhmelevtsova et al., 2022).
- Excessive tilling has been proven to cause soil erosion, but organic farms have been using light tillage for years to circulate organic matter back into the soil. There is a push in some developed countries to move farmers toward "no-till" practices. However, "no-till" outside of organic agriculture includes the termination of cover crops with herbicides, along with the continued use of synthetic fertilizers and pesticides (Real Organic Project, "Real Organic Symposium 2023").

Pollution is bad for both security and safety as it does the following:

Pollution affects supply, yield, and security:

- Ammonia, nitrogen (affecting soil)
- Ozone (reducing plants' ability to develop)
- "Black carbon (BC) is produced from incomplete combustion of biomass and fossil fuels and persists for centuries to millennia in the environment" (Coppola et al., 2022)

Pollution affects safety:

- "Forever chemicals" and "everywhere chemicals"
- Microplastics
- Pesticides
- Herbicides
- Fertilizers
- Runoff from animal waste
- Machinery (e.g., oil, gas, diesel, industrial lubricants, and coolants)

Recommendations

1. **Provide education to reach farmers, and co-design with them a shift from industrial agriculture models to regenerative agricultural models.**
2. **Offer incentives to allow the transition to regenerative farming practices**:
    a. **Increase lands farmed organically by 25%**
    b. **Reduce pesticide use by 50%**
    c. **Reduce fertilizer use by 20%**
    d. **Reduce use of antibiotics for livestock use by 50%**
    e. **Create residue-free foods:**
        i. **Find non–oil-based alternatives to pesticide and fertilizers**
3. **Provide funding for regenerative agricultural, conservation, and sustainable farming-related projects**:
    a. **Secure funding for transition**
    b. **Use total cost of ownership over decades**
4. **Offer tools for soil and water regeneration, solutions, frameworks, and markets for farmers**:
    a. **Set targets for regenerative and organic content in institutional food programs**
5. **Implement a cross-industry, closed-loop farming system**:
    a. **Up-cycle waste from partnering food and beverage industries to use leftovers as fertilizer to reduce the need for, and costs of, chemical fertilizer**
    b. **Form a direct communication channel between farmers and retailers to exchange information about harvest conditions and market demand**
    c. **Implement limits on ground water use to preserve optimum water tables**

6. **Organize responsibility at various levels for protecting the land that recognizes the land as nature rather than as industry. Hold these bodies accountabl**e:
    a. **Define and use indicators other than GDP, which may be more appropriate indicators of a successful society**
    b. **Include long-term and future generations in decision-making processes**
    c. **Develop methods to anticipate consequences of decisions**
    d. **Find methods for staying calm in the face of problems that arise and for educating the public on the long-term benefits of change such as to reduce pollution and practice regenerative farming.**

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Air Pollution and Food Production

   UNECE Sustainable Development Goals. "Air Pollution and Food Production." UNECE, Environmental Policy, Air Pollution.

   > *"[Ammonia and nitrogen compounds affect] soil quality and thus the very capacity of the soil to sustain plant and animal productivity."*
   >
   > *"Ozone precursor emissions (nitrogen oxides and volatile organic compounds) are of particular concern for global food security as these compounds react to form ground-level ozone. This, in turn, penetrates into the plant structure and impairs its ability to develop. Ozone was estimated to cause relative global crop losses for soy 6-16%, wheat 7-12% and maize 3-5%. At a European level, a study in 2000 of the economic losses due to the impact of ozone on 23 crops amounted to 6.7 billion Euros."*

2. Short-Lived Climate Pollutants and Food Security

   Climate & Clean Air Coalition. "Short-Lived Climate Pollutants and Food Security." About SLCPs, Benefits of Action, Food Security.

   > *"A warmer climate adds many challenges to food production. There is an increase in pests and diseases, and more frequent and extreme droughts and floods. Heat stress causes poor yields, or worse, crop failures. Together these impacts put pressure on domestic and global food systems and increase the likelihood of supply chain disruptions and competition for increasingly limited resources."*
   >
   > *"Air pollution stunts crop growth by weakening photosynthesis. Tropospheric ozone alone causes annual losses of approximately 110 million tonnes of major staple crops: wheat, rice, maize and soybean. This represents around 4% of the total annual global crop production, and up to 15% in some regions."*

"Black carbon (a component of fine particulate matter or PM2.5) also harms crops when it covers their leaves, where it absorbs more sunlight and increases the plant's temperature. While in the atmosphere, black carbon affects plants by reducing the amount of sunlight that reaches the earth and disrupting rainfall patterns."

3. Special Report—Climate Change and Land

IPCC. Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H. -O. Pörtner, D. C. Roberts, P. Zhai et al., eds. In press. 2019.

"Four pillars of food security: availability, access, utilization, and stability"

"Observed climate change is already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events."

4. Roundup Lawsuit Update August 2022

Gaines, Mari. "Roundup Lawsuit Update." *Forbes Advisor,* updated 2 Feb. 2024.

"Studies have shown that the chemical might cause illness to humans and cause damage to the environment. The International Agency for Research on Cancer categorizes glyphosate as possibly carcinogenic to humans—essentially, the IARC is saying this toxin may cause cancer."

"A study from the University of Washington found that exposure to glyphosate increased an individual's risk of non-Hodgkin's lymphoma by 41%."

"The CDC recently released findings that up to 80% of Americans may have traces of Roundup in their urine, showing they have been exposed to it. Considering that 200 million pounds of Roundup are sprayed annually on U.S. crops, it is not surprising most of the population has been exposed to it."

5. Microplastics in Food

Alexis, Amber Charles. "What Do We Know About Microplastics in Food?" *Medical News Today*, 18 Feb. 2022.

"The microplastic chemicals present in food are a mixture of those that manufacturers deliberately add, such as fillers and stabilizers, and those that accumulate as byproducts, such as residues and impurities."

"Using eco-friendly packaging reduces Trusted Source the exposure to and migration of microplastics in the food supply."

Further resources

1. Hilimire, Kathleen, Sean Gillon, Blair C. McLaughlin, Brian Dowd-Uribe, and Kate L. Monsen. "Education Programs." *Agroecology and Sustainable Food Systems* 38, no. 6 (19 May 2014): 722–743.
2. Lindwall, Courtney. "Industrial Agriculture Pollution 101." NRDC. Updated 21 July 2022.
3. Ritchie, Hannah, Pablo Rosado, and Max Roser. "Environmental Impacts of Food Production." Our World In Data (online resource). 2022.
4. Smith, Jeremy M. B. "Grassland" in *Encyclopedia Britannica*, 13 Mar. 2020. Accessed 30 June 2022.
5. UN Environment Programme (UNEP) and the Food and Agriculture Organization (FAO) of the United Nations, UN Decade on Ecosystem Restoration. *Ecosystem Restoration Playbook: A Practical Guide to Healing the Planet*. Developed for World Environment Day 2021.

Issue 3: Extraction—Food waste and food loss contribute to human consumption overshooting beyond planetary boundaries

Background

As human consumption grows, immense pressure is placed on existing ecological safe havens, particularly rainforests, to yield to economic pressures. Transitioning from current to sustainable future systems means tackling food loss and food waste as a priority.

The need to feed 9 billion people by 2050 is pushing a rethink of the type of diets society/ies should adopt to operate within the capacity of the planet and to support a healthy population (Willett et al., 2019). Furthermore, food waste globally stands at more than 30%, representing a waste of 25% of all the water used by agriculture and 8% of global GHG emissions (Champions 12.3).

Current models in countries where sprawling suburbs encroach on arable lands, grasslands, and forests are not sustainable.

Recommendations

1. **Prioritize reduction of food loss.** Food loss and food waste mean that greater than 25% of all food produced globally is wasted before it reaches the people it needs to feed. Reducing food loss and food waste should help alleviate poverty, generate benefits for women, avoid agricultural expansion into natural ecosystems, reduce GHG emissions, and avoid depletion and/or pollution of aquifers (Goodwin, 2023).
2. **Severely limit the use of arable lands, grasslands, and forests for infrastructure builds, such as residences and industrial structures**.

Issue 4: Transition—Lack of investment in land sustainability

Background

Smallholder farmers lack access to capital, resources, stable markets, and general infrastructure to develop sustainable practices and build agro-economies. Transitioning to and scaling sustainable farming is fraught with challenges.

Farming is often inaccessible to new entrants who may have new ideas or more sustainable approaches. Smallholder farmers do not have the same level of access to technologies that boost productivity and crop resilience.

Smallholder farmers face the following economic challenges that can put their livelihood at risk:

- *Technology:* Many smallholder farmers do not have access to smartphone technologies, which makes it difficult to access markets for their agricultural produce.
- *Capital:* Traditional financial institutions may not be accessible to smallholder farmers, which can disable their ability to invest in more sustainable agricultural practices.
- *Markets:* Local and smallholder farmers often walk several kilometers to reach the market, carrying their produce. They can lose up to 40% of their harvest during the postharvest.
- *Capacity:* Most smallholder farmers across the developing world still practice subsistence farming versus sustainable agricultural practices (Alexander, 2020).
- As rural poverty increases, young people are driven into cities in search of employment, further deepening poverty cycles in the rural areas and increasing the difficulty of community revitalization.
- In some countries, "agriculture continues to be the main source of employment, livelihood, and income for between 50% to 90% of the population. Of this percentage, small farmers make up the majority, up to 70% to 95% of the farming population" (Kwa, 2021).

Transitioning farming practices is a risky business. For instance, how are the immediate cost hurdles addressed? Furthermore, climate change solutions are about scale, and smallholder farmers are a fragmented sector. Economic incentives are needed to encourage the shift to sustainable agriculture.

Food is produced within business models that may be incompatible with net-positive impacts and meaningful environmental, social, and corporate governance. Industrialized agriculture and shareholders are not incentivized to change practices, leading to a lack of scale in transitions. Consumers may have an illusion of choice when, in effect, 70% to 80% of grains are produced by only four companies globally and 60% of agricultural seeds and agricultural chemicals are produced by just three companies (Lakhani, Uteuova, & Chang, 2021). A change in the concentration of suppliers may be as, or more, important than changes made by individual consumers.

Recommendations

1. **Mobilize capital more efficiently by using surgical microfinance on subnational and community-based levels:**
    a. "Research from the *World Development Journal* found agricultural growth to have two to three times more impact on poverty reduction than equivalent growth in other industries" (Zamarelli, 2020)
    b. Community-based capital allocation can help remove intermediaries so that more resources go to farmers and land stewards.
    c. More capital in the hands of smallholder farmers can help de-risk their agribusiness and inspire innovation.
2. **Concentrate efforts to bridge the digital divide and alleviate energy poverty for smallholder farmers and rural agricultural communities by enabling technologies such as mobile phones, decentralized finance, and microgrids:**
    a. Giving smallholder farmers access to information about buyers and sellers through the internet can increase their revenues and reduce inefficiencies.
    b. Decentralized finance and peer-to-peer lending would decrease smallholder farmers' reliance on external (and sometimes misaligned) actors and unlock new avenues of sustainable agribusiness financing.
    c. Tapping into the abundant clean energy potential for smallholder farmers and providing reliable electricity access can serve as a foundation for other enabling technologies.
3. **Invest in human capital development for rural agrarian communities along with skills promotion and technology integration**:
    a. Given the opportunity, smallholder farmers can pursue sustainable farming practices and develop innovative methods.
    b. Increased human capital and training helps smallholder farmers de-risk their subsistence operations and could provide sufficient incentive to adopt more sustainable practices.
    c. Investing in human capital enables knowledge transfer within communities, across subsectors, and between generations.
    d. Helping smallholder farmers adapt to and integrate new technologies further reduces their reliance on external parties and induces exponential and network effects.
4. **Develop and enforce regulation for transition of farming practices for all types of farming to ultimately achieve sustainable farming with net-positive impacts and meaningful environmental, social, and corporate governance for the farming sector.**
5. **Incentivize the transition of farming practices to more regenerative sustainable farming models for industrialized agriculture and shareholders as well as smallholder farmers.**
6. **World agricultural seed and supply production should not be held by a small number of global monopolies.**
7. **Food production should be distributed around the globe and over a plethora of producers. This can improve diversity and help mitigate risks**.

Further resources

1. Harvey, Fiona. "Food Price Rises Around the World Are Result of 'Broken' System, Say Experts." *The Guardian*, 24 Aug. 2022.

Issue 5: Environmental degradation—Upstream over downstream mitigation

Background

Environmental degradation and climate change have a far-reaching impact not only "on the land" but also on the landholders, the food supply system, the consumer, all the way to the insurance industry.

Consumers are often unaware of the impact their decisions have on land sustainability. The cost of environmental degradation is sometimes invisible to consumers, and they may be unaware of how their choices impact the environment. How do societies bring that to the center of consumers' everyday decisions? An extreme lack of transparency often exists regarding food systems.

The root causes of degradation should be examined at the source, upstream, in new systems and communicated within the entire food system. Transparency, traceability, and informed consumers could support high levels of prevention and mitigation to reduce negative impacts on lands before they happen.

Environmental degradation puts food production at risk, as do severe weather events. The insurance industry is well aware of the increased risks associated with food production. It requires oversight prior to any projects being initiated. With an increase in natural disasters, higher variability in local weather, and negative impacts on crop yields globally, the impacts of climate change in particular are generating large increases in insurance costs (Beam, 2023; Garthwaite, 2021) to the point where some areas are becoming uninsurable (Climate Council, 2022). The threat to agriculture risks undermining food security. Farmers can help build long-term resilience to climate change by changing farming practices, and the insurance industry can enable these efforts by supporting climate-smart projects.

In general, although cleaner production of goods of any kind and reduction of waste postproduction is increasingly being questioned, levels of consumption are rarely discussed. For example, consumers are told that they need to replace cars with fossil-fuel combustion engines with electric vehicles without contemplating the need to use cars at all or without considering the overall impact of producing and operating electric cars versus the lower overall GHG emissions. Information about such considerations is often lacking or, at a minimum, poorly communicated to the consumer.

Recommendations

1. **Identify the root causes of ecosystem degradation, and address the root causes; practice upstream mitigation.**
2. **Help consumers and purchasers become more well informed by providing easy access to information, communicating extensively and practicing transparency and traceability.**
3. **As a consumer, take responsibility.** Consumers are powerful:
   - **Start small by asking where food comes from.**
   - **Consider shopping at a local farmers market if it is near.**
   - **Plan for healthy meals.**

- **Try to reduce the amount of food waste.**
- **Research what labels such as "USDA Organic" really mean.** What kind of production and distribution practices are used to produce organic food? For example, USDA Organic fruits and vegetables no longer need to grow in soil to be labeled organic.
- **Protect the farming sector**—large farming operations and small landholders—by providing appropriate insurance tools:
- To keep the farming community operating during times of increased risks, **make protection through insurance available to cover against losses** that could require resupplying of planting materials, loan reductions, and forgiveness. Provide yield-based insurance (One Acre Fund, 2022).

4. **Industries such as banking and insurance have a role to play in identifying the damage as they assess it prior to providing the green light for implementation or for funding**. **Iterative engagement with the insurance industry is needed to adapt the metrics used to approve or deny projects swiftly enough to capture the urgency of the challenges that are faced.** Many of the key tenets of *strong sustainability by design* defy easy measurement, and that ambiguity does not lend itself to actuarial modeling. **An iterative dialogue with insurance experts should enable an adaptive framework on which to build many of the solutions recommended in this chapter.**
5. **Support climate-smart agriculture** (World Bank Group, 2024).
6. **Consider friendshoring in the supply chain with like-minded communitie**s (Ellerbeck, 2023).
7. **Trade with regions and countries who support climate-friendly agriculture, ethical animal husbandry, and ethical and sustainable mining operations.**

Further resources

1. Verma, Shrey, Gaurav Dwivedi, and Puneet Verma. "Life Cycle Assessment of Electric Vehicles in Comparison to Combustion Engine Vehicles: A Review." *Materials Today: Proceedings* 49, pt. 2 (2022): 217–222.
2. Kirshenbaum, Sheril, and Douglas Buhler. "Americans Are Confused About Food and Unsure Where to Turn for Answers, Study Shows." Alliance for Science, 9 Mar. 2018.

Issue 6: Need for integration—Use ancestral wisdom to sustain land with a diversity of global and local voices

Background

The voices of Indigenous peoples and their ancestral wisdom have been sidelined in peoples/societies relationships with lands, resulting in further exploitation. Integrating historical wisdom together with emergent discoveries will lead to cyclical regeneration. Furthermore, the diversity of voices is not heard in techno-driven solutions. The tech approach to facing the challenges is at best human centered and does not include the voice of nonhumans, such as the environment (solutionism).

The digital divide and lack of access to communications technology has been a barrier to support food, land and water systems (Ng et al., 2021). Solutions are created and developed not from a place of "context" but from a place of "imagined empathy." (Morozov, 2014). Furthermore, technologies originating in the economically dominant global north should be promulgated respecting the traditions, history, and Indigenous viewpoints of adopting countries without necessarily reinforcing current power structure (Mohamed, Png, & Isaac, 2020).

- For centuries, Indigenous peoples have stewarded the land, sustainably providing for themselves and their communities for future generations: ranging from the Arctic tundra of the Inuit in Canada; the lush rainforest of the Manobo in the southern Philippines, or the desert of the Maasai in Kenya.
- Currently, Indigenous peoples only make up 5% of the world's population, yet they protect 85% of the world's biodiversity in forests, deserts, grasslands, and marine environments (Hawken, 2021).
- Unfortunately, the effects of colonization have marginalized Indigenous peoples, systemically silencing and oppressing these groups from participation in governance and stewardship of the land. In extreme cases, this marginalization has led to genocide; today, the effects linger as generational trauma through displacement, loss of culture, values, and ultimately a fractured relationship with the land that was once stewarded by their peoples.

Recommendations

1. **Learn the history of the lands that are lived and worked on:**
    a. **If on colonized lands, recognize that societies have historically benefited and continue to benefit from the ongoing colonization of Indigenous peoples.**
    b. **If not on colonized lands, recognize the Indigenous peoples whose traditional livelihoods and stewardship of land may be threatened by the interests of the nation-state or corporations.**
    c. **Consult histories written, spoken, and performed by Indigenous authors.**
2. **Work toward decolonization by amplifying and supporting Indigenous peoples**:
    a. **Respect Indigenous leadership and sovereignty.**
    b. **Build meaningful alliances and collaborations with respective Indigenous peoples.**

c. **Conduct business with Indigenous-owned businesses when possible.**

3. **Implement the United Nations Declaration on the Rights of Indigenous Peopl**e (UNDRIP).
4. **Include a diversity of voices in decision making so that solutions are developed from a point of "context."** The techno-driven solutions approach to facing the challenges is at best human centered and does not include the voice of nonhumans, such as the environment.
5. **Promulgate technologies originating in the economically dominant global north to respect the traditions, history, and Indigenous viewpoints of adopting countries.**
6. **Overcome and address the digital divide to provide communications technology in support of food, land, and water systems**.

Further resources

1. The Anti-Oppression Network. "Allyship."
2. Jones, Benji. "Indigenous People Are the World's Biggest Conservationists, But They Rarely Get Credit for It," *Vox,* 11 June 2021.
3. Kimmerer, Robin Wall. *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teaching of Plants*. Minneapolis, MN: Milkweed Editions, 2013.
4. UN General Assembly, Resolution 61/295, *Declaration on the Rights of Indigenous Peoples*, A/RES/61/295. 13 Sept. 2007.

References

1. Alexander, L. "Sustainable Farming in Developing Countries." The Borgen Project, 25 Mar. 2020.
2. Amelung, W., D. Bossio, W. de Vries, I. Kögel-Knabner, J. Lehmann, R. Amundson, R. Bol, C. Collins, R. Lal, J. Leifeld, B. Minasny, G. Pan, K. Paustian, C. Rumpel, J. Sanderman, J. W. van Groenigen, S. Mooney, B. van Wesemael, M. Wander, and A. Chabbi. *Towards a Global-Scale Soil Climate Mitigation Strategy*. Nature News, 27 Oct. 2020.
3. Bailey, A., L. Meyer, N. Pettingell, M. Macie, and J. Korstad. "Agricultural Practices Contributing to Aquatic Dead Zones." *Ecological and Practical Applications for Sustainable Agriculture* (June 2020): 373–393.
4. Bardgett, Richard, James M. Bullock, Sandra Lavorel, Peter Manning, Urs Schaffner, Nicholas Ostle, Mathilde Chomel et al. "Combatting Global Grassland Degradation." *Nature Reviews Earth & Environment* 2, no. 10 (Sept. 2021): 720–735.
5. Beam, Adam. "Wildfire-Prone California to Consider New Rules for Property Insurance Pricing." Associated Press, 28 Sept. 2023.
6. Bingham, Heather C., Edward Lewis, John Tayleur, Cleo Cunningham, Naomi Kingston, Neil D. Burgess, Neville Ash, Trevor Sandwith, and Kathy MacKinnon, eds. *Protected Planet Report 2020*. UNEP-WCMC and IUCN: Cambridge UK, and Gland, Switzerland. Updated May 2021.
7. Boeraeve, F., N. Dendoncker, J. T. Cornélis, F. Degrune, and M. Dufrêne. "Contribution of Agroecological Farming Systems to the Delivery of Ecosystem Services." *Journal of Environmental Management* 260 (Apr. 2020).
8. Champions 12.3. (website).
9. Climate Council. "Uninsurable Nation: Australia's Most Climate-Vulnerable Places." 3 Mar. 2022. Accessed 17 Nov. 2023.
10. Coppola, Alysha I., Sasha Wagner, Sinikka T. Lennartz, Michael Seidel, Ward Nicholas D., Thorsten Dittmar, Cristina Santín, and Matthew W. Jones. "The Black Carbon Cycle and its Role in the Earth System." *Nature Reviews Earth & Environment* 3 (2022): 516–532.
11. Ellerbeck, Stefan. "What's the Difference Between 'Friendshoring' and Other Global Trade Buzzwords?" World Economic Forum, Supply Chains and Transportation, 17 Feb. 2023.
12. European Union (EU). "Natural Capital Accounting." Nature and Biodiversity.
13. FoodPrint. "Food and the Environment." Project of GRACE Communications Foundation.
14. Goodwin, Liz. "The Global Benefits of Reducing Food Loss and Waste." World Resources Institute, 20 Apr. 2023.
15. Gregor, Howard F. "The Plantation in California." *The Professional Geographer* 14, no. 2 (Mar. 1962).
16. Hawken, Paul. *Regeneration: Ending the Climate Crisis in One Generation*. New York: Penguin Books, 2021.
17. Hayes, Michael N., and Alan L. Olmstead. "Farm Size and Community Quality: Arvin and Dinuba Revisited." *American Journal of Agricultural Economics* 66, no. 4 (Nov. 1984): 430–436.

18. Hhmelevtsova, Ludmila Eugenevna, Ivan Sergeevich Sazykin, Tatiana Nikolaevna Azhogina, and Marina Alexandrovna Sazykina. "Influence of Agricultural Practices on Bacterial Community of Cultivated Soils." *Agriculture* 12, no. 3 (Mar. 2022): 371.
19. IPCC. *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, eds. In press. 2019.
20. Kwa, Aileen. *Agriculture in Developing Countries: Which Way Forward?* Trade-Related Agenda, Development and Equity (T.R.A.D.E). Occasional Papers 4, June 2021.
21. Lakhani, N. L., A. Uteuova, and A. Chang. "The Illusion of Choice: Five Stats that Expose America's Food Monopoly Crisis." *The Guardian*, 18 July 2021.
22. Lowder, Sarah K., Marco V. Sánchez, and Raffaele Bertini. "Which Farms Feed the World and Has Farmland Become More Concentrated?" *World Development* 142 (June 2021).
23. Mohamed, Shakir, Marie-Therese Png, and William Isaac. "Decolonial AI: Decolonial Theory as Sociotechnical Foresight in Artificial Intelligence." *Philosophy and Technology* 33 (2020): 659–684.
24. Molotoks, A., P. Smith, and T. P. Dawson. "Impacts of Land Use, Population, and Climate Change on Global Food Security." *Food and Energy Security 10*, no. 1 (Nov. 2020).
25. Morozov, Evgeny. To Save Everything, Click Here: The folly of Technological Solutionism. Public Affairs, 2014.
26. Ng, Michelle, Nicoline de Haan, Brian King, and Simon Langan. *Promoting Inclusivity and Equity in Information and Communications Technology for Food, Land, and Water Systems.* Cali, Colombia: Consultative Group on International Agricultural Research (CGIAR) Platform for Big Data in Agriculture, 2021.
27. One Acre Fund. "The Case for Farming Insurance to Help Smallholders Build Climate Resilience." 8 Nov. 2022. Accessed 7 Nov. 2023.
28. Rai, Prabhat Kumar, and J. S. Singh. "Invasive Alien Plant Species: Their Impact on Environment, Ecosystem Services and Human Health." *Ecological Indicators* 111 (Apr. 2020).
29. Real Organic Project. "Hydroponic."
30. Real Organic Project. "Real Organic Virtual Symposium 2023." Symposium 2023.
31. Smith, Jeremy M. B. "Grassland" in *Encyclopedia Britannica*, 13 Mar. 2020. Accessed 30 June 2022.
32. Sonter, Laura J., Marie C. Dade, James E. M. Watson, and Rick Valenta. "Renewable Energy Production Will Exacerbate Mining Threats to Biodiversity." *Nature Communications* 11, 4174 (2020).
33. Sun, Jian, Yi Wang, Shilong Piao, Miao Liu, Guodong Han, Junran Li, Eryuan Liang et al. "Toward a Sustainable Grassland Ecosystem Worldwide." *Innovation* 3*,* no. 4 (May 2022).
34. Tilman, D. "Global Environmental Impacts of Agricultural Expansion: The Need for Sustainable and Efficient Practices." *Proceedings of the National Academy of Sciences* 96, no. 11 (May 1999): 5995–6000.

35. UN Food and Agriculture Organization (FAO) and UN Environment Programme (UNEP). *The State of the World's Forests 2022: Forest Pathways for Green Recovery and Building Inclusive, Resilient and Sustainable Economies*. Rome: FAO, 2022.

36. Whiting, Kate. "6 Charts that Show the State of Biodiversity and Nature Loss—And How We Can Go 'Nature Positive'." World Economic Forum, 17 Oct. 2022.

37. Willett, Walter, Johan Rockström, Brent Loken, Marco Springmann, Tim Lang, Sonja Vermeulen, Tara Garnett et al. "Food in the Anthropocene: The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems." *The Lancet* 393, no. 10170 (2 Feb. 2019): 447–492.

38. World Bank Group. "Climate-Smart Agriculture." Understanding Poverty, Topics. Last updated 26 Feb. 2024.

39. Zamarelli, Dan. "Sustainable Farming in Developing Countries." *The Borgen Project* (blog), 29 Mar. 2020.

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CHAPTER 10: HUMAN WISDOM AND CULTURE

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- Mila Aliana, author, editor, and contributor, Norfolk, United Kingdom
- Cyndi Coon, author, editor, and contributor, Los Ojos, New Mexico, United States
- Andy Heppelle, author, editor, and contributor, San Francisco, United States

Honorary Co-Chair:

- Keisha Taylor-Wesselink (PhD), author, editor, and contributor, Dublin, Ireland

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- Bruce Preville, author and contributor, California, United States
- Ernesto Vega Janica, author and contributor, New Jersey, United States

HUMAN WISDOM AND CULTURE

Future Vision

It is 2030.

Human wisdom and culture continue to offer an emotional and intellectual connection that binds humans together. In 2022, a worldwide cultural evolution emerged as humans across the Earth chose a holistic shift toward intergenerational stewardship of the systems we inhabit and impact on the Earth and re-committed to the ancient human wisdom to again become stewards and caretakers of life and nature. All concepts, designs, and implementations of sustainable and regenerative efforts are now prioritized as being in service to all life, the biodiversity of Earth, which includes humans.

As humans became aware of their environment and understood that their ecosystems provided what they needed to sustain their lives, they developed a caring relationship with Earth and other natural forces and resources.

For example, for more than 60,000 years, Aboriginals of Australia practiced this caring relationship with nature and passed the wisdom to their future generations (AAP, 2023; Nature-Bound Australia, “Aboriginal Culture”).

Introduction

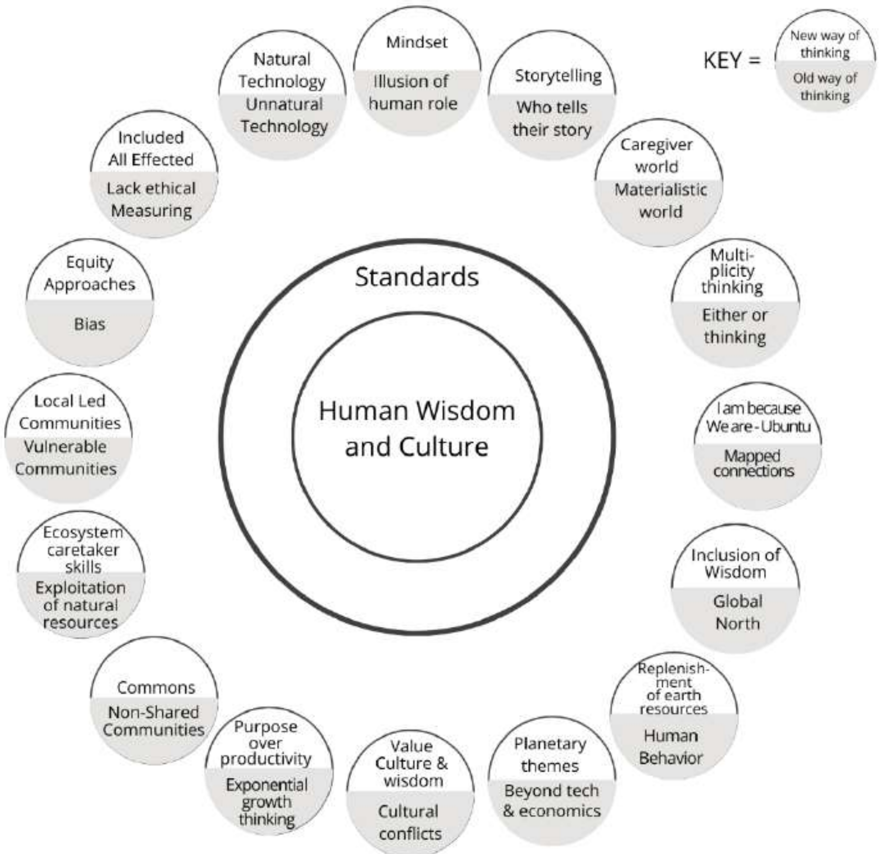

Figure 1. Human Wisdom and Culture Chapter Map

The culture, philosophy, knowledge, values, wisdom, and mindset of any society impact the society's infrastructure and patterns of governance. To prioritize the focus for any sustainable, regenerative, and intergenerational initiative initiatives, transformation of the mindset, culture, and society must come first before any technological and infrastructure transformations are developed or implemented.

A shift in consciousness is needed for a future that re-includes intergenerational stewardship that aims to seek and situate scientific materialism in alignment with non-materialism and healthier ecosystems. These ecosystems include dimensions that can connect humanity to the natural systems of our world and then enable a more holistic engagement with scientific instruments, and future thinking to build the future we want.

Human wisdom may not be gained through calculation as much as it is received through insight, where for brief glimpses, humanity is open to the connection people share with all living beings around them. It takes much work and skill to deprogram and quiet people's chattering minds. Certain aspects of humanity have transitioned in their cultural beliefs, valuing elements such as unfettered economic expansion, potentially detrimental competitiveness, and the emphasis on individual autonomy. In this context, groups of Indigenous peoples continue the culture of connection to Earth and intergenerational stewardship as their communities of practice in ancient traditions of mindfulness and conscious connection to the bigger world around us. Therefore, threads of ancient human wisdom and culture continue to thrive in the weave of societies in our world today.

Indigenous wisdom and lifestyles are not exclusive to Aboriginals. As humans migrated to new areas on Earth, they created their own ways of life and consumption, which may not have been in accordance with the ways of the Aboriginal ancestors. Maintaining a culture of respect and care for nature is understood and implemented by many people around the world. However, somewhere along the timeline of human history, humans began to dominate, take, and consume as they wished with no consideration or knowledge of planetary limitations. They lost touch with the wisdom of how ecosystems work and the necessity for care and stewardship to enable regeneration, hence disrupting planetary balances and the chain of life.

Although Aboriginals are the oldest civilizations, many others, Indigenous Peoples, ancestors and regions of the world also have shown wisdom and care for the planet. Notably, the Chinese, Japanese, and other Asian cultures and tribes have tremendous wisdom about nature, Mother Earth, and sustainable living. For example, Persian culture is deeply connected with nature (Yachkaschi & Yachkaschi, 2012)—celebrating every seasonal change, setting the calendar year based on seasons, planting, harvesting, believing in the responsibility to maintain life for future generations, honoring the origin of life and birth, and more.

The deep knowledge of the interconnectedness of all things is held within the ancestral (Indigenous) wisdom from generation to generation. Ancestral wisdom holds collective knowledge of the land, sea, and sky and deepens understanding of how life naturally evolves and of its impact (i.e., climate change) on livelihoods, cultures, and ways of life. It provides the concrete context of communities in relation to the environment and provides practical solutions on how to adapt. It also offers examples of how to act sustainably and regeneratively to co-create conditions for life to continuously evolve.

Therefore, human wisdom involves integrating ancestral wisdom and modern wisdom to protect the planet Earth and all life's existence that humans depend on while advancing into the future of human well-being and sustainable development. *Intergenerational stewardship* is a phrase that captures this intention of being a steward of the systems of nature in our lifetimes to preserve, protect, and regenerate those systems for the generations to come.

Finally, an effort should be made to preserve and promulgate these advanced skills, applied science, and planet-positive initiatives and to explore how integrating them into human development cycle(s) could be beneficial in solving technological challenges facing current and future societies. The authors recognize that the human element has been missing in many technology- and economy-driven decisions.

This chapter on human wisdom and culture focuses on Indigenous wisdom and the cultures to be considered, included, and asked about, outlining the process through mindset, story, and human experience. This discussion does not focus on technology other than that which comes from nature.

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

Issue 1: The need for an expanded mindset—the role of humans in the evolution of planet Earth

Background

Humans evolved from all the living species that existed and evolved during the 4.5 billion-year history of Earth (National Geographic, "Age of Earth Collection"). Earth itself evolved within the 13.7 billion years of the universe's evolution (Ralls, "History of Earth in Exactly 2000 Words"; Peebles et al, 1994).

In the last 0.4 billion years (400 million years), scientists are aware of five major mass extinction events that have occurred (Dutfield, 2021). At every mass extinction, approximately 70% to 95% of all living species died. The last extinction eradicated the dinosaurs. The current rate of biodiversity loss may indicate another mass extinction age. The ability of the changing systems of nature to continue to support the biodiversity of life on Earth has been irreversibly altered in the 70 years between 1950 and 2020. In that same time frame, the human population of Earth has grown from 2.6 billion in 1950 to 8 billion in 2023 (Worldometer website). Therefore, human thinking now needs to expand to consider this new reality. Intergenerational stewardship thinking is needed more than ever before.

In the context of the regenerative lifecycle of life, it seems that death and life are inherently interconnected within Earth's evolution in which death becomes compost for the "new."

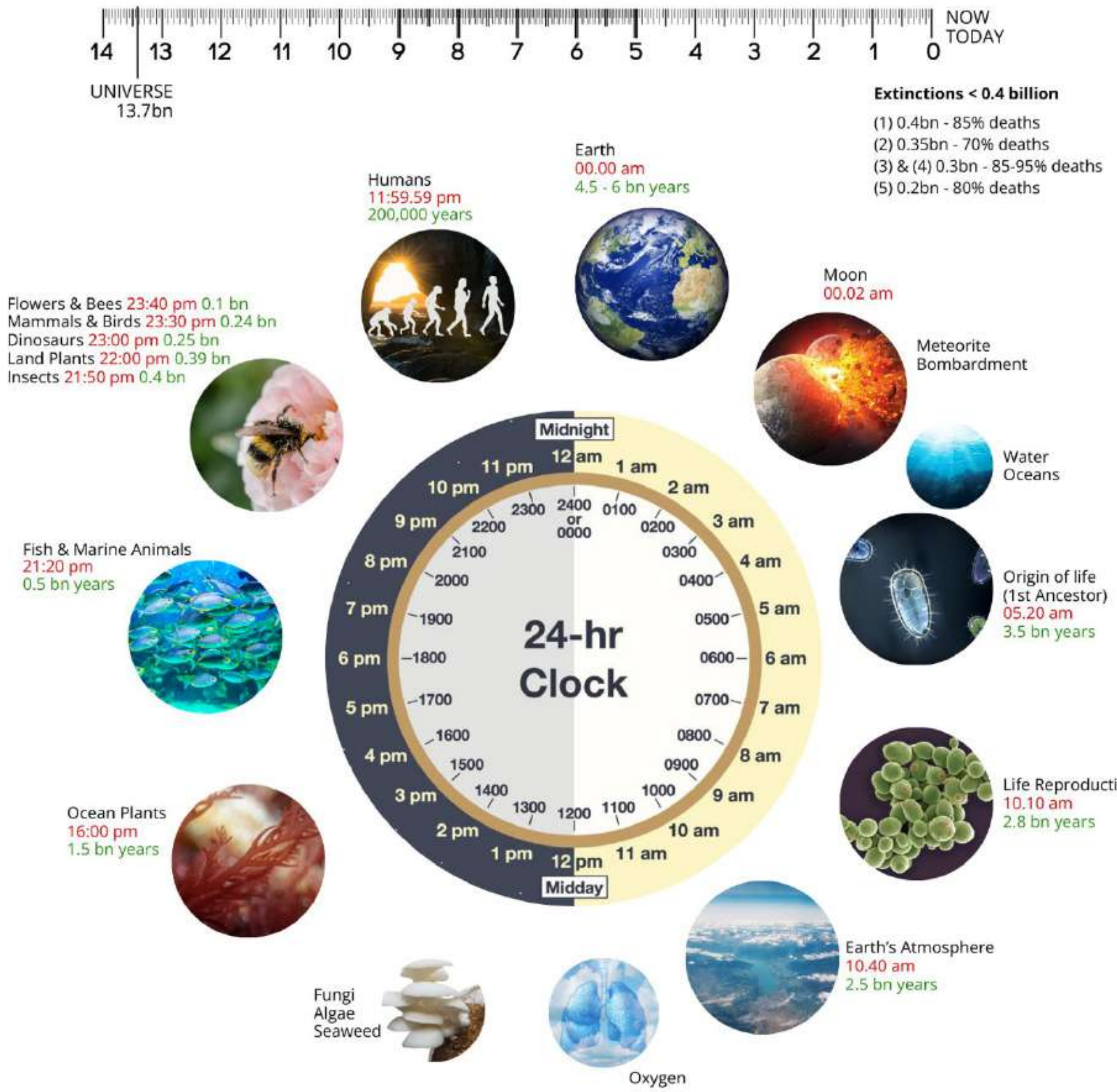

Figure 2: Birth of Earth
(Chart developed by Mila Aliana. Visually created by Co-Chair Cyndi Coon)

The advent of farming and agriculture transformed Earth's natural landscapes, locally and globally. As humans settled down because they could now produce their own food and increase its availability, human civilization flourished and the human population began to increase dramatically. Only during the last 500 years has technology advanced rapidly.

Indeed, human wisdom is relatively new in the greater scheme of the Earth's 4.5 billion-year evolution. Yet, we have a misconception that humans are the dominant species on Earth, with the illusion of control over, and separation between, human life and nature (White, 1948).

The Aboriginals of Earth are cognizant of their place in the history of Earth, their traditional ancestral (Indigenous) wisdom and life pathways, and as such, they live accordingly as caretakers of life and nature, as intergenerational stewards.

Recommendations

Guiding the progression of human culture and consciousness should involve encouraging a sense of connection with nature. This subtle shift might help us see ourselves as part of nature's tapestry. In doing so, a natural feeling of responsibility may emerge, leading us to recognize our roles as thoughtful stewards and caretakers of life and the natural world:

1. **Transform consciousness**. One needs to make the system visible unto itself for the system and its participants to be responsible for co-creating a new system from a shift in consciousness.
2. **To transform any ecosystem, a substantial number of its significant participants need to shift their consciousness.** This shift is essential so that the mindset and culture, which gave birth to the old system, does not shape the new one, thereby facilitating a pivotal transition into the new system.
    a. **Dispel the misconceptions of human supremacy over the complexities of nature and the perceived separateness from it and Earth's systems.**
    b. **Support growing a sense of connection with nature.**
    c. **Encourage the development of a sense of responsibility for, and stewardship of, life and the natural world.**
3. **Learn from the existing caretakers of life and nature.** Learn from Indigenous peoples (Aboriginals), their wisdom, and life pathways.
4. **Recognize humans as nature.** Experiment and embrace a culture in all our thinking, being, and doing that is aligned with the flourishing lifecycle of life and nature.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Carbon, Claus-Christian. "Understanding Human Perception by Human-Made Illusions." *Frontiers in Human Neuroscience* 8 (31 July 2014): 566.
2. Gray, John. "An illusion with a Future." *Dædalus Journal of the American Academy of Arts & Sciences* 133, no. 3 (Summer 2004): 10.
3. Oliver, Tom. "The Illusion of Individualism Helped Us Succeed As a Species—But Now the Scales Are Tipping." BBC Science Focus, 7 Mar. 2020.

Issue 2: The lack of understanding of the regenerative and sustainability story and concepts

Background

Humans love stories. Stories uphold social systems, help with finding a common understanding, and support trust. Stories are powerful. Stories often influence human behavior. Potentially, some systems that could actually be destroying the Earth may be upheld by a story that is continually reinforced in society as well as in the media.

If a way can be found to change or refocus the peoples' collective story, the story of humans all around the globe, societies can change the/their/our global collective consciousness, and hence make different decisions—different from the decisions that are grounded in the current collective consciousness.

Joseph Campbell's *The Hero's Journey* revealed the commonalities in the human journey through tracing the commonalities in the myths of cultures throughout the world (Wikipedia, "A Hero's Journey"; Campbell, 1990).

Currently, in parts of the world, that is often called the "West", there is a dominant and globalized understanding of "the economic system," money, and capitalist system in which all people—we—are involved. This can be described as a global story.

And yet, there are other stories in common to many and potentially all cultures with varying twists. The opportunity to change from the current "broken" system is given by these "other stories in common."

Charting the similarities in the human experience with the focus on the common regenerative and sustainability story and concepts can bring about a changed mindset and collective consciousness.

Recommendations

1. **Create a common story that supports a shift in understanding of peoples' relationships to all life.** Identify, by working collectively, similarities of sustainability issues in varying countries and communities to create this common story. Doing so may also help to shift the collective story from one that prioritizes unlimited growth and exploitation of life to a story that does not recommend growth at all costs and prioritizes a harmonious ecosystem:
    a. **Chart the journey societies are going through with a view to a positive sustainable transformation**. The hero's Journey template/methodology (Wikipedia, "A Hero's Journey"; Campbell, 1990) may be adapted to chart this journey.
    b. **Use "story" to enable new consciousness.** Human brains release pleasure chemicals and engage differently with story than with unconnected information. The use of story to engage humans connects them more holistically to new information. Use stories to enable new consciousness.
2. **Guide humans to explore, experience, and learn for themselves the connections to nature.** Human beings take ownership in what they create and discover, more than in things handed to them. Setting a pattern to guide humans, at scale, to explore and learn for themselves the connections to

nature, through story, and to connect emotionally and intellectually to intergenerational stewardship concepts will contribute to the shift needed to create a more sustainable world, a long-term healthy planetary biosphere.

3. **Share and socialize this story of regeneration and sustainability with other organizations.** Engage and encourage feedback from others to refine the story and help to change mindsets toward enabling collective and sustainable change.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Bekhrad, J. "The 100 Stories that Shaped the World." BBC Culture. 22 May 2018.
2. Bernier, Andrew. "Sustainability Storytelling is Not Just Telling Stories About Sustainability." *Encyclopedia of the World's Biomes* 5, Elsevier (2020).
3. Cajete, Gregory. "Children, Myth, and Storytelling: An Indigenous Perspective." *Global Studies of Childhood* 7, no. 2 (8 June 2017).
4. Chan, Adrienne S. "Storytelling, Culture, and Indigenous Methodology." In *Discourses, Dialogue and Diversity in Biographical Research: An Ecology of Life and Learning* (2021): 170–185.
5. Diaz, Clarisa. "How Can Indigenous Knowledge Help Us Create Sustainable Food Systems?" World Economic Forum, Sustainable Development, 3 Dec. 2021.
6. Fernández-Llamazares, Álvaro, and Mar Cabeza. "Rediscovering the Potential of Indigenous Storytelling for Conservation Practice." *Conservation Letters* 11, no. 3 (May/June 2018): 1–12.
7. Hofman-Bergholm, Maria. "Storytelling as an Educational Tool in Sustainable Education." *Sustainability* 14, no. 5 (2022): 2946.
8. Iseke, Judy. "Indigenous Storytelling as Research." *International Review of Qualitative Research* 6, no. 4 (Winter 2013): 559–577.
9. Robson, David. "Our Fiction Addiction: Why Humans Need Stories." BBC Culture. 3 May 2018.
10. Starovoitov, Sasha. "Narrating Landscapes: How Indigenous Storytelling Can Unlock Our Environment's Past." Columbia Climate School, Climate Earth, and Society, State of the Planet, 2 Sept. 2021.
11. UN Department of Economic and Social Affairs (UNDESA). *State of the World's Indigenous Peoples*. ST/ESA/328. Division for Social Policy and Development, Secretariat of the Permanent Forum on Indigenous Issues. New York: United Nations, 2009.
12. Wedner, Franzisca, Amornpan Tungarat, and Stella Lemke. "Sustainability as Cognitive "Friction": A Narrative Approach to Understand the Moral Dissonance of Sustainability and Harmonization Strategies." *Frontiers in Communication* 5 (20 Feb. 2020).

Issue 3: The materialistic worldview is devoid of a wisdom-centric philosophy

Background

The crisis that has engulfed today's society is the result of the continuous desire of human beings to "move forward" at the expense of the natural ecosystems around them. Hence, we have an urgent need to bring about a radical change in the philosophy underlying this worldview by putting nature before thinking about self. The harmonious integration between human beings and nature is possible when the entire universe is seen as one single family, including the ecosystem comprising myriad flora and fauna, the planetary biosphere.

Recommendations

1. **Provide education about caregiving-oriented economics and sustainability**. Beginning at young ages, provide education at multiple levels and institutions globally that demonstrates how caregiving-oriented economics and sustainability can lead to a shift in consciousness and action and, thus, enable leading to holistic planetary and human health.
2. **Include nature in decision-making processes.** When making a decision that has a bearing on nature, it is imperative to include the latter in the discussions in the initial stages of the decision-making process.
3. **Look at the world from a broader perspective when devising a strategy rather than looking at it through a narrow and hollow "self-centered" lens.**
4. **Consider biodiversity exploration in design and organizing principles for any organization, project, product, or service.**
5. **Consider nature as a stakeholder in any project**. This approach applies to any analysis of the strengths, weaknesses, opportunities, and threats of projects and designs.
6. **Adopt a holistic approach to your work**. Consider impacts to the rest of the natural world and how the rest of the natural world interacts with you in your work.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Al Madani, Amr. "What Can Ancient Wisdom Teach Us About Sustainability?" World Economic Forum, Sustainable Development, 4 Mar. 2022.
2. Intezari, Ali. Integrating Wisdom and Sustainability: Dealing with Instability." *Business Strategy and the Environment* 24, no. 7. (Nov. 2015): 617–627.
3. Kamal Borah, Surjya. "Ancient Indian Wisdom and Sustainable Development." *Quest–The Journal of UGC-HRDC Nainital* 6, no. 3 (Jan. 2012): 537.

Issue 4: Duality, (either / or) thinking, a human bias, dominates decision making

Background

A consistent bias exists in decision-making processes in which most problem–solution efforts must be one or the other, simplifying options to traditional human wisdom versus modern (technological) wisdom. Indeed, much of modern technology has as its foundation traditional human wisdom and in varied forms continues to be influenced by it.

Recommendations

1. **Identify how communities can endorse, promote, and embrace duality efforts—efforts to "integrate" human wisdom and technology know-how**. Work via transdisciplinary means with diverse population representation to embrace duality efforts. Cognitive diversity is a primary means to implement sustainable solutions for the greater good where both human and technology wisdom can collaborate in sync and human wisdom itself can be viewed as technology in itself.
2. **Promote active participation/workshops in learning and documenting traditional peaceful behaviors by individuals and societies.** Particular attention should be given to human responsibilities/roles applied by First Nations and Indigenous peoples, especially those that could be scalable to other communities and processes.
3. **Train and implement decision makers in the art and science of consensus building.** Working through disagreements to creative thinking is not intuitive to human cultures. The binary approach of thinking and deciding is both a human and a technological standard. Either/or may not always be superior to a both/and outcome.
4. **Implement history and human wisdom educational and recovery programs.** Knowing what has worked or what hasn't worked in other communities, and/or at different times in history. These programs should help acquire more experience and skills to resolve current and future tasks at hand. This concept applies to hard (technical) skills as well as to soft skills, such as human wisdom.
5. **Develop and engage in outreach educational programs on human wisdom, acknowledgment, and realization of deeper self-knowledge and on the impact of humans' actions on others and the environment.**
6. **Foster intergenerational work to learn across generations and to build intergenerational co-creation and stewardship.** This work should incorporate biodiversity in thinking in those intergenerational conversations, explorations, projects, and mentoring and learning relationships.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Grant, Adam. *Think Again: The Power of Knowing What You Don't Know.* Viking, 2021.
2. Hodgkin, R. A. "Techne, Technology and Inventiveness." *Oxford Review of Education* 16, no. 2 (1990): 207–17.
3. ITU. "Indigenous-Led Tech Solutions for a Better Planet." International Telecommunications Union, 9 Aug. 2021.
4. Menjawin, Mamu. *El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica* (Spanish Edition). Geraldo Morales Dominguez, 2016.
5. Vega Janica, Ernesto. *Pueblo Iku: Science, Nature and Art of the Arhuaco*. Ernesto Vega Janica, 2020.

Issue 5: Lack of awareness of "I am because we are"—Ubuntu philosophy

Background

Ubuntu is a Nguni word that means "I am because you are" and originates from South Africa. A person's identity is linked to others, especially to the community. This concept resonates with the sustainability crisis. However, not enough emphasis is placed on just how much this is so. For example, a big corporation that dominates a poorer community may have thwarted through business decisions someone from a vulnerable group who may have been the missing link helping to find a cure for a disease that plagued a community member. This holds true for sustainability in general. The actions of a corporate entity may incidentally cause tremendous pain. Yet these dots are not usually connected. Indeed, for every action there are consequences, intended, unintended, and, potentially unanticipated consequences.

Recommendations

1. **Design a methodology that incorporates Ubuntu for sustainability:**
    a. **Explain through a type of system thinking how those who perpetuate harm can also be severely affected. And move beyond the Western human-centric perspective to illustrate this at the ecosystem level.**
    b. **Guide experiential learning at scale in organizations as part of the strategic decision-making process to engage leaders in these new patterns of thought and reinforce, through success stories,** examples of when this way of thinking benefits the current situation: organizations, societies, employees, colleagues, customers, clients, stakeholders (including the rest of nature), and the generations of all of those who will follow.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Chigangaidze, Robert K. "Environmental Social Work Through the African Philosophy of Ubuntu: A Conceptual Analysis." *International Social Work* 66, no. 6 (18 Mar. 2022).
2. Church, Jacqueline. "Sustainable Development and the Culture of uBuntu." *De Jure* 45, no. 3 (Jan. 2012): 511–531.
3. Crippen, Matthew. "Africapitalism, Ubuntu, and Sustainability." *Environmental Ethics* 43, no. 3 (2021): 235–259.
4. Enviropaedia. "Eco-Ubuntu." Authored by Archbishop Emeritus Desmond Tutu. Archbishop Emeritus Desmond Tutu.

5. Etieyibo, Edwin. "Ubuntu and the Environment." In T*he Palgrave Handbook of African Philosophy*, edited by Adeshina Afolayan and Toyin Falola. New York: Palgrave Macmillan, 2017.
6. Gwaravanda, Ephraim. "Ubuntu Environmental Ethics: Conceptions and Misconceptions." In *African Environmental Ethics*, edited by M. Chemhuru*. The International Library of Environmental, Agricultural and Food Ethics* 29 (2019). Springer, Cham.
7. Overson, Shumba. "Commons Thinking, Ecological Intelligence and the Ethical and Moral Framework of Ubuntu: An Imperative for Sustainable Development." *Journal of Media and Communication Studies* 3, no. 3 (Mar. 2011): 84–96.
8. Sabelo, Mhlambi. "From Rationality to Relationality: Ubuntu as an Ethical and Human Rights Framework for Artificial Intelligence Governance." *Carr Center for Human Rights Policy Discussion Paper Series*, Harvard Kennedy School, 8 July 2020.
9. Tafadzwa Chibvongodze, Danford. "Ubuntu is Not Only about the Human! An Analysis of the Role of African Philosophy and Ethics in Environment Management." *Journal of Human Ecology* 53, no. 2 (Feb. 2016): 157–166.
10. Terblanché-Greeff, Aida C. "Ubuntu and Environmental Ethics: The West Can Learn from Africa When Faced with Climate Change." In *African Environmental Ethics*, edited by M. Chemhuru. *The International Library of Environmental, Agricultural and Food Ethics* 29 (2019). Springer, Cham.

Issue 6: The dominance of the Global North in policy development and in the use of technology

Background

As native communities and First Nations have been the Earth's caretakers for the longest time, their vast knowledge and expertise are crucial for a sustainable future. However, there can be a bias toward "human wisdom" being defined by global or developed nations. The language of many Indigenous or marginalized populations is often not even acknowledged by these bodies, thereby immediately ostracizing them from any efforts toward sustainability and the applicability of their valued experience. For instance, most efforts regarding sustainability do not recognize, nor are aware of, the seminal knowledge First Nations stewards can bring as noted in documents like the 6th Assessment Report of the UN IPCC (IPCC, Climate Change 2021).

Which countries are considered part of the Global North?

The Global North generally includes the United States, Canada, England, nations of the European Union, as well as Singapore, Japan, South Korea, and some countries in the Southern Hemisphere, such as Australia and New Zealand.

Recommendations

1. **Prioritize the inclusion of wisdom from Indigenous peoples globally, from regions outside and inside of the Global North, in all "global" efforts.** That includes the teaching of philosophy, ethics, and economics, and including these areas in any "global" institution.
2. **Start every human gathering with the ancient human tradition of land acknowledgment.** When conducting any meeting on known traditional Indigenous territories, the simple act of recognizing those traditional territories and peoples names demonstrates respect and connection to the thousands of years of human connection in that place and invokes ancient human wisdom of connection to place and the Earth.
3. **A conscious effort should be made to include the active participation of first nations and Indigenous communities when defining "human wisdom" guidance/manuals/concepts.**
4. **Promote active participation/workshops in learning and documenting traditional peaceful behaviors by individuals and societies.** Pay particular attention to human responsibilities/roles applied by First Nations and Indigenous peoples, especially those that could be scalable to other communities and processes.
5. **Implement history and human wisdom educational and recovery programs.** Knowing what has worked or what hasn't worked in other communities, and/or during different times in history. These programs should help us acquire more experience and skills to resolve our current and future tasks. This concept applies to hard (technical) skills as well as to soft skills, such as human wisdom.

6. **Develop and deliver outreach educational programs on human wisdom, acknowledgment, and realization of deeper self-knowledge and on the impact of humans' actions on others and the environment.**

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Azar, B. "Are your findings 'WEIRD'?" *Monitor on Psychology* 41, no. 5 (May 2010).
2. Ekedegwa Odeh, Lemuel. "A Comparative Analysis of Global North and Global South Economies." *Journal of Sustainable Development in Africa* 12, no. 3 (2010).
3. Menjawin, Mamu. *El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica* (Spanish Edition). Geraldo Morales Dominguez, 2016.
4. Native Land Digital (website).
5. Sabzalieva, Emma, Magdalena Martinez, and Creso Sá. "Moving Beyond 'North' and 'South': Global. Perspectives on International Research Collaborations." *Journal of Studies in International Education* 24, no. 1 (Feb. 2020): 3–8.
6. Vega Janica, Ernesto. *Pueblo Iku: Science, Nature and Art of the Arhuaco.* Ernesto Vega Janica, 2020.

Issue 7: Unsustainable resource extraction and economic growth considerations prevail in global policy, technology design, and deployment

Background

> *"Resource extraction has more than tripled since 1970, including a fivefold increase in the use of non-metallic minerals and a 45 percent increase in fossil fuel use. By 2060, global material use could double to 190 billion tons (from 92 billion), while greenhouse gas emissions could increase by 43 percent. The extraction and processing of materials, fuels, and food contribute half of total global greenhouse gas emissions and over 90 percent of biodiversity loss and water stress"* (UNEP, 2019).

Urgent transition is needed in multiple technical fields, including in energy production; the design and installation of the built environment; the manufacturing of goods and materials for human consumption, particularly new transportation, communication, and technology devices; metrics and global methodologies; as well as in many other fields, to shift from a mindset and practice of extraction toward giving back more than what human society takes; that is, to promote circularity and intergenerational stewardship thinking.

These technical recommendations will have minimal effect, however, if a conscious human behavior change does not occur, and such a change must occur from within each individual and collectivity (social group). Having a deep auto-evaluation of our acts, the consequences on the environment and other generations, as well as of our own tolerance for the uncertainties, is our path to wisdom, and so it will be required for the survivability of our human species.

The time to act is now (or more appropriately 30 to 50 years ago). Nature will continue its evolution process with or without humans. Humans must extend positive impact and tenure in this land.

William McDonough and Michael Braungart, in their seminal work *Cradle to Cradle* (McDonough & Braungart, 2002), lay out principles for circular design and production. They strongly encourage the global community of designers and builders of all things that consume materials to consider circularity and their proposed principles for circular design and production.

Recommendations

1. **Apply intergenerational stewardship and circular economy design principles to all things that humans design, build, and manufacture, realizing a "built-in" cradle-to-cradle and regenerative approach.**
2. **Engage in and support the shift from a mindset and practice of extraction toward *giving back more than what we take* as well as toward circularity and intergenerational stewardship thinking**. That includes rethinking current metrics and methodologies, as well as technical fields.
3. **Implement land/natural resources recovery programs hopefully in underserved communities and natural biodiversity-protected areas.**

4. **Consider, promote, and prioritize rural, simple applications with scalable potential over more technologically "advanced" options** (that may take longer time to be implemented).
5. **To scale their adoption, support and enable intergroup exploration of the following concepts:**
    a. **Intergenerational stewardship**
    b. **Regenerative approach**
    c. **Circular economy**
    d. **Regenerative approach**
    e. **Cradle-to-cradle approach**
    f. **Biodiversity protection**
    g. **Land/natural resources recovery**
    h. **Rural/simple applications and solutions before technological "advanced" options**
6. **Develop and deliver outreach educational programs on human wisdom, acknowledgment, and realization of deeper self-knowledge and on the impact of humans' actions on others and the environment**.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Kallis, Giorgos. "In Defense of Degrowth." Ecological Economics 70, no. 5 (2011): 873–880.
2. McDonough, William. Net-Positive: Waging Peace Through Commerce by Design. McDonough Innovation, 2022.
3. Menjawin, Mamu. *El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica* (Spanish Edition). Geraldo Morales Dominguez, 2016.
4. Polman, Paul, and Andrew Winston. Net Positive: How Courageous Companies Thrive by Giving More Than They Take." Harvard Business Review Press, 2021.
5. Vega Janica, Ernesto. *Pueblo Iku: Science, Nature and Art of the Arhuaco*. Ernesto Vega Janica, 2020.

Issue 8: Lack of inclusion of arts, creativity, and culture in proposed solutions to achieve long-term sustainability

Background

Human/social wisdom should extend beyond "technical" solutions to include the arts, culture, and social pillars, going beyond science, technology, engineering, and mathematics (STEM). Unfortunately, on top of limited exposure and promotion, arts, culture, and other soft skills, like languages and natural sustainable vision, are complex concepts and practices with contested definitions and multiple histories across different geographical regions (see SHAPE-ID). Therefore, a considerable effort should be made to recognize these disciplines and their potential value add when trying to solve local community and global issues, such as those intended by the IEEE Planet Positive 2030 (PP 2030) Initiative.

Recommendations

As art, culture, languages, and other soft skills could improve pathways to proper implementation of STEM projects/applications in diverse communities worldwide, the following recommendations should be considered:

1. **Promote the inclusion of arts, humanities, and culture in general as equal partners and co-creators in the development of goals and solutions.**
2. **Identify, document, and promote existing STEM + arts and culture (STEaM) programs and/or applications.**
3. **Learn from past sustainable innovations that would not exist without being led by and involving the arts, humanities, and culture.**
4. **Foster education and communications programs for intergenerational stewardship that include STEaM to illuminate, expand thinking, excite the imagination, engage hearts, and make visual and emotional connections between the art and science needed for the necessary regenerative and at-scale solutions to achieve a sustainable future.**

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Clarke, Marie. "STEM to STEAM: Policy and Practice." In *The STEAM Revolution*. Springer, Cham, 2018.
2. Evans, Rob. The 2021 Collaboration Code Casebook. Imaginal Labs LLC, 2022.
3. Huutoniemi, Katri, Julie Thompson Klein, Henrik Bruun, and Janne Hukkinen. "Analyzing interdisciplinarity: Typology and Indicators." *Research Policy* 39, no. 1 (Feb. 2010): 79–88.
4. Karlqvist, Anders. "Going Beyond Disciplines: The Meanings of Interdisciplinarity." *Policy Sciences* 32, no. 4 (1999): 379–383.
5. Krzysztof, Kania, Catherine Lemaire, and Lenna Swinnen. *Integration of Social Sciences and Humanities in Horizon 2020—Participants, Budget and Disciplines: 4th Monitoring Report on SSH Flagged Projects Funded in 2017 Under the Societal Challenges and Industrial Leadership Priorities*. European Commission, Directorate-General for Research and Innovation, Publications Office, 2018.
6. Taylor Wesselink, Keisha, and Doireann Wallace. "Draft System of Preconditions for Successful Arts, Humanities and Social Sciences Integration." *SHAPE-ID*, 28 Jan. 2021.
7. Vienni Baptista, Bianca. "Reconfiguring Interdisciplinary and Transdisciplinary Spaces for Arts, Humanities and Social Sciences Integration." *SHAPE-ID*, 1 May 2021.

Issue 9: The need to expand knowledge while respecting and highlighting the added value of other cultures and their wisdom

Background

Imitating/copying others is a powerful way to honor people, culture, skills, and overall wisdom. This practice also establishes a close and harmonious relationship in which people or communities are in "sync" with each other, and even with the environment, provided the proper guidance is given or copied.

Unfortunately, this is not always an altruistic goal, and in many cases, conflict can erupt when parties appropriate or don't respect each other's cultural roots and differences. Therefore, an effort needs to be made to avoid conflict and simply focus on the added value that others can have in processes and thoughts. After all, we are all humans, and as such, we are just one. There are no "others" and "us"; there is just "all of us."

Recommendations

The key premise should be including/emulating/copying the added value of other cultures and their wisdom in peace while respecting others and avoiding conflict, all with the goal of looking toward humanity's future direction and survival.

1. **Promote well-rounded skills, techniques, and social interactions based on peace and ecological harmony.** The intent should be to promote local (soft) skills with a regional, well-founded, and proven basis that could have global scalable potential.
2. **Encourage consensus/agreement-building skills and techniques.** The foundational skills of achieving agreement consist of the use of "appreciative inquiry" techniques. Improving the use of open-ended questions, active listening, restatement for clarification, seeking commonality, and building creative solutions are the primary tools used to "manage the conflict" of disagreement.
3. **Implement history and human wisdom educational and recovery programs.** They are knowing what has worked or what hasn't worked in other communities, and/or at different times in history. These programs should help individuals, teams and communities of any kind acquire more experience and skills to resolve current and future tasks. In other words, having more "tools" in the "tool bag" will make carrying out the work easier. This concept applies to hard (technical) skills as well as to soft skills, such as human wisdom.
4. **Develop and deliver outreach educational programs on human wisdom, acknowledgment, and realization of deeper self-knowledge, and on the impact of humans' actions on others and the environment.**
5. **Create avenues for keepers of Indigenous wisdom to be leaders and owners of processes and their outcomes in ways that allow for nonexploitative communal benefit.**

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Cialdini, Robert. *Pre-Suasion: A Revolutionary Way to Influence and Persuade*. Simon & Schuster, 2018.
2. Fisher, Roger, and William Ury. Getting to Yes: Negotiating Agreement Without Giving In. Penguin Books, 2011.
3. Menjawin, Mamu. *El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica* (Spanish Edition). Geraldo Morales Dominguez, 2016.
4. Stone, Douglas, Bruce Patton, Sheila Heen, and Roger Fisher. *Difficult Conversations: How to Discuss What Matters Most*. Viking Penguin, 2010.
5. Vega Janica, Ernesto. *Pueblo Iku: Science, Nature and Art of the Arhuaco*. Ernesto Vega Janica, 2020.

Issue 10: Purpose over productivity needs to be a priority for positive environmental impact

Background

Individuals and societies with deeper ethical or moral values and self-conscious discipline of serving others while supporting sustainable growth have the proven ability to maintain healthy social communities in harmony with others and with less damaging effects on the environment. Recent ideas in net-positive thinking have been published by Paul Polman and Andrew Winston in their book *Net Positive* (Polman & Winston, 2021). They encourage leaders to embark on a journey of long-term thinking that focuses attention on the whole system being impacted by decisions being made. They challenge leaders to work in ecosystems of purpose to regenerate and give back to the ecosystems that have sustained life on this planet. They map a way forward for all of us humans to engage in the world around us, applying patterns of decision, and taking that to mean "give back more than you take from the world around you."

Intergenerational stewardship for the children in the current generation and for the seven generations to come must be considered key stakeholders.

Recommendations

1. **A conscious effort should be made to identify and promote role models in lieu of the "greater good," focusing on higher standards of peaceful living, collaboration, and respect of each other's point of view.** Current diversity and inclusion initiatives can gain guidance from native and First Nations wisdom, based primarily on cultures of peace and ecological harmony. These efforts can be coupled with a focus on the science of positive psychology that has proven practices of meditation, kindness, and "flow" (living to your purpose).
2. **A net-positive context should be applied to every organization, designing and taking action for the long-term, holistic well-being of all parts of the systems impacted by the human-managed organizations of our world.** Intergenerational stewardship for the children in the current generation and for the seven generations to come must be considered key stakeholders in this work.
3. **Promote active participation/workshops in learning and documenting traditional peaceful behaviors by individuals and societies.** Pay particular attention to human responsibilities/roles applied by First Nations and Indigenous peoples, especially those that could be scalable to other communities and processes.
4. **Implement history and human wisdom educational and recovery programs.** Knowing what has worked or what hasn't worked in other communities, and/or at different times in history. These programs should help us acquire more experience and skills to resolve our current and future tasks at hand. This concept applies to hard (technical) skills, as well as to soft skills, such as human wisdom.
5. **Develop and deliver outreach educational programs on human wisdom, acknowledgment and realization of deeper self-knowledge, and the impact of humans' actions on others and the environment.**

6. **Enlist communities of the willing across public–private partnerships to spread human wisdom through models like those described in *Net Positive*, ideas that call us all to design with heart, with purpose, with the long term of future generations of all life on Earth, exhorting us to unleash human energy for an inclusive and sustainable future**.

Further Resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. IEEE. "Wellbeing." In *Ethically Aligned Design*. IEEE, 2019.
2. Menjawin, Mamu. *El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica* (Spanish Edition). Geraldo Morales Dominguez, 2016.
3. Taylor, Matt, and Gail Taylor. "MG Taylor Modeling Language." MG Taylor Corporation, 1997.
4. Vega Janica, Ernesto. *Pueblo Iku: Science, Nature and Art of the Arhuaco*. Ernesto Vega Janica, 2020.

Issue 11: Lack of commons—shared resources and an asset-based approach are needed for a community-based development approach

Background

Asset-based community development (ABCD) (see DePaul University, ABCD), or asset-based community-driven development, is a bottom-up, community-driven way of working that focuses on community strengths and assets rather than on lack of resources and problems.

Assets are seen as more than just money but also as micro in scale. If someone needs a lift and another person needs help with their taxes, they can exchange and barter for a more sustainable outcome for all. These interactions forward a mindset of sustainability with better well-being for all and potentially the environment. ABCD is rooted in an asset mindset and not in a deficit mindset (not in relation to financiers) that everyone lives on this planet with an abundance of assets (not financial) that can support and help others.

Furthermore, the Nobel Prize Winner Elinor Ostrom found that collective action can be effective when using a common-pool resource (CPR) (see Nordman, 2021). This open-access resource environment or domain may benefit all for the social well-being of a particular community.

Recommendations

1. **Use ABCD to identify existing resources and strengths versus only what is lacking.**
2. **Use the methodology of asset-based community development for changing mindsets on what are assets and for supporting and developing community and encouraging bartering and exchange of goods and services.**
3. **Look at experimenting with a local commons approach within community-driven initiatives.**

Further Resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Nurture Development. "Asset Based Community Development (ABCD)."
2. Svizzero, Serge, and Clement Tisdell. *Barter and the Origin of Money and Some Insights from the Ancient Palatial Economies of Mesopotamia and Egypt*. HAL Open Science, 2019.

Issue 12: Omission to invite existing caretakers of the planet hinders ecosystem regeneration, restoration, and maintenance efforts, as well as intergenerational stewardship thinking and design

Background

One of the main purposes of humans is to be caretakers of our planet, not just the appropriators or exploiters of natural resources for what is usually seen as a financial short-term gain. The sooner humans realize this purpose, of caretakers of the land/nature, the sooner we can work on the solutions and changes needed for our survival.

Currently, 80% of the natural resources and biodiversity are under the care of 5% of the people, most of them First Nations and Indigenous peoples (Raygorodetsky, 2018). And even though these communities have the expertise, and centuries' worth of skills, modern industries, political divisions, and many other elements keep these communities marginalized, underestimated, and in many cases even under the constant pressure of colonization and cultural alienation.

Recommendations

1. **Use expert ecosystem regeneration, restoration, and maintenance efforts.**
2. **Include intergenerational stewardship thinking and design in all things.**
3. **Consciously listen to and emulate the role of Earth caretakers, including the provision of proper scenarios for the First Nations and Indigenous peoples to play their valuable role in global sustainability.**
4. **Promote active participation/workshops in learning and documenting traditional farming methodologies, cultural/social behaviors, and human responsibilities/roles by First Nations and Indigenous peoples, especially those that could be scalable to other communities and processes.**
5. **Implement history and human wisdom educational and recovery programs.** Knowing what has worked or what hasn't worked in other communities, and/or at different times in history. These programs should help us acquire more experience and skills to resolve our current and future tasks. This concept applies to hard (technical) skills as well as to soft skills, such as human wisdom.
6. **Develop and deliver outreach educational programs on human wisdom, acknowledgment, and realization of deeper self-knowledge, and on the impact of humans' actions on others and the environment.**
7. **Foster intergroup learning and co-creation opportunities with leaders at all community levels.** Include leaders from local school board to city, province, state, region, and national agencies and leaders who are able to learn from and incorporate thinking and patterns of being from Indigenous communities and other communities that foster holistic thinking practices.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. McDonough, William. Net-Positive: Waging Peace Through Commerce by Design. McDonough Innovation, 2022.
2. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things.* New York: North Point Press, 2002.
3. Menjawin, Mamu. El Libro de los Mamus, apuntes sobre la Historia, La Geografía y la Sabiduría de una Cultura de Paz y Armonía Ecológica (Spanish Edition). Geraldo Morales Dominguez, 2016.
4. Polman, Paul, and Andrew Winston. "Net Positive: How Courageous Companies Thrive by Giving More Than They Take." *Harvard Business Review Press*, 2021.
5. Sena, Kanyinke. "Recognizing Indigenous Peoples' Land Interests Is Critical For People And Nature ." World Wildlife Fund, 22 Oct. 2020.
6. Vega Janica, Ernesto. Pueblo Iku: Science, Nature and Art of the Arhuaco. Ernesto Vega Janica, 2020.

Issue 13: The lack of a stage for new leaders from vulnerable/marginalized communities hinders the development of sustainable solutions

Background

The leadership teams addressing the global challenges of achieving long-term sustainability and preserving biodiversity lack significant participation by Indigenous peoples and marginalized communities and, hence, do not have access to the vast experiences of these communities.

In some cases, vulnerable/marginalized communities have faced basic needs, such as the needs for clean water, food, education, clothing, communications, and more. These communities may suffer from natural disasters like earthquakes, volcano eruptions, and storms, with potentially fewer resources and less advanced notice than other, technologically more developed societies. These challenging conditions can often require creative, simple (from the manufacturing and sourcing point of view), and timely solutions recognizing the potential lack of resources and the urgency to resolve the tasks promptly.

Recommendations

1. **Involve community group representatives from vulnerable/marginalized groups in the creation of sustainable solutions as leaders and owners in the process. Invite them to share their experience in achieving "the most with the least."**
2. **Document scalable projects/solutions and foster such projects in other communities.**
3. **Promote active participation/workshops in learning and documenting traditional farming methodologies, cultural/social behaviors, and human responsibilities/roles by First Nations and Indigenous peoples, especially those that could be scalable to other communities and processes.**
4. **Foster and act on *inclusion by design* in industry and government "design shops" and working sessions where decisions are being made and biodiversity, human wisdom, culture, and intergenerational stewardship is an imperative.**

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Bendell, Jem, Neil Sutherland, and Richard Little. "Beyond Unsustainable Leadership: Critical Social Theory for Sustainable Leadership." *Sustainability Accounting, Management and Policy Journal* 8, no. 4 (Sept. 2017).

2. Ezeanya, Chika. “Research, Innovation, and Indigenous Knowledge in Sub-Saharan Africa: In Search of a Nexus.” In *Economic Integration, Currency Union, and Sustainable Growth in East Africa*, edited by Almas Heshmati. Advances in African Economic, Social and Political Development, AAESP. Berlin: Springer, 2016.
3. Ezeanya, Chika, and Abel Kennedy. “Integrating Clean Energy Use in National Poverty Alleviation Strategies: Opportunities and Challenges in Rwanda’s Girinka Program.” In *Political Economy of Clean Energy Use.* United Nations University World Institute for Development Economics Research. Oxford: Oxford University Press, 2017.
4. Fadahunsi, Olayemi. “Climate Change on the Front Line: Why Marginalized Voices Matter in Climate Change Negotiations.” *Global Witness* (blog), 9 Aug. 2017.
5. McDonough, William. Net-Positive: Waging Peace Through Commerce by Design. McDonough Innovation, 2022.
6. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things.* North Point Press, 2002.
7. Polman, Paul, and Andrew Winston. Net Positive: How Courageous Companies Thrive by Giving More Than They Take.” Harvard Business Review Press, 2021.
8. Stuart, Elizabeth, and Jessica Woodroffe. “Leaving No-One Behind: Can the Sustainable Development Goals Succeed Where the Millennium Development Goals Lacked?” *Gender & Development* 24, no. 1 (Feb. 2016): 69–81.
9. Taka. “*Map Kibera: Empowering Africa’s Biggest Slum with Collective Wisdom*.” Harvard Business School Digital Initiative, 2018.
10. Taylor Wesselink, Keisha, and Doireann Wallace. “Draft System of Preconditions for Successful Arts, Humanities and Social Sciences Integration.” *SHAPE-ID*, 28 Jan. 2021.
11. UN Office for Disaster Risk Reduction (UNDRR). “Meet the Women Who Stand Up for Marginalized Groups.” UNDRR Regional Office for Asia and Pacific, 2021.
12. UNESCO Institute for Lifelong Learning. *Community-Based Learning for Sustainable Development.* Policy Brief UIL/2017/PI/H/6. 2017.
13. Williams, Logan D. A. Eradicating Blindness: Global Health Innovation from South Asia. Palgrave MacMillan, 2018.

Issue 14: Disregard of past / traditional sustainable technologies can hinder environmental stewardship

Background

A bias exists toward “modern” or “emerging” technology as the key driver to ecological sustainability when, in fact, various traditional practices could potentially produce as much nourished land, water, or air regeneration as any modern technology.

The deployment and application of current industrial and emerging technologies can positively and negatively impact the environment. For example, while technologies can be used to monitor water levels or air quality in a disaster zone and improve city mobility by using optimization and sensors, the manufacturing processes involved in their components, testing, shipping, and so on, and the energy needed to power these sensors and systems, can also greatly impact the environment in a negative way. Hence, the use of modern and emerging technologies should be considered carefully before being applied to mitigate environmental issues. There is no guarantee they will work as expected or surpass well-established natural approaches.

In addition, any potential benefits can be diminished when the environmental impacts associated with producing, shipping, operating, and end-of-use handling of these industrial and emerging technologies are taken into account. This trade-off about the use of industrial and emerging technologies and their impact on the environment should be analyzed to determine whether the pros are higher than the cons.

Yet, as far as the Earth’s millions of years of evolution go, there is no better “machine” to clean air, produce oxygen, reduce global warming, and provide soil/land management than a healthy forest and/or natural reservoirs, including the ocean. In the forests, lands, and the ocean, there are no battery storage, solar panels, or wastewater treatment plants, except what nature engineered or created.

Lasting change will only be possible through the collective actions of many in the industrial, commercial, and legislative fields, so support from multiple stakeholders will be needed where recognition and utilization of traditional practices can be considered in partnership with modern and emerging technologies. Therefore, supply chains will need to be evaluated to identify potential opportunities to involve traditional farming methods, sustainable processes, and systematic change. Transparency and accountability while avoiding a bias toward new or emerging technology in isolation will allow for more pragmatically innovative solutions to be used for a positive effect.

Recommendations

1. **Evaluate innovation in manufacturing, agriculture, built environments, and energy and water production and management, as well as in other product production technologies.** Evaluation needs to be based on traditional and Indigenous sustainable applications to identify how these processes performed and improved through centuries of evolution.
2. **Replace existing approaches with state-of-the-art technology only if the rate of gains and losses is positive and greater than 10%.** Losses must consider energy cost and carbon footprint to create the technology, technology maturity, and so on.

3. **Consider evaluation of applications in light of equity for all people in a community, region, or country, including where the rights of the Indigenous or marginalized residents and planetary ecosystems are prioritized above exponential growth.** Having these insights should help identify the applicability of sustainable technologies. Traditional practices related to land, water, and air regeneration are often ignored in lieu of favoring modern or emerging technology concepts in current times.
4. **Identify, document, and promote traditional methodologies, that is, experiences from Indigenous communities in various regions of the world.**
5. **Innovate further to meet the challenges of improving transparency and traceability.** Blockchain and vessel monitoring can help, but adoption takes time and further innovation is necessary.
6. **Encourage local/regional sustainable produce and supplies.** This will increase resiliency: for example in the case of pandemics, weather-related events, and political/social unrest which can create supply/demand volatility and interrupt supply chains.
7. **Consider biomimicry and ancient and nature-based solutions in design processes for all things—products, structures, and services.**
8. **Consider circularity and intergenerational stewardship concepts in the process, product, technology, and organizational model, targeting operating model and culture designs**.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Foley, Jonathan. "Occam's Razor for the Planet." *Medium*, 5 Mar. 2021.
2. McDonough, William. Net-Positive: Waging Peace Through Commerce by Design. McDonough Innovation, 2022.
3. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things.* North Point Press, 2002.
4. Polman, Paul, and Andrew Winston. Net Positive: How Courageous Companies Thrive by Giving More Than They Take." Harvard Business Review Press, 2021.
5. Walmart. "Regeneration of Natural Resources: Forests, Land, Oceans ." Walmart, ESG Reporting, Environmental, 2022.
6. Walmart Sustainability Hub. "THESIS Index."

Issue 15: Lack of transparent tracking of human rights, the need for ethics-based trackable measurability, monitoring, and accountability

Background

Many multinational corporations/companies (MNCs) and NGOs/governmental organizations (GOs) every year put tremendous amounts of effort and investments in trying to address global or regional issues through impact-driven initiatives, especially in rural and underdeveloped areas. However, due to a lack of evidence-based measurability and accountability information that can be readily shared with all stakeholders, the public may only glimpse what's taken place in an organization's deeply embedded annual corporate social responsibility (CSR) reports or from anecdotal stories on social media.

After being "discovered", human wisdom and the best sustainable practices are not adequately shared to inspire more efficient resource use and inclusive involvement. As vast amounts of empirical data and inputs are available from both the past and ongoing sustainable development goals (SDGs) and environmental, social, and corporate governance (ESG) efforts, technologies such as artificial intelligence (AI) and blockchain may be able to help unleash aspired and inspired ideas and actions. Specifically, blockchain technologies such as distributed autonomous organizations (DAOs), nonfungible tokens (NFTs), and "smart contracts" can radically reduce the supply chain waste, delay, and obscurity of transactions by democratizing decision-making.

Recommendations

1. **Incorporate Ubuntu philosophy to map connectivity and show links between actions and impacts.** Creating a framework unifying Internet of Things (IoT), AI, and blockchain technology across all countries/regions would help put an end to issues of data availability. Creating a framework unifying IoT, AI, and blockchain technology across all countries/regions would help put an end to issues of data availability. Accountability and evidence-based decisions require metrics, measurement (data) and analysis; they are part of monitoring the impact of actions to progress toward a more sustainable planet Earth.
2. **Work with leading AI experts and representative stakeholders to develop an AI+Blockchain consensus-based platform (such as DAOs, NFTs, and "smart contracts") to better discover, assimilate, and share human wisdom and sustainable development and deployment practices worldwide.**
3. **Promote and educate NGOs/GOs and MNCs to use this AI data-driven platform to guide and monitor their SDG/ESG efforts and impacts.**
4. **Use this open platform to track and monitor issues associated with the IEEE Planet Positive 2030 Initiative and the SDG implementations.**
5. **Use this platform to give Indigenous or marginalized communities a better chance of letting their voices be heard and getting the best help from other stakeholders.**

6. **Promote the use of home/household/building/office/shop sensors able to detect the presence of individuals, and turn off unnecessary energy usage, so energy is not wasted.**
7. **Consider people-centered Internet design principles** (see People-Centered Internet website) **for internet, technology, data, process, organization, security, privacy, and network design**.

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Lane, Anne, and Bree Devin. "Operationalizing Stakeholder Engagement in CSR: A Process Approach." *Corporate Social Responsibility and Environmental Management* 25, no. 3 (2017): 267–280.
2. Nasdaq. "ESG Reporting Software & ESG Data Tools." Nasdaq CSR ESG Reporting.
3. Participatory Methods (website).
4. Project Drawdown. "Table of Solutions."

Issue 16: Confusion regarding nature versus technology OR nature plus technology

Background

In many societies, one generation tries to make “life better” for the next generation.

In Western societies, especially, this motivation has led to innovation often being the purpose of human life, with the main goal to make lives more comfortable. Wherever humans step, some may want the place to turn into a technological oasis, launching into things unknown and unseen before and thus moving further and further away from nature.

People frequently do not take notice of the sights around them—the beauty of nature, emerging pandemics—until those sights explode and change lives drastically. As humans, we are too busy to look because we spend our time warping reality to our standards. As a result, we play a dirty trick on ourselves.

Humanity has achieved great things, for example: the human genome has been decoded; the development of AI started in the mid 1900’s; artificial fertilizer helps feed people around the globe for about 100 year; hand hygiene, clean water and sanitation services are a major achievement for a healthier populations; electricity generation from wind and sun.

There is something more—for millennia, our ancestors explored the intricacies of science, trying to explain the world around them. They followed a path from simple mechanisms to developing devices that can measure light years in the universe. And, in the late 1800s/early 1900s, they discovered the duality of light—wave and particle (photon) properties, leading to the exploration of the world beyond atoms: the quantum world.

With quantum physics, humanity took a huge step forward in the era of electronics and modern technologies: It brought solar energy, computers, and quantum chemistry.

any of these fundamental discoveries happened “by chance”; others were discovered through careful questioning, experimentation, testing, observation, and analysis. Scientists and engineers found quantum effects in natural processes: genome crossover, photosynthesis, thermonuclear fusion in the sun (Editors of Encyclopedia Britanicca, “Thermonuclear Reaction”), and plausibly, a quantum nature of our consciousness.

Therefore, if a newly discovered or developed technology is already incorporated in nature - possibly in every living cell—then such technologies are nothing but mere copies and modifications of what is already present in nature (biomimicry).

Recommendations

1. **In scientific research and the development of technologies, learn to “collaborate” with nature and learn from nature.** Practically, all the discoveries so far may be a tiny drop in the ocean of nature’s “secrets” that are yet to be discovered.
2. **Bring changes to educational systems, which will inspire students and pupils to view monumental discoveries on the edge of life sciences and STEM subjects** (e.g., explain biological effects using physics and math and elaborate modern views upon ecology).

3. **Introduce regular open-air classes for school and kindergarten students.**
4. **Engage intergenerational and interdisciplinary groups in watershed, beach, water body, ocean, and biodiversity restoration, regeneration, and stewardship.** Leverage models like Students and Teachers Restore a Watershed (STRAW) to school children, teachers, parents, and business leaders to converge on plots of land that need restoration and work on them together. Leverage this and other examples at scale across communities and geographies (Point Blue Conservation Science, “STRAW Program”).
5. **Simplify scientific language in textbooks to make them more colorful, so that children can really fall in love with discovering.**
6. **Raise the level of STEM and ecology education in developing countries.**
7. **Give more opportunities to people from Indigenous communities to cooperate in “adjacent to nature” scientific areas, thus, introducing new perspectives to scientific investigations.**

Further resources

When involving Indigenous participants and communities, please consider the rights of Indigenous Peoples as stated by the Human Rights Office of the United Nations in *Free, Prior, and Informed Consent* (UN OHCHR, 2013).

1. Adams, Betony, and Francesco Petruccione. “Quantum Effects in the Brain: A Review.” Cornell University, Qualitative Biology, Neurons and Cognition (17 Oct. 2019).
2. IBM. “What is Quantum Computing?” IBM, Topics.
3. Lanese, Nicoletta. “Why Does DNA Spontaneously Mutate? Quantum Physics Might Explain.” LiveScience.com, 17 Mar. 2021.
4. Sacilotti, Marco, Euclides Almeida, Claudia C. B. O. Mota, Frederico Dias Nunes, and Anderson S. L. Gomes. “Can the Photosynthesis First Step Quantum Mechanism be Explained?” Cornell University, Physics, Chemical Physics (2010).

References

1. AAP. “First Nations Wisdom Harnessed to Protect the Environment.” NITV, Environment. 24 Nov. 2023.
2. Campbell, Joseph. The Hero’s Journey: Joseph Campbell on His Life and Work. New York: Harper & Row, 1990.
3. Editors of Encyclopedia Britanicca. “Thermonuclear Reaction.”
4. Nature-Bound Australia. “Aboriginal Culture—Timeless Wisdom a Pathway to Enlightenment.”
5. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things.* New York: North Point Press, 2002.
6. People-Centered Internet (website).
7. Point Blue Conservation Science. “STRAW Program.”
8. SHAPE-ID (website).
9. UN Environment Programme (UNEP). *The Nature-Based Solutions for Climate Manifesto: Developed for the UN Climate Action Summit 2019*. 14 Aug. 2019.
10. UN Human Rights, Office of the High Commissioner (UN OHCHR). *Free, Prior and Informed Consent of Indigenous Peoples*. Indigenous Peoples and Minorities Section, OHCHR Rule of Law, Equality and Non-Discrimination Branch. Sept. 2013.
11. Wikipedia, s. v. “Hero’s Journey.”
12. Worldometer (website).
13. Yachkaschi, Ali, and Schirin Yachkaschi. “Nature Conservation and Religion: An Excursion into the Zoroastrian Religion and Its Historical Benefits for the Protection of Forests, Animals and Natural Resources.” *Forest Policy and Economics* 20 (July 2012): 107–111.

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CHAPTER 11: SUSTAINABILITY COMMONS

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Committee Members

Committee Co-Chairs

- Cyrus Hodes, FL, United States
- Usha Jagannathan, AZ, United States

Committee Members

- Akshaya Venkatesh, IL, United States
- Alpesh Shah, NJ, United States
- Amir Banifatemi, CA, United States
- Anand Rao, MA, United States
- Armin Hamrah, CA, United States
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- Mei Lin Fung, CA, United States
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- Nikhil Jain, CA, United States
- Peter Mangiafico, CA, United States
- Sarah Grace Manski, VA, United States
- Sigmund Kluckner, Austria
- Tamara Singh, Singapore

SUSTAINABILITY COMMONS

Future Vision

It is 2030.

The sustainability commons is now the go-to platform, a digital knowledge commons, for all things ClimateTech. It is always up to date thanks to an engaged contributors' base and is easily accessible by stakeholders around the world, facilitating discovery and adoption of climate solutions and enabling climate action decisions.

"Content is easily verifiable, and information about its quality is well captured, making the content trustworthy…People have access to valued, contextualized sustainability knowledge that is easily understood, can be trusted, and may be adopted to help enable the planet to get to net zero and thrive over the long term" (WSIS+20 High-Level Event 2024, "IEEE Knowledge Café: Knowledge Sharing for Sustainable Development").

Sustainability knowledge is only important when put into use. Having and sharing knowledge is a foundation of influence and, therefore, of power to lead change. Desert communities in the Sahara have shared their clean energy, water, food solutions, and best practices with great success. Communications technologies for the arctic areas have been greatly advanced and shared on the commons to support better access to health care, education, and sharing resources. The progress made in achieving the IEEE Positive Planet 2030 vision has been possible by deploying effective models of knowledge and expertise sharing that has empowered communities to benefit from collective know-how worldwide.

Technology itself enabled an effective governance and organization model for the *sustainability commons*—a dynamic, ever-changing, contextualized sustainability data, information, knowledge, and solutions tool available online for communities to access, share, and adopt to enable the planet to thrive in the long term.

A key enabler of the commons took place in the mid-2020s when mechanisms like decentralized autonomous organizations, or DAOs[85], began to proliferate in response to the growing concern over the lack of regulation regarding emerging technologies such as those involved in generative artificial intelligence (AI) and the Metaverse (Connor, 2022). Rather than address these issues top down, countries, companies, and individuals around the world demanded personal data protection as represented in key laws like the European Union (EU) General Data Protection Regulation (GDPR), enabled with "personal agents" that functioned at an algorithmic level to represent all people's individual identity, data, and choices at the same speed and context of algorithms (GDPR.EU, 2018).

The commercial web of early Internet data brokers, driven in large part by advertising, gave way to real-world, digital, and virtual communities whose members voted on projects with genuine agency, including the prioritizing of protecting the planet and all people above short-term profit and growth. This initiative, that is, growth in engaged digital and virtual communities, led to the greatest proliferation of innovation in modern times, in which it was only by fostering caring communities where all people knew their votes and voices counted that our modern sustainability commons was born. Commons that do not list the Intergovernmental Panel on Climate Change (IPCC) or Paris Agreement goals are immediately not trusted in both smaller or internationally oriented DAO-type settings (Reiff, 2023).

[85] In his article, "DAOs Could Hold the Answer to Better Data Governance Guidelines," Dan Connor explains: "In a DAO, contributors vote on the direction of projects, creating a feedback loop that doesn't currently exist in AI-driven systems. Rather than simply honing complexity into simplicity, by asking humans whether they accept the internal decisions, DAOs bend the arc of data models toward community centricity."

Introduction

Definition of sustainability commons

A digital sustainability commons refers to a dynamic mapping of who is doing what and where, in all climate and sustainability technologies (Heid et al., 2022).[86] The commons will be made available to all to enable and increase visibility of solutions and best practices, ultimately allowing governments, businesses, civil society organizations, and individuals to make the most effective decisions based on their circumstances.

In her 1990 book, *Governing the Commons: The Evolution of Institutions for Collective Action*, American political economist Elinor Ostrom describes the sustainability commons as "long-enduring, self-organized, and self-governed" (Ostrom, 1990, p. 58). Known for her work on the governance of common-pool resources, such as forests, fisheries, and water systems, Ostrom won the Nobel Memorial Prize in Economic Sciences in 2009. *Governing the Commons* is considered a seminal work in the field of institutional analysis and the management of common-pool resources. In this book, Ostrom presents case studies of successful management of common-pool resources by communities around the world and proposes a set of design principles for the institutions that govern these resources. On page 58 of the book, Ostrom discusses the importance of "local knowledge" in the management of common-pool resources and argues that it is often more effective than external expertise or formal regulations.

Part of building the commons will be to highlight the requirements to sustain the commons over time, as well as its organization and governance mechanisms. The commons would be expert vetted and organized with proper contextualization on relevant climate and sustainability technologies and how they could be leveraged for the query at hand to help various stakeholders to decarbonize their sectors/industries.

Beyond the sharing of knowledge, the sustainability commons could be a platform to help gather information, regardless of whether this information is readability available (open source).

The sustainability ecosystem consists of academics, corporate leaders, policy makers, regulators, activist groups, and others who might have differing agendas, follow different frameworks and methodologies, and make claims/counterclaims that are difficult to verify. The sustainability commons will create a trusted and verifiable framework; methodology; catalog of models, tools, and platforms; and appropriate governance for the different stakeholders to contribute to, build on, and verify the claims. As an outcome of this initiative, the participants in the sustainability commons will evaluate metrics, rewards, business models, ownership, funding, resourcing, curation, and governance using other similar examples (e.g., Wikipedia, open-source communities, and DAO models).

[86] In their 2022 article, “Delivering the Climate Technologies Needed for Net Zero” in *McKinsey Sustainability*, authors Bernd Heid, Martin Linder, and Mart Patel identify “ten families of climate technologies” and explain: “Most climate technologies are viable only if other climate technologies are also implemented at the level of facilities, enterprises, regions, or value chains.”

Issue 1: Thinking in silos

Background

Currently, sustainability knowledge and information is spread over a large number of stakeholders, each of them thinking and acting in their own ecosystems and disciplines. This problem, however, is not limited to scientific disciplines; it can also be found with gender-balance concerns, inclusion of local/Indigenous groups, and consideration for the big picture of environmental, social, and governance issues within the sustainability fields.

Recommendation

1. **Enhance trusted information flow between various thematic and geographic areas, as well as between stakeholder groups to help with faster uptake of sustainability solutions.**

Issue 2: Lack of long-term viability of previous "commons" projects

Background

Lots of commons-aligned projects, especially with a heavy focus on knowledge commons, tend to have a model of grant- or subsidy-funded operations. This model, however, can become a challenge in the long term as the projects are dependent on a constant funding stream from public entities, philanthropies, and other well-intentioned donors. Along those lines, the platform and overall project will have to prove its worth in the long run: through strong and coherent metrics, an innovative business model, shared ownership between all members of the sustainability commons, and other specific proof of the efficient use of resources.

Recommendations

1. **Develop the sustainability commons for long-term viability.**
2. **Develop an innovative business model that supports long-term viability and that includes shared ownership and efficient use of resources.**
3. **Secure resources—human resources, financial resources, and so on—that will support the sustainability commons.**
4. **Design a platform, interoperable platforms, and tools, including AI tools, so that they are flexible and can incorporate future technological enhancements.**
5. **Develop one or more technical standards for such a Sustainability Commons.** An example would be "IEEE P7801 Recommended Practice for Technical Knowledge Commons Initiatives and Platforms," currently under development). A technical standard should lead to interoperability between such sustainability commons and thus support a federation of commons.

Issue 3: Limited access to knowledge and expertise

Background

The free flow of knowledge and expertise is essential. In the sustainability commons, where different points of view and diverse solutions to common problems are encouraged, maintaining the integrity of content and platforms becomes crucial to prevent greenwashing, marketing, or other dubious activities. This balance between free-flowing knowledge and responsible content moderation is essential.

Fortunately, a key opportunity comes from EU regulation focused on climate and nature-based goals going into effect in 2024 (European Commission, “Nature Restoration Law"). U.S. reporting needs come from the U. S. Securities and Exchange Commission (U.S. SEC, 2022). Companies will be required to disclose their climate-related risks, such as the impact of climate change on their business operations and supply chains.

Greenwashing, or "greenwishing," arises from intentional or unintentional misrepresentation of company activities related to climate and planetary issues. To counter this issue, the concept of unified cooperation for stakeholder benefit and distributed cooperation becomes essential in the context of sustainability commons. Unified cooperation fosters collaboration and authentic action, promoting transparent reporting and knowledge sharing. Distributed cooperation recognizes the need for collective action across diverse actors, integrating different perspectives and expertise. By leveraging these approaches, the sustainability commons serve as a platform for shared resources, innovation, and collective problem-solving, empowering stakeholders to implement sustainable practices and contribute to a greener future.

Recommendations

1. **Design, develop, implement, and maintain the sustainability commons to serve as a platform for shared resources, data, innovation, and collective problem-solving.** Such a sustainability commons should serve to empower stakeholders to implement sustainable practices and contribute to a greener future.
2. **Help ensure the integrity of content and platforms.**
3. **Promote free flow of knowledge and expertise and encourage different points of view.**
4. **Provide for responsible and transparent content moderation.**
5. **Take measures to prevent “greenwashing” and similar such activities.**
6. **Promote transparent reporting.**
7. **Enable collaboration and cooperation, including distributed cooperation**.

Issue 4: Need for accessible common "language"

Background

Potential contributors to the sustainability commons will come from a variety of disciplines and geographies, each with its own language and terminology. The more different fields are gathered in one shared information space, the more important it will be to have a coherent and agreed set of concepts, definitions, and terms, representing the same idea in different areas of work. Setting up a commons-wide ontology will be crucial to support this issue. Also critical to this issue is the recognition that certain Indigenous and other traditions have oral cultures as a key means of communication, which beyond being honored provide the opportunity to recognize non-Western ideals of a commons to be explored and proliferated as part of the examination of a sustainability commons overall.

Recommendations

1. **Build and provide a commons-wide ontology based on an agreed-to set of concepts, definitions, and terms.**
2. **Make assets on the commons accessible** (written language, visual, auditory).

Issue 5: Need for shareable and verifiable data and models

Background

Currently, various sustainability models have been built for specific domains and specific countries at different levels of granularity. These sustainability models have different sets of assumptions and different types of data sets, making verifiability of claims and the modular development of models a significant challenge. Having a hyper-catalog of data sets, a modular model architecture, and a repository for contributing, sharing, and building sustainability models will be a critical component of sustainability commons.

Recommendations

1. **Design and develop the following:**
    a. **A hyper-catalog of data sets**
    b. **A modular model architecture**
    c. **A repository for contributing, sharing and maintaining trusted data, analyses and models**
    d. **Sustainability models**

Issue 6: Need for transparent and inclusive governance

Background

As a public good, the sustainability commons need to adopt a governance model that respects voices from a variety of contributors and supporters—in terms of both the strategic direction of the overall commons and the curation and related decisions. Existing governance models might not even fit this type of activity, giving this effort the chance to invent or deploy innovative models instead.

Recommendations

1. **Adopt a governance model that respects voices from a variety of contributors and supporters—in terms of both the strategic direction of the overall commons and the content curation and related decisions.**

Issue 7: Steps to help building a sustainability commons initiative

The following recommendations will help **initiate building a sustainability commons initiative**. These recommendations comprise both process guidelines and design principles.

Recommendations

1. **Map existing initiatives**. A key starting point will be to understand existing initiatives and the sustainability commons regarding climate technology. As a result, examples from universities, research centers, corporations, governments, startup accelerators, and others will be needed to recognize gaps in the existing landscape, learn lessons from prior attempts to address this need, and identify partners for implementation. For example, a model worth mentioning is the shareholder commons[87], in which companies band together to address climate issues for the greater good, a form of "stakeholder" capitalism that could be more sustainable for a majority of stakeholders rather than just one small group of shareholders.
2. **Build a global repository with multi language support.** A true sustainability commons should be global by design, which means building in support for different languages from the beginning. But for this commitment to be truly global, the design should go beyond multilingual support to include building tools and an architecture that can be customized for various contexts by communities.
3. **Design to empower distributed communities.**
4. **The governance and ownership of such a sustainability commons should strike a balance to be both as inclusive as possible and retain effective decision-making.** Therefore, all stakeholders should be empowered, whether individuals or communities, and control should not be centralized. Various organizational and technological designs should be tested to achieve these objectives. For example, new technologies should be explored, such as setting up a DAO or working with more established legal structures like data trusts.[88]
5. **Design for easy access to maximize engagement.** The design of a sustainability commons should encourage the growth of a network of contributors, as well as should incentivize engagement by both contributors and consumers. Therefore, tools need to be in place for two-way interaction with the commons for access and contribution of content.
6. **Optimize for discoverability of relevant content**. Facilitating the discovery of relevant content must be critical to help ensure that the commons will be useful (and adopted) for potential users (customers). To do so, best practices should be employed to increase discoverability of data and content, as well as to build on ideas of gamification.

[87] This information is given as an example of a for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[88] The Climate Data Trust is a data trust that was established in 2020 to help communities and businesses adapt to climate change by sharing data on climate change impacts and solutions. The trust has already been used to support a number of projects, including a study on the impact of sea level rise on coastal communities and a study on the effectiveness of renewable energy projects. This information is given as an example of a data trust for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

7. **Provide feedback loops and pathways for adoption.** A sustainability commons is only as useful as the solutions it helps deploy. Therefore, building simple pathways for adoption (how can content be linked to problem solving) and the right feedback loops (has content helped solve problems) must be considered.
8. **Build on what already exists.** The sustainability commons should leverage existing efforts, not reinvent a new solution. Likewise, when it is operational, it should facilitate sustainability innovation, enabling more reuse and rediscovery of existing solutions rather than reinvention and duplication.
9. **Start building with a specific focus area.** The organization(s) building a sustainability commons should focus on a specific area or problem sets as a starting point to build out a pilot and iterate before scaling it up further. This process could be determined by the organization launching such efforts in collaboration with first clients. The starting point should be carefully selected to showcase the potential for a technology commons by identifying an area that has both sufficient resources and demand (areas such as carbon removal, renewable energy, or circular economy).
10. **Provide incentives as keys for uptake.** A sustainability commons should be designed to encourage discovery, deployment, and documentation of content for reuse. The same principle applies to the design of products, processes, and incentives through the commons.
11. **Incorporate trustworthy quality control and content review.** Users need to trust that the content is genuine and ideally have value-added data that provide information or a rating on technologies, data, and documents in the sustainability content. Therefore, finding ways for users to receive existing metadata or reviews, as well as value-added assessments of content, is important.

Case Studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. California Climate Commons (website).

   Description quoted from the website:

   > *"**Science and data supporting climate change resilience in California.** The California Climate Commons digital library was launched in 2011 by the California Landscape Conservation Cooperative (The CA LCC, one of 22 LCCs in North America). It provided unprecedented access to climate change science for conservation practitioners, introducing innovative ways to understand and incorporate this emerging information.*
   >
   > *In 2018 the National Landscape Conservation Cooperative program was discontinued and is now the **California Landscape Conservation and Adaptation Partnership (CAL CAP)**.*
   >
   > *The Climate Commons digital library ceased being updated in 2018, but you may still search the archived Climate Commons catalogs and articles."*

2. Creative Commons (website).

   Description quoted from the website:

   > *"Creative Commons is an international nonprofit organization that empowers people to grow and sustain the thriving commons of shared knowledge and culture we need to address the world's most pressing challenges and create a brighter future for all."*

3. Crowdsourcing Sustainability (website).

   Description quoted from the website:

   > *"Crowdsourcing Sustainability is unleashing the power of people everywhere to help reverse global heating as quickly and equitably as possible. Join our community of over 200,000 people from 150+ countries to rebuild a safe, healthy, and just world together!"*

4. Earth Journalism Network, Climate Commons (website)

   Description quoted from the website:

   > *"**Internews** initially developed the **Earth Journalism Network** (EJN) in 2004 to enable journalists from low- and middle-income countries to cover the environment more effectively. This is now a truly global network working with reporters and media outlets in virtually every region of the world. Following the mission to improve the quantity and quality of environmental reporting, EJN trains journalists to cover a wide variety of issues, develops innovative online environmental news sites and produces content for local media–including ground-breaking investigative reports. EJN also establishes networks of environmental journalists in countries where they don't exist and builds their capacity where they do."*

5. Future Earth Networks. "Knowledge-Action Networks."

   Description quoted from the website:

   > *"The Future Earth Knowledge-Action Networks (KANs) bring together innovators from academia, policy, business, civil society and more to address the world's most pressing sustainability challenges.*
   >
   > *KANs are collaborative frameworks that facilitate highly integrative sustainability research on some of today's most pressing global environmental challenges. Their aim is to generate the multifaceted knowledge needed to inform solutions for complex societal issues."*

6. UN Climate Change. "Global Climate Action."

   Description quoted from the website:

   > *"The Global Climate Action portal is an online platform where actors from around the globe - countries, regions, cities, companies, investors and other organizations - can register their commitments to act on climate change.*
   >
   > *Launched by UN Climate Change, Peru and France in 2014, the portal was born of the realization that addressing climate change will take ambitious, broad-based action from all segments of society, public and private."*

7. The Oxford Climate Tech Initiative's Real Time Crowdsourced R+D Systems Map.
8. Shareholders Commons (website).

   Description quoted from the website:

   > *"Founded in 2019, this is an independent, non-profit organization that addresses social and environmental issues from the perspective of shareholders who diversify their investments to optimize risk and return."*

9. UN Environment Programme (UNEP). "Publications and Data.")

   Description quoted from the website:

   > *"The UN Environment Programme offers more than 15,000 items, from real-time data tools and platforms to key reports, publications, fact sheets, interactives and more."*

10. WWF Climate Crowd (website).

    Description quoted from the website:

    > *"Climate Crowd is a bottom-up community-driven initiative. Working with communities and local organizations in over 30 countries, Climate Crowd collects data on climate impacts to communities, analyzes the data, presents the data back to the communities, and works with them to develop, fund and implement on-the-ground solutions that help people and nature adapt to a changing climate."*

Further resources

1. Carbon Disclosure Project (website)
2. Climate Action 100+ (website).
3. Community Climate Collaborative (website).
4. Prime Coalition and Rho AI. *CRANE User Report 2021*, 2021.
5. Design for Change USA (website).
6. International Carbon Action Partnership (website).
7. IPCC, Links (website).
   Luiken, Maike, and Alpesh Shah. *Policy Brief: Scaling Climate Goals Through the Use of Technical Experts and Digital Technical Knowledge Commons*. T7 Task Force Climate and Environment. Think7, 22 Apr. 2022.
8. Climate Mapping for Resilience and Adaptation (website).
9. Wikipedia, s.v. "List of Climate Change Initiatives."

References

1. Climate Action Data Trust (website).
2. Connor, Dan. "DAOs Could Hold the Answer to Better Data Governance Guidelines." VentureBeat, 8 May 2022.
3. European Commission (EC). "Nature Restoration Law." Energy, Climate Change, Environment, Nature & Biodiversity.
4. European Union (EU). "Complete Guide to GDPR Compliance." General Data Protection Regulation (GDPR.EU), 2018.
5. Heid, Bernd, Martin Linder, and Mark Patel. "Delivering the Climate Technologies Needed for Net Zero." *McKinsey Sustainability*. 18 Apr. 2022.
6. Ostrom, Elinor. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, MA: Cambridge University Press, 1990.
7. Reiff, Nathan. "Decentralized Autonomous Organization (DAO): Definition, Purpose, and Example." Investopedia, *Cryptocurrency*. 30 Sep. 2023.
8. The Shareholder Commons (website).
9. U.S. Securities & Exchange Commission. "SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors." Press release, 21 Mar. 2022.
10. WSIS+20 High-Level Event 2024. "IEEE Knowledge Café: Knowledge Sharing for Sustainable Development." Session 348, 29 May 2024.

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THE ARTS

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CHAPTER 12: THE ARTS

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Committee Members

Committee Co-chairs

- Anja Puntari, Finland & Italy
- Guenter Koch, Austri & Spain

Committee Members

- Sara Bennett, United States
- Subhajit Khush Das, India
- John Favaro, Italy
- Wardah Jamil, USA & Brunei
- Hironobu Murata, Japan
- Christina Merl, Austria & Netherlands
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- Ananya Sen Gupta, United States
- Hermine Schuring, Austria & Netherlands
- Massimiliano Viel, Italy

THE ARTS

Future Vision

It is 2030.

Art has provided humanity with a newfound focus on empathy supporting a broad change in the zeitgeist of policy, business, and technology in general.

Thanks to art, humans now have a space for systemic thinking that has helped people around the world to understand the complexity of overcoming planetary challenges through the interplay of many disciplines. In other words, in this process, art has played an integral role in combining the different pieces together and representing a fragmented world of various interpretations and truths. More than anything, art has shown stakeholders' different points of view, brought people together in a joint action to save the planet, and connected humans to a profound sense of meaningfulness. As a result, the much needed technological solutions and redesigns have taken place.

In 2030, the concept of art has reformed; it has its place empowering people in all their daily surroundings as one strong wire in the social fabric. When in earlier decades art's intrinsic value widened to social and participatory realms (as arts in health, as part of mental well-being, and other fragile groups), in 2030, art is now integrated into various powerful working contexts, with big impacts on the lives of many (political, corporate, and more). Art enables a creative approach breaking through limitations of norms, serving as a medium to reach new knowledge. Diversity and a cross-disciplinary approach are evidently important, and art can build bridges between people and enable exchange and co-creation.

In 2030, art has been accepted as a key enabler of human and planetary flourishing, harkening back to an era when millennia before the development of the scientific method, oral, spoken, and visual manifestations of cultural traditions formed the historical bases of art unified families, communities, tribes, and regions as peaceful modes of communication and unification.

The enormous change that occurred in the last seven years, beginning in 2023, was not linear. At that time, no single entity existed, and no clear events were available to lead people, companies, and countries into a completely different lifestyle. The change happened because many different movements and actors, across politics, business, and society at large, joined forces. Artists, with their ability to grasp glimpses of the future, led the way with their artworks. They guided people on the path of *deep listening and emotional connectivity*. With their art, they revealed what is really important and helped to ask: What is the legacy of humanity to the future generations, and what kind of world do people want to create? Artists contributed to the renewal of the systems and their norms, restrictions that define possibilities of development, pushed humanity's imagination to the next level, and enabled discoveries of new, unseen ways of being, doing, and existing in this world. This contribution paved the way to reducing greenhouse gas emissions dramatically, to stopping the extinctions of species, to regenerative new agricultural processes, and to healing Earth's ecosystems.

Introduction

As the effects of climate change become increasingly apparent, it is more important than ever that humans take action to protect the planet. While science and technology are crucial in addressing environmental issues, art plays a powerful role in raising awareness and inspiring change. The climate crisis is a crisis in the relationship of humanity with the planet. Art contributes to the change in this relationship, as well as to how humans interact with nature and the planet as whole.

Through various forms of expression such as visual art, music, literature, and film, artists convey the urgent need for change and the importance of sustainability. Art can be used as a means of communication and advocacy that can inspire the public to demand more from policymakers and industry leaders. The emotional impact of art can be particularly powerful in encouraging people to take action and become more invested in environmental causes.

Art can also serve as a means of promoting empathy and understanding, which is especially important when dealing with complex environmental issues. For example, a photograph of a polar bear struggling to find food in the melting Arctic can evoke a sense of empathy and urgency in a way that a data chart or scientific report may not. Through art, people can see the tangible effects of climate change and be moved to take action to protect the planet.

Art is a way to tap into tacit knowledge and connect to thoughts and ideas that cannot be expressed in any other way. This value is understood within the private and individual domain, but now it is topical for various organizations and systems in need of creative renewal for a sustainable change. It is essential to “build new bridges” of cross-disciplinary collaborations, to create access for art to support all kinds of communities.

In addition, many artists are now incorporating sustainable practices into their work. By using recycled materials, reducing waste, and minimizing their carbon footprint, artists are not only raising awareness about environmental issues but also serving as examples for others to follow.

The power of art in encouraging change should not be underestimated. It plays a vital role in supporting people in creating an emphatic relation to the environment. As we[89] work toward a more sustainable future, art should be supported and promoted to awaken environmental consciousness.

Art cannot save the planet on its own, but it can play an important role in raising awareness and inspiring change that is necessary for preserving the Earth for future generations. Art is a powerful medium that evokes emotions, creates empathy, and inspires people to take action.

[89] “we” as in “humans”

Issue 1: The need to make people feel the urgency of climate change—emotions push people into action

Background

Besides the tangible and measurable aspects of climate change, the transformation of a personal environment also touches emotional dimensions on both a collective and an individual level. Art can be the space where emotions emerge, where difficult emotions can be handled in an appropriate way, and where emotional energy can become a driving force for positive change.

Emotions play a key role in fueling behaviors that generate action on all levels in society. David McLelland (McLelland et al., 1953), in his early research on behavioral issues in the 1950s, gave emotions the most fundamental causal dimension and showed how people who managed to gain extreme success in their careers were pushed by intrinsic motivation and good management of their emotions to excellence. Some decades later, Daniel Goleman[90] not only introduced this interpretation to a wider audience but also showed the direct connection between the role of emotions and the levels of individual and collective performance.

Climate change fuels a wide range of emotions from dark emotions like despair, grief, rage, fear, and anxiety to passion and love to act in front of a global challenge. If managed well, the emotions connected to climate change, even the difficult ones, can become a driving force for making necessary change. People can come to recognize the presence of the emotions in them and can learn how to channel the energy they create in a constructive way. Poorly managed emotions, however, can become destructive and cause the opposite effect of creating climate resistance and opposition toward positive climate actions or, for some people, the inability to act in front of the global challenge.

Art and artful methods can help elaborate the emotional dimension in relation to climate change in several ways. Artful practices can help develop emotional awareness and intelligence both on individual and collective levels, increasing human:

- Ability to *recognize*, both in them and in others, the emotions that often drive behavior (consciously or unconsciously)
- Ability to *give an appropriate name* to what is felt, in other words, to be emotionally literate
- Understanding of *how to welcome, control, manage, and direct* emotions to be constructive, rather than falling prey to them
- Understanding of *how to talk* about emotions connected to climate change
- Knowledge about *how to influence others* through emotions, that is, sensibilize them on the topic

[90] Daniel Goleman, American psychologist, is one of the main theorists on the role of emotional intelligence in life and in people's actions. His ideas are a combination of interdisciplinary reasoning between neurology and behavioral sciences. His most popular work is *Emotional Intelligence* by Bantam Books (1995).

Artworks can simplify and amplify at the same time. If on the one hand, they allow the transfer of complex concepts on an immediate descriptive level, then on the other hand, they bring out the emotional attributes in a more marked and distinctive manner. In this sense, they represent a privileged and direct access to the experiential world of people. While in contact with an artwork, the person is predisposed to a deeper exploration of their experience, of resistances, of pressures to move forward. Sometimes artworks that have a strong statement or express a clear provocation reach a person's sensibility in an immediate way. In the work of the Spanish artist Isaan Cordal (2011), *Politicians Discussing Global Warming*, for example, highly elegant men are drowning in a pond of water. This artwork can create *annoyance* and *irritation* in people. In the work of the Italian artist Sarah Ciracì (2021), *Sacrilegio*, the artist represents a bas relief of cows in an intensive farm. This piece makes many people feel *sad* and *angry* while thinking about how animals are treated in intensive farming and what are the consequences of this way of producing meat. Both art pieces spur strong emotions in people who see and reflect on their meaning.

But if artworks fire up human emotions, then they also provide the possibility to observe things from a distance. In fact, art can bring humanity closer to the meaning of lived experience, but at the same time, it can also allow people to take the right emotional distance to be able to observe, consider, evaluate, and reevaluate what is happening. By objectifying the interiority of thought, the people reflecting on climate change can physically detach themselves from it and look at it from new angles to create an action plan needed for the change.

Recommendations

1. **Encourage employing/using art to raise awareness and inspire change that is necessary for preserving the Earth's biosphere for future generations.**
2. **Actively involve people and communities in workshops that use art to reflect and manage the emotional side of climate change.**
3. **Invest in educational projects that use art as a means to stimulate emotional awareness in relation to climate change.**
4. **Give space (time and physical momentum) to elaborate on the emotional dimension in an adequate way.**
5. **Welcome all kinds of emotions to the co-reflection process, and use the artworks as a space to read and elaborate on the feelings connected to climate change.**
6. **Invite people to make an action plan and to use the emotional energy as a driver to fuel the change.**

Issue 2: The need to enforce society's relational capital in the fight for climate change—how to increase opportunities to engage with art

Background

Global warming is the most complex collective challenge humankind as a species has ever faced. This challenge can only be coped with if the human species creates strong social bonds and collaboration. In fact, collaboration and cooperation are the key to tackling the environmental destruction that is currently happening. How to relate in a constructive way and become aware of the relationships that tie humans together (i.e., the interdependent nature of human existence) is the basis of collective survival.

The arts can work as a *boundary object* that connects people from diverse backgrounds and positions to each other to promote mutual understanding through discussion toward a common goal. The concept of boundary objects was proposed by Susan Leigh Star and James R. Griesemer in 1989. It originally began with the perspective of how professionals, amateurs, and others could collaborate across boundaries in the organization and operation of the museum context.

The arts especially help transcend traditional social barriers and norms, and social relational capital is a valuable by-product of artistic activity (Crossick & Kaszynska, 2016). For example, public art creates a sense of relationship and ownership in a city or region and enhances social connectedness. In addition, a 2016 art research project revealed that small-scale community art activities are more likely to benefit residents versus large-scale urban renewal projects (Crossick & Kaszynska, 2016). The creativity that social art projects cultivate may help collectivities to cocreate innovative solutions to environmental challenges locally. One example would be a work by the world-famous Argentinian artist Thomas Saraceno called "Museo Aerosolar." "Museo Aerosolar" had its birth in the Isola district in Milan, Italy, in 2007. For four months, the artist gathered with local cultural associations in Isola plastic bags to create an immense flying sculpture. The project represented an opportunity to transform what most would consider garbage into an object capable of bringing together the work of an entire community and embodied the vision of a future without pollution. The focus of the artwork is not as much on the result of the work than on the process of collective activation toward a common goal. Saraceno has since 2007 repeated "Museo Aerosolar" in 20 other sites around the world.

Therefore, art is a way to build relational capital in all kinds of spaces and communities, and it needs to be acknowledged as one relevant medium of transformation.

Recommendations

1. **Incorporate environmentally friendly art activities into lifestyles;** for example into hobbies that occupy a certain amount of time in human lives by replacing existing energy-consuming private activities. Traditional culture in harmony with nature is a reference (Japanese culture, for example, can incorporate various nature-infused artistic activities, such as tea ceremonies, flower arrangement, and poetry like haiku, inspired by intuitive penetration into nature and life).
2. **Build social relational capital through art activities in all kinds of communities and organizations.**
3. **Fund artist and art interventions that focus specifically on social and environmental aspects.**

Issue 3: The urgency to tackle the complexity of environmental change—expressing powerful contexts through art

Background

Art is a concept in constant flux. By default, art has its roots in communities and human expression, in the need for rituals and reflection. Art asks: What is humanity, and what are the stories of humankind? In modern times, the value of art is intrinsic. Art is used to manifest sophistication and human existence thriving, not only surviving.

What is happening in the environment and what kind of actions should be fostered is a so-called "wicked problem" (Rittel & Webber, 1973). There is no one simple solution to the changes and challenges happening globally right now. Art is one way to communicate the most complex challenges of all times, without the need to simplify them.

In the same manner that Renaissance art was the catalyst to grasping a new era, now, in this decade of environmental crises, art has a role to embody this shift, paving the way toward the future. Art is a tool to fill the imagination gap, to envision the future, to grasp that the world is not a disaster of business as usual but the one humans are working on, hope to create, and are truly wishing for.

Art is the tacit knowledge and language for all that which otherwise does not have a form, a way to be shared and experienced. In times of crises, art is not an addition or an ornament but the essential medium by which to explore unseen horizons together with people from various cultures, backgrounds, and disciplines.

Recommendations

1. **Test and pilot new forms of collaborations in which the arts and artistic expertise are integrated into decision-making, problem-solving, and future scenario work.**
2. **Support policies in which art is recognized as one key element for tackling "wicked problems."**
3. **Create the means, funding, and pilots for new cross-sectorial collaborations and actions that enable exchange between artists, stakeholders and experts from different fields.**
4. **Acknowledge artistic expertise as one essential skill and approach needed to resolve the most complex challenges and support the skill-building needed for new, to be established, cross-sectoral collaborations.**

Further resources

1. Kouzmine-Karavaïeff, Johanna, and Khawar Hameed. *Artists, Designers & Business in Cross-Sector Collaboration: A Report on the Untapped Potential for Systemic Change.* Artisans of Innovation, 2022.
2. Northern Dimension Partnership on Culture (NDPC). *Creative Industries' Future Session and Q&A with Futurist Roope Mokka: Imagination Gap*. YouTube video. 29 Sept. 2022.
3. Salzburg Global Seminar 2021. *The Creative Power of the Arts: Reimagining Human and Planetary Flourishing*. Session 717, Apr.–Nov. 2021.

Issue 4: Need to sensibilize business leaders to act through art interventions

Background

Traditionally art has had a passive role in the business context, being for example a visual embellishment inside offices or adding value to company collections through smart art acquisitions. Participatory art and art interventions that bring business leaders to reflect on the consequences of their actions can radically change decision-making today.

Company value is no longer considered only through economic aspects. Companies that invest time and energy on the dimensions of environmental, social, and corporate governance (ESG) tend to become in the long run more sustainable, even from the business (economic) point of view. Companies sensitive toward environmental and social themes gain in reputation and brand equity—for example through bigger commitment and engagement from the people who work for the company—and tend to create more solid relationships with clients and other stakeholders.

Contemporary managers have the following challenges:

- Harnessing long-term vision while bringing in the results asked for by the market today
- Perceiving correctly the relationships of different actors in a complex business and societal ecosystem
- Understanding the consequences of decisions taken from both an environmental and a societal point of view

Art interventions can help with these issues by:

- Creating clearness through visual means and visual thinking
- Enabling a process of co-thinking in meetings
- Activating a creative process to invent new alternative solutions for making business
- Sensibilizing business leaders toward environmental issues
- Transferring artistic skills to business leaders: emotional intelligence, sensibility toward others, aesthetical intelligence, creativity, and cultivating curiosity

Examples of how companies can interact with artists to create more sustainable business and to communicate their stories are shown in the case studies below.

Creating specific shows/events/assets that connect company history, business challenges, and the concept of *greenshift* can be an efficient way to sensibilize stakeholders in society.

Recommendations

1. **Bring artists inside companies and let them actively stimulate people's thinking processes.**
2. **Use artworks as triggers to stimulate creative thinking and inventing the new.**
3. **Create interdisciplinary working groups where people from different professional backgrounds need to solve environmental company challenges together.**
4. **Visualize. Use artful thinking, exhibition making, and curatorial techniques to sensibilize people in companies to the subject of *greenshift* and sustainable business**.

Case Studies

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1. Partnership between Manufacturer and an Arts Foundation

   As a practical example of how companies can interact with artists to create more sustainable business, a global manufacturer of kitchen products has created a steady partnership with an associated arts foundation. The company has manufacturing plants in Italy, Poland, Mexico, Germany, India, and China.[91] The collaboration has created a steady residency of artists inside company locations to boost constant innovation, creativity, and a different way of thinking and has pioneered the investigation of the potential link between art and industry[92] to create a more sustainable company culture.

2. Partnership between a Construction Company and a Museum

   Another good example of this practice are the shows of a construction company in the spaces of the Triennale Museum in Milan, Italy (Webuild with Triennale Milano, 2023).[93] Three large shows were used to tell the world about the construction challenges of the company. In this case, exhibition making, large-scale installations, and good curatorial practice make evident the impact of the activities of the company in construction sites all around the world. Creating specific shows that connect company history, business challenges, and the concept of *greenshift* can be an efficient way to sensibilize people and leaders in companies to act in a more sustainable way.

[91] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[92] Fondazione Ermanno Casoli is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[93] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

Issue 5: The need for artists and scientists to join forces toward achieving environmental sustainability—the power of STE(a)M

Background

Collaborations driven by art and science, sometimes referred to as *STEaM* [science, technology, engineering, and mathematics (STEM) plus arts and culture], can not only engage the public at multiple levels but also help solve problems in environmental sustainability. Artists and scientists observe and interpret the environment, including, and especially, humanity's place in it. Patterns and motifs abound in the natural world, animate and inanimate, which are studied by artists and scientists alike, albeit toward different disciplinary aims and employing different methods (University of Iowa Technology Institute, 2022). Such creative interdisciplinary efforts can be employed toward the goals of environmental sustainability.

The issue is not whether, but how, artists and scientists can work effectively to enable this type of STEaM-powered technical solution toward robust environmental sustainability. The languages, methods, and visualizations applied across STEaM disciplines are different, as is the target audience. Furthermore, funding challenges abound for truly interdisciplinary STEaM collaborations, especially efforts that connect STEaM creators across the world. Basic technological infrastructure is often missing, such as real-time reliable collaborative platforms, for artists and field scientists constantly on the move, often working from remote areas with limited connectivity. These technical issues, as well as disciplinary diversity, biases across art and STEM disciplines, and lack of interdisciplinary project training, can pose challenges for successful art and science collaborations that lead to actionable environmental sustainability. STEaM-powered technology, itself developed collaboratively by artists and scientists, can help in this regard by providing unified learning, collaborative, and communication platforms.

Role of art since the beginning of time

The connection between empirically acquired knowledge of sustainable living within the natural environment and artistic exposition of such knowledge is an ancient one. Millennia before the development of the scientific method and maybe even before artistic disciplines were formalized, ancient cultures across human history developed ecologically sensitive cultural practices based on artistic visualizations, practical observations, and knowledge-based understanding of the environment they lived in. For example, the Indus Valley civilization relics refer to the deity Pashupati, meaning “the lord of the animals” (Government of India, Pashupati Seal, 2500 BCE). This deity, which personified the human connection to the greater animal world, and later evolved into the prominent Hindu deity Shiva, embodies cultural practices aligned with ecologically sustainable living philosophies across ancient India. Some of these cultural practices are still in vogue, in the form of traditional religion, and often are artistically driven through musical chanting and traditional dance forms (Harrison, 1997; Khush Das, 2021).

Case study

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In a video of a Pashupati seal from Indus Valley civilization, the artist uses traditional hand gestures and body movements from Bharatnatyam, a classical Indian dance form, to illustrate the water cycle as part of his interpretation of an ancient Sanskrit hymn (Shoklam, "Akasat Patitam Toyam"), stating, "As water from all resources reaches the sea so do all seekers to knowledge." It is a classic case study in how art creates a bridge between a scientifically verifiable phenomenon (i.e., the water cycle and ocean being the ultimate sink of falling water) and the theological journey of spiritual seekers toward divine knowledge and wisdom. The traditional idea of knowledge and spirituality explored here also inherently includes the idea of respecting water bodies like rivers as a sustainable natural resource. The Namami Gange effort by the government of India also uses the mythical and artistic visualization of the River Ganga (Ganges) as a mother to harness sustainability efforts (Namami Gange, Anthem, 2016; Namami Gange, Official Anthem of National Mission on Clean Ganga, 2020).

Similar ecologically sensitive cultural practices abound in most Indigenous cultures around the world, often observed to this day with rituals seeking blessings from the earth, river, air, and other natural elements. Such rituals, which acknowledge the profound importance of the natural ecosystem and humanity's place in it, also were built on ancestral knowledge of ecological sustainability, passed down among the generations. Such practical knowledge was often driven by practical "from-the-field" observations that were similar, albeit primitive, compared with modern-day empirical studies. This knowledge was also imbued with rich artistry of mythological storytelling, sculptures, paintings, dance traditions, and so on that informed and engaged the public with the need to uphold their stewardship of natural land they inherited from their ancestors.

Today, however, with rapid degeneration of the natural environment due to large-scale deforestation, urban growth, and water/air pollution, these ancient practices designed for the ancestral environment may need to adapt to better connect the public psyche toward modern-era sustainability goals. Artists can still remind people us of these root practices through ancient art traditions, inspire growth beyond ritualistic habits to seek greater meaning, and engage the public to connect back with nature, just like in ancient times. The practical modern-era issue then is how environmental science and engineering (e.g., pollution studies) can inform art to encourage public opinion toward making this change. This fundamental issue ties deeply to the issues of cross-disciplinary training, dearth of sponsorship, and the technically reliable collaborative platforms mentioned above.

Sometimes the choice of a broad "popular" audience over a technical one for dissemination of new findings can be a mechanism for leveraging collective interest, understanding, and attitudes about issues deemed important by specialists whose communicative tools don't have much societal impact. This approach requires collaboration and conversations among the STEM population and the art and culture population to create bridges and mutual understanding of the details and the large patterns of technical material, as well as of the cultural contexts, currents, and media. One example of this is a book (Bennett, 2003) published for a general, nonacademic readership in Colombia that provides an accessible heuristic and cultural framework, as well as graphics that effectively convey the large patterns of the country's primate fauna, along with their beauty, ecosystem importance, and vulnerability.

A more theoretical yet profound example of successful STEaM collaboration would be the celebrated interactions between the Dutch artist MC Escher and scientists of his time (especially Sir Roger Penrose, see O'Leary, 2023). Such collaborations influenced both mathematics and art and, in its wake, architecture and human perceptions of reality (Overstreet, 2022). One wonders what Escher, with his seemingly endless mathematical curiosity and inspiration from nature's motifs, would create today in this era of extreme environmental vulnerability. And yet, despite these successes, the issue of disengagement between artists and scientists remains a reality to this day if for no other reason than a simple lack of connection between the art and STEM disciplines.

The complementary pursuit of the measurable and the meaningful regarding environmental sustainability challenges can be harnessed using STEaM-powered projects. What needs to happen now, in the wake of climate change and related extreme events, is the harnessing of objective understanding of the environment with emotional cognition that enables responsible stewardship of the natural resources all people inherit from their ancestors.

The ancient Sanskrit saying *Satyam Shivam Sundaram* translates into English as "The truth leads to divinity, which leads to beauty." As creative thinkers, both artists and scientists seek the beauty inherent in nature as their intellectual reward, and harnessing this common interest toward sustainability can indeed restore the environment to its natural sanctity.

Recommendations

1. **Combine the objective understanding of the environment with emotional cognition to enable responsible stewardship of the natural resources all people inherit from their ancestors.**
2. **Look for beauty; look for patterns.** Geometry in nature and the beauty and dynamism of morphing shapes, patterns, and motifs, appeals to artists and scientists alike. This natural connection to beauty and patterns can be harnessed within successful STEaM collaborations, especially those that combine artificial intelligence (AI) and art. The key idea is for artists and scientists to come together and integrate how people observe nature.
3. **Use art to engage.** Art appeals to human emotional cognition, and therefore, science-informed art can respond to environmental sustainability challenges in a way that engages the public and policymakers. For example, artistic creativity is at the forefront of the Namami Gange initiative by the government of India (Primer Minister of India, "Namami Gange"; Namami Gange, Anthem, 2020).
4. **Connect sponsors and STEaM creators.:** Successful collaborations need cross-disciplinary funding, especially across international borders, as ecosystems in dire need of sustainability engagement may have the proper artistic resources but may not have the proper scientific resources, and vice versa.
5. **Create STEaM project platforms.** Create freely available STEaM-friendly platforms that allow asynchronous, easy-to-use tools for creators to share knowledge and expertise across different sustainability projects.[94] The key idea is to allow artists and field scientists who may operate via

[94] An activity underway is IEEE P7801™ Recommended Practice for Technical Knowledge Commons Initiatives and Platforms**.** Such a platform could also be used to share artistic knowledge, tools etc.

diverse time zones and potentially limited Internet connectivity to be able to share ideas and knowledge and work toward sustainability aims. While broad collaborative platforms that might generally solve these problems exist, these may be too generic, without easy-to-use features integrated for STEaM creation, and many STEaM creators lack the resources or training to steer these one-size-fits-all platforms toward successful project environments.

6. **Share ways of knowing; ask powerful questions.** Create public-domain knowledge dissemination and discussion forums where artists and scientists can identify key sustainability challenges and brainstorm important STEaM projects. Such forums must allow virtual, asynchronous, and hybrid participation given the inability of many artists and scientists to cross borders due to funding and visa issues.
7. **Connect traditional wisdom with short-term objectives that leverage and support long-term goals.** Build a common knowledge base of traditional/Indigenous art and cultural practices related to environmental sustainability aims that are measurable in the short term (e.g., how to fish sustainably). Such knowledge, which is usually documented in the long term across historic art, can be made freely available to scientists across the world to learn from practical and ancient wisdom. This knowledge sharing may lead to new scientific engagement regarding some old questions but in ways that are easily measurable and/or implementable in the short term (e.g., how much fishing is too much?). Such practical wisdom can be brought to light and examined through the lens of scientific rigor; then the distilled knowledge can be used for attaining sustainability goals across different spatiotemporal scales.
8. **Use art to communicate science.:** Enable knowledge sharing of scientifically investigated sustainability methodologies using art for effective public education and engagement (e.g., the visually illustrated book on Colombian monkeys and their ecosystems, see Bennet, 2003).
9. **Use science to make art more meaningful.** Artists invested in environmental sustainability can benefit from robust scientific knowledge and STEM collaborators to render their art more meaningful to the needs of modern-area sustainability challenges. For example, an artist knowledgeable on the water cycle and the connectedness of different water bodies (e.g., groundwater and river systems) can make a much more powerful statement on water pollution than can an artist who is not knowledgeable on these things.
10. **Disrupt perceptions that art and science are "too different."** Currently, public perception is that STEM and art are too "opposite" as disciplines to work together. A big part of this perception is how mathematics and science subjects are taught in schools and how children are ranked and separated based on their early ability to perform on time-sensitive tests. Gender-based biases also create artificial social barriers for successful STEaM fulfillment of young minds. While this is slowly changing, much remains to be done. Facilitate and model STEaM educational outreach and training at the elementary and high-school level where young minds can experience art and science through integrated STEaM projects.

Issue 6: Artificial intelligence needs art to confront the multifaceted challenges posed by AI systems' emergence

Image: John Favarro

Background

Most citizens have heard by now of *machine learning* and *deep neural networks*. This technology is the basis for the advances making the news in the worldwide press. Unfortunately, this technology is not only invisible (like all software) but also literally *impenetrable*. The reason is that this kind of software iterates in a way it appears to *learn*. Algorithms adapt as they iterate, so that what the software does after a certain point in time is no longer what it did when it was designed and implemented.

That may be acceptable for a program providing programmed recommendations on the nearest restaurant to visit, but this software is also being used in mission-critical systems like self-driving cars and medical diagnostics. In these contexts, it is important to understand what the software is doing. One major challenge now confronting engineers everywhere is how to understand how the software has evolved based on new data in conjunction with programming once in the field. The state of the art dealing with this so-called "explainability problem" is relatively young, with research not universally available via standardized governance or genuine content to end users.[95]

[95] A key resource as an introduction to transparency, accountability, and personal data issues can be found in IEEE's *Ethically Aligned Design* document, as well as in the IEEE 7000 Standards Series that formally combines applied ethics to systems engineering.

Notwithstanding the issues around explainability, the strides in machine learning are so impressive that the European Union has been concerned for many years about the effect it will have on society—for example, on the future of work. After establishing leadership recently in the protection of privacy with its General Data Protection Regulation, Europe has prepared various legislations concerning the *ethics* of artificial intelligence. In this regard an independent High-Level Expert Group (HLEG) set up by the European Commission issued a document (EC, updated 2022) in April 2019 titled "Ethics Guidelines for Trustworthy AI." The document immediately positions itself by evoking the concept of "human-centered AI,"[96] and one thread that tends to run throughout the exposition is the idea of *transparency*. As mentioned, machine learning technology produces programs and activities that could be dangerous to use in critical applications (like in self-driving vehicles on highways) because nobody understands what they do or, even more problematic, what they'll do *next*. That is, what will the AI programming instruct if a person suddenly appears in front of the car or, for example, turns off the road into a ditch and risks the safety of the passengers? This issue is not just a technical one but also an *ethical* one—a surprisingly old one, too. More than 50 years ago, the Trolley Problem (Wikipedia, "Trolley Problem") was posed and became essentially the genesis of current efforts to confront ethical problems of decision-making in the context of autonomous vehicles (not just automobiles).

Consider another example of the issue of transparency in AI. Some types of work that in the past could only be performed by humans—intellectual work, not just manual labor—could be carried out by devices equipped with AI, such as customer care robots, automated legal assistants, and robot investment advisors. But not many have considered another aspect: that the use of AI applications might cost somebody their job because it may well be a robot who is interviewing them for that job. Some recruiting tools (Ideal, "AI for Recruiting") handle tasks like reading job applications and deciding which ones deserve further study. It is already a serious matter that an AI application might decide not to give somebody a job because there is some evidence (Metz, 2019) that machine learning programs can absorb biases against underprivileged groups (by the training data they ingest). But it is even worse when the applicant does not even know that it was a robot who did not give them that chance.

This is where the "human-centered" guidelines of the European Commission's expert group become relevant. These guidelines state that humans have a right to know when they are being "processed" by an AI application rather than by a human being. That is, humans have a right to *transparency* (see IEEE SA, IEEE 7001-2021, for recommendations and support on these issues) in the matter of whether AI is involved in any decision-making process related to them. Furthermore, the guidelines admonish people/society to "pay particular attention to situations involving more vulnerable groups such as children, persons with disabilities and others that have historically been disadvantaged or are at risk of exclusion, and to situations which are characterized by asymmetries of power or information, such as between employers and workers."

The European Commission has done something necessary by expanding the scope of oversight beyond the previously narrow boundaries. And this is where art can step in to make a potential contribution: No discipline is more human-centered than art, combining influences from philosophy, ethics, psychology, literature, and other disciplines that are proving to be central to confronting the central challenges to a trustworthy and ethical approach to AI in today's society.

Are artists and engineers currently interacting with respect to AI and its primary challenges? There is good news and bad news in this regard: The bad news is that so far little has been reported in the arts *specifically* on helping machine learning specialists understand their software and to direct it toward ethical behavior (see Clancy & Tweed; for more information on Art and AI, see UNESCO's Recommendation on the Ethics of

[96] Prioritizing human-centered or "human in the loop" control for AI is mirrored in multiple global principles on AI, including IEEE's *Ethically Aligned Design* document whose first principle is human rights with a focus on human well-being and environmental flourishing.

Artificial Intelligence, adopted by acclamation by 193 Member States at UNESCO's General Conference in November 2021). The good news, however, is that artists are very interested in applying machine learning *within their own profession*. The first step in any potential collaboration is awareness; therefore, this is an important first step.

Currently, the artistic community is more interested in applying machine learning to its own creations, but once artists become fluent in the technology, they will be able to start pondering ways to confront the major issues arising around the introduction of AI into the world of today. As a specific example, consider the following two different definitions of *art*:

- Art is manifested in an artifact (a painting, sculpture, musical composition) that makes a deep emotional impression on a person.
- Art involves a person (the artist) attempting to communicate (emotions, ideas) to other people (the viewers, the listeners) through artifacts such as paintings, sculptures, and musical compositions.

Both definitions are in common use today. If the first definition is accepted, then it is valid to consider an artifact (painting, musical composition) generated by AI as art if it stimulates an emotion in the viewer or listener. But if the second definition is accepted, then art must be a human enterprise—it is *communication between humans*. Can there be such a thing as nonhuman art? The engineering community is not equipped to answer this question. The artistic community can help to resolve the question by engaging directly in AI technology. Can artists infuse machine learning programs with their artistic impulses in such a way that it becomes human-to-human communication? No one knows yet, but the artistic community can help find out, and it could have vast implications for creating a truly human-centered AI, expressing human values, which is the goal of the many social initiatives underway today, the so-called "complex adaptive coalitions, where business, government, social entrepreneurs, educators, competing superpowers and moral philosophers all come together to define how we get the best and cushion the worst of A.I."[97] Artificial intelligence needs art to be a part of these coalitions.

Recommendations

1. **Create the space and occasion for AI engineers to engage with the artistic community.** AI engineers should engage with the artistic community. The Artists and Machine Intelligence initiative provides an example: "By supporting this emerging form of artistic collaboration we open our research to new ways of thinking about and working with intelligent systems." In his essay "Art in the Age of Machine Intelligence," Blaise Aguera y Arca makes several interesting observations that are relevant to these ideas. First, he notes, "Art has always existed in a complex, symbiotic and continually evolving relationship with the technological capabilities of a culture." He then discusses the possibilities of neural-like systems to investigate topics as varied as culture, ideas, and "the working of our own minds." He further notes that this "requires that we apply ourselves rigorously and imaginatively across disciplines" and that there is "no shortage of engineers and scientists who are thoughtful and eager to engage with artists and other humanists."

[97] Thomas Friedman, "Our Promethean Moment," *New York Times*, Opinion, 21 Mar. 2023.

2. **Help the artistic community to learn the fundamentals of AI technologies to be able to interact in a more efficient way with AI professionals**. The artistic community should go beyond mere usage of AI to learn the fundamentals of AI technologies. Much is currently being done to provide education in machine learning to artists. Machine learning software is notoriously difficult to create, but it is also notoriously difficult to use for non-experts. Therefore, there have been efforts to package the intricate algorithms and data structures into something more approachable for artists and musicians (Wekinator website)[98], and free online classes for musicians and artists (Kadenze, "Machine Learning for Musicians and Artists"[99]). These efforts are especially important for the stated goals: For artists to be able to help people to visualize and externalize the intricacies of machine learning modules, they need to have a basic grasp of the fundamentals of machine learning. Artists should not shy away from machine learning technology, not only as a tool for their own endeavors but also as an object of their own attention, with a view toward assisting AI engineers.
3. **Give incentives to the artistic community to exploit AI technologies for its work.** The artistic community should utilize AI technologies for its work. Machine learning is being used to create many different types of art. The visual arts are well represented so far. Tom White is examining "the ability of neural networks to create abstract representations from collections of real-world objects." Some of the results of his "perception engine" implementations may be found here.[100] A particularly well-known example is stable diffusion, which is used to generate images based on text descriptions. The figure is a photo of a statue that has been enhanced by the Prisma app (Prisma Labs website)[101], which uses machine learning to transfer artistic styles to photos. Much is likewise happening concerning the relationship between machine learning and music, ranging from composition to performance.

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Issue 7: The need to grow understanding of the effects of climate change in all factions of society—use of art and digital technologies to make these concepts more accessible

Background

"Climate Change is the defining issue of our time and we are at a defining moment," reads the issue page of the United Nations (UN, "Global Issues: Climate Change"). The article goes on to point out how human impacts have affected the climate. In short, "human influence" is warming the atmosphere, increasing weather and climate extremes, and putting natural ecosystems at risk. The problem is that this large-scale issue can be difficult for many people to grasp. It can be hard to imagine what a future impacted by climate change may look or feel like. Therefore, people may be less willing to engage with the issue when they have many other pressing demands on their daily lives. With this in mind, employing creative methods in the arts, including using digital means, can offer people a way to more readily experience the issue. Using digital art forms might allow for more people to engage with climate change in a way that can make it feel less amorphous and more real.

A variety of digital art forms may be used to invite people into conversations and experiences that shift understanding, perceptions, and feelings about climate change, ultimately propelling people to take positive actions as a result. This opportunity invests in digital forms of artistic expression as a means to help the public to better imagine how changes in the climate might affect humans, all life, the entire planetary biosphere.

For example, the arts may be used in virtual realities to experience the effects of climate change. As one example, climate researcher Juliano Calil (Rott, 2019) through his "Fleming Park Project" invited people to experiment with a future affected by climate change by taking part in a virtual reality (VR) experiment. The participants could experience their community as if it was "underwater" and as if the effects of climate change were real. As climate change "presents many challenges to coastal communities and to those trying to prepare for its impacts, How do you show people—and convince them—of a possible future?" (Rott, 2019) VR technology and the creation of a virtual reality that helps to perceive the consequences of climate change can help to do that.

Visualization in general is a powerful tool. The Icelandic artist Ruri has created maps on the change of sea level in coastal areas in collaboration with geographer Gunnlaugur M. Einarsson. In his work "Future Cartography X" (Rúrí, 2012), global warming is shown to result in progressive reduction of some of the Earth's coastlines, following the drastic rise of sea levels. The gradual decline of the topographical zero line is based on the observation of sea levels at the time of the initial mapping of the terrain.

New combinations of arts and technical possibilities may be explored to make climate change tangible. As one example, artists can use sound recordings to help articulate how the planet is changing. Consider the work of the researcher Grant Dean, which was recently featured in a *New York Times* article about the "music of ice" creating recordings of melting glacial ice. These recordings are used in installations, which serve both as an artistic experience but also help people to hear the effects of a warming climate. In this way, the use of technology and artistic expression invites a new way of accessing information about the changes happening in a particular area that might otherwise feel invisible to those who do not have access to visit or see these effects in person (Currin, 2023). The recordings are considered “beautiful, but there’s a slow violence to the sounds, too.” Also: “The sounds are political statements that are not available to our ears unless they’re recorded. They create space for empathy” (Currin, 2023).

Recommendations

1. **Promote and enable cooperation between scientists and digital artists.** Scientists should cooperate with digital artists to make scientific data more accessible to the public. One paper (Sommer & Klöckner, 2021) suggests that “climate change art is capable of changing people’s opinions, as long as the message is hopeful, and gives people ideas for change” (Amsen, 2019)
2. **Use techniques of visualization and sound design to make evident and perceivable effects of climate change.**

Issue 8: Define "climate art" as a new language of aesthetics to create new ideas for articulating climate concerns to provoke action

Background

Contemporary art and classic art approach the theme of climate change and sustainability in different ways, reflecting the changing attitudes and concerns of society over time. One significant difference between modern and classic art is the focus on science and technology. Contemporary art tends to be more scientific and technologically oriented, reflecting advances in science and technology and their impact on the environment. Artists are using new materials, techniques, and technologies to create works that address climate change, such as pieces that incorporate digital media, electronic sensors, or living materials.

Many contemporary artworks are interactive, immersive, and experiential, inviting the viewer to participate and engage with the work. Some artworks even require the viewer's participation to be completed, such as works that rely on sensors or other forms of audience interaction. Classic art, on the other hand, was typically viewed as a static object to be admired and appreciated from a distance.

In contemporary art, climate change has become increasingly prominent with many artists using their work to explore and raise awareness about the environmental challenges societies and ecosystems face. In general, climate change is being addressed by a wide range of artists across many different disciplines. While there are too many to list, several well-known artists have devoted their work to the topic and continue to use their art as a means of raising awareness and inspiring action.

With the creation of awareness about the catastrophic development toward an end-time scenario, actionist art forms clearly gain priority over more static forms of representation. This priority is realized in the form of performances or media productions, such as film productions, which are the most popular form with the greatest reach for triggering actionism.

Recommendations

1. **Promote funding programs and large cross-border—possibly global—initiatives to enable art with relation to environmental issues and awareness raising.**
2. **Promote and enable art that explicitly addresses the issues of environmental disasters, climate damage, and the accumulation and use of waste products for art performances.**
3. **Promote visits to art exhibitions and artistic performances devoted to subjects of climate change and strong sustainability.**
4. **Adopt cinema films about climate catastrophe in public TV programs.**
5. **Organize visits to buildings made of new sustainable materials that serve as templates of advanced architecture.**
6. **Initiate cross-disciplinary and trans-disciplinary workshops between citizens, architects, construction enterprises, and artists.**

7. **Call for competitions in photographic documentation of using new sustainable materials in architecture and art (e.g., with sculptures)—materials causing no or minimal environmental impact.**

Further resources

1. Acute Art. "Marina Abramovic."
2. Chasing Ice (website).
3. Eating Our Way to Extinction (website).
4. Edward Burtynsky. "The Anthropocene Project."
5. Harvey, Fiona. "Margaret Atwood: Women Will Bear Brunt of Dystopian Climate Future." *The Guardian*, 31 May 2018.
6. Subhankar Banerjee (website).
7. Wikipedia, s. v. "2040 (film)." Last modified 28 Apr. 2023.
8. Wikipedia, s. v. "Before the Flood." Last updated 14 Mar. 2023.
9. Wikipedia, s. v. "Burning (2021 film)." Last modified 17 Feb. 2023.
10. Wikipedia, s. v. "David Attenborough: A Life on Our Planet." Last updated 24 Mar. 2023.
11. Wikipedia, s. v. "The Day the Earth Stood Still." Last modified 17 Apr. 2023.
12. Wikipedia, s. v. "Don't Look Up." Last modified 6 May 2023.
13. Wikipedia, s. v. "The Drowned World." Last modified 22 Oct. 2022.
14. Wikipedia, s. v. "The Great Derangement: Climate Change and the Unthinkable." Last modified 17 Apr. 2023.
15. Wikipedia, s. v. "An Inconvenient Truth." Last modified 3 May 2023.
16. Wikipedia, s. v. "Princess Mononoke." Last modified 4 May 2023.

Issue 9: The need for waste and waste management as a space for innovation and change of attitude toward waste

Background

Contemporary lifestyles generate a lot of waste. Therefore, how to turn today's living/societies into a more sustainable direction, that is, lifestyles that generate no or very little waste, is one of the big (environmental) issues of the current time.

Currently, a movement is emerging to revitalize communities through contemporary art that focuses the attention specifically on waste. Communities, citizens, artists, and various organizations are collaborating to create artworks and art interventions in the local environment by using waste as materials or by interacting with the waste management system. In fact, environmental art can be seen as a movement to enable art in local surroundings. Environmental artworks can include elements such as sound, light, color, and different kinds of everyday objects, and the audience's actions can be material for the artworks, as well as provide a space for innovative thinking.

For example, American artist John Sabraw combines art and science in his creative work. He works with scientists and environmentalists to extract toxic acid mine drainage from polluted rivers and then to process it into pigments to create beautiful paintings. Profits from his artwork also help to restore the environment of the river, making his work a recycling-oriented art form (Sabraw website; Sabraw, 2017).

Another example from Japanese art is the aim of creating new value through craftsmanship by using discarded or unused parts, tools, and scrap materials from manufacturing processes. For instance, an ultralight backpack is made by taking unused airbags from a decommissioned car body and reusing them as fabric (Pehrson, 2021).

The management of waste requires infrastructure and technological innovation. How to manage this in a sustainable way is also a challenge for all communities. Amager Bakke in Copenhagen, Denmark, is a combined heat and power waste-to-energy plant from the previous generation. It combines several interesting aspects: Besides being a power and waste incinerator, it is also a recreational facility for dry skiing, hiking, and wall climbing and an example of exceptional contemporary architecture. The plant[102] has received several design and architecture awards for the aesthetics of the building. The incinerator opened its doors in 2017, aiding the city of Copenhagen in its aim to become carbon neutral by 2025, and has since then become a strong symbol of the city and part of the local identity of the people.

[102] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

Recommendations

1. **Visualize the waste materials in the city/community (e.g., material flow diagram).**
2. **Host an upcycle idea workshop with artists, craftsmen, engineers, citizens, experts on the circular economy, and more.**
3. **Prototype some of the ideas from integrated upcycle workshops and promote them through websites or exhibitions.**
4. **Create an upcycle matching platform consisting of artists, waste materials, technologies, and companies.**
5. **Connect and combine different needs into one solution.** For example, reusing some parts from a device at the end of its current use and processing other parts for feedstock for different applications; the needs in this case would be handling of waste and the need for resources, such as parts for different devices and materials for new devices and/or processes, that could include materials for art.

Further resources

1. Kastner, Jeffrey, ed., and Brian Wallis, survey. *Land and Environmental Art*. London: Phaidon Press, 2005.

Issue 10: The need to invent new sustainable materials through artistic practices

Background

The authors of "The Jena Declaration" (TJD) proclaim that they:

> *Call upon all relevant political and scientific institutions, including funding agencies, to use the UN "Decade of Action "as a time to ensure that the cultural dimension is at the core of sustainability programs. This also includes the need to "integrate the arts", as well as findings from the humanities and social sciences into the co-design of future, culturally and regionally diverse "ways of living sustainably."* (The Club of Rome, 2021)

The speaker of TJD, Benno Werlen, claims that a "new aesthetics" in its materialization must be discovered and applied to express the concerns of strong sustainability. The question of what this new language in art is (i.e., what new forms of expression could be) can be answered in one dimension with regard to the material used for artistic expressions: Artists and designers are experimenting with a wide range of new and unconventional materials to create works that address aspects of climate change.

These materials include the following

- *Recycled materials*: Many artists are using materials that would otherwise end up in the landfill, such as recycled plastics, paper, and textiles.
- *Natural materials*: Some artists are using natural materials that are sustainable and renewable, such as bamboo, wood, clay, or natural stones.
- *Alternative plastics*: Several new types of plastics are made from renewable resources or are biodegradable, such as polylactic acid (PLA) and polyhydroxyalkanoates (PHAs).
- *Electronic waste*: Some artists are using electronic waste, such as discarded computer parts and circuit boards, to create new works.
- *Air pollution*: A few artists are using air pollution as a material for their art. For example, Anirudh Sharma has created a device that captures carbon soot from diesel generators and turns it into ink.
- *Living materials*: Some artists are experimenting with living materials, such as mycelium (the root-like structure of mushrooms) and algae, to create works that have a low impact on the environment. Examples of this choice for an artistic medium selection is argued in articles like that from Amanda Boetzkes (Boetzkes, 2021) on the aesthetics of plastic capitalism or in exhibition projects like "Reflecting Oil" from the Austrian artist Erich Logar (Expo 2020 Press release, 2021), which is a laboratory performance project using crude oil. These two examples are just a small sample of the hundreds more like them.

Architecture, as the artistic discipline in which the question of the materials to be used plays the most relevant role in translating design into concrete construction, is unquestionably of the greatest importance with regard to the selection of building materials.

In the effort to reduce the carbon footprint of architecture and make buildings more sustainable, architects and designers are increasingly turning to new materials and construction techniques that are more environmentally friendly. Here are some materials recommended for sustainable architecture, as well as some to avoid.

Recommended materials (Sample List)

- ***Wood***: Wood is a renewable resource that can be used for construction, and it has a lower carbon footprint than many other building materials. It also has natural insulating properties, which can help reduce energy consumption.
- ***Bamboo***: Like wood, bamboo is a renewable resource that can be grown and harvested quickly. It is also lightweight and durable with a high strength-to- weight ratio.
- ***Rammed earth***: Rammed earth construction involves compressing soil and other natural materials to create sturdy, durable walls. It is a low-energy, low-carbon construction method that can also provide natural insulation.
- ***Recycled materials***: Using recycled materials such as reclaimed wood, glass, and steel can help reduce the environmental impact of construction by reducing waste and minimizing the need for new resource extraction.
-

Materials to avoid (Sample List)

- ***Concrete***: The production of concrete is a significant source of carbon emissions, and its manufacture and transportation require large amounts of energy. While it can be made more sustainable with the use of recycled materials and alternative cement mixtures, it should be used judiciously.
- ***Steel:*** Steel production is also a significant source of carbon emissions, and its high embodied energy means that it has a large environmental impact. Again, steel can be made more sustainable with the use of recycled materials and alternative production methods.
- ***PVC***: PVC, or polyvinyl chloride, is a widely used plastic that has a large carbon footprint due to its production and disposal. Its use in construction should be minimized in favor of more environmentally friendly materials.
- ***Foam insulation:*** Many types of foam insulation, while effective at reducing energy consumption, can release harmful chemicals and have a high embodied energy. Alternative natural insulation materials like wool, cellulose, or straw bale should be considered instead.
-

In general, the use of locally sourced and renewable materials, along with alternative construction techniques and the reduction of waste and energy consumption, can help make architecture more sustainable and better adapted to climate conditions.

Recommendations

1. **Promote art exhibitions that explicitly address the issues of environmental disasters, climate damage, and the accumulation and use of waste products for art performances.**
2. **Call for art productions preferring new sustainable materials in art and in art-producing processes.**
3. **Request exhibitions with an explicit mission of expressions demonstrating and using sustainable materials.**
4. **Create architectural competitions making prescriptions on the construction material to be used.**
5. **Fund programs for artists and art schools with a mission to address the climate catastrophe and search for and use renewable materials.**
6. **Offer art workshops in schools to teach children how to make "art" from waste materials.**
7. **Use locally sourced and renewable materials, along with alternative construction techniques emphasizing low impact, maintainability, longevity, and circularity of the "product."**

Further resources

1. ArchDaily Team. "Which Building Construction Materials Are Ecological?" *ArchDaily*, 14 June 2022.
2. Art in Context. "Recycled Art—Exploring Impressive Art Made from Recycled Materials."
3. Dücker, Maxime. "13 Incredible Artivists Using Recycled Materials in Their Art." *Causeartist*.
4. Friedman, Vitaly. "40 Terrific Works of Art Made from Common Trash." *JotForm* (blog), 25 Jan. 2023.
5. Shrink That Footprint Staff Writer. "7 Eco Friendly Art Supplies to Sustain the Environment."

Issue 11: Need to increase the dialogue between artists, policymakers, and the public to use art as a platform for environmental activism

Background

Artists, through their work, have the potential to act as powerful motivators for politicians to take up concerns on climate change. Art has the ability to reach people on an emotional level and therefore can contribute to raising awareness and to mobilizing action on climate issues.

Artists have various means and ways to use their influence. Throughout history, artistic activism has been used to raise public awareness and to apply pressure on politicians to take up the concerns expressed by artists. Artists can also facilitate forward discourse and through artistic practices provide a platform for dialogue to connect artists with the policymakers and the public in a meaningful setting. Artistic actions can, therefore, contribute in a significant way to the decision-making process.

The following examples demonstrate how artistic activist actions by artists could stimulate politicians to make decisions on climate change:

- The Climate Clock created by the artists Gan Golan and Andrew Boyd, a public art installation that displays a countdown of the time remaining before the world reaches a critical tipping point (Climate Clock website.
- The Divestment Movement (Rapier, 2022), which calls on institutions such as universities, religious organizations, and pension funds to divest from fossil fuels, has been driven in part by creative activism. For example, in 2015, a group of artists and activists staged a “die-in” at the Louvre Museum in Paris to protest the museum’s ties to the oil and gas industry. Since then, the movement has grown significantly, with institutions representing trillions of dollars in assets divesting from fossil fuels.
- Danish-Icelandic artist Olafur Eliasson’s large-scale installations that explore issues related to climate change, such as “Ice Watch” in Paris, which featured 12 large ice blocks taken from the Greenland ice sheet arranged in a clock formation to symbolize the urgency of addressing climate change.
- The Artivist Collective (The Artivist Foundation website), a group of artists and activists using art as a tool for social and environmental justice. Their work includes public installations, murals, and performance art pieces that highlight issues related to climate change and environmental degradation.
- The Yes Men, a group of artists and activists using satire and performance art to draw attention to social and environmental issues also on climate change. They have created high-profile pranks and hoaxes, including posing as representatives of the US Chamber of Commerce and ExxonMobil to highlight their opposition to climate action.
- American artist Mel Chin creates works that address climate change. His most well-known project, "Revival Field," involves using plants to remove heavy metals from polluted soil, demonstrating the potential of how natural systems can address environmental problems.

As for institutions, art and culture are connected to environmental policies on several levels. Since international policies play a significant role in the shared issue of the climate crisis, the role of cultural relations and diplomacy cannot be underestimated. Many governments use cultural diplomacy to promote their environmental policies and to build relations between civil society and cultural actors. For example, the German Federal Foreign Office has a program called *Kultur und Klima* ("Culture and Climate") that promotes cultural exchange and collaboration on environmental issues (Blumenreich, 2022).

One prominent political personality who has promoted interventions from the art community to inform about their environmental policies is Alexandria Ocasio-Cortez[103]. The US representative has collaborated with artists and designers to create graphics, posters, and social media campaigns to promote her "Green New Deal" proposal. She has also highlighted the role of art in advancing climate justice, stating, "[A]rt has a critical role to play in shaping our political and social realities." Another politician is Elizabeth May, the former leader of Canada's Green Party, who is known for her advocacy of the arts in environmental policy-making. She has worked with artists and cultural organizations to promote environmental issues and has emphasized the importance of using creative methods to communicate complex environmental problems to the public.

The potential between arts and policymakers is not only on the level of advocacy but also in the creation of new forms of dialogues and how to integrate art into the decision-making process as one resource and tool to create new knowledge. As one example, the Committee for the Future in the Finnish Parliament has been working together with artists to reach new visions related to the future of Finnish society (Riksdage, 2022). In these processes, the Committee for the Future combined working groups of scientists, experts, and artists to enable a multidisciplinary approach for a deeper level of understanding of the use of art for the members of the Parliament. New cross-disciplinary methodologies on the highest levels of decision-making should be explored to support decision makers' abilities to tackle issues of a complex nature, such as the climate crisis (Ståhle, 2007).

Recommendations

1. **Launch and support platforms for dialogue between artists, policymakers, and the public.**
2. **Fund and support joint art projects between artists and citizens with intentions to engage the policy-making level.**
3. **Integrate art and artistic expertise into all levels of policy- and decision-making.**
4. **Motivate policymakers to include art and art action to stimulate ideas for their lawmaking and regulation making processes.**

[103] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. This example is provided to demonstrate how any politician or policy member can utilize art and does not represent an explicit or implicit political endorsement from IEEE.

Issue 12: The need to connect arts to the SDGs—use arts to generate the narrative

Background

Artists are always asking questions of themselves and others, connecting themselves to the world, interacting with it, and expressing themselves to encourage people to have a positive view of themselves.

Art activities are defined as a series of activities from the birth of an idea to its expression and delivery to people. Such activities have a sense of "surprise," "playfulness," and "excitement" that open people's hearts and minds, and they create opportunities to melt away divisions and differences with others, transform values, and become a force for the regeneration of loose connections.

In contrast to the objective and analytical approach of science, the subjective and integrative approach of art is capable of moving people's hearts and creating behavioral change.

Artists, who have the power to find what is buried or unnoticed in the world, can also bring value and potential to the surface of society and can create opportunities to discover and solve social issues. For example, UNESCO asks, "How can culture help fill implementation gaps in the achievement of the 17 SDGs?" Some approaches for the IEEE Planet Positive 2030 Initiative could be implemented by considering the value of art to the SDG agendas.

- For SDG 3 "Good Health and Well-Being," art's value is in building a community through arts-based activities, arts festivals, and so on. One possible approach is to form a foundation for community behavioral change for climate action by strengthening social relational capital. For example, The Setouchi Triennale (Japan) is a grand regional revitalization project under the theme of "Restoration of the Sea." With the help of contemporary art, the Triennale uses islands that have been forgotten amid modernization as its stage, with the hope that the island's older persons will smile, and that the Inland Sea can become the "Sea of Hope" for all regions on Earth.
- For SDG 4 "Quality Education," art's value is to foster emotion and sensitivity through arts appreciation education, arts communication, and so on. Therefore, one possible approach is to nurture a sense of awe of nature and empathy for the Earth. For example, many picture books and videos for children clearly illustrate how humans are blessed by the bounty of nature. Museums also play important roles to support and provide learning opportunities in support of the SDGs.
- For SDG 8 "Decent Work and Economic Growth," art's value is to improve productivity through well-being and creative workspaces. Therefore, one possible approach is to reduce energy consumption by economic activities. For example, today's innovation centers and other facilities are designed to enhance creativity and productivity, with art, background music, sophisticated employee cafeterias, and other devices to appeal to and possibly improve the five senses.
- For SDG 9 "Industry, Innovation, and Infrastructure," art's value is to combine different elements through inclusive and holistic thinking. Therefore, one possible approach is to apply science and technology to the green industry by supporting artistic creativity and expertise. For example, an off-grid hotel is independent of existing electricity, gas, water, and other infrastructure and is self-sufficient in energy and water through the power of nature. Energy generated by solar panels is

stored in storage batteries, and water is filtered and sterilized from rainwater collected from the roof for domestic use.

- For SDG 11 “Sustainable Cities and Communities,” art’s value is to preserve nature and culture through preserving cultural heritage. Therefore, one possible approach is that preserving cultural heritage will help protect nature and make the city more sustainable. For example, once registered as a World Heritage site, it is necessary to pass on to the future not only the heritage sites themselves but also the rich natural environment and the livelihoods and beliefs of the people who live there.
- For SDG 12 “Responsible Consumption and Production,” art’s value is to foster craftsmanship through local traditional arts and culture. Therefore, one possible approach is to manufacture and reuse/recycle with biodegradable materials and non-artificial components. Culture, particularly traditional knowledge systems and environmental management practices of Indigenous and local peoples, provides insights that enable better management of ecological challenges, preventing biodiversity loss, reducing land degradation, and mitigating the effects of climate change. For example, waste food materials such as food peels and cores are formed into tableware using proprietary technology. After use, the tableware is collected, crushed, and dried at the plant before being processed into feed, fertilizer, and so on.
- For SDG 13 “Climate Action,” SDG 14 “Life Below Water,” and SDG 15 “Life on Land,” art’s value is to raise questions through socially engaged arts practices, art and science collaborations, and so on. Therefore, one possible approach is to provide an opportunity to think about what each person can do as a personal matter. For example, at the botanical park, after viewing vegetation from around the world, a large screen shows images of Earth if climate change cannot be improved at this rate, and questions are posted on the pathway leading to the exit.
- For SDG 17 “Partnerships,” art’s value is to draw a desirable vision through vision design, communication design, and so on. Therefore, one possible approach is to create and communicate a vision that people can sympathize with. For example, a research institute draws a picture of lifestyles in the bio economy era and tries to promote changes in social systems.

SDGs	Arts' value	Example of arts' activities	Approaches
Goal 3: Good Health and Well-Being	Building a community	Arts club activities, Arts festival, clowns working in hospitals, art in mental health therapies, etc.	Formation of a foundation for community behavioral change for climate action by strengthening social relational capital
Goal 4: Quality Education	Fostering emotion and sensitivity	Arts appreciation education, Arts communication, etc.	Nurture a sense of awe of nature and empathy for Earth
Goal 8: Decent Work and Economic Growth	Improving productivity	Well-being and creative workspaces, etc.	High productivity can reduce energy consumption from economic activities
Goal 9: Industry, Innovation, and Infrastructure	Combining different elements	Inclusive and holistic thinking, artistic expertise included in industries and development of innovations, etc.	Apply science and technology to green industry by creativity
Goal 11: Sustainable Cities and Communities	Preserving nature and culture	Preserving cultural heritage, etc.	Preserving cultural heritage will help protect nature and make the city more sustainable
Goal 12: Responsible Consumption and Production	Fostering craftsmanship	Local traditional arts and culture in circular economy developments, etc.	Manufacture and reuse/recycle with biodegradable materials and non-artificial components
Goal 13: Climate Action	Asking questions	Social art, museum pedagogy, and artworks of climate change for raising awareness, etc.	Provide an opportunity to think about what each person can do as a personal matter
Goal 17: Partnerships for the Goals	Drawing a desirable vision	Vision design, communication design, new cross-disciplinary collaborations with artists and other sectors, etc.	Create and communicate a vision that people can sympathize with

Table 1. SDGs and Art.
(*Credit: Hironobu Mirata)*

Recommendations

1. **Dedicate time to reflect on how art interventions can be integrated into the various areas of SDGs.**
2. **Promote, invest, and enable projects that interact with art to achieve the SDGs.**
3. **Calculate social return on art investment such as carbon reduction effects of art activities.**
4. **Organize conferences, workshops, and competitions focused on best achieving as many of the SDGs as possible.**
5. **Build contacts with finance investors using the SDG criteria for their investments** (e.g., UNGSII).

Further resources

1. Art Setouchi (website).
2. Gardens by the Bay. “Cloud Forest.”
3. Manninen, Jussi, Riitta Nieminen-Sundell, and Kaisa Belloni, eds. *People in the Bioeconomy 204*4. VTT Visions 4. Finland: VTT, 2014.
4. Northern Dimension. “NDI Policy Brief 18: Culture Must Be Recognized As a Driver of Sustainable Development.”
5. UNESCO World Heritage Convention (website).

Issue 13: The need to choose a problem-solving approach to reach sustainability—the Bauhaus design and policy approach to reach sustainability

Background

Art as a form of self-expression uses various media, such as paintings, sculpture, photography, performances, and new media, to communicate ideas, emotions, and experiences. The primary focus of art is to create something aesthetically challenging, emotionally resonant, and thought provoking. Art is often not necessarily bound by any functional or commercial considerations.

Design, in contrast, is the process of creating functional and aesthetically pleasing objects, systems, and environments. Design often involves problem-solving and creating solutions that meet specific needs and requirements. The primary focus of design is to create something useful that meets specific needs, while being visually pleasing. Design can contribute to achieving climate goals by creating sustainable products, buildings, systems, and solutions that reduce greenhouse gasses. Art and design are related but distinct fields that have different goals and applications.

Art is a form of self-expression focused on creating aesthetically challenging and emotionally resonant works, while design is a problem-solving process focused on creating functional and aesthetically pleasing objects, systems, and environments that meet specific needs.

The concept of seeing the contribution arts play in the interplay of a Gesamtkunstwerk ("Holistic Artwork") is an approach that was successfully realized in art and design production in the West during the World War I era through the Bauhaus (Dezeen Magazine) philosophy, which has been revived by the European Union (EU) to inform its current cultural framework strategy. The *New European Bauhaus* (NEB) initiative summarizes the concepts of the so-called "European Green Deal" in an overall aesthetic image (EU, "New European Bauhaus").

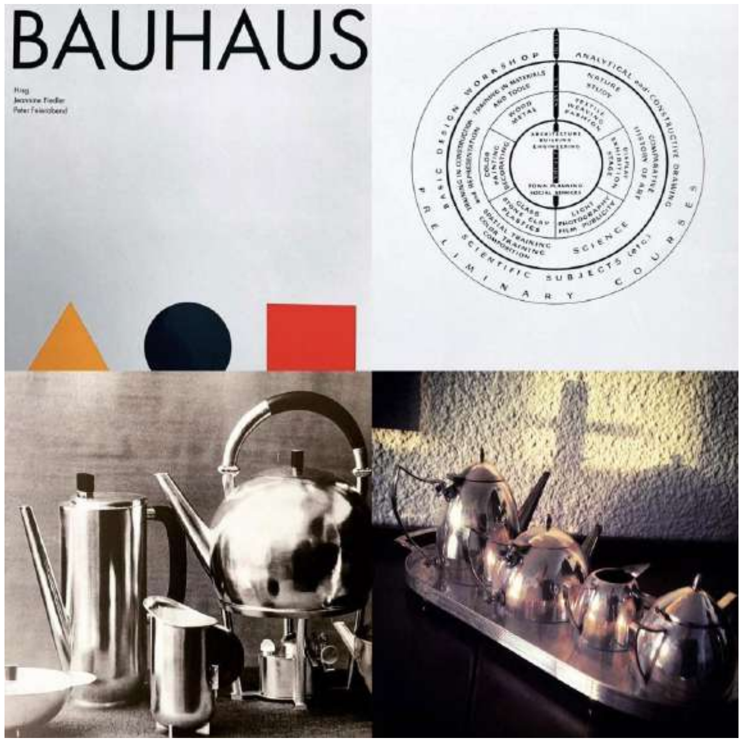


Photo credit: Günter Koch

Global influence through a reform art movement in Germany in reaction to World War I

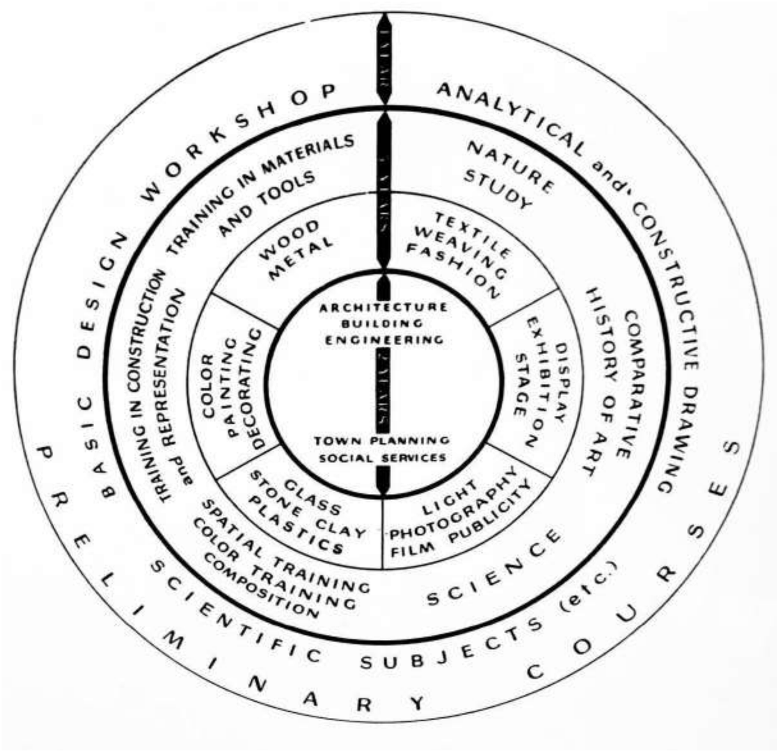
The Bauhaus was an art school founded in 1919 in Germany that is still relevant today in many ways, particularly in terms of its approach to the relationship between art, design, and society. The school's focus on combining form and function and its emphasis on practical design solutions for everyday life has had a lasting impact on modern art and design.

In relation to climate change, the Bauhaus approach of using design to address social and environmental issues has inspired many contemporary artists and designers to find sustainable solutions to the world's problems. The school's focus on using new materials and technologies to create functional, sustainable designs has influenced the use of eco-friendly materials and innovative design solutions in contemporary art.

The Bauhaus approach to collaboration and interdisciplinary work is relevant in today's art perception on climate change. The school brought together artists, designers, architects, and engineers to work collaboratively on projects, and this interdisciplinary approach has inspired many other contemporary artists and designers to work across disciplines to address environmental issues.

Finally, the Bauhaus approach to education, which emphasized learning through experimentation and practical experience, has inspired a generation of contemporary artists and designers to find innovative ways to address climate change.

The school's focus on problem-solving, creativity, and innovation has had a lasting impact on art education and continues to inspire artists and designers to find sustainable solutions to the world's problems. The ability to bring together many artists across many cultures is converging these days into an international cultural program of the EU. The NEB adds a cultural and creative dimension to the European Green Deal to show how sustainable innovations can provide tangible and positive experiences to be implemented in everyday lives.



Bauhaus School

The NEB combines the grand vision of the European Green Deal with concrete changes on the ground—changes that will improve people’s daily lives, changes they can experience in a tangible way in buildings, in public spaces, and in the form of fashion or furniture. The NEB aims to create a new lifestyle that balances sustainability with good design, uses less carbon, and is inclusive and affordable for all.

The NEB started in the early 2020s and has been and will be included in many existing EU programs to support the achievement of the SDGs as a contextual element or priority without a dedicated budget.

The funds to be made available for implementation are provided by various EU programs. In addition, the European Commission encourages EU member states to apply the core values of the NEB in their national territorial and socioeconomic development strategies and to use the relevant parts of their building and resilience plans and cohesion policy programs to build a better future while achieving strong sustainability goals for all.

The framework concept of the NEB provides a key motivational movement to mobilize civil society (while still being a political project) to take up art and design as instrumental to achieving the climate goals in the form of collaborative projects.

Recommendations

1. **Foster research and identify funding opportunities within the New European (NEB) program and its successor on European, national, and global levels, where global applications of NEB would be implemented via cultural sensibilities and adaptations to non-European regions.**
2. **Participate in public art projects oriented by an objective of the European sustainability strategy framed by the European Green Deal, many of them installed in decentralized places, especially in European countries.**
3. **Communicate stories about Bauhaus's influence beyond Germany and Europe (e.g., in East Asia).**
4. **Organize visiting tours to the "consecration sites" of Bauhaus in Weimar, Dessau, and Berlin** (Gropius Center).

Further resources

1. Dezeen Magazine.
2. European Union. "New European Bauhaus." Beautiful, Sustainable, Together.
3. Wikipedia, s. v. "Bauhaus." Last modified 30 Apr. 2023.

Issue 14: The need to create empathy toward the environment—artistic listening exercises

Background

Among the issues involved in developing empathy for the environment, foremost is that of developing sensitivity toward the world, natural or not. One way to develop this sensitivity in a sensory way is to address the sounds heard on a soundwalk.

In 1969, the composer Murray Schafer (Schafer, 1969) proposed the practice of walking around a city and paying attention to the sounds nearby: both those produced by cars or human beings in general and those produced by the atmosphere, such as by the wind or by birds and other nonhuman beings.

His purpose was to draw attention to noise pollution (i.e., the physical and psychological effects produced by continuous exposure to sounds and noises beyond a certain tolerance threshold).

Schafer called this sound world in which humanity is immersed "soundscape." Thus, through the World Soundscape Project at the Simon Fraser University in Vancouver (Canada), he initiated both the analytical study of soundscapes and the possibility of specifically creating new soundscapes and, therefore, the formation of the so-called musical genre of soundscape music.

Many years have passed since the proposal of these concepts, but the practice of developing a sensitivity toward the soundscape by choosing a specific path and then crossing it on foot in silence, to which the musician Hildegard Westerkamp has given the name of "soundwalk" (Westerkamp, 2006) has not been developed and disseminated adequately. For this reason, new life should be given to this practice to increase public interest in environmental issues.

Recommendations

1. **Develop the criteria for building a soundwalk as an art form to create better understanding of the environment**
2. **Maintain the didactic aspect of sensitivity training, practicing soundwalks in schools of all levels.**
3. **Underline the ecosystem nature of the soundscape, even in the contrast: human and nonhuman.**
4. **Extend the idea of soundscape also to sound environments that are prevented by the mere presence of humans (birds or insects that stop producing sound if a human being is present) or that are not normally perceptible due to the limits of their hearing system.**
5. **Bring the soundwalk also to formats linked to digital** (podcast, streaming) **or analog** (radio) **distribution**.

Case study

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1. The Sound Walk

   For the use of the soundwalk as a tool for developing environmental awareness in city design in different places such as Berlin, London, and other cities, see Radicchi, A. and others, 2021, "Sound and the healthy city" in *Cities & Health* 5, no.1-2: 1-13.

Further resources

1. Schafer, R. Murray. The Soundscape: Our Sonic Environment and the Tuning of the World. Rochester, VT: Destiny Books, 1993.
2. Truax, Barry. *Acoustic Communication*. New York: Ablex Publishing, 1984.

Issue 15: Reconnecting with nature is essential for humans to devise integrated strategies to meet climate change challenges—tapping into inner knowing and guidance

Background

The climate crisis poses unprecedented challenges, and humans can neither solely rely on past experiences nor on science-based knowledge and technology to solve it. Saving the planet requires adaptation of lifestyles and behaviors, as well as training human capabilities, such as empathy and awareness, so that humanity can tap into its inner knowing and guidance, which will help people to respect nature and maintain their human dignity.

Especially in Western societies, many people hardly use their senses and "antennas" anymore as they rely increasingly on technology to provide data and information. People have lost touch with nature and have disconnected from their spiritual selves (Schuring, 2019). Many do not know their purpose in this world, which is connected to living a meaningful and joyful life. While technology, for example, AI, offers us many escapes, it may also make people lazy when it comes to human capability cultivation (Merl, 2022). From an ethical point of view, it seems like human dignity could be soon lost.

Most human beings are convinced that technologies can further improve life in many ways. Accordingly, a strong focus has been placed on technological advancements, which has resulted in tech-focused policies, funding programs, educational curricula, and mindsets. And so, while the world has become a global village and while humans have started to outsource production processes, monitoring, and decision-making processes to algorithms, people have often forgotten about the benefits and wisdom of local, place-based, Indigenous knowledge—inner knowing and guidance that has helped to cultivate human life throughout history while respecting natural forces and the rights of nature (GARN, "What are the Rights of Nature?").

Indigenous knowledge, local or place-based knowledge, can help humanity reconnect with human capabilities and develop the power of inner knowing and guidance while re-learning how to work with the energies and other life forms in the world. The cultivation of inner knowing and guidance can lead to a much-needed change in mindset and ultimately to a change of behavior and lifestyle. However, it takes the willpower, the insight, and most importantly, the daily practice to make these changes. Institutionalizing awareness-building and future skills training based on Indigenous knowledge can help here.

Indigenous Cultures and Mindset: According to many Indigenous cultures, thinking is reflected in speech, and words are reflected in actions: Humans think, talk, and act. Thus, according to these Indigenous approaches, the thinking does not only come from the mind but also is a cooperation between the heart and the mind. Indigenous knowledge is also often referred to as "inner knowing" or "inner guidance": the ability to look at and within oneself with awareness, and to relate this inner view to the outer world. Life is a cyclic process where everything is connected with each other; reciprocity is an important aspect as "you harvest what you sow."

The Western approach, on the contrary, is seen by many as being driven by capitalism and consumption and puts emphasis on the here and now, following a straight linear timeline with a certain goal to be reached. Indigenous cultures respect their ancestors and the generations that follow and see themselves as part of the eternal circle of life. Human beings are part of the bigger picture; they are part of nature and not superior to nature. Indigenous peoples know that they can always rely on Mother Earth, and so they treat nature with respect. Treating nature with respect includes not exploiting nature. To save the planet, humans need to stop seeing aspects of nature as natural resources but as fellow beings. In this line of thinking, it is not about short-term self-optimization but about connecting with the self and perceiving ourselves as part of nature in the long run.

Recommendations

1. **Institutionalize human capability cultivation with nature and art-inspired coaching methodologies.**
    a. Provide more funding and research programs that focus on embodiment and art-inspired coaching.
    b. Include embodiment and meditation practices in educational curricula and organizational training.
2. **Push behavioral change by means of embodiment practices, such as meditation, qigong, yoga, and poetry reading.** These practices will help develop human senses regarding nature and individual spirit.
3. **Stop making use of meditation, qigong, or yoga solely for the purpose of self-optimization, but bring this into the perception of the whole picture.** Kindness to ourselves will lead to kindness toward others, not only toward human beings but toward all beings.
4. **Design and institutionalize culturally grounded and socially relevant rituals or ceremonies. They** are Indigenous ways to go with the cycles of life, to bring matter and spirit together in a communicative way. Educational programs can help form an intent in humanity’s heart and mind that is of service to the self and the surrounding world.

Further resources

1. Schuring, Hermine. A Life in Service: Stories & Teachings from Mala Spotted Eagle. BookBaby, 2019.

The book *A Life in Service* contains the wisdom and Indigenous knowledge passed on by Mala Spotted Eagle to Hermine Schuring. Mala shared the knowledge of Indigenous elders and his life experiences with Hermine, putting the focus on the importance to walk in balance on Mother Earth. Pollution in our minds creates pollution everywhere else, as all life on this planet is connected.

Issue 16: Effective "narratives" about climate change are urgently needed for people to get engaged—use the work of Indigenous artists to educate and inform wider audiences about the impact of climate change to create possible solutions stemming from Indigenous wisdom?

Background

Indigenous epistemologies view the world as relational and are based on the idea of kinship, where every animate and inanimate object has a relationship with each other (Abdilla et al., 2021). Historically, Indigenous art has been created with total respect to the environment. Materials used are natural with no overconsumption of resources. The Emberá of Panama, for example, weave palm leaves dyed with natural pigments to create brightly colored masks used for traditional ceremonies. It unifies the concept that art and nature are inseparable. In a changing world, Indigenous artists seek ways to share their narrative about the impact of climate change on their homelands using various technologies.

The case studies below demonstrate where Indigenous artists have woven together traditional techniques and wisdom with technology to illustrate the impact of climate change on their culture and lands. They express their values and knowledge for future generations through their art. Note that no singular Indigenous perspective exists, however, and this issue seeks to provide general guidance while respecting the diversity of views among all Indigenous peoples.

Recommendations

1. **Use virtual reality/augmented reality experiences to bring viewers awareness and create a sense of empathy, as well as of urgency.** This approach also helps provide a voice for Indigenous peoples as the story can be told through their own words and artwork without having viewers walk through Indigenous lands.
2. **Embrace country-centered design from Australian Indigenous peoples' systems where humans and technology are agents of the same system and can't be observers outside the system.** Use agent-based modeling techniques.
3. **Provide opportunities for Indigenous artists to preserve their stories and histories through technology.** Give them sovereignty over the work produced.

Case studies

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1. Yuméweuš

   Steve Yazzie is a Navajo artist whose work "Yuméweuš" consists of hydroponic towers that explore the interconnectedness of "you," "me," "we," and "us" and the relationships that exist between these words. The towers are the intersectionality of Indigenous customs and science. The sand paintings feature the chemical structure for amaranth, which grows in the hydroponic towers instead of healing Indigenous designs (Yazzie, 2022).

2. Gold King & Associates

   A secondary work by Yazzie consists of a real estate advertising sign for Gold King & Associates placed outside a property that asks people to call a number (720.281.9199), where they hear a message that could be a story or poem about colonization of Indigenous lands, the impact of climate change and environmental destruction, or the idea of kinship. Callers then have the option of leaving their own message.

3. Rise: From One Island To Another

   > *'Poetry, as with other art forms, can speak to us" on "various"…levels. I feel that in the art space, you leave room for mistakes, for conversation. For humanity. I am not an expert on a scientific level, but I am an expert on being a human being. And we definitely need our humanity in this situation."* (Aka Niviâna at the 2019 Global Landscapes Forum)

   Rise is a visual collaborative project between two young climate activists and poets, Aka Niviâna from Greenland and Kathy Jetnil-Kijiner from the Marshall Islands. Through poetry and imagery, they take the viewer on a journey of two island homelands impacted by climate change: the rising sea levels affecting the Marshall Islands and the melting glaciers of Greenland. The film places both poets on top of a melting glacier in Greenland where their collaborative effort tells the story of their ancestors, humanity's interconnectedness, the damage inflicted to the land, and their resilience in the face of monumental environmental loss. The result is a visually stunning film that highlights human interdependence and is a call to action.

4. Unceded Territories

   Artist Lawrence Paul Yuxweluptun from the Musqueam, Squamish, and Tsleil-Waututh First Nations (currently known as "British Columbia") collaborated with filmmaker Paisley Smith to create an immersive virtual reality experience where viewers throw oil paint in the environment that is Yuxweluptun's artwork. Once the viewer has finished throwing the paint, they are shown that the oil paint has destroyed the painting beyond reversal. Unbeknownst to the viewer, they are the colonizers, and by exercising their will on the environment, they are leaving a trail of destruction and devastation in their wake. The intent is to bring awareness to non-Indigenous populations as to how they are participants of habitat destruction and pollution through consumption and how hundreds of years of consumption in the name of progress has directly impacted Indigenous communities who have lost their lands and livelihoods (Guo, 2020).

5. Ngapulara Ngarngarnyi Wirra (Our Family Tree)

   Australian football player Adam Goodes has performance data recorded via a biometric device. Adam is Adnyamathanha, where the peoples belong to two blood groups and their kinship ascribes to either the North or South winds. The sounds of the North and South wind were recorded as they moved around a sacred tree (wirra) on Adnyamathanha land. Inside the tree, an elder is recorded speaking in the Adnyamathanha language. A machine learning model combines the spoken Adnyamathanha language with the sounds of the North and South winds. In the culmination of the piece, Adam's biometric is used to create a point cloud around a 3D model of the tree (wirra) where the North and South winds combined with spoken language move through the point cloud. By combining ancestral ways and artificial intelligence, it demonstrates a way to illustrate kinship between humans and algorithms, as well as a way to preserve ancestral ways and customs respectfully (Abdilla, 2020).

Further resources

1. Lewis, Jason Edward. *Indigenous Protocol and Artificial Intelligence Position Paper*. Honolulu, Hawaiʻi: The Initiative for Indigenous Futures and the Canadian Institute for Advanced Research (CIFAR), 2020.

Issue 17: Effective narratives about climate change are urgently needed for people to get engaged—using polyphonic[104] storytelling and poetry as methodologies

Background

From a human perspective, saving the planet is about finding humanity's purpose and identity on this planet, the ability to respect all humans, and the willingness to live humbly. Cross-cultural, cross-hierarchical, cross-generational, transdisciplinary, and transgender conversations (Merl, 2023) in communities of practice (Wenger-Trayner & Wenger-Trayner, 2020) that are inspired by polyphonic storytelling and poetry can play a crucial role in this. They can help humans harness the power of imagination and move constructive climate narratives forward (Böhringer, 2023).

The prevailing climate narrative, which is often nourished and spread by mass media and social networks, may paralyze individuals and systems rather than to drive behavioral change. This is why the recommendations provided under this Issue are based on a series of pilot workshops that were conducted on the theme of climate change that support the idea that building more poetry and polyphonic storytelling into existing curricula and educational programs can help humanity develop the skills needed to create impactful climate narratives that can drive behavioral change and lead to concrete action steps in the real world.

> *"Six conversation-based workshops on environmental themes were conducted with an arts based, multimethod approach (McNiff, 2017) between November 2022 and February 2023. Participants were between 21 and 63 years of age and comprised engineers, IT experts, social workers, office workers, legal experts, journalists, public officials, company managers, researchers, creative designers, and part-time students from Austria, Germany; the Netherlands; Italy; and Bosnia. Group size varied between 6 and 30. Five groups met online via a video-conferencing tool as members were geographically dispersed; one group met in person in Vienna.*
>
> *Participants were taken on a poetic journey where they had to deal with a variety of mostly environment-related ancient and contemporary poems, Indigenous poetry and classic literature, poetic video inputs, sketches, and images (see below). The experiment was split into two parts. Part 1 aimed at defining the prevailing climate narrative as perceived and told by participants, referred to as 'Narrative 1.' Part 2 aimed at coming up with an alternative climate narrative, referred to as 'Narrative 2.' Qualitative text analysis (Miles, Huberman, & Saldana, 2019) revealed that Narrative 1 is clearly overshadowed by negative feelings and emotions, such as sadness, guilt, anger, frustration, fear, fury, and a feeling of helplessness, while Narrative 2 is built on optimism, gratitude, love of life, respect for the other, the willingness to take risks, and the courage to fail in the effort to create a good situation for humankind. Both narratives are built on four climate-related pillars or value systems that were identified during Part 1 of the thought experiment: 1) comfort and convenience; 2) health and safety; 3) expectations and social pressure; and 4) commercial interests. Overall, this pilot study (Merl, 2023) demonstrates how poetry*

[104] Polyphonic = producing many sounds simultaneously; many-voiced.

can inspire a constructive polyphonic climate narrative" (adapted excerpts from Merl, 2023).

Many more such pilot studies need to be carried out in different contexts with multiple stakeholders to move an impactful collective climate narrative forward.

Please note that the poems and sketches used in the polyphonic storytelling pilot workshops are quoted below.

Recommendations

Qualitative, text-based analysis has provided the following recommendations aimed at "educators" (teachers, lecturers, curriculum developers, learning and development (L&D) professionals, organizational trainers, educational authorities, policy and decision makers):

1. **Build more poetry into existing curricula and thereby support the development of future skills or 21st-century skills that will help learners find their purpose and identity on this planet.**
2. **Provide effective train-the-trainer programs so that educators can adopt a teaching approach that allows them to effectively teach future skills and enable their learners to harness the power of imagination.**
3. **Establish multiple transdisciplinary, cross-cultural, cross-hierarchical, transgender, and transgenerational spaces.** That is where humans can re-learn with the help of artists how people see and listen to each other and how they can connect with each other to nourish a constructive climate narrative.
4. **Use poetry (artistic impulses) to deconstruct the prevailing climate narrative and spread constructive, collective (alternative) stories through (social) networks to reach as many stakeholders as possible.**
5. **Engage people in deep reflection and collective storytelling experiences so that they can move beyond their current fixation on tech as the solution to environmental problems.**

Klaus Kramer for Poetry in Business, Gesprudel, Sketch, Mixed Media Collage and Poem (2022)

Poems and sketches used in the polyphonic storytelling pilot workshops:

1. Gesprudel, by Klaus Kramer, 2022

   Herbstlichfließend in die Weite und den Raum
   Treibt ein gefallender Baum,
   in den Wassersprudel saugen sich Luft und Traum,
   im dichten Geäst verfangen der Schaum.
   Das Gestern schwimmt weiter im Morgen noch kaum,
   Zaghaft im Winterlicht den Frühling erlaubm;
   den Sommer nicht ahnen, mal schaun.

2. Excerpt from Ulysses, by Alfred Lord Tennyson

   […] Come, my friends,
   'T is not too late to seek a newer world.
   …
   For my purpose holds
   To sail beyond the sunset, and the baths
   Of all the western stars, until I die.
   It may be that the gulfs will wash us down:
   It may be we shall touch the Happy Isles,
   And see the great Achilles, whom we knew.

3. A Light Exists in Spring, by Emily Dickinson

   Not present on the Year
   At any other period –
   When March is scarcely here
   A Color stands abroad
   On Solitary Fields
   That Science cannot overtake
   But Human Nature feels…

Klaus Kramer for Poetry in Business, Ka Fee, Oil on Canvas (2022)

References

1. Abdilla A., M. Kelleher, R. Shaw, and T. Yunkaporta. *Out Of The Black Box: Indigenous Protocols for AI*. Old Ways, New. 2021.
2. Aguera y Arcas, Blaise. "Art in the Age of Machine Intelligence." Medium, Artists + Machine Intelligence, 23 Feb. 2016.
3. Alfred, Lord Tennyson. "Ulysses." Poetry Foundation.
4. Amsen, Eva. "Climate Change Art Helps People Connect With a Challenging Topic." *Forbes*, 30 Sept. 2019.
5. Anirudh Sharma (website).
6. The Artivist Foundation (website).
7. Bennett, Sara E. *Los Micos de Colombia*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, 2003.
8. Blumenreich, Ulrike. *Compendium: Country Profile—Germany.* Institute for Cultural Policy of the Kulturpolitische Gesellschaft. Feb. 2022.
9. Boetzkes, Amanda. "The Aesthetics of Plastic Capitalism." In *Knowledge for the Anthropocene*, edited by F. J. Carrillo and G. Koch. Edward Elgar Publishing, 2021.
10. Böhringer, Martin. "The World's Biggest Problem Solvers Need to Craft Better Narratives." World Economic Forum, 2 Jan. 2023.
11. Ciracì, Sarah. *Sacrilegio*, concrete, 100 x 100cm. 2021.
12. Clancy, Martin, and Rebekah Tweed. *The Voice of the Artist in the Age of the Algorithm.* IEEE and IEEE Standards Association (IEEE SA), Ethically Aligned Design for Artists.
13. Climate Clock (website).
14. The Club of Rome. "The Jena Declaration on Sustainability." 7 Sept. 2021.
15. Cordal, Isaan. *Follow the Leaders* installation series, including Politicians Discussing Global Warming miniature sculpture. Berlin 2011.
16. Crossick, Geoffrey, and Patrycja Kaszynska. "Understanding the Value of Arts & Culture: The AHRC Cultural Value Project." 2016.
17. Currin, Grayson Haver. "The Poignant Music of Melting Ice: Have a Listen." *New York Times*, 16 Mar. 2023.
18. Das, Subhajit Khush. "Instagram reel." 4 July 2021.
19. Dezeen Magazine (website).
20. Dickinson, Emily. "A Light Exists in Spring." Your Daily Poem.
21. Eduskunta Riksdagen, Verkkolähetykset. "Committee for the Future—Parliament of Finland." 2022.
22. European Commission (EC). "Ethics Guidelines for Trustworthy AI." *Shaping Europe's Digital Future*. Last updated 17 Nov. 2022.
23. European Union (EU). "New European Bauhaus." Beautiful, Sustainable, Together.

24. Expo 2020. "Austria Pavilion at Expo 2020 Addresses the Future of Work, Life, and Education." Press release. 15 Dec. 2021.

25. Fondazione Ermanno Casoli (website).

26. Friedman, Thomas. "Our Promethean Moment." *New York Times*, Opinion, 21 Mar. 2023.

27. Global Alliance for the Rights of Nature (GARN). "What Are The Rights of Naturehttps://www.garn.org/rights-of-nature/?"

28. Google. "Artists and Machine Intelligence (AMI)."

29. Government of India, Indian Culture. *Pashupati Seal.* Indus Valley Civilization 2500 BCE. 3.53 x 3.53 x 0.64 cm. National Museum Delhi.

30. Guo, D. "Indigenous Artists Use Technology to Tell Stories About Their Ancestral Lands." *Yes Magazine*, 15 June 2020.

31. Harrison, George. "Ravi Shankar's Chants of India: Mangalam." YouTube video. 1997.

32. Haver Currin, Grayson. "The Poignant Music of Melting Ice: Have a Listen." *New York Times*, 16 Mar. 2023.

33. Ideal. "AI for Recruiting: A Definitive Guide for HR Professionals."

34. IEEE Standards Association (IEEE SA). IEEE 7001-2021, IEEE Standard for Transparency of Autonomous Systems. 2021.

35. John Sabraw (website).

36. Kadenze. "Machine Learning for Musicians and Artists." Goldsmiths University of London online course.

37. Mainspring Media. "Rise: From One Island To Another." Vimeo video. 2018.

38. McLelland, David, John W. Atkinson, Russell A. Clark, and Edgar L. Lowell. *The Achievement Motive.* New York: Appleton-Century-Crofts, 1953.

39. McNiff, S. "Philosophical and Practical Foundations of Artistic Inquiry: Creating Paradigms, Methods, and Presentations Based in Art." In *Handbook of Arts-Based Research*, edited by P. Leavy. New York: Guilford, 2017.

40. Mel Chin (website).

41. Merl, Christina. "Human Intelligence Cultivation with the 2CG® Poetry Machine." *International Journal of Advanced Corporate Learning* 15, no. 1 (2022).

42. Merl, Christina. "Putting the Periphery in the Picture: How Effective Learning Design Leverages the Power of Polyphonic Storytelling to Push Future Skills Development." In *Creative Approaches to Technology-Enhanced Learning for the Workplace and Higher Education: Proceedings of The Learning Ideas Conference 2023*.

43. Metz, Cade. "We Teach A.I. Systems Everything, Including Our Biases." *New York Times*, 11 Nov. 2019.

44. Miles, Matthew B., A. Michael Huberman, and Johnny Saldana. *Qualitative Data Analysis: A Methods Sourcebook.* SAGE Publication, Jan. 2019.

45. Namami Gange. "Namami Gange Anthem." YouTube video. 7 July 2016.

46. Namami Gange. "Namami Gange: Official Anthem of National Mission on Clean Ganga." YouTube video. 14 June 2020.
47. Olafur Eliasson (website).
48. O'Leary, Denyse. "How Surreal Artist MC Escher Influenced Physicist Roger Penrose." Mind Matters, 9 Jan. 2023.
49. Overstreet, Kaley. "The History of the Penrose Stair and its Influence on Design." *Arch Daily*, 10 May 2022.
50. Pehrson, Greg. "Ultralight, Ultradurable, Ultracheap: A Backpack Made from Car Airbags." BackpackingLight, 4 Jan. 2021.
51. Prime Minister of India. "Namami Gange."
52. Prisma Labs (website).
53. Rapier, Robert. "The Divestment Movement Has Cost Organizations Billions of Dollars." Forbes, 27 Nov. 2022.
54. Rott, Nathan."An Eye-Opener: Virtual Reality Shows Residents What Climate Change Could Do," WUSF Public Media, 24 Nov. 2019.
55. Rúrí. Future Cartography. Digital print. 2012.
56. Sabraw, John. "Toxic Art." TEDxWarwick. YouTube video 2017. 4 Apr. 2017.
57. Saraceno, Thomas. *Museo Aero Solar*. Plastic bag installation and social process. 2007 and ongoing.
58. Schafer, R. Murray. *The New Soundscape: A Handbook for the Modern Music Teacher*. Don Mills, Ontario: BMI Canada, 1969.
59. Schafer, R. Murray. The Soundscape: Our Sonic Environment and the Tuning of the World. Rochester, VT: Destiny Books, 1993.
60. Schuring, Hermine. A Life in Service: Stories & Teachings from Mala Spotted Eagle. BookBaby, 2019.
61. Shlokam. "Akasat Patitam Toyam." (Sanskrit/English with translation, meaning and notes).
62. Sommer, Laura Kim, and Christian Andreas Klöckner. "Does Activist Art Have the Capacity to Raise Awareness in Audiences?—A Study on Climate Change Art at the ArtCOP21 Event in Paris." *Psychology of Aesthetics, Creativity, and the Arts* 15, no. 1 (2021).
63. Ståhle, Pirjo, ed. *Five Steps for Finland's Future.* Technology Review 202/2007. Helsinki: Tekes, 31 Jan. 2007, ref. pg. 4.
64. Star, Susan Leigh, and James R. Griesemer. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science* 19, no. 3 (1989): 387–420.
65. UNESCO. Recommendation on the Ethics of Artificial Intelligence. SHS/BIO/PI/2021.1. 2022.
66. United Nations (UN). "Global Issues: Climate Change."
67. University of Iowa Technology Institute. "Classical Indian Dances Could Help UI Engineering Professor Unlock Mysteries of Space and the Ocean." 24 Aug. 2022.
68. Webuild with Triennale Milano. *Exhibition: Building the Future Infrastructure and Benefits for People and Territories*. Fondazione La Triennale di Milano, 3–26 Mar. 2023.

69. Wekinator (website).
70. Wenger-Trayner, Etienne, and Beverly Wenger-Trayner. *Learning to Make a Difference: Value Creation in Social Learning Spaces.* Cambridge University Press, 2020.
71. Westerkamp, Hildergard. "Soundwalking as Ecological Practice." In *The West Meets the East in Acoustic Ecology. Proceedings for the International Conference on Acoustic Ecology*. Hirosaki, Japan: Hirosaki University, 2–4 Nov. 2006.
72. White, Tom. "Perception Engines." Medium, Artists + Machine Intelligence, 4 Apr. 2018.
73. Wikipedia, s. v. "Alexandria Ocasio-Cortez." Last updated 5 May 2023.
74. Wikipedia, s. v. "Amager Bakke." Last updated 2 May 2023.
75. Wikipedia, s. v. "Bauhaus." Last modified 30 Apr. 2023.
76. Wikipedia s. v. "Elizabeth May." Last updated 28 Apr. 2023.
77. Wikipedia, s. v. "Stable Diffusion." Last updated 4 May 2023.
78. Wikipedia, s. v. "Trolley Problem." Last modified 25 Apr. 2023.
79. Wikipedia, s. v. "The Yes Men." Last updated 17 Mar. 2023.
80. The World Soundscape Project (website).
81. Yazzie, S. Yuméweuš. Yazzie Studios. 2022.

Acronyms

ABCD	asset-based community development
AGI	artificial general Intelligence
AHAM	Association of Home Appliance Manufacturers
AI	artificial intelligence
AIS	artificial intelligence systems
ANSI	American National Standards Institute
API	application programming interface
AR	augmented reality
PCP	Asian Citrus Psyllid
bn	billion
B-Corp	B Corporation
BSAT	Basic Sustainability Assessment Tool
CARB	California Air Resources Board
CDC	Centers for Disease Control and Prevention
CDM	clean development mechanism
CICS	caring, inclusive, circular, sustainable
CMRA	Climate Mapping for Resilience and Adaptation (U.S. dashboard application)
CO_2	carbon dioxide
COP	Conference of the Parties
COP15	Conference of the Parties 15
COP28	Conference of the Parties 28
CSR	corporate social responsibility
D4S	digitalization for sustainability
DAO	decentralized autonomous organizations
DLT	distributed ledger technology
DNA	deoxyribonucleic acid
DPP	digital product passport (European Union)
EPA	Environmental Protection Agency (United States)
ESG	environmental, social, and governance
ESPR	ecodesign for sustainable products regulation (Europe)
EQUIP	Environmental Quality Incentives Program

EU	European Union

EU-28 The member states of the European Union (EU): Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, and including the United Kingdom

FAO	Food and Agriculture Organization
FDA	Food and Drug Administration (United States)
FSC	The Forest Stewardship Council
G20	Group of 20
GBF	Global Biodiversity Framework (Kunming-Montreal)
GDP	gross domestic product
GDPR	general data protection regulation
GHG	greenhouse gas
GHGe	greenhouse gas emissions
GLOSS	Global Sea Level Observing System
GMP	good manufacturing practice
GMSLR	global mean sea-level rise
GNH	gross national happiness
GO	governmental organization
GPI	genuine progress indicator
GS	gold standard
GRI	Global Reporting Initiative
GWP	global warming potential
HDI	Human Development Index
HLEG	high-level expert group
IAASB	International Auditing and Assurance Standards Board
ICT	information and communications technology
IEA	International Energy Agency
IESBA	International Ethics Standards Board for Accountants
IFAC	International Federation of Accountants
IFRS	International Financial Reporting Standards
IMF	International Monetary Fund
IMO	International Maritime Organization
IoT	Internet of Things

IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC Intergovernmental Panel on Climate Change (United Nations body for assessing the science related to climate change)

ISFL Initiative for Sustainable Forest Landscapes (BioCarbon Fund)

ISSB International Sustainability Standards Board

IUCN International Union for Conservation of Nature

IUU illegal, unregulated, and unreported (fisheries)

KPI key performance indicator

L&D learning and development (professional)

LIC lower-income countries

LLII label, license, identity, interoperability

MAAS mobility as a service (in Europe)

MARPOL Prevention of Pollution from Ships

MCA marine conservation areas

MNC multinational corporation/company

ML machine learning

MIT Massachusetts Institute of Technology

MOD Mobility on Demand (in the United States)

MPA marine protected areas

MRV measurement, reporting, and verification (of GHG mitigation)

MtCO2 metric tons of carbon dioxide

NASA National Aeronautics and Space Administration

NBS nature-based solutions

NDC nationally determined contributions

NEB New European Bauhaus

NGO non-governmental organization

NFT non-fungible token

NLP natural language processing

NLEA Nutrition Labeling and Education Act of 1991 (United States)

NRCS National Resource Conservation Stewardship

NOAA National Oceanic and Atmospheric Administration

OECD Organisation for Economic Co-operation and Development

P&L profit and loss (financial)

PETA People for the Ethical Treatment of Animals

PR	public relations
QA	quality assurance
R&D	research and development
REDD and	reducing emissions from deforestation and forest degradation in developing countries

REDD+ The '+' stands for additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks.

SASB	Sustainability Accounting Standards Board
SDG	Sustainable Development Goal (United Nations)
SNAP	Soil Nutrient Application Planner (SNAP PLUS program)
SOD	Sudden Oak Death
STEaM	STEM + Arts and Culture
STEM	science, technology, engineering, and mathematics
STPP	sodium tripolyphosphate
tCO2e	metric tons of carbon dioxide equivalent emissions
TD	transdisciplinary
TJD	The Jena Declaration
TRL	technology readiness level (TLR)
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDESA	DESA-EN | United Nations United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UN SDG	United Nations Sustainable Development Goal
USDA	U.S. Department of Agriculture | USDA
U.S. SEC	United States Securities and Exchange Commission
VCM	voluntary carbon market
VCS	verified carbon standard
VERRA	Verified Carbon Standard - Verra
VR	virtual reality
WBCSD	World Business Council for Sustainable Development
WEF	Water Environment Foundation
WEF	World Economic Forum
WHO	World Health Organization
WRI	World Resources Institute
WQT	water quality trading

XR	extended reality

Bibliography

1. The 15-Minute City (website).
2. Abdilla A., M. Kelleher, R. Shaw, and T. Yunkaporta. *Out Of The Black Box: Indigenous Protocols for AI.* 2021.
3. Achlim, Yasmina. "Environmental Impact of Salmon Farming." One Green Planet Earth.
4. Adams, Chris, Rym Baouendi, Tim Frick, Tom Greenwood, and Dryden Williams. "Estimating Digital Emissions." Sustainable Web Design. Updated 17 Apr. 2022.
5. Adamson, G., J. C. Havens, and R. Chatila. "Designing a Value-Driven Future for Ethical Autonomous and Intelligent Systems." *Proceedings of the IEEE* 107, no. 3 (Mar. 2019): 518–525.DOI: 10.1109/JPROC.2018.2884923.
6. Adhanom Ghebreyesus, Tedros. "Conflict, Climate Crisis and COVID: World Needs 'Peace for Health and Health for Peace'." World Health Organization, Commentaries, 7 Apr. 2022.
7. The Africa Center for Strategic Studies. "Famine Takes Grip in Africa's Prolonged Conflict Zones." 15 Oct. 2024.
8. Agarwal, Mayur. "10 Methods for Oil Spill Cleanup at Sea." Marine Insight, Marine Environment. 30 Apr. 2021.
9. Aguera y Arcas, Blaise. "Art in the Age of Machine Intelligence." Medium, Artists + Machine Intelligence, 23 Feb. 2016.
10. AirNow. "List of Partners."
11. Aknostic. "Regional Clouds in Europe: Embracing Sustainability and Open-Source Innovation." 11 Dec. 2023.
12. Albert, James S., Georgia Destouni, Scott M. Duke-Sylvester, Anne E. Magurran, Thierry Oberdorff, Roberto E. Reis, Kirk O. Winemiller et al. "Scientists' Warning to Humanity on the Freshwater Biodiversity Crisis." *Ambio* 50, no. 1 (2021): 85–94.
13. Alexander, L. "Sustainable Farming in Developing Countries." The Borgen Project, 25 Mar. 2020.
14. Alfred, Lord Tennyson. "Ulysses." Poetry Foundation.
15. Aliaga, Bernardo, Ward Appeltans, Rick Bailey, Julian Barbiere, Mathieu Belbeoch, Aileen Bohan, Elisabetta Bonotto et al. Edited by Henrik Enevoldsen, Kirsten Isensee, and Ikroh Yoon. *State of the Ocean Report 2022*. Paris: UN Educational, Scientific and Cultural (UNESCO) Intergovernmental Oceanographic Commission, 2022.
16. Alliance to End Plastic Waste (website).
17. Allhands, Joanna. "Pinal Farmers are Facing Water Shortages. Shouldn't They Be Growing Less Thirsty Crops?" *AZCentral*, 6 June 2021.
18. Alves, Bruna. "Biodiversity Loss: Statistics & Facts." Statista, 30 Apr. 2024.
19. Amelung, W., D. Bossio, W. de Vries, I. Kögel-Knabner, J. Lehmann, R. Amundson, R. Bol, C. Collins, R. Lal, J. Leifeld, B. Minasny, G. Pan, K. Paustian, C. Rumpel, J. Sanderman, J. W. van Groenigen, S. Mooney, B. van Wesemael, M. Wander, and A. Chabbi. *Towards a Global-Scale Soil Climate Mitigation Strategy*. Nature News, 27 Oct. 2020.

20. American Rivers. "How Sewage Pollution Ends Up In Rivers."
21. American Rivers. "National River Cleanup."
22. Amsen, Eva. "Climate Change Art Helps People Connect With a Challenging Topic." *Forbes*, 30 Sept. 2019.
23. Anderson, Cynthia, and Cindy Cooper, eds. The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education. Portland, OR: The Lemelson Foundation, 2022.
24. Andreoni, Manuela. "Why Pakistan Was Hit So Hard." *New York Times Climate Forward Newsletter*, 30 Aug. 2022.
25. Angarita, H., J. Craven, F. Caggiano, and G. Corzo. "SimBasin: A Serious Gaming Framework for Integrated and Cooperative Decision-Making in Water Management." *American Geophysical Union,* Fall Meeting 2016 (Dec. 2016).
26. Anirudh Sharma (website).
27. Antony, Anu. "What Are Some of the Latest Waste-to-Energy Technologies Available?" PreScouter, Oct. 2017.
28. Appioa, Francesco Paolo, Marcos Limab, and Sotirios Paroutis. "Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges." *Technological Forecasting and Social Change* 142 (May 2019): 1–14.
29. "Application of Southern California Gas Company (U904G) for Authority to Establish a Memorandum Account for the Angeles Link Project." *Before the Public Utilities Commission of the State of California. Application 22-02.* Filed 17 Feb. 2022.
30. Arcanjo, Marcus. "Has Climate Change Rendered the Concept of Sovereignty Obsolete?" Washington, DC: Climate Institute, Jan. 2019.
31. The Artivist Foundation (website).
32. ARUP. "Cities Must Help Produce More Food."
33. Atkinson, Katie. "Value-Based Argumentation for Democratic Decision Support." *Proceedings of the 2006 Conference on Computational Models of Argument: Proceedings of COMMA 2006.* Amsterdam: IOS Press, 2006: 47–58.
34. Atwood, Tricia. "New Research Documents Bottom Trawling as Major Source of Carbon Added to Atmosphere." Utah State Today, Utah State University, Land & Environment, 18 Jan. 2024.
35. Atwood, Tricia, Anastasia Romanou, Tim DeVries, Paul E. Lerner, Juan S. Mayorga, Darcy Bradley, Reniel B. Cabral, Gavin A. Schmidt, and Enric Sala. "Atmospheric CO2 Emissions and Ocean Acidification from Bottom-Trawling." *Frontiers in Maritime Science* 10 (17 Jan. 2024).
36. Australian Government Department of Climate Change, Energy, Environment and Water. "Australian Water Markets."
37. B Corporation (website).
38. Badgley, Grayson, Jeremy Freeman, Joseph J. Hamman, Barbara Haya, Anna T. Trugman, William R. L. Anderegg, and Danny Cullenward. "Systematic Over-Crediting in California's Forest Carbon Offsets Program." *Global Change Biology* 28, no. 4 (Feb. 2022).

39. Bailey, A., L. Meyer, N. Pettingell, M. Macie, and J. Korstad. "Agricultural Practices Contributing to Aquatic Dead Zones." *Ecological and Practical Applications for Sustainable Agriculture* (June 2020): 373–393.
40. Baker, David R. "Renewable Power Costs Rise, Just Not as Much as Fossil Fuels." *Bloomberg News*, 30 June 2022.
41. Baratto, Romullo. "Global Watersheds and Waterways Captured in Vibrant Colorized Maps." Translated by Nicolás Valencia. *Arch Daily*, 9 June 2020.
42. Barbiroglio, Emanuela. "Choosing Sufficiency for Greater Fulfillment and Satisfaction." *Horizon: The EU Research & Innovation Magazine*, 25 July 2022.
43. Bardgett, Richard, James M. Bullock, Sandra Lavorel, Peter Manning, Urs Schaffner, Nicholas Ostle, Mathilde Chomel et al. "Combatting Global Grassland Degradation." *Nature Reviews Earth & Environment* 2, no. 10 (Sept. 2021): 720–735.
44. Barkham, Patrick. "How Sussex Farmers Plan to Create a Wildlife Rich Green Corridor to the Sea." *The Guardian*, 22 July 2022.
45. Barkham, Patrick. "Should Rivers Have the Same Rights As People?." *The Guardian,* 25 July 2021.
46. Barrera, Lauren. "Reducing Fertilizer, Boosting Yields with Sap Analysis." No-Till Farmer, 31 Dec. 2021.
47. Barton, Dominic. "Capitalism for the Long Term." *Harvard Business Review,* Mar. 2011.
48. Bastin, Jean-Francois, Yelena Finegold, Claude Garcia, Danilo Mollicone, Marcelo Rezende, Devin Routh, Constantin M. Zohner et al. "The Global Tree Restoration Potential." *Science* 365, no. 6448 (July 2019): 76–79.
49. Bayulgen, Oksan, and Jeffrey W. Ladewig. "Vetoing the Future: Political Constraints and Renewable Energy."*Environmental Politics* 26, no. 1 (2017): 49–70.
50. Beam, Adam. "Wildfire-Prone California to Consider New Rules for Property Insurance Pricing." Associated Press, 28 Sept. 2023.
51. Beever, Jonathan, and Andrew O. Brightman. "Reflexive Principlism as an Effective Approach for Developing Ethical Reasoning in Engineering." *Science & Engineering Ethics* 22 (2016): 275–291.
52. Bekins, Barbara. "Case Studies in Groundwater Contaminant Fate and Transport." *Oxford Bibliographies*, 26 April 2018.
53. Bell, Lauren. "The 7 Most Sustainable Cities in the World." Rate It Green, Green Building & Design. 21 Sept. 2018.
54. Benkler, Yochai. The Penguin and the Leviathan: The Triumph of Cooperation Over Self-Interest. New York: Crown Business, 2011.
55. Benkler, Yochai. The Wealth of Networks: How Social Production Transforms Markets and Freedom. New Haven & London: Yale University Press, 2006.
56. Bennett, Sara E. *Los Micos de Colombia*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, 2003.
57. Bennett-Jones, Owen. "Should Animals Have the Same Rights as Humans?" BBC News, 26 May 2015.
58. Berge, Chloe. "This Canadian River is Now Legally a Person. It's Not the Only One." *National Geographic*, 15 Apr. 2022.

59. Bernard, Václav. “Remembering George Bernard Shaw with Ten of His Wittiest Quotes.” Bernard’s, News. 6 Aug. 2018.

60. Bernier, Andrew. “Sustainability Storytelling is Not Just Telling Stories about Sustainability.” In *Reference Module in Earth Systems and Environmental Sciences*, edited by M. I. Goldstein and D. A. DellaSala 430–437. *Encyclopedia of the World’s Biome*s 5, Elsevier (2020):

61. Biermann, Frank, Thomas Hickmann, Carole-Anne Sénit, Marianne Beisheim, Steven Bernstein, Pamela Chasek, Leonie Grob, et al. "Scientific Evidence on the Political Impact of the Sustainable Development Goals." *Nature Sustainability* 5 (2022).

62. Binder, Claudia R. “Transdisciplinarity: Co-Creation of Knowledge for the Future.” RCC Perspectives, no. 2 Minding the Gap: Working Across Disciplines in Environmental Studies (2014): 31–34.

63. Bingham, Heather C., Edward Lewis, John Tayleur, Cleo Cunningham, Naomi Kingston, Neil D. Burgess, Neville Ash, Trevor Sandwith, and Kathy MacKinnon, eds. *Protected Planet Report 2020*. UNEP-WCMC and IUCN: Cambridge UK, and Gland, Switzerland. Updated May 2021.

64. Birol, Faith. “Seven Steps to Make Electricity Systems More Resilient to Climate Risks.” World Economic Forum, 15 July 2021, accessed 30 Jan. 2023.

65. Bland, Alastair. “Biodegradable Fishing Gear Isn’t Good Enough.” *Hakai Magazine*, 14 Sept. 2023.

66. Blaufelder, Christopher, Cindy Levy, Peter Mannion, and Dickon Pinner. “A Blueprint for Scaling Voluntary Carbon Markets to Meet the Climate Challenge.” McKinsey Sustainability, 29 Jan. 2021.

67. Blue Latitudes. “Rigs-to-Reefs.”

68. *Blueprint for Ocean Climate Action: Recommendations for the Ocean Policy Committee*. June 2022.

69. Blumenreich, Ulrike. *Compendium: Country Profile—Germany.* Institute for Cultural Policy of the Kulturpolitische Gesellschaft. Feb. 2022.

70. Boano, Fulvio, Alice Caruso, Elisa Costamagna, Luca Ridolfi, Silvia Fiore, Francesca Demichelis, Ana Galvão et al. “A Review of Nature-Based Solutions for Greywater Treatment: Applications, Hydraulic Design, and Environmental Benefits.” *Science of the Total Environment* 711 (Apr. 2020).

71. Boetzkes, Amanda. “The Aesthetics of Plastic Capitalism.” In *Knowledge for the Anthropocene*, edited by F. J. Carrillo and G. Koch. Edward Elgar Publishing, 2021.

72. Boeraeve, F., N. Dendoncker, J. T. Cornélis, F. Degrune, and M. Dufrêne. “Contribution of Agroecological Farming Systems to the Delivery of Ecosystem Services.” *Journal of Environmental Management* 260 (Apr. 2020).

73. Böhringer, Martin. “The World’s Biggest Problem Solvers Need to Craft Better Narratives.” World Economic Forum, 2 Jan. 2023.

74. Bollier, D. (2016, June 25.) Beyond Development: The Commons as a New/Old Paradigm of Human Flourishing.

75. Borens, Moira, Sebastian Gatzer, Clarisse Magnin, and Björn Timelin. “Reducing Food Loss: What Grocery Retailers and Manufacturers Can Do.” McKinsey & Company, 7 Sept. 2022.

76. Borland, J. O. "Reverse Energy Injustice On Molokai Island To The Underserved Communities With 100% Energy From The Sun (Light & Heat) For Energy Cost Savings Equity." 2022 IEEE 49th Photovoltaics Specialists Conference (PVSC), Philadelphia, PA, USA, 2022: 0127–0130.

77. Bouckaert, Stéphanie, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner. *Net Zero by 2050: A Roadmap for the Global Energy Sector*. Paris: IEA, May 2021.

78. Boutros, Tristan. "The Ego: The Biggest Barrier to Success and Leadership." Process Excellence Network (PEX). 17 May 2015.

79. Brandt, Willy. *North-South: A Program for Survival.* Brandt Report. Cambridge, MA: MIT Press, 1980.

80. Brasueli, J. "As Heat Waves Become More Common, Bus Shelters Are Needed to Keep Transit Riders Onboard." *Planetizen,* 30 Aug. 2021.

81. Breyer, Christian, Siavash Khalili, Dmitri Bogdanov, Manish Ram, Ayobami Solomon Oyewo, Arman Aghahosseini, Ashish Gulagi, A. A. Solomon, Dominik Keiner, Gabriel Lopez, Poul Alberg Østergaard, Henrik Lund, Brian V. Mathiesen, Mark Z. Jacobson, Marta Victoria, Sven Teske, Thomas Pregger, Vasilis Fthenakis, Marco Raugei, Hannele Holttinen, Ugo Bardi, Auke Hoekstra, and Benjamin K. Sovacool. "On the History and Future of 100% Renewable Energy Systems Research." *IEEE Access* 10 (2022): 78176 –78218.

82. Brisco, Tony. "Boiling Point: Which Cities Are Taking Charge as California Shifts to Electric Buses?" *Los Angeles Times,* 12 July 2023.

83. Brown, Sandra, and Louis R. Iverson. "Biomass Estimates for Tropical Forest." *World Resource Review* 4, no. 3 (1992): 366–384.

84. Brondizio, Eduardo, Sandra Díaz, Josef Settele, and Hien T. Ngo, eds. *The Global Assessment Report on Biodiversity and Ecosystem Services.* Bonn, Germany: IPBES Secretariat, 2019.

85. Brundtland Commission. *Our Common Future*. World Commission on Environment and Development. Oxford University Press, 1987.

86. Budden, Philip, and Fiona Murray, "Strategically Engaging with Innovation Ecosystems," *MIT Sloan Management Review*, 20 July 2022.

87. Buesseler, Ken et al. and The Ocean Twilight Zone Team at Woods Hole Oceanographic Institution. *The Ocean Twilight Zone's Role in Climate Change*. Edited by Jesse Ausubel et al. The Ocean Twilight Zone Project.

88. Buhaug, Halvard, Tor A. Benjaminsen, Elizabeth A. Gilmore, and Cullen S. Hendrix. "Climate-Driven Risks to Peace Over the 21st Century." *Climate Risk Management* 39, no. 100471 (2023).

89. Bunch, Kevin. "Using Satellites to Measure How Thirsty Crops are in the St. Mary-Milk Rivers Region." International Joint Commission. *Shared Waters: Water Matters*, 16 Nov. 2020.

90. Bureau Veritas. "Powering Marine Decarbonization with Wind-Assisted Propulsion." Marine & Offshore.

91. Burger, Jaap, Julia Hildermeier, Andreas Jahn, and Jan Rosenow. *The Time is Now: Smart Charging of Electric Vehicles*. Regulatory Assistance Project: Apr. 2022.

92. Burgos-Debray, Elizabeth, ed. *I, Rigoberta Menchú. An Indian Woman in Guatemala.* New York and London: Verso, 1984.

93. Busker, Tim, Hans de Moel, Toon Haer, Maurice Schmeits, Bart van den Hurk, Kira Myers, Dirk Gijsbert Cirkel et al. "Blue-Green Roofs with Forecast-Based Operation to Reduce the Impact of Weather Extremes." *Journal of Environmental Management* 301 (Jan. 2022).

94. Café Thorium. "Ocean Twilight Zone." Woods Hole Oceanographic Institution.

95. Calderon, Ignacio. "Climate Change Is Intensifying the Effects of Fertilizer Runoff." *Modern Farmer,* 22 Dec. 2021.

96. California Climate Commons (website).

97. Callen, Tim. "Gross Domestic Product—An Economy's All." International Monetary Fund (IMF), Finance & Development.

98. Canada's Ocean Supercluster. "Port Integration and Enhancement of Data Project."

99. Canadell, J. G., and M. R. Raupach. "Managing Forests for Climate Change Mitigation." *Science* 320 (2008): 1456–1457.

100. Canadian Plastics. "This Non-Toxic Biodegradable Plastic Film Is Based on Seaweed." 1 Feb. 2021.

101. Carbon Disclosure Project (website).

102. Carbon Trust. "Briefing: What Are Scope 3 Emissions?"

103. Carić, Hrvoje. "Cruising Tourism Environmental Impacts: Case Study of Dubrovnik, Croatia." *Journal of Coastal Research*, no. 61 (Oct. 2011): 104–13.

104. Carnicer, Jofre, Andres Alegria, Christos Giannakopoulos, Francesca Di Giuseppe, Anna Karali, Nikos Koutsias, Piero Lionello et al. "Global Warming Is Shifting the Relationships between Fire Weather and Realized Fire-Induced CO_2 Emissions in Europe." *Scientific Reports* 12 (June 2022).

105. CBS News. "Lake of Garbage: Every Winter Pollution is Swept from Overflowing Landfills into Balkan Waterways." 26 Jan. 2021.

106. Ceballos, Gerardo, and Paul R. Ehrlich. "The Misunderstood Sixth Mass Extinction." *Science* 360, no. 6393 (June 2018): 1080–1081.

107. Center for Food Safety and Applied Nutrition. "Tracking and Tracing of Food." US Food and Drug Administration. Accessed 11 May 2023.

108. Center for Global Development. "Developed Countries are Responsible for 79 Percent of Historical Emissions."

109. Center for Partnership Systems (website).

110. Champions 12.3. (website).

111. Chandha, Saikiran. "Scientific Research Needs to Be More Transdisciplinary Than Ever." *Fast Company*, 19 Aug. 2022.

112. Chang, Liangyu, Liju Xu, Yaohu Liu, and Dong Qiu. "Superabsorbent Polymers Used for Agricultural Water Retention." *Polymer Testing* 94 (Feb. 2021).

113. Chen, William. "We Can Make Large Dams More Friendly to the Environment." *Scientific American*, Apr. 2018.

114. Chen, William, and Julia Olden. "Designing Flows to Resolve Human and Environmental Water Needs in a Dam-Regulated River." *Nature Communications* 8 (Dec. 2017).

115. Chesapeake Bay Foundation. "14 Things You Can Do to Clean Up Your Rivers, Streams, and the Chesapeake Bay."

116. Chesapeake Bay Foundation. "Water Quality Trading."

117. Chiavari, Joana and Cristina Leme Lopes. *Policy Brief---Brazil's New Forest Code, Part I: How to Navigate the Complexity*. Climate Policy Initiative, 2015.

118. Chibvongodze, Danford T. "Ubuntu is Not Only about the Human! An Analysis of the Role of African Philosophy and Ethics in Environment Management." *Journal of Human Ecology* 53, no. 2 (2016): 157–166.

119. The Chisholm Legacy Project. "Policies for the People."

120. Cho, Renée. "Recycling in the U.S. Is Broken: How Can We fix It?" Columbia Climate School, State of the Planet, Sustainability. 13 Mar. 2020.

121. Cilliers, Paul. *Complexity and Postmodernism: Understanding Complex Systems.* London and New York: Routledge, 1998.

122. Ciracì, Sarah. *Sacrilegio*, concrete, 100 x 100cm. 2021.

123. City of Oakland, Public Works. "Oakland Community Gardening Program."

124. Clancy, Heather. "Carbon-Sucking Concrete is Capturing Attention and Funding." GreenBiz, 6 May 2021.

125. Clancy, Martin, and Rebekah Tweed. *The Voice of the Artist in the Age of the Algorithm.* IEEE and IEEE Standards Association (IEEE SA), Ethically Aligned Design for Artists.

126. C40 Cities. "Clean Air Accelerator." Feb. 2022.

127. Clear Choices Clean Water, Indiana. "Fertilizer and Water."

128. Climate Accountability Institute. "Carbon Majors Project."

129. Climate Action 100+ (website).

130. Climate Action Data Trust (website).

131. Climate Action Tracker. "The CAT Thermometer." Dec. 2023.

132. Climate Change AI (website).

133. Climate Change AI. "AAAI 2022 Fall Symposium: The Role of AI in Responding to Climate Challenges."

134. Climate Clock (website).

135. Climate Council. "Uninsurable Nation: Australia's Most Climate-Vulnerable Places." 3 Mar. 2022. Accessed 17 Nov. 2023.

136. Climate Interactive. The EN-ROADS Climate Solutions Simulator (online resource).

137. Climate Mapping for Resilience and Adaptation (website).

138. Climate Watch (with major processing by Our World in Data). "Total Greenhouse Gas Emissions, Excluding Land Use and Forestry" [dataset].

139. Climate-ADAPT. "Improved Water Retention Capacity in the Agricultural Landscape." Database, Adaptation Options, 7 June 2016, updated 9 Mar. 2023.

140. Climate-KIC. "Monitoring, Reporting and Verification Sector." Co-funded by the European Union.

141. The Club of Rome. "The Jena Declaration on Sustainability." 7 Sept. 2021.

142. Clutton-Brock, Peter, David Rolnick, Priya L. Donti, Lynn H. Kaack, Nicolas Miailhe, Raja Chatila, Marta Kwiatkowska et al. *Climate Change & AI: Recommendations for Government Action*. Climate Change AI, Centre for AI & Climate, and the Global Partnership for Artificial Intelligence (GPAI), 2021.

143. Coalition for Digital Environmental Sustainability (CODES). *Action Plan for a Sustainable Planet in the Digital Age.* 2022.

144. Combes, Stacey. "Protecting Freshwater Ecosystems in the Face of Global Climate Change." World Wildlife Fund, Jan. 2003.

145. Comer, Bryan. "Choose Wisely: IMO's Carbon Intensity Target Could Be the Difference Between Rising or Falling Shipping Emissions This Decade." *The International Council on Clean Transportation (ICCT)* (blog). 18 May 2021.

146. Community Climate Collaborative (website).

147. Conklin, Jeff. "Growing a Global Issue Base: An Issue-Based Approach to Policy Deliberation." *Directions and Implications of Advanced Computing: Conference on Online Deliberation*, DIAC-2008.

148. Connor, Dan. "DAOs Could Hold the Answer to Better Data Governance Guidelines." VentureBeat, 8 May 2022.

149. Conspicuous Capitalism (website).

150. Coppola, Alysha I., Sasha Wagner, Sinikka T. Lennartz, Michael Seidel, Ward Nicholas D., Thorsten Dittmar, Cristina Santín, and Matthew W. Jones. "The Black Carbon Cycle and its Role in the Earth System." *Nature Reviews Earth & Environment* 3 (2022): 516–532.

151. Cordal, Isaan. Follow the Leaders Installation Series, including Politicians Discussing Global Warming Miniature Sculpture. Berlin 2011.

152. Cornwall, Warren. "The Plastic Eaters: Bacterial Enzymes Can Digest Some Plastic Waste. Scientists Warn to Harness Them for Recycling." *ScienceAdviser,* 1 Jul. 2021.

153. Cox, Paul Alan, David A. Davis, Deborah C. Mash, James S. Metcalf, and Sandra Anne Banack. "Dietary Exposure to an Environmental Toxin Triggers Neurofibrillary Tangles and Amyloid Deposits in the Brain." *Proceedings of The Royal Society B* 283, no. 1823, (Jan. 2016).

154. Craven, Joanne, Hector Angarita, G. A. Corzo Perez, and Daniel Vasquez. "Development and Testing of a River Basin Management Simulation Game for Integrated Management of the Magdalena-Cauca River Basin." *Environmental Modelling & Software* 90 (Apr. 2017).

155. Crawford, Kate. The Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press, 2021.

156. Christian, Kayti. "Sustainability Certifications: What Do They Actually Mean?" The Good Trade, 15 Apr. 2022.

157. Crossick, Geoffrey, and Patrycja Kaszynska. "Understanding the Value of Arts & Culture: The AHRC Cultural Value Project." 2016.

158. Crow, Daniel, Insa Handschuch, Gabriel Saive, and Leonie Staas. "Behaviour Change: Strategies and Case Studies for Reaching Net-Zero by 2050," EnergyPost, 8 Nov. 2021.

159. Curiosity Stream. "Going Circular."

160. Currin, Grayson Haver. "The Poignant Music of Melting Ice: Have a Listen." *New York Times*, 16 Mar. 2023.

161. Cuthbertson, Anthony. "€2 Billion Underground 'Water Battery' Turns on in Switzerland." *Independent*, 5 July 2022.

162. Cymru Masnach Deg (Fair Trade Wales). "Our Interview with Repair Cafe Wales." 28 Oct. 2021.

163. Dahl, Thomas E., and Gregory J. Allord. "History of Wetlands in the Conterminous United States." *United States Geological Survey Water Supply Paper* 2425, US Geological Survey, National Water Summary on Wetland Resources. 1997.

164. Dalili, Nadia, Miako Ushio, and Aurelie Cosandey-Godin. "Mitigating Shipping Impacts on Cetaceans in Canada: Lessons Learned and Best Practices." WWF-Canada, Dec. 2020.

165. Dalin, Carole, Yoshihide Wada, Thomas Kastner, and Michael J. Puma. "Groundwater Depletion Embedded in International Food Trade." *Nature* 543 (Mar. 2017).

166. Daly, Herman E. *Beyond Growth: The Economics of Sustainable Development*. 1996.

167. Daly, Herman E. *Steady State Economics*. 2nd ed. Washington DC: Island Press, 1981.

168. Dasgupta, Shreya. "The Ups and Downs of Marine Protected Areas: Examining the Evidence." Mongabay, 25 Jan. 2018.

169. The Data Team. "Climate Change Will Affect Developing Countries More Than Rich Ones." *The Economist*, 9 May 2018.

170. Davis, Anna J. "The Role of Nuclear Energy in the Global Energy Transition." The Oxford Institute for Energy Studies, Aug. 2022.

171. Davis, Kermal. "Devastating for the World's Poor: Climate Change Threatens the Development Gains Already Achieved." UN Chronicle, from vol. XLIV, no. 2 "Green Our World!" 2007.

172. Davis, Shawna. "Having Chickens Reduces Your Food Waste, and There's Proof." dengarden, 30 Dec. 2022.

173. The DEAL Team. "What is the Doughnut?" Doughnut Economics Action Lab. 15 July 2020.

174. Deep Space Food Challenge (website).

175. Dekimpe, Valérie. "Dam Busters: Tearing Down Concrete Walls to Save Atlantic Salmon." *France24*, 15 Apr. 2022.

176. Delaney, Kevin. "Harnessing the Power of Parked EVs." *Cisco Newsroom*, 27 June 2022.

177. Dao, David, Catherine Cang, Clement Fung, M. Zhang, Nick Pawlowski, R. Gonzales, Nick Beglinger, and Ce Zhang. "GainForest: Scaling Climate Finance for Forest Conservation using Interpretable Machine Learning on Satellite Imagery." International Conference on Machine Learning 2019.

178. Dellesky, Carrie. "The City Dwellers Who Are Growing Food in India, China and Brazil." Rozenberg Quarterly, March 2015.

179. Deloitte. "Perspectives #1: What is ESG?"

180. den Hartog, Harry. "Shanghai's Regenerated Industrial Waterfronts: Urban Lab for Sustainability Transitions?" *Urban Planning* 6, no. 3 (Feb. 2021).

181. Denchak, Melissa. "Green Infrastructure: How to Manage Water in a Sustainable Way." NRDC, 25 July 2023.

182. Denchak, Melissa. "Water Pollution: Everything You Need to Know." NRDC, 11 Jan. 2023.

183. DePaul University. Asset-Based Community Development Institute (ABCD).

184. Derla, Katherine. "4 Billion People Face Water Shortage: Rising Populations, Agriculture Drive Water Demand." *Tech Times*, 15 Feb. 2016,

185. Dermus, Deniz. "Care Ethics and Paternalism: A Beauvoirian Approach." *Philosophies* 7, no. 3 (May 2022).

186. Derr, Jennifer. "The Dammed Body: Thinking Historically about Water Security & Public Health." Daedalus, *Journal of the American Academy of Arts & Sciences* 150, no. 4 (Fall 2021).

187. Design for Change USA (website).

188. Desing, Harald et al. "Powering a Sustainable and Circular Economy—An Engineering Approach to Estimating Renewable Energy Potentials within Earth System Boundaries." *Energies* 12, no. 24 (Dec. 2019).

189. Desjardins, Jeff. "NASA Satellites Show Disturbing Trends in Water Supply." *Visual Capitalist*, 22 June 2015.

190. Dezeen Magazine (website).

191. Diamond, Jared. Collapse: How Societies Choose to Fail or Succeed. New York: Penguin, 2005.

192. Dickinson, Emily. "A Light Exists in Spring." Your Daily Poem.

193. Dodds, Walter K., Joshua S. Perkin, and Joseph E. Gerken. "Human Impact on Freshwater Ecosystem Services: A Global Perspective." Environmental Science & Technology, no. 47 (2013): 9061–9068.

194. Donoff, Elizabeth. "Nobel Prize for the Discovery of the Blue LED." *Architect Magazine*, 6 Dec. 2016.

195. Dorian, James P., Herman T. Franssen, and Dale R. Simbeck, MD. "Global Challenges in Energy." *Energy Policy* 34, no. 15 (2006): 1984-1999.

196. Dosemagen, Shannon. "Writing" (website).

197. Doughnut Economics Action Lab. "About Doughnut Economics."

198. Dudgeon, David, Angela H. Arthington, Mark O. Gessner, Zen-Ichiro Kawabata, Duncan J. Knowler, Christian Leveque, Robert J. Naiman, Anne-Helene Prieur-Richard, Doris Soto, Melanie L. J. Stiassny, and Caroline A. Sullivan. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." *Biological Reviews* 81 (2006): 163–182.

199. Duke University, Nicholas School of the Environment. "Land-Building Marsh Plants Are Champions of Carbon Capture." 5 May 2022.

200. Dumiak, Michael. "This Dutch City is Road-Testing Vehicle-to Grid Tech." *IEEE Spectrum*, 27 June 2022.

201. Dutzik, Tony, Piper Crowell, and John Rumpler. *Wasting Our Waterways: Toxic Industrial Pollution and the Unfulfilled Promise of the Clean Water Act.* Environment America Research & Policy Center, Fall 2009.

202. Earth Charter (website).

203. Earth Overshoot Day (website).

204. Ecowatch. "Rivers, Lakes, and Oceans Poisoned with 180 Million Tons of Mine Waste Every Year." Deep Green Resistance News Service.

205. Eduskunta Riksdagen, Verkkolähetykset. "Committee for the Future—Parliament of Finland." 2022.

206. Egger, Matthias. "The Other Source: Where Does Plastic in the Great Pacific Garbage Patch Come from?" The Ocean Cleanup, 1 Sept. 2022.

207. Eisler, Riane T. *The Chalice and the Blade: Our History, Our Future.* San Francisco: Perennial Library, 1988.

208. Eisler, Riane T. *The Real Wealth of Nations: Creating a Caring Economics.* San Francisco: Berrett-Koehler Publishers, Inc., 2007.

209. Elbein, Saul. "As Climate-Driven Drought Slams Farms in U.S. West, Water Solutions Loom." Mongabay, 17 Dec. 2021.

210. Elbein, Saul. "How Climate Change Is Making Fires Worse." The Hill, 24 June 2022.

211. Elkington, John. *Green Swans: The Coming Boom in Regenerative Capitalism*. New York: Fast Company Press, 2020.

212. Ellen MacArthur Foundation. "The Circular Economy in Detail." Circular Economy, 15 Sept. 2019.

213. Ellen MacArthur Foundation. "What is a Circular Economy?" Circular Economy Introduction.

214. Ellerbeck, Stefan. "What's the Difference Between 'Friendshoring' and Other Global Trade Buzzwords?" World Economic Forum, Supply Chains and Transportation, 17 Feb. 2023.

215. Elliot, Josh K. "Woman's Puppy Playdate Ends with 3 Dogs Dead from Toxic Algae." *Global News*, 12 Aug. 2019.

216. Elo, Merja, Jonne Hytönen, Sanna Karkulehto, Teea Kortetmäki, Janne S. Kotiaho, Mikael Puurtinen, and Miikka Salo, eds. *Interdisciplinary Perspectives on Planetary Well-Being*. Oxon, England: Routledge, 2024.

217. Engler, Henry. "'Double Materiality': New Legal Concept Likely to Play in Debate Over SEC's Climate Plan." Thomas Reuters, 12 Apr 2022.

218. The Environmental Trading Network. "Organizations and Tools."

219. Eros, Tibor, Virgilio Hermoso, and Simone Langhans. "Leading the Path Toward Sustainable Freshwater Management: Reconciling Challenges and Opportunities in Historical, Hybrid, and Novel Ecosystem Types." WIRES Water Wiley (June 2022).

220. ETH Zurich Systemic Design Labs (website).

221. Etieyibo, Edwin. "Ubuntu and the Environment." In *The Palgrave Handbook of African Philosophy*, edited by Adeshina Afolayan and Toyin Falola. New York: Palgrave Macmillan, 2017.

222. European Commission (EC). "2050 Long-Term Strategy." Climate Action, EU Action, Climate Strategies and Targets.

223. European Commission (EC). "Business & Biodiversity." Energy, Climate Change, Environment, *Green Business*.

224. European Commission (EC). "Ecodesign for Sustainable Products Regulation." Energy, Climate Change, Environment; Standards, Tools and Labels; Products, Labeling Rules and Requirements; Sustainable Products.

225. European Commission (EC). "Ethics Guidelines for Trustworthy AI." Shaping Europe's Digital Future. Last updated 17 Nov. 2022.

226. European Commission (EC). "Farm to Fork Strategy." Horizontal Topics.

227. European Commission (EC). *The Future of Cities*. Joint Research Centre. Luxembourg: Publications Office of the European Union, 2019.

228. European Commission (EC). "Illegal Fishing." Sustainable Fisheries, Rules.

229. European Commission (EC). "Nature Restoration Law." Energy, Climate Change, Environment, *Nature & Biodiversity*.

230. European Commission (EC). "Social Segregation: How Can Cities become More Inclusive?" report on The Future of Cities.

231. European Commission. "Waste from Electrical and Electronic Equipment (WEEE)." Energy, Climate Change, Environment, Waste and Recycling.

232. European Network for Rural Development (website).

233. European Parliament. "EU Measures Against Climate Change." Topics, Climate and Environment, *Climate Change*, 7 Aug. 2018.

234. European Space Agency (ESA). "The 2024 Global Methane Budget Reveals Alarming Trends." 9 Oct. 2024.

235. European Union. "Complete Guide to GDPR Compliance." General Data Protection Regulation (GDPR.EU), 2018.

236. European Union (EU). "Natural Capital Accounting." Nature and Biodiversity.

237. European Union (EU). "New European Bauhaus." Beautiful, Sustainable, Together.

238. Evans, Simon. "Analysis: Which Countries Are Historically Responsible for Climate Change?" 5 Oct. 2021.

239. Evja (website).

240. Evoqua Water Technologies. "Sustainability Impact Map."

241. "Excessive Water Use." City of Show Low, Arizona.

242. Fallon, Scott. "Humpback Whales Continue Surprising Resurgence off NJ Shores." NorthJersey.com, 19 July 2022.

243. Farhan, Aulia Riza, R. Bambang Aditya, Dendi Mahabror, Romy Ardianto, and Kalu Nicolaus Naibaho. *Calculation Model of Economic Losses Due to Illegal Fishing Activities in Indonesian Territorial Waters.* Indonesia Marine Fellows Program Report, 2018.

244. Fatima, Iffat, Markus Funke, and Patricia Lago. "From Goals to Actions: Providing Guidance to Software Practitioners with KPIs." *TexchRxiv*, 1 Sept. 2023.

245. Federal Energy Management Program. "Water-Efficient Technology Opportunities." Energy.gov. Accessed Aug. 2022.

246. Ferreira, Alanielson, Roberto Ventura Santos, Tarcísio Silva de Almeida, Maryene Alves Camargo, José André Filho, Caetano Rodrigues Miranda, Saulo de Tarso Alves dos Passos, Alvaro David Torrez Baptista, Colombo Celso Gaeta Tassinari, Valentina Alzate Rubio, and Gabriel Godinho Capistrano. "Unraveling the Rapid CO2 Mineralization Experiment Using the Parana Flood Basalts of South America." Scientific Reports 14, no. 8116 (6 Apr. 2024).

247. Figueres, José María. "Here's How We Can Reduce Shipping Industry Emissions." World Economic Forum, 23 Oct. 2020.

248. Fischer-Benitez, Cecilia. "Volunteer Spotlight: When Tech Is the Last Piece of the Puzzle." *Code For America,* 25 Aug. 2020.

249. Flannigan, M. D., B. J. Stocks, and B. M. Wotton. "Climate Change and Forest Fires," *The Science of the Total Environment* 262 (2000): 221–229.

250. Flavelle, Christopher. "E.P.A. Is Letting Cities Dump More Raw Sewage Into Rivers for Years to Come." *New York Times*, 24 Jan. 2020.

251. Flavelle, Christopher, Rick Rojas, Jim Tankersley, and Jack Healy. "Mississippi Crisi Highlights Climate Threat to Drinking Water Nationwide." *New York Times.* 1 Sept. 2022, updated 4 Sept. 2022.

252. Florida Department of Health. "Harmful Algae Blooms—Economic Impacts."

253. Flower, David. "How Machine Learning and Edge Computing Power Sustainability." *Forbes Innovation.* 18 March 18, 2022.

254. Folsom, T. "Improved Bus Service on TenTimes Less Energy." 5th EAI International Conference on Intelligent Transport Systems (Lisbon, Portugal). Nov. 2021.

255. Fondazione Ermanno Casoli (website).

256. Food Cycle Science Corporation. "A Complete Overview of the Food Waste Crisis in Southeast Asia."

257. Food Forward NDCs. "Reducing Emissions from Rice Cultivation."

258. Food Shift. "Our Approach."

259. FoodPrint. "Food and the Environment." Project of GRACE Communications Foundation.

260. Foote, Natasha. "How to Plant, Grow, and Care for Almond Trees." *Gardener's Path,* 25 March 2023.

261. Forzieri, Giovanni, Vasilis Dakos, Nate G. McDowell, Alkama Ramdane, and Alessandro Cescatti. Emerging Signals of Declining Forest Resilience under Climate Change." *Nature* 608 (July 2022).

262. Fountain, Henry. "Deforestation Remains High, Despite International Pledges." *New York Times*, 28 Apr. 2022.

263. Fountain, Henry. "Tropical Forest Destruction Accelerated in 2020." *New York Times,* 31 Mar. 2021. Updated 2 Nov. 2021."

264. Frank, Adam, David Grinspoon, and Sara Walker. "Intelligence as a Planetary Scale Process." *Cambridge University Press* 21, no. 2 (Feb. 2022).

265. Friedman, Thomas. "Our Promethean Moment." *New York Times*, Opinion, 21 Mar. 2023.

266. Fugro. "Ocean Science Initiatives."

267. Gai, Yijun et al. "Health and Climate Benefits of Electric Vehicle Deployment in the Greater Toronto and Hamilton Area." *Environmental Pollution* 265, pt. A (2020).

268. Gardels, Nathan. "Planetary Homeostasis." *NOEMA,* 22 July 2022.

269. Gathering for Open Science Hardware (GOSH). "GOSH Manifesto." 2016.

270. Gawel, Antonia. "4 Key Steps Towards a Circular Economy." World Economic Forum, 14 Feb. 2019.

271. Gedamke, J., J. Harrison, and L. Hatch. "Ocean Noise Strategy Roadmap." NOAA, 2021.

272. Gelt, Joe. "Home Use of Greywater, Rainwater Conserves Water—and May Save Money." Tucson, AZ: University of Arizona Water Resource Research Center, 1993.

273. Gensler, Gary. "Statement on Proposed Mandatory Climate Risk Disclosures." U.S. Securities and Exchange Commission (SEC). 21 Mar. 2022.

274. Gergel, Igor. "Waste to Energy Technologies: Overview." Waste To Energy International, 19 May 2021.

275. German Zero. "Creating a Better Climate."

276. Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati, "A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." Journal of Cleaner Production 114 (2016): 11–32.

277. Giddens, Anthony. The Constitution of Society: Outline of the Theory of Structuration. Cambridge, MA: Polity Press, 1984.

278. Gidigbi Jenkins, Stephanie, Rob Moore, Becky Hammer, Erik D. Olson, Luke Tonachel, Khalil Shahyd, Douglass Sims et al. "Invest in 21st Century Infrastructure." NRDC.

279. Gilligan, Carol. "In a Different Voice: Women's Conceptions of Self and of Morality." *Harvard Educational Review* 47, no. 4 (Nov. 1977): 481–517.

280. Gladwell, Malcolm. The Tipping Point: How Little Things Can Make a Big Difference. New York: Little, Brown, 2000.

281. Global Accounting Alliance. A Call to Action in Response to the Nature Crisis.

282. Global Dialogue on Seafood Traceability (website).

283. Global Ocean Acidification Observing Network (GOA-ON) (website).

284. Global Oneness Project. *Sawubona*. YouTube video. 8 Feb. 2007.

285. Global Plastic Action Partnership (GPAP) (website).

286. Global Reporting Initiative (GRI) (website).

287. Going Green. What is the Most Sustainable City in the World? YouTube video.

288. Gold, Zachary, Joshua Sprague, David Kushner, Erick Zerecero Marin, and Paul Barber. "eDNA Metabarcoding s a Biomonitoring Tool for Marine Protected Areas." *PLoS ONE* 16, no. 2 (Feb. 2021).

289. Goldfarb, Ben. *Eager: The Surprising, Secret Life of Beavers and Why They Matter.* White River Junction, VT and London, UK: Chelsea Green Publishing, 2018.

290. Goodchild, Melanie. *Gichi Gaakinoo'imaatiwin (Original Ways of Knowing)*. Vimeo video. Updated 2021.

291. Goodchild, Melanie. "Relational Systems Thinking: The Dibaajimowin (Story) of Re-Theorizing 'Systems Thinking' and 'Complexity Science'." *Journal of Awareness-Based Systems Change* 2, no. 1 (2022).

292. Goodwin, Liz. "The Global Benefits of Reducing Food Loss and Waste." World Resources Institute, 20 Apr. 2023.

293. Google. "Artists and Machine Intelligence (AMI)."

294. Gøtzsche Lange, I., and C. Neysa Rodriquez. "Urban Green Spaces: Combining Goals for Sustainability and Placemaking." *Europe Now,* 11 May 2021.

295. Government of Canada. *Hydrogen Strategy for Canada: Seizing the Opportunities for Hydrogen, A Call to Action.* Natural Resources Canada, Dec. 2020.

296. Government of Canada. "RETScreen Clean Energy Management Software." Natural Resources Canada; Maps, Tools, and Publications; Tools; Data Analysis Software Modelling Tools.

297. Government of India, Indian Culture. *Pashupati Seal*. Indus Valley Civilization 2500 BCE. 3.53 x 3.53 x 0.64 cm. National Museum Delhi.

298. Gray, Brian, Jennifer Harder, and Karrigan Bork. "Implementing Ecosystem-Based Management." *Duke Environmental Law & Policy Forum* 31 (2021).

299. Gray, Erin, and Charlie Bloch. "INSIDER: Systems Mapping—A Vital Ingredient for Successful Partnerships." World Resources Institute, Technical Perspective, Finance, 17 Aug. 2020.

300. Gregor, Howard F. "The Plantation in California." *The Professional Geographer* 14, no. 2 (Mar. 1962).

301. Green, Nancy L., Michael Branon, and Luke Roosje. "Argument Schemes and Visualization Software for Critical Thinking about International Politics." *Argument and Computation* 10, no. 10 (2018): 1–13.

302. Green America. "Climate Victory Gardens."

303. Green Marine. "Certification, Results." Accessed 12 Mar. 2023.

304. Green Marine. *Green Marine Environmental Program: Performance Indicators For Ship Owners 2022*. Green Marine Management Corporation, 2022.

305. Green Swans Book Club. *Regeneration by Paul Hawken*. Volans YouTube video. 9 Nov 2022.

306. Greenhouse Gas (GHG) Protocol (website).

307. Greer, Rachel, Timo von Wirth, and Derk Loorbach. "The Waste-Resource Paradox: Practical Dilemmas and Societal Implications in the Transition to a Circular Economy." *Journal of Cleaner Production* 303 (2021).

308. Gregor, Howard F. "The Plantation in California." *The Professional Geographer* 14, no. 2 (Mar. 1962).

309. Griffin, Paul. The Carbon Majors Database: CDP Carbon Majors Report 2017. CDP Report. July 2017

310. Groffman, Peter M., J. Morgan Grove, Colin Polsky, Neil D. Bettez, Jennifer L. Morse, Jeannine Cavender-Bares, Sharon J Hall et al. "Satisfaction, Water and Fertilizer Use in the American Residential Macrosystem." *Environmental Research Let*ters 11, no. 3 (Feb. 2016).

311. Groh, Elke D., and Charlotte v. Möllendorff. "What Shapes the Support of Renewable Energy Expansion? Public Attitudes between Policy Goals and Risk, Time, and Social Preferences." Energy Policy 137 (2020).

312. Grosspietsch, David, Marissa Saenger, and Bastien Girod, "Matching Decentralized Energy Production and Local Consumption: A Review of Renewable Energy Systems with Conversion and Storage Technologies." *WIREs Energy and Environment* 8, no. 4 (9 Jan. 2019).

313. Guest Blogger for the Internationalist. "Navigating Rough Waters: The Limitations of International Watercourse Governance." *The Internationalist* and *International Institutions and Global Governance Program* (blog), *Council on Foreign Relations*, 2 Sept. 2020.

314. Guha, Nabarun. "Gangetic River Dolphins in Assam Decline in the Wake of Anthropogenic Pressures." Mongabay, 24 Aug. 2022.

315. Gunathilake, Miyuru, Yasasna Amaratunga, Anushka Perea, Chamaka Karunanayake, Anura Gunathilake, and Upaka Rathnayake. "Statistical Evaluation and Hydrologic Simulation Capacity of Different Satellite-Based Precipitation Products (SbPPs) in the Upper Nan River Basin, Northern Thailand." *Journal of Hydrology: Regional Studies* 32 (Dec. 2020).

316. Guo, D. "Indigenous Artists Use Technology to Tell Stories About Their Ancestral Lands." *Yes Magazine*, 15 June 2020.

317. Guo, Joy. "How Can Blockchain Open Access to Carbon Markets?" World Economic Forum, 28 July 2022.

318. Habitat for Humanity. "Housing and Climate Change: Habitat for Humanity International's Position."

319. Hagens, Nate. *The Great Simplification: Film on Energy, Environment, and Our Future.* YouTube video, 19 May 2022.

320. Hall, Stephen. "Can Crops Grow Better Under Solar Panels? Here's All You Need to Know About 'Agrivoltaic Farming." World Economic Forum, Industries in Depth, 26 July 2022.

321. Hanan, Niall P., and Julius Y. Anchang. "Satellites Could Soon Map Every Tree on Earth." *Nature* 587 (2020).

322. Hansen, J. P., P. A. Narbel, and D. L. Aksnes. "Limits to Growth in the Renewable Energy Sector." *Renewable and Sustainable Energy Reviews* 70 (2017).

323. Harayama, Yuko. "Society 5.0: Aiming for a New Human-Centered Society: Japan's Science and Technology Policies for Addressing Global Social Challenges," *Hitachi Review* 66, no. 6 (2017): 558–559.

324. Harrison, George. "Ravi Shankar's Chants of India: Mangalam." YouTube video. 1997.

325. Haver Currin, Grayson. "The Poignant Music of Melting Ice: Have a Listen." *New York Times,* 16 Mar. 2023.

326. Hawken, Paul. *Regeneration: Ending the Climate Crisis in One Generation*. New York: Penguin Books, 2021.

327. Hayes, Michael N., and Alan L. Olmstead. "Farm Size and Community Quality: Arvin and Dinuba Revisited." *American Journal of Agricultural Economics* 66, no. 4 (Nov. 1984): 430–436.

328. Heaven, Will Douglas. "DeepMind's Game-Playing AI Just Beat 50-Year-Old Record in Computer Science." *MIT Technology Review, 5* Oct. 2022.

329. Heggie, Jon. "Why is America Running Out of Water?" *National Geographic Science*, 12 Aug. 2020.

330. Heid, Bernd, Martin Linder, and Mark Patel. "Delivering the Climate Technologies Needed for Net Zero." McKinsey Sustainability. 18 Apr. 2022.

331. Held, Virginia. *The Ethics of Care: Personal, Political, and Global.* New York: Oxford University Press, 2006.

332. Henfrey, Thomas. "Designing for Resilience: Permaculture as a Transdisciplinary Methodology in Applied Resilience Research." *Ecology & Society* 23, no. 2 (2018).

333. Hentsch, Rachel. "SDG Leadership Labs: Supporting UN Country Teams to Achieve Agenda 2030." *Medium, Field of the Future* (blog), 10 Dec. 2021.

334. Herrera, Tilde. "How 'Buy Nothing' Facebook Groups Are Emerging as Sites for Mutual Aid." Eater, 1 July 2022.

335. Hhmelevtsova, Ludmila Eugenevna, Ivan Sergeevich Sazykin, Tatiana Nikolaevna Azhogina, and Marina Alexandrovna Sazykina. "Influence of Agricultural Practices on Bacterial Community of Cultivated Soils." *Agriculture* 12, no. 3 (Mar. 2022): 371.

336. Hickel, Jason, and Aljosa Slamersak. "Existing Climate Mitigation Scenarios Perpetuate Colonial Inequalities." *The Lancet Planetary Health* 6, no. 7 (July 2022): e628–e631.

337. Hickel, Jason, Sam Fankhauser, and Kate Raworth. "How to Save the Planet: Degrowth vs Green Growth?" The Smith School, School of Geography and the Environment. Video recording. 2 Sept. 2022.

338. High Ambition Coalition for Nature and People (website).

339. Higman, P. J., H. D. Enander, D. A. Hyde, P. J. Badra, and K. M. Korroch. *Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands.* Michigan Natural Features Inventory, Michigan State University, *MNFI Report Number 2019-19*, 2019.

340. Hill, Rosemary, Chrissy Grant, Melissa George, Catherine J. Robinson, Sue Jackson, and Nick Abel. "A Typology of Indigenous Engagement in Australian Environmental Management: Implications for Knowledge Integration and Social-Ecological System Sustainability." *Ecology and Society* 17, no. 1 (2020).

341. Hilimire, Kathleen, Sean Gillon, Blair C. McLaughlin, Brian Dowd-Uribe, and Kate L. Monsen. "Education Programs." *Agroecology and Sustainable Food Systems* 38, no. 6 (19 May 2014): 722–743.

342. Hong Vo, Duc, Anh The Vo, Chi Minh Ho, and Ha Minh Nguyen. "The Role of Renewable Energy, Alternative and Nuclear Energy in Mitigating Carbon Emissions in the CPTPP Countries." *Renewable Energy* 161 (2020).

343. Horn-Muller, Ayurella. "This Destructive Fishing Style Doesn't Just Harm Marine Life." *National Geographic*, 18 Jan. 2024.

344. Hougaard, Rasmus, and Jacqueline Carter. "Ego is the Enemy of the Good." *Harvard Business Review*, 6 Nov. 2018.

345. Hough, Emily, and Nathaniel Counts. "How Climate Change Affects Our Mental Health, and What We Can Do About It." The Commonwealth Fund, Explainer. 29 Mar. 2023.

346. HUB Ocean (website).

347. HUB Ocean. "Data Catalog."

348. Hug, Laura, Brett J. Baker, Karthik Anantharaman, Christopher T. Brown, Alexander J. Probst, Cindy J. Castelle, Cristina N. Butterfield et al. "A New View of the Tree of Life." *Nature Microbiology* 1, no. 16048 (Apr. 2016).

349. Hughes, Neal. "Water Markets Are Not Perfect, But Vital to the Future of the Murray-Darling Basin." *The Conversation,* Mar. 2021.

350. Hussain, Iftikar, Haiyan Wang, Muhammad Safdar, Quoc Bang Ho, Tina D. Wemegah, and Saima Noor. "Estimation of Shipping Emissions in Developing Country: A Case Study of Mohammad Bin Qasim Port, Pakistan." *International Journal of Environmental Research and Public Health* 19, no. 19 (Sept. 2022).

351. Hussein, R. M. R. "Sustainable Urban Waterfronts Using Sustainable Assessment Rating System." World Academy of Science, Engineering and Technology. *International Journal of Architectural and Environmental Engineering* 8, no. 4 (2014).

352. Ideal. "AI for Recruiting: A Definitive Guide for HR Professionals."

353. IEA. *Data Centres and Data Transmission Networks*. Paris: IEA, Sept. 2022.

354. IEA. "Infrastructure and Jobs Act: Nationwide Network of EV Chargers." 10 July 2024.

355. IEA. "Kenya." IEA 50, Countries & Regions, Africa.

356. IEA. "Net Zero Roadmap: A Global Pathway to Keep the 1,5 C Goal in Reach." New Zero Emissions. 2023 Update.

357. IEA. *World Energy Outlook 2022*. Paris: IEA, 2022.

358. IEEE. "IEEE Code of Ethics," adopted by the IEEE Board of Directors, 2020, accessed Feb. 2023.

359. IEEE. "The Role of Community Networks in Advancing Universal Access to the Internet." IEEE Position Statement, 2021.

360. IEEE. "Special Report: Water vs. Energy." *IEEE Spectrum*. 28 May 2010.

361. IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems. "Well-being." In Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems. 1st ed. IEEE, 2019.

362. IEEE Standards Association (IEEE SA) "Green Hydrogen." Industry Connections Activities.

363. IEEE Standards Association. *IEEE P2890, Draft Recommended Practice for Provenance of Indigenous Peoples' Data*.

364. IEEE Standards Association (IEEE SA). *IEEE P3469, Draft Standard for an Environmental Liability Process Model for Accounting in Systems Engineering*.

365. IEEE Standards Association (IEEE SA). IEEE P7000/D7, Draft Model Process for Addressing Ethical Concerns During System Design. (20 April 2021).

366. IEEE Standards Association (IEEE SA). *IEEE 7001-2021, IEEE Standard for Transparency of Autonomous Systems.* 2021.

367. IEEE Standards Association (IEEE SA). *IEEE 7010-2020, IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being*.

368. IEEE Standards Association (IEEE SA). *IEEE 7800, IEEE Recommended Practice for Addressing Sustainability, Environmental Stewardship and Climate Change Challenges in Professional Practice*.IEEE Standards Association, Industry Connections. The Sustainable Infrastructures and Community Development Industry Connections Program (website). IEEE Standards Association Planet Positive 20230 (website).

369. IEEE-USA Board of Directors. *Commercial Nuclear Energy and Technology Leadership*. IEEE-USA Position Statement, 24 June 2022.

370. Illuminem (website).

371. Incubation Network (website).

372. Indakwa, Edward, and Elizabeth Wamba. "Voices for Wetlands and Water: Case Studies on Water Resources Management and WASH in Kenya." Wetlands Organization, 2021.

373. Independent Electricity System Operator (IESO). "What's Phantom Power and How Can You Track It?" Save on Energy: Power What's Next.

374. Indigenous Corporate Training (website), accessed 16 Aug. 2022.

375. Infed (website).

376. Institute for Regenerative Design and Innovation (website).

377. Institute of Integrated Regenerative Design (website).

378. International Auditing and Assurance Standards Board (IAASB). https://www.iaasb.org/

379. International Carbon Action Partnership (website).

380. International Coral Reef Initiative. "Coral Reef Restoration Guidelines."

381. International Ethics Standards Board for Accountants (IESBA). https://www.ethicsboard.org/

382. International Federation of Accountants (IFAC). https://www.ifac.org

383. International Labour Organization. "50 Million People Worldwide in Modern Slavery."Press release. 12 Sept. 2022.

384. International Solid Waste Association (ISWA) (website).

385. International Sustainability Standards Board (ISSB) (website).

386. International Trade Centre. "Sustainability Map."

387. The Internet Society. "Connecting the Unconnected."

388. Into the Outdoors. *A Water Pollution Solution—A Case Study in Success*. YouTube video. Aug. 2021.

389. IPBES. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, C. N. Zayas, eds. Bonn, Germany: IPBES Secretariat, 25 Nov. 2019.

390. IPCC. "AR6 Synthesis Report." In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva, Switzerland: IPCC, 2023: 35-115.

391. IPCC. "Climate Change: A Threat to Human Wellbeing and Health of the Planet. Taking Action Now Can Secure Our Future." Press release no. 2022/08/PR. 28 Feb. 2022.

392. IPCC. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds. Cambridge and New York: Cambridge University Press, 2021.

393. IPCC. *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H. -O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, eds. In press. 2019.

394. IPCC. "Summary for Policymakers." In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer, eds. Cambridge and New York: Cambridge University Press, 2019.

395. IPCC. "Summary for Policymakers." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate*

Change. V. Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds. Cambridge and New York: Cambridge University Press, 2021.

396. IPCC, Links (website).

397. ITC Sustainability Map (website).

398. IUCN (International Union for Conservation of Nature) (website).

399. Jacobs, Jane. *The Death and Life of Great American Cities*. New York: Random House, 1961.

400. Jacobson, Mark Z., Anna-Katharina von Krauland, Stephen J. Coughlin, Emily Dukas, Alexander J. H. Nelson, Frances C. Palmer, and Kylie R. Rasmussen. "Low-Cost Solutions to Global Warming, Air Pollution, and Energy Insecurity for 145 Countries." *Energy & Environmental Science* 15, no. 3343 (2022).

401. Jameel, Y., C. M. Patrone, K. P. Patterson, and P. C West. Climate–Poverty Connections: Opportunities for Synergistic Solutions at the Intersection of Planetary and Human Well-Being. Project Drawdown. 2022.

402. James, Barry. "Overuse Leading to Food Shortages, Study Warns: Less Water, and Less to Eat. *New York Times*, 18 Oct. 2002.

403. Janjua, N. K., O. K. Hussain, F. K. Hussain, and E. Chang. "Philosophical and Logic-Based Argumentation-Driven Reasoning Approaches and their Realization on the WWW: A Survey." *The Computer Journal* 58, no. 9 (2014).

404. Jaumotte, Florence, Myrto Oikonomou, Carlo Pizzinelli, and Marina M. Tavares. "How Pandemic Accelerated Digital Transformation in Advanced Economies." *IMF Blog,* 21 March 2023.

405. Jensen, David. "How Can You Support the Launch of the CODES Action Plan on 2 June at Stockholm +50." SparkBlue, 21 May 2022.

406. John Sabraw (website).

407. Johnson, Ashanti, and Melanie Harrison. "The Increasing Problem of Nutrient Runoff on the Coast." *American Scientist* 103, no. 2 (March–April 2015): 98.

408. Johnson, Emma. "All Aboard for Nature: Improving Outdoor Access Through Public Transportation." EESI (Environmental and Energy Study Institute), 29 July 2021.

409. Johnston, Whitney. "Salesforce Unveils New Policy Priorities to Protect the Ocean." Salesforce, 8 June 2022.

410. Joly, Josephine, and Luke Hurst. "Four-Day Week: Which Countries Have Embraced It and How's It Going So Far?" EuroNews, updated 23 Feb. 2023.

411. Kadenze. "Machine Learning for Musicians and Artists." Goldsmiths University of London online course.

412. Kadwa, Farheen. "How Canada's Shipping Industry Can Reduce its Climate Change Impacts." WWF-Canada, 24 Nov. 2021.

413. Kaiser, Matthias, and Peter Gluckman. "Looking at the Future of Transdisciplinary Research." *Center for Science Futures*, 2023.

414. Kalnina, Renate, Ieva Demjanenko, Kristaps Smilgainis, Kristaps Lukins, Arnis Bankovics, and Reinis Drunka. "Microplastics in Ship Sewage and Solutions to Limit Their Spread: A Case Study." *Water* 14, no. 22 (Nov. 2022): 3701.

415. Kalogeropoulos, Dimitrios, and Paul Barach. "The Role of Telehealth in Enabling Sustainable Innovation and Circular Economies in Health." *Telehealth and Medicine Today 8, no 1* (2023).

416. Kamiya, G. et al. *Energy Storage.* IEA Technical Report.

417. Kampa,Eleftheria, Gerardo Anzaldúa, Sindre Langaas, and Peter Kristensen. *Rivers and Lakes in European Cities*. EEA Report, no. 26/2016. Copenhagen, Denmark: European Environment Agency, 2016.

418. Kaplan, Robert S., and Karthik Ramanna. "Accounting for Climate Change: The First Rigorous Approach to ESG Reporting." *Harvard Business Review*, Nov–Dec. 2021.

419. Karlamangla, Soumya. "Here's Where California Really Uses Its Water." *New York Times*, 10 Dec. 2021.

420. Kauppi, Pekka, and Roger Sedjo. "Technological and Economic Potential of Options to Enhance, Maintain, and Manage Biological Carbon Reservoirs and Geo-engineering." In *TAR Climate Change 2001: Mitigation*. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, 2018.

421. Kavi, Lucy et al. "Environmental Justice and the Food Environment in Prince George's County, Maryland: Assessment of Three Communities." *Frontiers in Built Environments* (18 Oct. 2019).

422. Kempener, Rudd, and Frank Neumann. "Salinity Gradient Energy: Technology Brief." *IRENA Ocean Energy Technology Brief* 2 (June 2014).

423. Khush Das, Subhajit. "Instagram Reel." 4 July 2021.

424. Kim, Milena Kiatkoski, Michael M. Douglas, David Pannell, Samantha A. Setterfield, Rosemary Hill, Sarah Laborde, Laura Perrott, Jorge G. Álvarez-Romero et al. "When to Use Transdisciplinary Approaches for Environmental Research." *Frontiers in Environmental Science* 10 (9 May 2022).

425. Kirkpatrick, Barbara, Richard Pierce, Yung Sung Cheng, Michael S. Henry, Patricia Blum, Shannon Osborn, Katie Nierenberg et al. "Inland Transport of Aerosolized Florida Red Tide Toxins." *Harmful Algae* 9, no. 2 (Feb. 2010).

426. Kirstein, Lucie, Ronald Halim, and Olaf Merk. *Decarbonising Maritime Transport: Pathways to Zero-Carbon Shipping by 2035*. Paris: The International Transport Forum, 2018.

427. Klesse, Stefan, Meinrad Abegg, Sven E. Hopf, Martin M. Gossner, Andreas Rigling, and Valentin Queloz. "Spread and Severity of Ash Dieback in Switzerland–Tree Characteristics and Landscape Features Explain Varying Mortality Probability." *Frontiers in Forests and Global Change* 4 (Mar. 2021).

428. Komor, Paul, and Morgan Bazilian. "Renewable Energy Policy Goals, Programs, and Technologies." *Energy Policy* 33, no. 14 (2005).

429. Kotrikla, Anna Maria, Alexandros Zavantias, and Maria Kaloupi. "Waste Generation and Management Onboard a Cruise Ship: A Case Study." *Ocean & Coastal Management* 212 (Oct. 2021).

430. Krey, V., O. Masera, G. Blanford, T. Bruckner, R. Cooke, K. Fisher-Vanden, H. Haberl et al. "Annex II: Metrics & Methodology." In C*limate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*,

edited by O. R. Edenhofer, Y. Pichs-Madruga, E. Sokona, S. Farahani, K. Kadner, A. Seyboth, I. Adler et al. Cambridge and New York: Cambridge University Press, 2014.

431. Krishnan, Mekala, Hamid Samandari, Jonathan Woetzel, Sven Smit, Daniel Pacthod, Dickon Pinner, Tomas Nauclér, Humayun Tai, Annabel Farr, Weige Wu, Danielle Imperato. *The Net Zero Transition: What It Would Cost, What It Could Bring.* McKinsey Global Institute, Jan. 2020.

432. Krockow, Eva M. "What's Your Locus of Control—And Why Does It Matter?" *Psychology Today*, 24 April 2024.

433. Kruzman, Diana. "Cities Are Investing Billions in New Sewage Systems. They're Already Obsolete." *Grist,* 8 Mar. 2022.

434. Kuban, Adam. "Transdisciplinary Collaboration: An Introduction." National Association of Geoscience Teachers.

435. Kumar, Pushpam. "This Index Measures Progress and Sustainability Better Than GDP." Columbia Climate School, Climate, Earth, and Society, *State of the Planet,* 9 Oct. 2018.

436. Kuznets, S. "How To Judge Quality." *The New Republic*, 20 October 1962.

437. Kwa, Aileen. *Agriculture in Developing Countries: Which Way Forward?* Trade-Related Agenda, Development and Equity (T.R.A.D.E). Occasional Papers 4, June 2021.

438. Lai, Charmaine, Subutai Ahmad, Donna Dubinsky, and Christy Maver. "AI Is Harming Our Planet: Addressing AI's Staggering Energy Cost." *Numenta* (blog), 24 May 2022.

439. Lake George Association. "Invasive Species are Challenging our Water Quality and Landscape."

440. Lakhani, N. L., A. Uteuova, and A. Chang. "The Illusion of Choice: Five Stats that Expose America's Food Monopoly Crisis." *The Guardian*, 18 July 2021.

441. Lange, Steffen, and Tilman Santarius. "Digital Reset: Redirecting Technologies for the Deep Sustainability Transformation." D4S Digitalization for Sustainability, 2023.

442. Lassaletta, Luis, Gilles Billen, Bruna Grizzetti, Juliette Anglade, and Josette Garnier. "50 Year Trends in Nitrogen Use Efficiency of World Cropping Systems: The Relationship between Yield and Nitrogen Input to Cropland." *Environmental Research Lett*ers 9, no. 10 (Oct. 2014).

443. Lazard, Olivia. *The Blind Spots of the Green Energy Transition.* TED Talks, TED Countdown New York Session 2022.

444. Le Page, Michael. "Trees Are Dying at Increasing Rates in Forests Across Europe." *New Scientist*, 15 Nov. 2021.

445. Lee, Andrew Chee Keng, Hannah C. Jordan, and Jason Horsely. "Value of Urban Green Spaces in Promoting Healthy Living and Wellbeing: Prospects for Planning." *Risk Management and Healthcare Policy* 8 (Aug. 2015).

446. Leitch, Carmen. "How Microbes Can Help Clean a Toxic River." LabRoots, 23 Aug. 2020.

447. Lennon, Michael, Marisa Zalabak, and Lubja Dajani. "Activating Collective Intelligence to Engineer Transdisciplinary Impacts." *2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (Oct. 2020): 2762–2769.

448. Lent, Jeremy. "Something Far More Deeply Interfused." In *That Patterning Instinct.*" Prometheus, 2017.

449. Lenton, Tim, and Bruno Latour. "Gaia 2.0: Could Humans Add Some Level of Self-Awareness to Earth's Self-Regulation?," *Science* 361, no. 6407 (14 Sept. 2018): 1066–1068.

450. Leporini, Mariella, Barbara Marchetti, Francesco Corvaro, and Fabio Polonara. "Reconversion of Offshore Oil and Gas Platforms into Renewable Energy Sites Production: Assessment of Different Scenarios." *Renewable Energy* 135 (May 2019).

451. Levidow, Les, and Sujatha Raman. "Sociotechnical Imaginaries of Low-Carbon Waste-Energy Futures: UK Techno-Market Fixes Displacing Public Accountability." *Social Studies of Science* 50, no. 4 (Feb. 2020).

452. Lewis, Barnaby. "How Smart Farming Is Changing the Future of Food." ISO News, 15 June 2022.

453. Liew, Robert. "Can Wind Power Become Truly Carbon Neutral?" Wood MacKenzie, 8 July 2021.

454. Lin, Janice. *Beyond Power: Opportunities and Challenges for Green Hydrogen.* Green Hydrogen Coalition, June 2020.

455. Lindsey, Rebecca. "Climate Change: Global Sea Level." NOAA, Climate.gov. 19 Apr. 2022.

456. Lindwall, Courtney. "Industrial Agriculture Pollution 101." NRDC. Updated 21 July 2022.

457. Lindwall, Courtney. "Rich, Polluting Nations Still Owe the Developing World." NRDC Explainer, 22 Jan. 2022.

458. Lipták, Béla. "Hydrogen Is Key to Sustainable Green Energy." Control, 24 Jan. 2022.

459. Liu, Chenfei et. al. "A Review of Building Energy Retrofit Measures, Passive Design Strategies and Building Regulation for the Low Carbon Development of Existing Dwellings in the Hot Summer–Cold Winter Region of China." *Energies,* 2023, 16(10), 4115.

460. Living Seawalls (website).

461. Lloyd's Register. "Zero-Carbon Fuel Monitor: Findings." Maritime Decarbonisation Hub.

462. London Hydro. "Green Button Platform."

463. Loomis, Brandon. "Phoenix Names a Heat Officer, with a Goal of Easing the Risk of Rising Temperatures." *Arizona Republic*, 7 Oct. 2021.

464. The Los Angeles Times Editorial Board. "Finally, a Bus-Lane Building Boom in Los Angeles." *Los Angeles Times,* 219 Oct. 2023.

465. Lovgren, Stefan. "Rivers and Lakes are the Most Degraded Ecosystems in the World." *National Geographic Environment*, 1 Mar. 2021.

466. Löw, Fabian, Klaus Stieglitz, and Olga Diemar. "Terrestrial Oil Spill Mapping Using Satellite Earth Observation and Machine Learning: A Case Study in South Sudan." *Journal of Environmental Management* 298 (Nov. 2021).

467. Lowder, Sarah K., Marco V. Sánchez, and Raffaele Bertini. "Which Farms Feed the World and Has Farmland Become More Concentrated?" *World Development* 142 (June 2021).

468. Lubell, Sam. "7 Cities Transforming their Rivers From Blights to Beauties**."** *Wired*, 4 Aug. 2016.

469. Luiken, Maike, and Alpesh Shah. *Policy Brief: Scaling Climate Goals Through the Use of Technical Experts and Digital Technical Knowledge Commons.* T7 Task Force Climate and Environment. Think7, 22 Apr. 2022.

470. Luscher, D. "Introducing the 15-Minute City Project." 16 June 2021.

471. Macdonald Fueyo, Judith. "Technical Literacy versus Critical Literacy in Adult Basic Education." *Journal of Education*170, no. 1 (Jan. 1988).

472. Maersk. Sustainability at Maersk, Our ESG Priorities. "Responsible Ship Recycling."

473. Mainspring Media. "Rise: From One Island To Another." Vimeo video. 2018.

474. Malinowski, Matt, Max Dupuy, David Farnsworth, and Dara Torre. *Combating High Fuel Prices with Hybrid Heating: The Case for Swapping Air Conditioners for Heat Pumps.* CLASP (Cooperative Labeling and Appliance Standards Program), 2022.

475. Malmodin, Jens, Nina Lövehagen, Pernilla Bergmark, and Dag Lundén. *ICT Sector Electricity Consumption and Greenhouse Gas Emissions—2020 Outcome*. 20 April 2023.

476. "A Man From Peru Has Found an Ingenious Way to Clean Lakes, and It's a Breakthrough the Earth Was Crying For." Bright Side, 30 March 2019.

477. Mann, Paul. "Can Bringing Back Mammoths Help Stop Climate Change?" *Smithsonian Magazine*, 14 May 2018.

478. Marchant, Natalie. "Thinking Like Leonardo da Vinci Will Help Children Tackle Climate Change." World Economic Forum, Emerging Technologies, 2021.

479. MarineBio. "Marine Conservation."

480. Marine Stewardship Council (MSC). *Get Certified: Your Guide to MSC and ASC Chain of Custody Certification Process.* 2019.

481. Marohn, Kirsti. "Wet Spring, Warm Temps in Minnesota Could Spur Toxic Algae Blooms." *MPR News*, 18 June 2022.

482. Masood, Ehsan. "More Than Dollars: Mega-Review Finds 50 Ways to Value Nature." *Nature, 15* July 2022.

483. Mâsse, Louise C., Richard P. Moser, Daniel Stokols, Brandie K. Taylor, Stephen E. Marcus, Glen D. Morgan, Kara L. Hall, Robert T. Croyle, and William M. Trochim. "Measuring Collaboration and Transdisciplinary Integration in Team Science." *American Journal of Preventive Medicine* 35, no. 2S (Aug. 2008).

484. Masterson, Victoria. "What to Do with Ageing Oil and Gas Platforms—And Why It Matters." World Economic Forum, Energy Transition, 2 Apr. 2024.

485. Masterton, Victoria, and Ian Shine. "What is the Circular Economy?" World Economic Forum, Circular Economy, 14 June 2022, updated 10 Mar. 2023.

486. Matson, John, and Chris Potter. "Clean Energy 101: Heat Pumps." RMI (Rocky Mountain Institute), Buildings, July 2022.

487. Maxwell, Sean L., Richard A. Fuller, Thomas M. Brooks, and James E. Watson. "Biodiversity: The Ravages of Guns, Nets and Bulldozers." *Nature* 536, no. 7615 (2016).

488. Mayor of London/London Assembly. "Our Fight Against Climate Change." Programmes and Strategies, Environment and Climate Change.

489. Mays, Chris, Vivi Vajda, and Stephen McLoughlin. "Toxic Slime Contributed to Earth's Worst Mass Extinction—And It's Making a Comeback." *Scientific American*, 1 July 2022.

490. Mazzucato, Mariana. The Entrepreneurial State: Debunking Public vs. Private Sector Myths. New York: Public Affairs, 2015.

491. Mazzucato, Mariana. *Mission-Oriented Research & Innovation in the European Union: A Problem-Solving Approach to Fuel Innovation-Led Growth*. European Commission Directorate-General for Research and Innovation Publications Office, 2018.

492. McBride, B. B., C. A. Brewer, A. R. Berkowitz, and W. T. Borrie. "Environmental Literacy, Ecological Literacy, Ecoliteracy: What Do We Mean and How Did We Get Here?" E*cological Society of America (ESA) Journal*, 31 May 2013.

493. McLelland, David, John W. Atkinson, Russell A. Clark, and Edgar L. Lowell. *The Achievement Motive*. New York: Appleton-Century-Crofts, 1953.

494. McDonough, William. "William McDonough Articulates Circular Carbon Economy Framework for the G20." William McDonough website. 30 Mar. 2021.

495. McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point Press, 2002.

496. McNiff, S. "Philosophical and Practical Foundations of Artistic Inquiry: Creating Paradigms, Methods, and Presentations Based in Art." In *Handbook of Arts-Based Research*, edited by P. Leavy. New York: Guilford, 2017.

497. McPhee, Chris, Martin Bliemel, and Mieke van der Bijl-Brouwer. "Editorial: Transdisciplinary Innovation (August 2018)." *Technology Innovation Management (TIM) Review 8,* no. 8 (Aug. 2018): 3–6.

498. MDPI *Sustainability.* "Sustainable Education and Approaches."

499. Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens. *The Limits to Growth*. A Potomac Associates Book. New York: Universe Books, 1972.

500. Meininger, Kathleen. "Community Noise Lab Studies Urban Pollution, Environmental Injustice." *The Brown Daily Herald*, 25 Feb. 2022.

501. Mel Chin (website).

502. Melanie Goodchild (website).

503. Meli, Paula, José María Rey Benayas, Patricia Balvanera, and Miguel Martínez Ramos. "Restoration Enhances Wetland Biodiversity and Ecosystem Service Supply, but Results Are Context-Dependent: A Meta-Analysis." PLoS ONE 9, no. 4 (Apr. 2014).

504. Mendell, Russell, Mathias Einberger, and Katie Siegner. "FERC Could Slash Inflation and Double Renewables with These Grid Upgrades." RMI (Rocky Mountain Institute), Electricity, 7 July 2022.

505. Mercado, Luz. "The Role of Community Gardens During the COVID-19 Pandemic." Columbia University Mailman School of Public Health News, 25 Feb. 2021.

506. Meredith, Sam and Lucy Handley. "'It Is Entirely Doable, and It Is Doable Fast': Experts on How to Navigate the Energy Transition." *CNBC*, 22 Nov. 2021.

507. Merl, Christina. "Human Intelligence Cultivation with the 2CG® Poetry Machine." *International Journal of Advanced Corporate Learning* 15, no. 1 (2022).

508. Merl, Christina. "Putting the Periphery in the Picture: How Effective Learning Design Leverages the Power of Polyphonic Storytelling to Push Future Skills Development." In *Creative Approaches to Technology-Enhanced Learning for the Workplace and Higher Education: Proceedings of The Learning Ideas Conference 2023* (forthcoming).

509. Merrill, Laura et al. *Making the Switch: From Fossil Fuel Subsidies to Sustainable Energy*. Nordic Council of Ministers, 10 May 2017.

510. Meshel, Tamar, and Moin A. Yahya. "International Water Law and Fresh Water Dispute Resolution: A Cosean Perspective." *University of Colorado Law Review* 92, no. 2 (18 Mar. 2021).

511. Metcalfe, Anya N., Theodore Kennedy, Gabriella A. Mendez, and Jeffrey D. Muehlbauer. "Applied Citizen Science in Freshwater Research." *Wiley Interdisciplinary Reviews (WIREs): Water* 9, no. 2 (Jan. 2022).

512. Metz, Cade. "We Teach A.I. Systems Everything, Including Our Biases." *New York Times*, 11 Nov. 2019.

513. Middel, Helen, and Francesca Verones. "Making Marine Noise Pollution Impacts Heard: The Case of Cetaceans in the North Sea within Life Cycle Impact Assessment." *Sustainability* 9, no. 1138 (June 2017).

514. Miles, Matthew B., A. Michael Huberman, and Johnny Saldana. *Qualitative Data Analysis: A Methods Sourcebook*. SAGE Publication, Jan. 2019.

515. Miller, Riel. "Learning, the Future, and Complexity. An Essay on the Emergence of Futures Literacy." *European Journal of Education* 50, no. 4 (10 Dec. 2015).

516. "Mining Landfills." Mission 2016: The Future of Strategic Natural Resources, MIT.edu.

517. MIT Global System for Sustainable Development (GSSD). Updated 27 Aug. 2020. "Mapping Sustainability."

518. MNC Editorial Team. "The First Faces of Manhattan." MessyNessyChic, 31 May 2021.

519. Mohamed, Shakir, Marie-Therese Png, and William Isaac. "Decolonial AI: Decolonial Theory as Sociotechnical Foresight in Artificial Intelligence." *Philosophy and Technology* 33 (2020): 659–684.

520. Moldanová, Jana, Ida-Maja Hassellov, Volker Matthias, Erik Fridell, Jukka-PekkaJalkanen, Erik Ytreberg, Markus Quante et al. "Framework for the Environmental Impact Assessment of Operational Shipping." *Ambio* 51 (July 2022): 754–769.

521. Molotoks, A., P. Smith, and T. P. Dawson. "Impacts of Land Use, Population, and Climate Change on Global Food Security." *Food and Energy Security 10*, no. 1 (Nov. 2020).

522. Molur, S., K. G. Smith, B. A. Daniel, and W. R. T. Darwall, compilers. *The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India*. Cambridge, UK, and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation, 2011.

523. Morgan, James. "Effects of Marine Protected Areas." *World Wildlife*, Fall 2016.

524. Moriarty, Patrick, and Damon Honnery. "Feasibility of a 100% Global Renewable Energy System." *Energies* 13, no. 21 (22 Oct. 2020).

525. Morozov, Evgeny. To Save Everything, Click Here: The folly of Technological Solutionism. Public Affairs, 2014.

526. Morseletto, Piero. "Targets for a Circular Economy." *Resources, Conservation, and Recycling* 153 (2020).

527. Moustier, Paule. "Short Urban Food Chains in Developing Countries: Signs of the Past or of the Future?" *Natures Sciences Sociétés* 25, no. 1 (2017): 7–20.

528. Mudur, Ganapati. "Slow Progress on Sanitation Puts 2.6 Billion People at Risk." BMJ 329, no. 7465 (4 Sept. 2004): 528.

529. Muljat, Marissa. "Riverside Intermediate: Agriculture, Engineering, & Environment." *This is Fishers*, Summer 2023.

530. Murray, Aphra. "Cobalt Mining: The Dark Side of the Renewable Energy Transition." Earth.org. 27 Sept. 2022.

531. Murray, Fiona, and Scott Stern, "Accelerating Innovation-Driven Entrepreneurial Ecosystems," in *Innovation and Public Policy,* National Bureau of Economic Research Conference Report, Austan Goolsbee and Benjamin F. Jones, eds. Chicago, IL: University of Chicago Press, 2022.

532. Mwanza, Kevin. "African Countries Should 'Decolonize' Water, Recognize Customary Rights: Report." *Reuters*, Oct. 2018.

533. Myscofski, Megan. "Not Here for Some Agrarian Fantasy." *Arizona Public Media*, 25 July 2022. Last updated 1 Aug. 2022.

534. Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, and X. Zhang. *Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer. Cambridge and New York: Cambridge University Press, 2007.

535. Naibaho, Nicolaus. *Strengthening the Role of Ports in Combating Illegal, Unreported and Unregulated Fishing in Indonesia*. New York: Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs, United Nations, 2017.

536. Naishadham, Suman. "How San Diego Secured Its Water Supply, at a Cost." AP News, 29 May 2022.

537. Namami Gange. "Namami Gange Anthem." YouTube video. 7 July 2016.

538. Namami Gange. "Namami Gange: Official Anthem of National Mission on Clean Ganga." YouTube video. 14 June 2020.

539. Nargi, Lela. "The Miyawaki Method: A Better Way to Build Forests." *JSTOR Daily*, 24 July 2019.

540. NASA and Columbia University. "Maps." Socioeconomic Data and Applications Center (SEDAC).

541. National Academies of Sciences, Engineering, and Medicine. *Gaseous Carbon Waste Streams Utilization: Status and Research Needs.* Washington, DC: The National Academies Press, 2019.

542. National Ag Safety Database (NASD). "Disposal of Hazardous Household Waste." Clemson University Cooperative Extension Service.

543. National Agricultural Law Center. "Water Law: An Overview."

544. National Centers for Environmental Information. "World Ocean Database." NOAA.

545. National Environmental Satellite Data and Information Service (NESDIS), NOAA (website).

546. National Institutes of Environmental Health Sciences (NIEHS). "Algal Blooms." NIH. Last updated 8 Sep. 2021.

547. National League of Cities. "Ready to Rebuild Initiative 2023."

548. National Ocean Service. "Ocean Facts: Our World Ocean."

549. National Park Service. "Indigenous Fire Practices Shape Our Land." Updated 4 Feb. 2022.

550. National Wildlife Federation (NWF). "Combatting Invasive Species."

551. National Wildlife Federation (NWF). "Kids and Nature Programs."

552. The Nature Conservancy. "Great Lakes Aquatic Invasive Species."

553. The Nature Conservancy. "Our Goals for 2030: Build Healthy Cities."

554. Natural Resources Canada. *Major Energy Retrofit Guidelines for Commercial and Institutional Buildings: Office Buildings*. 2015.

555. Natural Resources Defense Council (NRDC). "Water Pollution: Everything You Need to Know." 11 Jan. 2023.

556. "Nebraska and Colorado Face Off Over Water." *AP News*, 18 May 2022.

557. Neumann, Nadja. "14 Recommendations for the Protection of Freshwater Biodiversity Beyond 2020." Press release. Liebniz Institute of Freshwater Ecology and Inland Fisheries, Oct 2020.

558. News in Germany. "Less Traffic Jams with a 9-Euro Ticket. Analysis of TomTom Data. Economy." July 2022.

559. Newcomb, Tim. "Scientists Are Reincarnating the Woolly Mammoth to Return in 4 Years." *Popular Mechanics*, 20 Jan. 2023.

560. Ng, Michelle, Nicoline de Haan, Brian King, and Simon Langan. *Promoting Inclusivity and Equity in Information and Communications Technology for Food, Land, and Water Systems.* Cali, Colombia: Consultative Group on International Agricultural Research (CGIAR) Platform for Big Data in Agriculture, 2021.

561. Nishitani, Makiko, Martina Boese, and Helen Lee. "The Production of Precariousness and the Racialisation of Pacific Islanders in an Australian Horticultural Region." *Journal of Ethnic and Migration Studies* (Feb. 2023).

562. NIST. Information Technology Laboratory. "AI Risk Management Framework."

563. Nix, Steve. "3 Ways Your Trees Can Be Stolen." ThoughtCo. Last updated 13 Aug. 2019.

564. Njambi, Rose. "Tackling Deforestation in India: Why You Need Satellite Data." UP42, 20 Sept. 2021.

565. NOAA. "Hazardous Waste." Damage Assessment, Remediation, and Restoration Program (DARP). Last updated 27 Apr. 2023.

566. NOAA. "Lower Duwamish River."Damage Assessment, Remediation, and Restoration Program. Last updated Jan. 2023.

567. NOAA. (2024). Great Lakes Habitat Restoration (website). https://www.fisheries.noaa.gov/national/habitat-conservation/great-lakes-habitat-restoration

568. NOAA. "Restoring Rivers to Reverse Impacts from Pollution." Damage Assessment, Remediation, and Restoration Program (DARP), 3 May 2021.

569. NOAA. "U.S. Billion-Dollar Weather and Climate Disasters." National Centers for Environmental Information (NCEI), 2023.

570. NOAA. "What Are Microplastics?" Facts.

571. NOAA. "What is Harmful Algal Bloom?" Last updated 27 Apr. 2016.

572. NOAA. "What is Nutrient Pollution?" National Ocean Service. Last updated 20 Jan. 2023.

573. Noack, Mark. "Is Mountain View Losing Its Trees? New City Data Still Leaves Question Up in the Air." *Mountain View Voice,* 1 July 2018.

574. Nobre, Carlos A., Gilvan Sampaio, Laura S. Borma, Juan Carlos Castilla-Rubio, José S. Silva, and Manoel Cardoso. "Land-Use and Climate Change Risks in the Amazon and the Need of a Novel Sustainable Development Paradigm." *Proceedings of the National Academy of Sciences* 113, no. 39 (Sept. 2016).

575. Noddings, Nel. "Caring: A Relational Approach to Ethics and Moral Education." 2nd ed. Oakland, CA: University of California Press, 2013.

576. Nokia. "AVA—Energy Efficiency: For Cost-Efficient and Sustainable Networks." Network Solutions, BSS/OSS, AVA-Energy Efficiency.

577. Northwest Power and Conservation Council (NPCC). "Dams: Impact on Salmon and Steelhead."

578. Nosowitz, Dan. "Study: There Are Ways to Dramatically Reduce Agricultural Water Pollution." Modern Farmer, 4 Aug. 2021.

579. NPR Staff. "Water Wars: Who Controls The Flow?" *NPR All Things Considered*, 15 June 2013.

580. NSW Government. "Gayini Nimmie-Caira Project." Water in New South Wales, NSW Dept of Planning and Environment within Australia. Project completed 2019.

581. Nuclear Energy Agency (NEA). "NEA Small Modular Reactor (SMR) Dashboard."

582. Nurture Development. "Asset Based Community Development (ABCD)."

583. OASIS. Observing Air-Sea Interaction Strategy.

584. Ocean Frontier Institute. "North Atlantic Carbon Observatory."

585. Ocean Frontier Institute. "Ocean Data & Technology."

586. Ocean Insight (website).

587. Ocean Literacy (website).

588. Ocean Risk and Resilience Action Alliance (website).

589. Ocean Visions. Ocean-Based Carbon Dioxide Removal Road Maps.

590. Office of Energy Efficiency & Renewable Energy. "Department of Energy Announces Pledges from 21 Organizations to Increase the Energy Efficiency of Semiconductors and Bolster American Manufacturing." 21 Sept. 2022.

591. O'Connell, Daniel J., and Scott J. Peters. *In the Struggle: Scholars and the Fight Against Industrial Agribusiness in California.* New York: New Village Press, 2021.

592. O'Hara, Casey C., Melanie Frazier, and Benjamin S. Halpern. "At-Risk Marine Biodiversity Faces Extensive, Expanding, and Intensifying Human Impacts." *Science* 372, no. 6537 (2021): 84–87.

593. Oladini, Dolly. "4 Ways Cities Are Using Low-Cost Sensors to Improve Air Quality." Clear Air Fund Blog, 21 June 2022.

594. Olafur Eliasson (website).

595. O'Leary, Denyse. "How Surreal Artist MC Escher Influenced Physicist Roger Penrose." Mind Matters, 9 Jan. 2023.

596. Oletic, Dinko, and Vedran Bilas. "How Thirsty the Crops Are: Emerging Instrumentation for Plant-Based Field Measurement of Water Stress." *IEEE Instrumentation & Measurement* 23, no. 2, Apr. 2020.

597. "Omaha, Nebraska's Riverfront Revitalization Project on a Brownfield Wins International Sustainable Infrastructure Award." *Revitalization, The Journal of Urban, Rural and Environmental Resilience* 159, 15 Nov. 2021.

598. One Acre Fund. "The Case for Farming Insurance to Help Smallholders Build Climate Resilience." 8 Nov. 2022. Accessed 7 Nov. 2023.

599. One Planet Network. *Rethinking, Extending, Re-using: Harnessing Digital Technologies for the Circular Economy*. 2023.

600. Oppenheimer, Michael, Bruce C. Glavovic, Jochen Hinkel, Roderik van de Wal, Alexandre K. Magnan, Amro Abd-Elgawad, Rongshuo Cai et al. "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities." Chp. 4 in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Edited by Hans-O Pörtner et al. Cambridge and New York: Cambridge University Press, 2019.

601. Organisation for Economic Co-operation and Development (OECD). OECD Data. "Meat Consumption."

602. Organisation for Economic Co-operation and Development (OECD). OECD iLibrary. "Measuring the Environmental Impacts of Artificial Intelligence Compute and Applications: The AI Footprint." 15 Nov. 2022.

603. Ostrom, Elinor. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, MA: Cambridge University Press, 1990.

604. Our World in Data. "Global Direct Primary Energy Consumption."

605. Our World in Data. "Total Greenhouse Gas Emissions, Excluding Land Use and Forestry."

606. Overstreet, Kaley. "The History of the Penrose Stair and its Influence on Design." *Arch Daily*, 10 May 2022.

607. Owens, Gene for U.S. Agency for International Development, Office of Energy, Environment & Technology, Global Bureau Environment Center. *Best Practices Guide: Economic and Financial Evaluation of Renewable Energy Projects*. Washington, DC: USAID, 2002.

608. Pacheco, Miguel. "Have Your Energy Drink and Drink It Too: How Hydrogen Fuel Cells Can Supply Drinking Water Along with Electricity." *Medium*, 16 May 2023.

609. Pal, Sanchari. "How Three Startups Are Using Innovative Methods to Clean and Restore River Ganga." The Better India, 12 Jan. 2017.

610. Parker, Alison, Shannon Dosemagen, and Ashley Schuett. "Low-Cost and Open Tools for Environmental Decision-Making." *The Wilson Center* (blog), 5 April 2022.

611. Parker, Halle. "Most of Louisiana's Waterways Are Polluted. Biggest Reasons? Fertilizer and Sewage." New Orleans Public Radio (WWNO), 6 Apr. 2022.

612. Parkinson, Giles. "France's Troubled Nuclear Fleet a Bigger Problem for Europe Than Russia Gas." *Renew Economy,* 5 Aug. 2022.

613. Partnerism (website).

614. Pasqualetti, Martin. "Social Barriers to Renewable Energy Landscapes." *Geographical Review* 101, no. 2, (Apr. 2011).

615. Pathak, Minal et al. *Technical Summary in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by Priradarshi R. Shukla et al. Cambridge, UK and New York, NY: Cambridge University Press (2022): 66.

616. Pavlenko, Nikita, Bryan Comer, Yuanrong Zhou, Nigel Clark, and Dan Rutherford. *The Climate Implications of Using LNG as a Marine Fuel.* Working Paper 2020-02. International Council on Clean Transportation (ICCT), Jan. 2020.

617. Pawlukiewicz, Amy. ““7 Ways to Ensure Your Water is Always Hot.” *Angi*, 17 Oct. 2022.

618. Pearce, Fred. “Rivers in the Sky How Deforestation is Affecting Global Water Cycles.” *YaleEnvironment 360,* Yale School of the Environment, 24 July 2018.

619. Perez, Carlota. Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages. Cheltenham, UK, and Northampton, MA: Edward Elgar, 2002.

620. Perić, T., P. Komadina, and N. Račić. “Wastewater Pollution from Cruise Ships in the Adriatic Sea.” *Promet* 28, no. 4 (2016): 425–33.

621. Perlas, N. *Shaping Globalization: Civil Society, Cultural Power and Threefolding*. Center for Alternative Development Initiatives, Global Network for Threefolding. 2000.

622. Pershing, Jonathan, and Jim Mackenzie. “Removing Subsidies: Leveling the Playing Field for Renewable Energy Technologies.” In *Renewable Energy.* Edited by Dirk Assmann. London: Routledge, 2006.

623. Peters, D., K. Vold, D. Robinson, and R. A. Calvo. “Responsible AI—Two Frameworks for Ethical Design Practice.” *IEEE Transactions on Technology and Society* 1, no. 1 (Mar. 2020): 34–47.

624. Peterson, Greg, Chanwoo Bae, and Derek White. “A BC Ferries Case Study: Lessons Learned In Setting.” MarineLink, 27 Apr. 2021.

625. The Pew Charitable Trusts. "The Case for Marine Protected Areas: A Way to Safeguard Biodiversity, Bolster Fisheries, and Protect Ocean Habitat."

626. Phong, L. H. “The Relationship Between Rivers and Cities: Influences of Urbanization on the Riverine Zones: A Case Study of Red River Zones in Hanoi, Vietnam.” *WIT Transactions on Ecology and The Environment* 193 (2015).

627. Pirni, Alberto, Maurizio Balistreri, Marianna Capasso, Steven Umbrello, and Federica Merenda. “Robot Care Ethics Between Autonomy and Vulnerability: Coupling Principles and Practices in Autonomous Systems for Care.” *Frontiers in Robotics and AI* 8 (16 June 2021).

628. Plastic Action Centre. “Here’s Where the World’s Plastic Waste Will End Up, by 2050.”

629. Pless, Shanti, Stacey Rothgeb, Ankur Podderm, and Noah Klammer. *Integrating Energy Efficiency into the Permanent Modular Construction Industry.* NREL Buildings Integration Research.

630. Pokojska, Justnya. “Competencies of the Future as a Transdisciplinary.” *Proceedings of the 13th International Multi-Conference on Complexity, Informatics and Cybernetics* (IMCIC 2022).

631. Pollin, Robert. “Nationalize the U.S. Fossil Fuel Industry to Save the Planet.” *The American Prospect*, 8 April 2022.

632. Polman, Paul, and Andrew Winston. “Net Positive: How Courageous Companies Thrive by Giving More Than They Take.” *Harvard Business Review Press*, 2021.

633. Polman, Paul, and Andrew Winston. "The Net Positive Manifesto." *Harvard Business Review Magazine*, Sept.–Oct. 2021.

634. Poore, J., and T. Nemecek. "Reducing Food's Environmental Impacts through Producers and Consumers." *Science* 360, no. 6392 (June 2018): 987–982.

635. Port of Vancouver, Vancouver Fraser Port Authority. "EcoAction Program." Climate Action at the Port of Vancouver.

636. Pörtner, Hans, Debra C. Roberts, Helen Adams, Ibidun Adelekan, Carolina Adler, Rita Adrian, Paulina Aldunce, et al. *Technical Summary in Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY: Cambridge University Press, 2022.

637. "Potential Problems with Cross-Border Water Issues: The U.S. and Canada in the 21st Century." In *Canada and the New American Empire*. (University of Victory, CA: Center for Global Studies and CBC News World.)

638. Potter Clive, Tom Harwood, Jon Knight, and Isobel Tomlinson. "Learning from History, Predicting the Future: The UK Dutch Elm Disease Outbreak in Relation to Contemporary Tree Disease Threats." *Philos Trans R Soc Lond B Biol Sci* 366, no. 1573(July 2011):1966–74.

639. Powell, William A., Andres E. Newhouse, and Vernon Coffey. "Developing Blight-Tolerant American Chestnut Trees." *Cold Spring Harbor Perspectives in Biology* 11, no. 7 (July 2019).

640. Preidt, Robert. "How Your Medicines Make Their Way into Rivers, Lakes and Bays." *US News & World Report*, 23 Aug. 2021.

641. USDA. *Preventing Runoff Into The Mississippi River*. *USDA* YouTube channel. Aug. 2011.

642. Prime Coalition and Rho AI. *CRANE User Report 2021*, 2021.

643. Prime Minister of India. "Namami Gange."

644. Prisma Labs (website).

645. Project Drawdown (website).

646. Project Drawdown. "Climate Solutions 101."

647. Project Drawdown. "Solutions Library."

648. ProSocial World (website).

649. Proulx. Annie. "Swamps Can Protect Against Climate Change, If We Only Let Them." *The New Yorker,* 27 June 2022.

650. Purpose (website).

651. Qazi, Moin. "Water Crisis: Thirsty Crops Drain India Dry." *QRIUS*, 18 Mar. 2018.

652. Rai, Prabhat Kumar, and J. S. Singh. "Invasive Alien Plant Species: Their Impact on Environment, Ecosystem Services and Human Health." *Ecological Indicators* 111 (Apr. 2020).

653. Rajendran, Sankaran, Fadhil N. Sadooni, Hamad Al-Saad Al-Kuwari, Anisimov Oleg, Himanshu Govil, Sobhi Nasir, and Ponnumony Vethamony. "Monitoring Oil Spill in Norilsk, Russia Using Satellite Data." *Scientific Reports* 11, no. 3817 (Feb. 2021).

654. Ram M., Bogdanov D., Aghahosseini A., Gulagi A., Oyewo A.S., Child M., Caldera U., Sadovskaia K., Farfan J., Barbosa LSNS., Fasihi M., Khalili S., Dalheimer B., Gruber G., Traber T., De Caluwe F., Fell H.-

J., Breyer C. *Global Energy System Based on 100% Renewable Energy—Power, Heat, Transport and Desalination Sectors.* Study by Lappeenranta University of Technology and Energy Watch Group. Berlin: Lappeenranta University of Technology, Mar. 2019.

655. Ramirez-Moreno, Mauricio A. et al. "Sensors for Sustainable Smart Cities: A Review." *Applied Sciences* 11, no. 17 (Aug. 2021).

656. Rapier, Robert. "The Divestment Movement Has Cost Organizations Billions of Dollars." *Forbes*, 27 Nov. 2022.

657. Raworth, Kate. Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. Chelsea Green, 2018.

658. Raygorodetsky, Gleb. "Why Traditional Knowledge Holds the Key to Climate Change." United Nations University (online resource), 13 Dec. 2011.

659. Real Organic Project. "Hydroponic."

660. Real Organic Project. "Real Organic Virtual Symposium 2023." Symposium 2023.

661. Reed, Chris, Katarzyna Budzynska, Rory Duthie, Mathilde Janier, Barbara Konat, John Lawrence, Alison Pease et al. "The Argument Web: An Online Ecosystem of Tools, Systems, and Services for Argumentation." *Philosophy & Technology* 30, no. 2 (2017): 137–160 .

662. Regan F. Patterson. "*Gender, Climate, and Transport in the United States*." WEDO (Women's Environment and Development Organization). July 2021.

663. Regeneration. "Methodology."

664. Regenesis Group (website).

665. Reichel, André. "Civil Society as a System." In *Civil Society for Sustainability: A Guidebook for Connecting Science and Society.* Edited by Ortwin Renn, André Reichel, and Joa Bauer. Bremen, Germany: Europaeischer Hochschulverlag GmbH and Co. KG, 2012.

666. Reiersen, Gyri, David Dao, Björn Lütjens, Konstantin Klemmer, Kenza Amara, Attila Steinegger, Ce Zhang, and Xiaoxiang Zhu. "ReforesTree: A Dataset for Estimating Tropical Forest Carbon Stock with Deep Learning and Aerial Imagery." arXiv.org, 6 Mar. 2024.

667. Reiff, Nathan. "Decentralized Autonomous Organization (DAO): Definition, Purpose, and Example." Investopedia, *Cryptocurrency*. 30 Sept. 2023.

668. Reinsch, William Alan, and Will O'Neill. "Hydrogen: The Key to Decarbonizing the Global Shipping Industry?," Center for Strategic and International Studies (CSIS), 13 Apr. 2021.Resilience (website).

669. Resilience. "Daniel Christian Wahl."

670. Richardson, W. John, Charles R. Greene, Jr., Charles I. Malme, and Denis H. Thomson. *Marine Mammals and Noise*. Academic Press, 1995.

671. Riem Natale, Antonella, and Roberto Albarea, eds. The Art of Partnership: Essays on Literature, Culture, Language and Education Towards a Cooperative Paradigm. Udine, Italy: Forum Editrice, 2003.

672. Rifkin, Jeremy. The End of the Work, The Decline of the Global Labor Force and the Dawn of the Post-Market Era. New York: Penguin, 2004.

673. Rifkin, Jeremy. The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World. Palgrave Macmillan, 2011.

674. Ritcher, Brian. *Water Share: Using Water Markets and Impact Investment to Drive Sustainability*. Washington, DC: The Nature Conservancy, 2016.

675. Ritchie, Hannah. "Sector by Sector: Where Do Global Greenhouse Gas Emissions Come From?" *Our World in Data*(online resource), 18 Sept. 2020, accessed 5 Sept. 2022.

676. Ritchie, Hannah, and Max Roser. "Clean Water." OurWorldInData.org, Sept. 2019. Last updated June 2021.

677. Ritchie, Hannah, Max Roser, and Pablo Rosado. "Fertilizers." OurWorldInData.org, 2022.

678. Ritchie, Hannah, Pablo Rosado, and Max Roser. "Breakdown of Carbon Dioxide, Methane and Nitrous Oxide Emissions by Sector." Our World in Data, Jan. 2024

679. Ritchie, Hannah, Pablo Rosado, and Max Roser. "Environmental Impacts of Food Production." Our World In Data (online resource), 2022.

680. Rittel, Horst W. J., and Melvin M. Webber. "Dilemmas in a General Theory of Planning,"*Policy Sciences* 4 (1973): 155–169.

681. River Cleanup (website).

682. Riyou Tsujino, Takakazu Yumoto, Shumpei Kitamura, Ibrahim Djamaluddin, and Dedy Darnaedi. "History of Forest Loss and Degradation in Indonesia." *Land Use Policy* 57 (2016): 335–347.

683. The Rivers Trust. "Cleaning Up Rivers."

684. The Rivers Trust. "Raw Sewage in Our Rivers."

685. Robinson, John, and Raymond J. Cole. "Sustainability." Building Research and Information 43, no. 2 (Mar. 2015).

686. Robinson, John, and Raymond J. Cole. "Theoretical Underpinnings of Regenerative Sustainability." *Building Research and Information* 43, no. 2 (Mar. 2015).

687. Romo, Adam. "Polygon Power: Putting Sustainability Systems on the Map." iseal, 18 Nov. 2020.

688. Root-Bernstein, Robert. "Correlation between Tools for Thinking; Arts, Crafts, and Design Avocations; and Scientific Achievement among STEMM Professionals." *Proceedings of the National Academy of Sciences of the United States of America* 116, no. 6 (Feb 2019): 1910–1917.

689. Rott, Nathan."An Eye-Opener: Virtual Reality Shows Residents What Climate Change Could Do," WUSF Public Media, 24 Nov. 2019.

690. The Royal Society. "Climate Change: Evidence and Causes, Question 20."

691. Royer, Alexandrine. "The Wellness Industry's Risky Embrace of AI-Driven Mental Health Care." Brookings, *Tech Stream*, 14 Oct. 2021.

692. Rúrí. Future Cartography. Digital print. 2012.

693. Ruwoko, Eve. "Work on Masters Qualification in Climate Change Goes Forward." University World News, Africa Edition, 29 Mar. 2023.

694. S&P Dow Jones Indices. "Investment Theme: Sustainability."

695. Saatchi, Sassan, Salvi Asefi-Najafabady, Yadvinder Malhi, Luiz E. O. C. Aragão, Liana O. Anderson, Ranga B. Myneni, and Ramakrishna Nemani. "Persistent Effects of a Severe Drought on Amazonian Forest Canopy."*PNAS* 110, no. 2 (24 Dec. 2012).

696. Sabraw, John. "Toxic Art." TEDxWarwick. YouTube video 2017. 4 Apr. 2017.

697. Safe Drinking Water Foundation. "Pesticides and Water Pollution."

698. San Llorente Capdevila, Anna, Ainur Kokimova, Saunak Sinha Ray, Tamara Avellán, Jiwon Kim, and Sabrina Kirschke. "Success Factors for Citizen Science Projects in Water Quality Monitoring." *Science of the Total Environment* 728 (Aug. 2020).

699. Saraceno, Thomas. *Museo Aero Solar*. Plastic bag installation and social process. 2007 and ongoing.

700. Sarkar, C. "The Rise of the Collaborative Economy." Interview with Jeremiah Owyang in *The Marketing Journal,* 12 Mar. 2016.

701. Schadel, B. R., and W. Wesela. APHIS List of Regulated Hosts and Plants Proven or Associated with Phytophthora ramorum. July 2020.

702. Schaefer, Adam M., Luke Yrastorza, Nicole Stockley, Kathi Harvey, Nancy Harris, Robert Grady, James Sullivan et al. "Exposure to Microcystin Among Coastal Residents during a Cyanobacteria Bloom in Florida." *ScienceDirect*, 5 Feb. 2020.

703. Schafer, R. Murray. *The New Soundscape: A Handbook for the Modern Music Teacher*. Don Mills, Ontario: BMI Canada, 1969.

704. Schafer, R. Murray. The Soundscape: Our Sonic Environment and the Tuning of the World. Rochester, VT: Destiny Books, 1993.

705. Schaffar, Wolfram. "Alternative Development Concepts and Their Political Embedding: The Case of Sufficiency Economy in Thailand." *Forum for Development Studies* 45, no. 3 (2018): 387–413.

706. Scharmer, C. Otto. *Theory U: Leading from the Future As It Emerges*. Oakland, CA: Berrett-Koehler Publishers, Kindle Edition, 2016: 29–114.

707. Schiff, D., A. Ayesh, L. Musikanski, and J. C. Havens. "IEEE 7010: A New Standard for Assessing the Well-being Implications of Artificial Intelligence." *2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (2020): 2746–2753.

708. Schlossberg, Tatiana. "Fertilizers, a Boon to Agriculture, Pose Growing Threat to U.S Waterways." *New York Times*, 27 July 2017.

709. Schmitt, M. T., S. D. Neufeld, C. M. L. Mackay, and O. Dys-Steenbergen. "The Perils of Explaining Climate Inaction in Terms of Psychological Barriers." *Journal of Social Issues* 76 (2020): 123–135.

710. Schmidt Ocean Institute. "Data Management."

711. Schnabel, Ronald. "Improving Water Quality Using Native Grasses." USDA Agricultural Research Service, Nov. 1999.

712. Schneider, Keith. "A River Restored Breathes New Life into Kuala Lumpur." Mongabay, Aug. 2018.

713. Schoonerboom, Judith, and R. Burke Johnson. "How to Construct a Mixed Methods Research Design." *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 69, suppl. 2 (5 July 2017): 107–131.

714. Schuelke-Leech, B., and M. Janczarski. "Incorporating Societal (Social) and Ethical Implications into the Design, Development, and Deployment of Technologies." *2019 IEEE International Symposium on Technology and Society (ISTAS)* (2019): 1–6.

715. Schultz-Bergin, Marcus. "The Primacy of the Public: Ethical Design for Technical Professionals, Chapter 6: Engineering & the Environment." Cleveland State University, 1 May, 2021.

716. Schuring, Hermine. A Life in Service: Stories & Teachings from Mala Spotted Eagle. BookBaby, 2019.

717. Schwartz, Roy, Jesse Dodge, Noah A. Smith, Oren Etzioni. "Green AI." Communications of the ACM. 13 Aug. 2020.

718. Science and Nonduality. *Story Disruption & Morphogenesis, Charles Eisenstein*. YouTube video. 27 Nov. 2015.

719. Scott, Michon, and Rebecca Lindsey. "Unprecedented 3 Years of Global Coral Bleaching: 2014–2017." NOAA, Climate.gov. 1 Aug. 2018.

720. "SDG Leadership Labs: Supporting UN Country Teams to Achieve Agenda 2030." u-school for Transformation by Presencing Institute, 9 Dec. 2021.

721. SDSN/FEEM 2021. *Roadmap to 2050: The Land-Water-Energy Nexus of Biofuels.* Sustainable Development Solutions Network (SDSN) and Fondazione Eni Enrico Mattei (FEEM). 2021.

722. Seabed 2030. The Nippon Foundation-GEBCO Seabed 2030 Project.

723. Sedlak, David. "How Development of America's Water Infrastructure Has Lurched Through History." *Pew*, 3 Mar. 2019.

724. Seametrics. "15 Interesting Facts About Water Pollution That You Should Know."

725. Semiconductor Research Corporation (SRC). "The Decadal Plan for Semiconductors: A Pivotal Roadmap Outlining Research Priorities." Insights & Initiatives. Oct. 2020.

726. Sengupta, Somini. "City Living, With Less Water." *New York Times*, 29 Apr. 2022.

727. SENSA Networks. **"**5 Technologies That Are Making Waste Disposal More Efficient." *SENSA Networks* (blog). 6 Nov. 2018.

728. Shaheen, S., and Cohen, A. "Mobility on Demand (MOD) and Mobility as a Service (MaaS): Similarities, Differences, and Potential Implications for Transportation in the Developing World." In *Mobility and Development: Innovations, Policies and Practices*. World Bank Group, Transport. Fall 2021.

729. Shahriari, K., and M. Shahriari. "IEEE Standard Review—Ethically Aligned Design: A Vision for Prioritizing Human Wellbeing with Artificial Intelligence and Autonomous Systems." *2017 IEEE Canada International Humanitarian Technology Conference (IHTC)* (2017): 197–201.

730. Shaikh Khatibi, Farzaneh, Aysin Dedekorkut-Howes, Michael Howes, and Elnaz Torabi. "Can Public Awareness, Knowledge and Engagement Improve Climate Change Adaptation Policies." *Discover Sustainability* 2, no. 1 (23 Mar. 2021): 1–24.

731. Shamoon, Ahmad, Abid Haleem, Shashi Bahl, Mohd Javaid, Sonu Bala Garg, Rakesh Chandmal Sharma, and Jatinder Garg. "Environmental Impact of Energy Production and Extraction of Materials—A Review." *Materials Today: Proceedings* 57, pt. 2 (2022): 936–941.

732. Shankar, S., and A. Reuther. "Trends in Energy Estimates for Computing in AI/Machine Learning Accelerators, Supercomputers, and Compute-Intensive Applications." In *Proceedings of the 2022 IEEE High Performance Extreme Computing Conference (HPEC),* Waltham, MA, USA, 19–23 Sept. 2022. IEEE: Piscataway, NJ, USA, 2022: 1–8.

733. Shannon, G., R. Issa, C. Wood, and I. Kelman. "Regenerative Economics for Planetary Health: A Scoping Review." *International Health Trends and Perspectives* 2, no. 3 (2022): 81–105.

734. Shared-Use Mobility Center (SUMC). "Take a RIDE with Me: Highlighting the Adoption of Citywide Microtransit in Wilson, NC." Resource Library. 17 Apr. 2023.

735. The Shareholder Commons (website).

736. Shearman & Sterling. “A Deeper Look at the Global Framework Principles for Decarbonizing Heavy Industry.” *Perspectives.* 28 June 2022.

737. Shlokam. “Akasat Patitam Toyam.” (Sanskrit/English with translation, meaning and notes).

738. “A Short History of Pest Management.” PennState Extension. Updated 30 June 2022.

739. Shrivastava, Paul, and Laszlo Zsolnai. “Wellbeing-Oriented Organizations: Connecting Human Flourishing with Ecological Regeneration.” *Business Ethics, the Environment & Responsibility* 31, no. 2 (2022): 386–397.

740. Shukla, Priyadarshi R. et al., ed. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY: Cambridge University Press, 2022.

741. Simpkins, Kelsey. “Amid Climate Change and Conflict, More Resilient Food Systems a Must.” CU Boulder Today, 15 July 2022.

742. Sindi, S. and R. Woodman. “Autonomous Goods Vehicles for Last-mile Delivery: Evaluation of Impact and Barriers.” *2020 IEEE 23rd International Conference on Intelligent Transportation Systems*, Rhodes, Greece. 20 Sept. 2020.

743. Singapore’s Zero Waste Master Plan. “Food Waste: What are others doing?”

744. Singh, Shashwat. “The American Southwest’s Water Crisis, and Why Canada May Have the Solution.” *Glimpse from the Globe.* 10 Jan. 2022.

745. Sisson, Patrick. "The Future of Urban Housing is Energy Efficient Refrigerators." *MIT Technology Review,* 23 Feb. 2022.

746. SLAC National Accelerator Laboratory. “DOE EES2 Pledge.” DOE, Energy Efficient Computing.

747. Slaughter, Anne-Marie. “3 Responsibilities Every Government Has Towards Its Citizens.” World Economic Forum, Education, 13 Feb. 2017.

748. Smith, Jeremy M. B. "Grassland" in *Encyclopedia Britannica*, 13 Mar. 2020. Accessed 30 June 2022.

749. Smith, Stephen and Samara Freemark. “Thirsty Planet—Israel: Using Technology, Engineering to Cut Reliance on Galilee.” *APM Reports* (American Public Media), 12 May 2016.

750. Sommer, Laura Kim, and Christian Andreas Klöckner. “Does Activist Art Have the Capacity to Raise Awareness in Audiences?—A Study on Climate Change Art at the ArtCOP21 Event in Paris.” *Psychology of Aesthetics, Creativity, and the Arts* 15, no. 1 (2021).

751. Sonter, Laura J., Marie C. Dade, James E. M. Watson, and Rick Valenta. “Renewable Energy Production Will Exacerbate Mining Threats to Biodiversity.” *Nature Communications* 11, 4174 (2020).

752. Southeastern Environmental Education Alliance (SEEA). “Landscape Analysis.”

753. Sovacool, Benjamin K. “Expannding Renewable Energy Access with Pro-Poor Public Private Partnerships in the Developing World.” *Energy Strategy Reviews* 1, no. 3 (2013): 181–192.

754. Sovacool, Benjamin, Noam Bergman, Debbie Hopkins, Kirsten E. H. Jenkins, Sabine Hielscher, Andreas Goldthau, and Brent Brossmann. “Imagining Sustainable Energy and Mobility Transitions: Valence, Temporality, and Radicalism in 38 Visions of a Low-Carbon Future.” *Social Studies of Science* 50, no. 4 (May 2020).

755. Speck, Jeff. Walkable City Rules: 101 Steps to Making Better Places. Washington, DC: Island Press, 2018.

756. Spiekermann, S. "From Value-Lists to Value-Based Engineering with IEEE 7000™." *2021 IEEE International Symposium on Technology and Society (ISTAS)* (2021): 1–6.

757. St. John, Jeff. "A Grassroots Coalition Turns to Solar and Batteries to Help New Orleans Cope with Disasters." *Canary Media*, 11 July 2022.

758. Stahel, Walter R. "The Circular Economy." *Nature* 531 (Mar. 2016): 435–438.

759. Ståhle, Pirjo, ed. *Five Steps for Finland's Future.* *Technology Review 202/2007*. Helsinki: Tekes, 31 Jan. 2007, ref. pg. 4.

760. Star, Susan Leigh, and James R. Griesemer. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science* 19, no. 3 (1989): 387–420.

761. State of Green. "10 Examples of Circular Economy Solutions." 21 July 2017.1.

762. Statista 2024. "Number of People Without Access to Electricity Worldwide in Selected Years from 2000 to 2023, by Region." Statista, Energy & Environment.

763. Stephens, Scott, Brandon Collins, Christopher Fettig, Mark Finney, Chad Hoffman, Eric Knapp, Malcolm North, Hugh Safford, and Rebecca Wayman. (2018). "Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire." *BioScience* 68, no. 2 (Feb. 2018): 77–88.

764. Stiglitz, Joseph, Amartya Sen, Jean-Paul Fitoussi. *Report by the Commission on the Measurement of Economic Performance and Social Progress*. 2009.

765. Stockholm Environment Institute (website).

766. Strandell, Helene, and Pascal Wolff, eds. Key Figures on Europe: 2017 Edition. Eurostat. European Union, 2017.

767. Streams, Kimber. "How to Get Your Broken Stuff Fixed for Free." *Wirecutter* Blog, *New York Times*. 21 Apr. 2023.

768. Student Conservation Association (SCA). "Urban Green." 2023.

769. Su, Guohuan, Maxime Logez, Jun Xu, Shengli Tao, Sebastien Villeger, and Sebastien Brosse. "Human Impacts on Global Freshwater Fish Biodiversity." *Science* 371, no. 6531 (19 Feb. 2021): 835–838.

770. Sun, Jian, Yi Wang, Shilong Piao, Miao Liu, Guodong Han, Junran Li, Eryuan Liang et al. "Toward a Sustainable Grassland Ecosystem Worldwide." *Innovation* 3, no. 4 (May 2022).

771. Sun, Zhongxiao, Paul Behrens, Arnold Tukker, Martin Bruckner, and Laura Scherer. "Global Human Consumption Threatens Key Biodiversity Areas." *Environmental Science & Technology* 56 (May 2022): 9003–9014.

772. Surfers Against Sewage. "Get Learning."

773. Suski, Pauline, Alexandra Palzkill, and Melanie Speck. "Sufficiency in Social Practices: An Underestimated Potential for the Transformation to a Circular Economy." *Frontiers in Sustainability* 3 (4 Jan. 2023).

774. Sustainable Hospitality Alliance. *Global Hotel Decarbonisation Report.* Nov. 2017.

775. Sustainable Travel International. "Carbon Footprint of Tourism." Offset.

776. Sustainable Web Design. "*Calculating Digital Emissions.*" Last updated 17 Apr. 2022.

777. Sweet, William V., Benjamin D. Hamlington, Robert E. Kopp, Christopher P. Weaver, Patrick L. Barnard, David Bekaert, William Brooks et al. *2022 Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines.* NOAA Technical Report NOS 01. Silver Spring, MD: National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, Feb. 2022.

778. Swim, Janet, Susan Clayton, and George Howard. "Human Behavioral Contributions to Climate Change: Psychological and Contextual Drivers." *American Psychologist* 66, no. 4 (2011): 251–261.

779. Swinton, Jonathan, and Whitney Gomez. "Platanista Gangetica, Ganges River Dolphin; Susu." Animal Diversity Web.

780. Sydney Business Insights. "Richard H. Thaler on Nudges and Choice Architecture." *Sydney Business Insights*YouTube channel. 15 Oct. 2021.

781. SYSTEMIQ. "Introducing the Global Commons Stewardship Framework." SYSTEMIQ Earth, 19 May 2022.

782. Takemura, Alison F. "What is Community Solar? And How Can You Sign Up?" *Canary Media*, 8 July 2022.

783. Tao, Y., L. Yang, S. Jaffe, and F. You. "Climate Mitigation Potentials of Teleworking Are Sensitive to Changes in Lifestyle and Workplace Rather Than ICT Usage." *Proceedings of the National Academy of Sciences (PNAS)* 120, no. 39 (18 Sept. 2023).

784. Task Force on Climate-related Financial Disclosures (TCFD).

785. Taylor Wesselink, Keisha. "Interdisciplinary and Transdisciplinary—Creating Maps for the Maze and Our Labyrinth." SHAPE-ID, 5 Oct. 2020.

786. Taylor Wesselink, Keisha, and Doireann Wallace. "Draft System of Preconditions for Successful Arts, Humanities and Social Sciences Integration." *SHAPE-ID*, 28 Jan. 2021.

787. Tchatchou, B., D. J. Sonwa, S. Ifo, and A. M. Tiani. 2015. Deforestation and Forest Degradation in the Congo Basin: State of Knowledge, Current Causes and Perspectives: Occasional Paper 144. Bogor, Indonesia: CIFOR, 2015.

788. Temesgen, Tatek, Thi Thuy Bui, Moonyoung Han, Teschung-il Kim, and Hyunju Park, "Micro and Nanobubble Technologies as a New Horizon for Water-Treatment Techniques: A Review." *Advances in Colloid and Interface Science* 246 (Aug. 2017).

789. Terblanché-Greeff, Aida C. "Ubuntu and Environmental Ethics: The West Can Learn from Africa When Faced with Climate Change." In *African Environmental Ethics*, edited by M. Chemhuru. *The International Library of Environmental, Agricultural and Food Ethics* 29 (2019). Springer, Cham.

790. Thompson, Phil. "Telcos Need to Cut Energy Consumption, and They Can Start with Lab Equipment." *Vanilla Plus,* 24 Feb. 2023.

791. Thünen, Johann Heinrich von. *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie (Vol. 1).* Hamburg, 1826. In: Deutsches Textarchive.

792. Tiberio, Guy. "Vehicle Information Labels: The Stickers You Need to Know!" Slide Presentation.

793. Tickner, David, Jeffrey J. Opperman, Robin Abell, Mike Acreman, Angela H. Arthington, Stuart E. Bunn, Steven J. Cooke et al. "Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan." *BioScience* 70, no. 4 (Apr. 2020): 330–342.

794. Tierney, John. "Wasted Waterfronts Why Cities Struggle to Build Along Rivers." *The Atlantic*, Oct. 2013.

795. Tilman, D. "Global Environmental Impacts of Agricultural Expansion: The Need for Sustainable and Efficient Practices." *Proceedings of the National Academy of Sciences* 96, no. 11 (May 1999): 5995–6000.

796. Toffler, Alvin. *The Third Wave*. New York: William Morrow, 1980.

797. Toffler, Alvin, and Heidi Toffler. *Creating a New Civilization: The Politics of the Third Wave*. Atlanta: Turner Publishing, 1995.

798. "Tolerance of Ambiguity." *Science Direct, 2015.*

799. TONTOTON (website).

800. Torkington, Simon. "These Innovations Are Pulling Plastic Pollution Out of Rivers to Stop It Reaching Our Ocean. Here's How." World Economic Forum, Feb. 2011.

801. Tötzer, Tanja, Sabine Sedlacek, and Markus Knoflacher. "Designing the Future—A Reflection of a Transdisciplinary Case Study in Austria." *Futures* 43, no. 8 (2011): 840–852.

802. Tsuro, Lewis. "The Impacts of Waste Dumping in Lake Malawi." *ResearchGate*, 7 May 2021.

803. UC Sustainable Agriculture Research and Education Program (US SAREP). "What is Sustainable Agriculture?" UC Agriculture and Natural Resources. Last updated 3 Aug. 2021.

804. Ullah Bhat, Sami, and Umara Qayoom. "Implications of Sewage Discharge on Freshwater Ecosystems." In *Sewage*, edited by Tao Zhang. IntechOpen, 2022.

805. u-school for Transformation by Presencing Institute. "Theory U."

806. UN. "Global Issues: Climate Change."

807. UN. "Goal 2: Zero Hunger." UN Sustainable Development Goals, The 17 Goals.

808. UN. *The 2nd World Ocean Assessment: World Ocean Assessment II*. 2 vols. New York: United Nations, 2021.

809. UN. "Trends in the Physical and Chemical State of the Ocean." Carlos Garcia-Soto, Levke Caesar, Anny Cazenave, Lijing Cheng, Alicia Cheripka, Paul Durack, Karen Evans, David Halpern, Libby Jewett, Sung Yong Kim, Guancheng Li, Ignatius Rigor, Sunke Schmidtko, Juying Wang and Tymon Zielinski, contributors. Chap. 15 in *The 2nd World Ocean Assessment: World Ocean Assessment II*, vol. II. New York: United Nations, 2021.

810. UN Climate Action. "Five Ways to Jump-Start the Renewable Energy Transition Now." May 2022.

811. UN Climate Action. "Renewables: Cheapest Form of Power." 19 July 2022.

812. UN Climate Change. "COP 28: What Was Achieved and What Happens Next?" 2023.

813. UN Climate Change. "Global Renewables and Energy Efficiency Pledge." UN COP28, UAE.

814. UN Climate Change. "The Paris Agreement."

815. UN Climate Change. *Summary of Global Climate Action at COP 28*. UNFCC, Global Climate Action, 11 Dec. 2023.

816. UN Climate Change, UNFCCC. "Payments for Environmental Services Program: Costa Rica." Climate Action, 2023 UN Global Climate Actions Awards.

817. UN *Conflict and Climate* (blog). United Nations, Climate Change. 12 July 2022.

818. UN Convention on the Law of the Sea (UNCLOS). "Outer Limit of the Territorial Sea." Art. 4.

819. UN Department of Economic and Social Affairs (UNDESA). "The 17 Goals." Sustainable Development.

820. UN Department of Economic and Social Affairs (UNDESA). "Goal 7: Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All." Sustainable Development, accessed 9 Nov. 2022.

821. UN Department of Economic and Social Affairs (UNDESA). "International Decade for Action 'Water for Life' 2005–2015."

822. UN Department of Economic and Social Affairs (UNDESA). "Transboundary Waters." International Decade for Action 'Water for Life' 2005–2015.

823. UN Development (UNDP). "Goal 6: Clean Water and Sanitation." UNEP and the Sustainable Development Goals, Why Do the Sustainable Goals Matter?

824. UN Development Programme (UNDP). "Goal 11: Sustainable Cities and Communities." The SDGs in Action.

825. UN Economic Commission for Europe. *The Human Rights to Water and Sanitation in Practice*. Publication E.20.II.E.12. 2019.

826. UN Educational, Scientific and Cultural Organization (UNESCO). *Groundwater: Making the Invisible Visible*.

827. UN Educational, Scientific and Cultural Organization (UNESCO). *Recommendation on the Ethics of Artificial Intelligence.* SHS/BIO/PI/2021.1. 2022.

828. UN Educational, Scientific and Cultural Organization (UNESCO). *State of the Ocean Report 2022: Pilot Edition*. IOC, Technical Series, 173. ICO/2022/TS/173. 2022.

829. UN Educational, Scientific and Cultural Organization (UNESCO). *UN Decade of Ocean Science for Sustainable Development, ECO Special Issue.* 2021: 15. Paris: UNESCO World Water Assessment Programme (WWAP), 2022.

830. UN Educational, Scientific and Cultural Organization (UNESCO). "Wadden Sea." World Heritage Convention.

831. UN Educational, Scientific and Cultural Organisation (UNESCO) World Water Assessment Programme. *The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible*. Paris: UNESCO World Water Assessment Programme (WWAP), 2022.

832. UN Environment Programme. "A Framework for Freshwater Ecosystem Management." 29 Nov. 2017.

833. UN Environment Programme (UNEP). "Cities and Climate Change." Resource Efficiency, What We Do, Cities.

834. UN Environment Programme (UNEP). "COP15 Ends with Landmark Biodiversity Agreement." News, Stories & Speeches, Story, Nature Action. 22 Dec. 2022.

835. UN Environment Programme (UNEP). *Ecosystem and Human Well-Being—Synthesis*. Millennium Ecosystem Assessment Report, 5 Apr. 2005.

836. UN Environment Programme (UNEP). "Goal 6: Clean Water and Sanitation." UNEP and the Sustainable Development Goals, Why Do the Sustainable Goals Matter?

837. UN Environment Programme (UNEP*). Kunming-Montreal Global Biodiversity Framework*. Convention on Biological Diversity, Conference of the Parties. CBD/COP/15/L.25 (18 Dec. 2022).

838. UN Environment Programme (UNEP). "Largest River and Wetland Restoration Initiative in History Launched at UN Water Conference." Press release. Mar. 2023.

839. UN Environment Programme (UNEP). *The Nature-Based Solutions for Climate Manifesto: Developed for the UN Climate Action Summit 2019*. 14 Aug. 2019.

840. UN Environment Programme (UNEP). "Spotlight on Climate Action." News.

841. UN Environment Programme (UNEP). "Pollution Action Note: Data You Need to Know." UNEP, Air, Pollution Action Note, 7 Sept. 2021, updated 30 Aug. 2022.

842. UN Environment Programme (UNEP) and the Food and Agriculture Organization (FAO) of the United Nations, UN Decade on Ecosystem Restoration. *Ecosystem Restoration Playbook: A Practical Guide to Healing the Planet*. Developed for World Environment Day 2021.

843. UN Food and Agriculture Organization (FAO). *Coping with Water Scarcity*. Rome: FAO, 2012.

844. UN Food and Agriculture Organization (FAO). *Evaluation of FAO'S Country Programme in Lebanon, 2016–2019.* Rome: FAO, 2020.

845. UN Food and Agriculture Organization (FAO). *International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing*. Rome: UN FAO, 2001.

846. UN Food and Agriculture Organization (FAO). *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW): Managing Systems at Risk.* Oxford and New York: FAO by Earthscan, 2011.

847. UN Food and Agriculture Organization (FAO). "The Status of Fishery Resources." The State of World Fisheries and Aquaculture 2022, Part 1, World Review.

848. UN Food and Agriculture Organization (FAO) and UN Environment Programme. *The State of the World's Forests 2020: Forests, Biodiversity and People.* Rome: FAO, 2020.

849. UN General Assembly. *Convention on the Rights of the Child*. Resolution 44/25, A/RES/44/25 (20 Nov. 1989).

850. UN General Assembly. *Declaration on the Right to Development*. Resolution 128, A/RES/41/128 (4 Dec. 1986).

851. UN General Assembly. *Declaration on the Rights of Disabled Persons.*Resolution 3447*,* A/RES/3447 (9 Dec. 1975).

852. UN General Assembly. *Report of the United Nations Conference on Environment and Development* (3–14 June 1992), Annex I: Rio Declaration on Environment and Development. A/CONF.151/26 (vol. I) (12 Aug. 1992).

853. UN General Assembly. *Universal Declaration of Human Rights*. Resolution 217 (III), A/RES/217 (111). 10 Dec. 1948.

854. UN Meetings Coverage and Press Releases. "Transboundary Water Management Cooperation Crucial for Sustainable Development, Peace, Security, Speakers Stress at Conference's Fourth Interactive Dialogue." UN 2023 Water Conference: March 2023.

855. UN News. "UN General Assembly Declares Access to Clean and Healthy Environment a Universal Human Right." United Nations, 28 July 2022, accessed 5 Sept. 2022.

856. UN Office of the High Representative for the Least Developed Countries. "About Small Island States." Landlocked Developing Countries and Small Island Developing States.

857. UN Security Council. "Climate Change 'Biggest Threat Modern Humans Have Ever Faced', World-Renowned Naturalist Tells Security Council, Calls for Greater Global Cooperation." Press release. 23 Feb. 2021.

858. UN University-Institute for Environment and Human Security (UNU-EHS). "2023 Executive Summary (website)."

859. UN Water. "Water Quality and Wastewater."

860. UN Water Decade Programme on Advocacy and Communication and Water Supply and Sanitation Collaborative Council. *The Human Right to Water and Sanitation. Media brief.*

861. UN World Tourism Organization (UNWTO). Climate Change and Tourism: Responding to Global Challenges. 2008.

862. University of Bath Center for Regenerative Design & Engineering for a Net Positive World (website).

863. University of Iowa Technology Institute. "Classical Indian Dances Could Help UI Engineering Professor Unlock Mysteries of Space and the Ocean." 24 Aug. 2022.

864. University of Missouri Center for Regenerative Agriculture (website).

865. University of Oxford. "Manure Used by Europe's First Farmers 8,000 Years Ago." *ScienceDaily,* 16 July 2013.

866. U.S. 117th Congress. *Infrastructure Investment and Jobs Act*. H.R. 3684. Public Law No: 117-58. (15 Nov. 2021).

867. U.S. Code of Federal Regulations 2022 § 301.92-2. *Restricted, Regulated, and Associated Articles; Lists of Proven Hosts and Associated Plant Taxa*. Title 7, Subtitle B, Chapter III, Part 301, Subpart X. Last amended May 2023.

868. U.S. Department of Agriculture (USDA). USDA Farm Service Agency. "Feed Grains and Oilseeds Analysis."

869. U.S. Department of Agriculture (USDA). "Guayule Go Native With This Promising Biofuel—and Biomedical—Crop." Agricultural Research, Feb. 2009.

870. U.S. Department of Agriculture (USDA). "Public Awareness Campaigns." Invasive Species Resources.

871. U.S. Department of Agriculture (USDA) National Invasive Species Information Center. "What Are Invasive Species?" About Invasive Species.

872. U.S. Department of Energy (DoE). "Declaration to Triple Nuclear Energy." Press release, 2 Dec. 2023.

873. U.S. Department of Energy (DoE). *Fuel Cells*. Energy Efficiency & Renewable Energy, Fuel Cell Technologies Office. Nov. 2015.

874. U.S. Department of Energy (DoE). "Semiconductor Supply Chain Deep Dive Assessment." 24 Feb. 2022.

875. U.S. Department of Energy (DoE). "Waste-to-Energy." Department of Energy, Office of Energy Efficiency & Renewable Energy.

876. U.S. Department of Transportation (DoT). *Putting People First: Smart Cities and Communities*. Federal Highway Administration. 9 June 2021.

877. U.S. Environmental Protection Agency (EPA). "Climate Change and Harmful Algal Blooms." Nutrient Pollution. Last updated 15 Dec. 2022.

878. U.S. Environmental Protection Agency (EPA). "Commercial Buildings." WaterFacts, WaterSense. Accessed June 2022.

879. U.S. Environmental Protection Agency (EPA). "Composting Food Waste: Keeping a Good Thing Going." Southeast New England Program, Oct. 2020.

880. U.S. Environmental Protection Agency (EPA). "Defining Hazardous Waste: Listed, Characteristic and Mixed Radiological Wastes." Hazardous Waste. Last updated 15 June 2022.

881. U.S. Environmental Protection Agency (EPA). "Frequent Questions about Landfill Gas." Landfill Methane Outreach Program (LMOP).

882. U.S. Environmental Protection Agency (EPA). "Harmful Algal Blooms." Nutrient Pollution. Last updated 25 Aug. 2022.

883. U.S. Environmental Protection Agency (EPA). "Initiatives to Create and Protect Healthy Watersheds." Healthy Watersheds Protection.

884. U.S. Environmental Protection Agency (EPA). "International E-Waste Management Network (IEMN)." International Cooperation.

885. U.S. Environmental Protection Agency (EPA). "Learn About Aquatic Trash." Trash-Free Waters. Last updated 31 Oct. 2022.

886. U.S. Environmental Protection Agency (EPA). "Smart Growth and Water." Smart Growth. Last updated 28 June 2022.

887. U.S. Environmental Protection Agency (EPA). "The Sources and Solutions: Agriculture." Nutrient Pollution. Last updated 28 Oct. 2022.

888. U.S. Environmental Protection Agency (EPA). "Statistics and Facts: Why Save Water?" WaterSense. Last updated 24 April 2023.

889. U.S. Environmental Protection Agency (EPA). "Sustaining Healthy Freshwater Ecosystems." Watershed Academy. Last updated 7 Mar. 2023.

890. U.S. Environmental Protection Agency (EPA). "Water Sense for Kids." WaterFacts, WaterSense. Accessed Mar. 2022.

891. U.S. Environmental Protection Agency (EPA). "Water Quality Trading." National Pollutant Discharge Elimination Systems (NPDES). Last updated 14 Dec. 2022.

892. U.S. Environmental Protection Agency (EPA). "Wetlands—Status and Trends." Water, Our Water, Wetlands.

893. U.S. Environmental Protection Agency (EPA). "What is a Circular Economy?" Circular Economy. Last updated 29 Sep. 2022.

894. U.S. Environmental Protection Agency (EPA). "Why Urban Waters?" Urban Waters Partnership. Last updated 10 June 2022.

895. U.S. Fish and Wildlife Service, National Wildlife Refuge System. *Climate Change Communications and Engagement Strategy for the National Wildlife Refuge System.* Feb. 2014.

896. U.S. Geological Survey (USGS). "Evaluating the Potential Benefits of Permeable Pavement on the Quantity and Quality of Stormwater Runoff." Upper Midwest Water Science Center. Mar. 2019.

897. U.S. Geological Survey (USGS). "The Potential for Geologic Hydrogen for Next-Generation Energy." 13 Apr. 2023.

898. *U.S. Global Leadership Coalition* (blog). "Climate Change and the Developing World: A Disproportionate Impact." Mar. 2021.

899. U.S. Securities & Exchange Commission. "SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors." Press release. 21 Mar. 2022.

900. U.S. Senate Bill S.1251. *Growing Climate Solutions Act*.

901. U.S. Tape & Label (USTL). "The Complete Guide to Automotive Labels."

902. U.S. Water Alliance (website).

903. "Using Transparency to Drive Progress on Responsible Ship Recycling." Ship Recycling Transparency Initiative.

904. Valentine, Katie. "NOAA Collects a Lot of Data on the Ocean. Here Are 4 Ways We Use It." *NOAA Research News.* 8 June 2020.

905. Vallance, Patrick. "We've Overexploited the Planet, Now We Need to Change if We're to Survive." *The Guardian*, 8 Jul. 2022.

906. van den Homberg, Marc, and Colin McQuistan. "Technology for Climate Justice: A Reporting Framework for Loss and Damage as Part of Key Global Agreements," chap. 22 in *Loss and Damage from Climate Change: Concepts, Methods and Policy Options.* Edited by Reinhard Mechler, Laurens M. Bouwer, Thomas Schinko, Swenja Surminski, and JoAnne Linnerooth-Bayer. *Climate Risk Management, Policy and Governance* book series. Springer Open: 29 Nov. 2018.

907. Van de Ven, A. H., and M. S. Poole. "Alternative Approaches for Studying Organizational Change." *Organization Studies* 26, no. 9 (2005).

908. Vanek Smith, Stacey. "The Twisty Logic Of The Drought: Grow Thirsty Crops To Dig Deeper Wells." *NPR All Things Considered*, 6 Aug. 2015.

909. Vaughan, Adam. "Amazon Rainforest Nears Tipping Point That May See It Become Savannah." *New Scientist*, 7 Mar. 2022.

910. Vaughan, Adam. "Forests Are Becoming Less Resilient Because of Climate Change." *New Scientist*, 13 July 2022.

911. Verdecchia, Roberto, Patricia Lago, and Carol de Vries. "The Future of Sustainable Digital Infrastructures: A Landscape of Solutions, Adoption Factors, Impediments, Open Problems, and Scenarios." *Sustainable Computing Informatics and Systems* 35 (2022).

912. Visram, Talib. "Low-Income Neighborhoods Have Fewer Trees. Here's Why That's a Problem." *Fast Company*, 22 June 2021.

913. Vyawahare, Malavika. "Tree-Planting Programs Turn to Tech Solutions to Track Effectiveness." *Mongabay*, 22 Nov. 2019.

914. Wada, Y., M. Flörke, N. Hanasaki, S. Eisner, G. Fischer, S. Tramberend, Y. Satoh, M. T. H. van Vliet, P. Yillia, C. Ringler, P. Burek, and D. Wiberg. "Modeling Global Water Use for the 21st Century: The Water Futures and Solutions (WFaS) Initiative and Its Approaches." *Geoscientific Model Development* 9 (2016): 175–222.

915. Wahl, Daniel Christian. "Salutogenic Cities & Bioregional Regeneration (Part I of II)." Medium, *Age of Awareness*, 20 Mar. 2020.

916. Wästfelt A., and Q. Zhang. "Reclaiming Localisation for Revitalising Agriculture: A Case Study of Peri-Urban Agricultural Change in Gothenburg, Sweden." *Journal of Rural Studies* 47, no. A (Oct. 2016): 172-185.

917. Water Detective. "How Can a River Clean Itself?"

918. Water Education Foundation. *WOW! The Wonders of Wetlands: An Educator's Guide.* The Watercourse.

919. Water Encyclopedia. "Pollution of Lakes and Streams."

920. Water Environment Foundation (WEF). "Stop, Don't Flush That." WEF Highlights, 12 June 2013.

921. Water Science School. "Total Water Use in the United States." USGS, US Department of the Interior. 8 June 2018.

922. Water Science School. "Trends in Water Usage in the United States, 1950 to 2015." USGS, US Department of the Interior. 18 June 2018.

923. Weber, M. J., M. J. Hennen, M. L. Brown, D. O. Lucchesi, and T. R. S. Sauver. "Compensatory Response of Invasive Common Carp Cyprinus carpio to Harvest, Fisheries Research." 10 Mar. 2016.

924. Weder, Franzisca, Amornpan Tungarat, and Stella Lemke. "Sustainability as Cognitive "Friction": A Narrative Approach to Understand the Moral Dissonance of Sustainability and Harmonization Strategies." *Frontiers in Communication* 5 (Feb. 2020).

925. Weaver, John Fitzgerald. "LA Could Soon Be Home to the Nation's Largest Green Hydrogen Infrastructure System." *PV Magazine*, 17 Feb. 2022.

926. Webuild with Triennale Milano. *Exhibition: Building the Future Infrastructure and Benefits for People and Territories*. Fondazione La Triennale di Milano, 3–26 Mar. 2023.

927. WeConservePA. "Economic Benefits of Smart Growth and Costs of Sprawl." Apr. 2012.

928. Wekinator (website).

929. Welch, J. "Visioning Strategy Through the "Johari Window": Discovering Critical "Unknowns" in a Rapidly Evolving Context." *Strategy & Leadership* 51, no. 5 (2023): 30–35.

930. Wellbeing Economy Alliance (website).

931. Wempen, Kristi. "Are You Getting Too Much Protein?" *Speaking of Health,* Mayo Clinic Health System, 29 Apr. 2022.

932. Wenger-Trayner, Etienne, and Beverly Wenger-Trayner. *Learning to Make a Difference: Value Creation in Social Learning Spaces*. Cambridge University Press, 2020.

933. Werrell, Caitlin, and Francesco Femia. "Climate Change Raises Conflict Concerns." *The UNESCO Courier*, 2018-2, e-ISSN 2220-2293.

934. Westerkamp, Hildergard. "Soundwalking as Ecological Practice." In *The West Meets the East in Acoustic Ecology. Proceedings for the International Conference on Acoustic Ecology*. Hirosaki, Japan: Hirosaki University, 2–4 Nov. 2006.

935. "What is 'Double Materiality' and Why Should You Consider It?" *Greenstone, A Cority Company* (blog), 25 Aug. 2021.

936. "What is the Seventh Generation Principle?" *Indigenous Corporate Training Inc.* (blog). Working Effectively with Indigenous Peoples, 30 May 2020.

937. Wheeler, Sarah Ann. "Assessing Water Markets around the World." Global Water Forum, Nov. 2021.

938. Wheeler, Sarah Ann, Adam Loch, Lin Crase, Mike Young, and R. Quentin Grafton. "Developing a Water Market Readiness Assessment Framework." *Journal of Hydrology* 552 (Sept. 2017): 807–820.

939. "When it Comes to Protein, How Much is Too much?" *Harvard Health Publishing*, Harvard Medical School, 30 Mar. 2020.Wise, Lindsay. "5 Reasons Farmers Grow Thirsty Crops in Dry Climates." *Austin American-Statesman*, 23 Sept. 2016. Last updated 25 Sept. 2018.

940. The White House. "Biden-Harris Administration Announces Plan to Maximize Purchases of Sustainable Products and Services as Part of the President's Investing in America Agenda." Press release. 1 Aug. 2023.

941. The White House. *National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics.* Office of Science and Technology Policy, Office of Management and Budget, Department of Commerce. Jan. 2023.

942. White, Tom. "Perception Engines." Medium, Artists + Machine Intelligence, 4 Apr. 2018.

943. Whiting, Kate. "6 Charts that Show the State of Biodiversity and Nature Loss—And How We Can Go 'Nature Positive'." World Economic Forum, 17 Oct. 2022.

944. William McDonough (website).

945. Wikipedia, s. v. "Alexandria Ocasio-Cortez." Last updated 5 May 2023.

946. Wikipedia, s. v. "Amager Bakke." Last updated 2 May 2023.

947. Wikipedia, s. v. "Animal Rights." Last modified 17 Apr. 2023.

948. Wikipedia, s. v. "Bauhaus." Last modified 30 Apr. 2023.

949. Wikipedia, s.v. "Choristoneura fumiferana."

950. Wikipedia s. v. "Elizabeth May." Last updated 28 Apr. 2023.

951. Wikipedia, s. v. "List of Climate Action Change iInitiatives."

952. Wikipedia, s. v. "Serious Game."

953. Wikipedia, s. v. "Stable Diffusion." Last updated 4 May 2023.

954. Wikipedia, s. v. "Trolley Problem." Last modified 25 Apr. 2023.

955. Wikipedia, s. v. "The Yes Men." Last updated 17 Mar. 2023.

956. Willett, Walter, Johan Rockström, Brent Loken, Marco Springmann, Tim Lang, Sonja Vermeulen, Tara Garnett et al. "Food in the Anthropocene: The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems." *The Lancet* 393, no. 10170 (2 Feb. 2019): 447–492.

957. Wise, Lindsay. "5 Reasons Farmers Grow Thirsty Crops in Dry Climates," Austin American-Statesman, 23 Sept. 2016. Last updated 25 Sept 1018.

958. Wittmann, Marion E., Sudeep Chandra, Kim Boyd, and Christopher L. Jerde. "Implementing Invasive Species Control: A Case Study of Multi-Jurisdictional Coordination at Lake Tahoe, USA." *Management of Biological Invasions* 6, no. 4 (Oct. 2015): 319–328.

959. "WMO Executive Council Endorses Global Greenhouse Gas Monitoring Plan." World Meteorological Organization, 6 Mar. 2023.

960. Woods Hole Oceanographic Institution. "Data & Repositories."

961. The World Bank. "How Eight Cities Succeeded in Rejuvenating Their Urban Land." Press release. 13 July 2016.

962. The World Bank. "Nearly 2.4 Billion Women Globally Don't Have Same Economic Rights as Men." Press release no. 2022/047/DEC. 1 Mar. 2022.

963. The World Bank. "Social Dimensions of Climate Change." Last updated 1 Apr. 2023.

964. World Bank Group. "Climate-Smart Agriculture." Understanding Poverty, Topics. Last updated 26 Feb. 2024.

965. World Business Council for Sustainable Development. "Sustainable Protein." Food & Nature, Food and Agriculture, Healthy & Sustainable Diets.

966. World Climate Tech Summit (website).

967. World Economic Forum. "First Movers Coalition." Accessed 12 Mar. 2023.

968. World Meteorological Organization (WMO). "The State of Greenhouse Gases in the Atmosphere Based on Global Observations Through 2020." *WMO Greenhouse Gas Bulletin*, no. 17 (Oct. 2021).

969. The World Soundscape Project (website).

970. World Travel & Tourism Council. "Economic Impact Research." Research.

971. World Wildlife Fund (WWF). *Gârla Mare: New Perspectives for the Danube River Floodplain Resilience and Livelihoods*. Fact sheet, Sept. 2010.

972. World Wildlife Fund (WWF). *Living Planet Report 2024 A System in Peril*. Gland, Switzerland, 2024.

973. Wouters, Patricia. "International Law—Facilitating Transboundary Water Cooperation." Global Water Partnership Technical Committee, *TEC Background Papers* 17 (2013).

974. Yang, Feikai, Dafang Fu, Chris Zevenbergen, and Eldon R. Rene. "A Comprehensive Review on the Long-Term Performance of Stormwater Biofiltration Systems (SBS): Operational Challenges and Future Directions." *Journal of Environmental Management* 302, pt. A (Jan. 2022).

975. Yao, Ling, Tang Liu, Jun Qin, Ning Lu, and Chengdu Zhou. "Tree Counting with High Spatial-Resolution Satellite Imagery Based on Deep Neural Networks." *Ecological Indicators* 125 (June 2021).

976. Yazzie, S. *Yuméweuš*. Yazzie Studios. 2022.

977. Yeung, Peter. "The Toxic Effects of Electronic Waste in Accra, Ghana." Bloomberg CityLab, 29 May 2019.

978. Young, Richael. "Trading Water, Saving Water." *PERC*. 19 July 2021.

979. Zamarelli, Dan. "Sustainable Farming in Developing Countries." *The Borgen Project* (blog), 29 Mar. 2020.

980. Zero Cool [pseud.], "Oil is the New Data," *Nature,* no. 9 (7 Dec. 2019).

981. Zingale, Nicolas, Julieta. Matos-Castaño, Abigail. Poeske, and Anouk. Geenen. "Transdisciplinarity and the Future: Conversations between Cleveland State University and University of Twente." *Change Forward: Visions and Voices of Higher Education's Future 2021–2022.* University Innovation Fellows, 28 Oct. 2022.

982. Žižek, Simona Šarotar, Matjaž Mulej, and Amna Potočnik. “The Sustainable Socially Responsible Society: Well-Being Society 6.0.” *Sustainability* 13, no. 16 (Aug. 2021): 9186.

983. ZoBell, Vanessa M. et al. “Underwater Noise Mitigation in the Santa Barbara Channel through Incentive-Based Vessel Speed Reduction.” *Scientific Reports* 11, no. 18391 (Sept. 2021).

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Phone: +1 732 981 0060
445 Hoes Lane, Piscataway, NJ 08854 USA