IEEE SA STANDARDS ASSOCIATION

IEEE planet positive 2030

Strong Sustainability by Design

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

TOWNS AND CITIES

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.

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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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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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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[1] 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

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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[2]. 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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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[3] 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[4] 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.

[3] 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.

[4] 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. **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[5].
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).[6]
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).

[5] 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.

[6] 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 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[7].

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

[7] 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

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