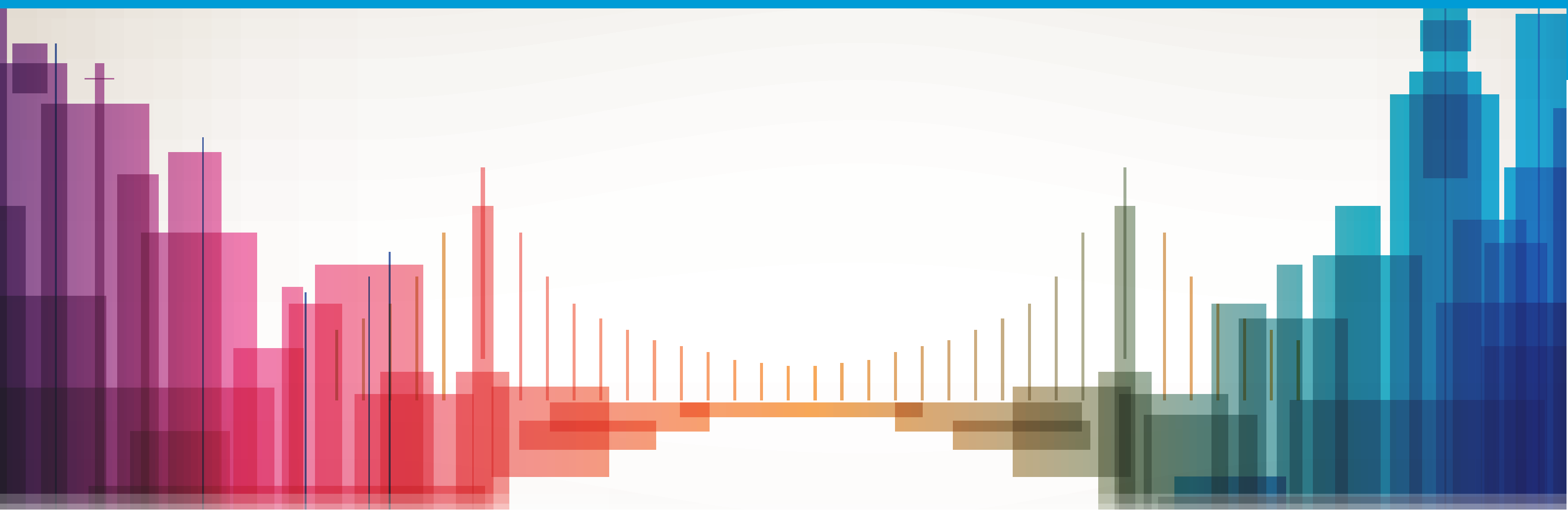
Guidelines for cities to achieve carbon Net Zero through digital transformation

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Foreword

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Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations or U4SSC members. In line with the U4SSC principles, this report does not promote the adoption and use of Smart City technology. It advocates for policies encouraging responsible use of information and communications technologies (ICTs) that contribute to the economic, environmental and social sustainability as well as the advancement of the 2030 Agenda for Sustainable Development.

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CIRCULAR ECONOMY

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Abbreviations and acronyms

Abbreviation	Full Form
BEVs	Battery electric vehicles
CO_2	Carbon dioxide
EU	European union
EV	Electric vehicles
FCHEVs	Fuel cell electric vehicles
HEVs	Hybrid electric vehicles
ICEs	Internal combustion engines
ICT	Information and communication technologies
MaaS	Mobility as a service
ZEB	Zero Energy Building

Executive summary

The objective of these Guidelines is to provide practical guidance on city digital transformation to achieve carbon Net Zero. These guidelines illustrate actionable recommendations to reduce their carbon footprint through the use of digital technologies.

These Guidelines build on the publication titled "*Methodology to assess Net Zero progress in cities*", which was also developed within the United for Smart Sustainable Cities Initiative (U4SSC).

While the methodology provided a thorough and valuable review of the current state of knowledge on Net Zero cities and potential areas for innovation, the Guidelines, through its case studies, demonstrate how cities are approaching their journey to achieve Net Zero.

The case studies from diverse geographical regions demonstrate the use of various digital technologies in key areas such as smart transportation, EV sharing, smart lighting, e-governance, smart waste management and recycling and more.

The Guidelines also provide concrete steps for cities to establish carbon neutrality and achieve a successful digital transformation. The Guidelines also put emphasis on the need for digital technologies to enhance efficiency in several areas including leveraging green ICTs for city economic growth and also transforming citizen behaviour.

Overall, the Guidelines for City Digital Transformation to Achieve Carbon Net Zero is a valuable resource for policymakers, city planners and other city stakeholders seeking to leverage digital technologies to reduce greenhouse gas emissions and achieve a Net Zero future.

1 Introduction

As cities face the pressing challenges of climate change and the need for sustainable development, digital transformation has emerged as a powerful tool to achieve carbon Net Zero and create people-centred urban environments. The integration between information and communication technologies (ICTs) and digital technologies into city systems holds significant potential to optimize resource management, reduce carbon emissions and enhance the quality of life of inhabitants. These Guidelines have been developed to support cities by exploring the pivotal role of ICTs and digital technologies in achieving Net Zero carbon emissions.

Cities can harness the power of digital transformation through the strategic integration of ICTs and digital technologies into various urban sectors including energy, transportation and buildings to name a few. By leveraging innovative solutions, cities can effectively address sustainability challenges and achieve Net Zero carbon. These Guidelines will provide actionable solutions to support cities in their journey towards Net Zero carbon, offering real-life case studies and insights into how ICTs and digital technologies can drive change.

The following sections of these Guidelines will delve into the multifaceted aspects of city digital transformation and its potential to achieve Net Zero carbon. It will build on the U4SSC deliverable titled "*Methodology to assess Net Zero progress in cities*".

By understanding the transformative power of ICTs and digital technologies, city leaders, policymakers and stakeholders can chart a path towards Net Zero emissions that also puts people at the centre.

2 Digital transformation for reaching carbon Net Zero in cities

As city populations grow, so the demand for services and the pressure on resources increase. This demand puts a strain on energy, water, and mobility services, all of which are fundamental to a city's prosperity and sustainability. Simultaneously, cities are incurring a digital transition process that needs to be implemented appropriately. As a result, it is evident that making our cities climate neutral and smart is an absolute necessity for achieving a twin green and digital transformation.

In today's ever-evolving digital technology landscape, a wealth of data on energy consumption, water consumption, geospatial information, and traffic patterns is constantly being generated. These data sources can offer cities the potential to make smarter, more sustainable and better-informed decision making. Cities can build robust data ecosystems that enable the collection, analysis and utilization of data for carbon-neutral and smart communities. By leveraging data from various sources, including climate sensors, weather forecasts and citizen feedback, cities can develop climate impact models to better understand and mitigate the effects of disruptive weather patterns and phenomena. These models can inform decision-making processes, enabling optimal mitigation and adaptation strategies to combat climate change and emergency management. By integrating digital technologies, cities can be optimized for greater efficiency and support the transition to carbon Net Zero.

The digital solutions available today can wield considerable advantages in urban areas. In the context of achieving carbon Net Zero and creating people-centred cities, city digital transformation plays a vital role. It enables cities to leverage technology to address pressing environmental challenges and optimize resource management. By embracing digital transformation, cities can unlock new opportunities for sustainability, innovation, and citizen engagement. ICT-based solutions could reduce commuting by 15–20 per cent and cut greenhouse gas emissions by 10–15 per cent, while urban digital twins could significantly improve a city's ability to simulate or model policy outcomes. An increasing amount of data is also being collected by various ICT and social media technologies that could support the cities and communities' transformation.

To accelerate the move towards carbon Net Zero cities, the following opportunities have been identified:

Figure 1: Opportunities

ICT to enhance city service efficiency:

ICTs can play a crucial role in optimizing energy, water and mobility services to improve a city's efficiency and contribute to its sustainability. For example, smart grids can enable real-time monitoring and management of energy consumption, allowing for better resource allocation and reducing wastage. Intelligent water-management systems can detect leaks and optimize water distribution, minimizing water waste. Additionally, the implementation of intelligent transportation systems such as traffic management solutions and ride-sharing platforms can help reduce commuting distances and promote sustainable mobility options, leading to a decrease in carbon emissions.

ICT to enhance buildings' efficiency:

The building sector, with a 39 per cent global GHG emissions' ratio, occupies a forefront position in the global GHG reduction strategies. Since 2015, in several countries, building regulations and certification systems for sustainable constructions have adopted stricter baseline energy and GHG emissions standards to make the construction sector more sustainable (Amoruso *et al*., 2022).

Digital technologies can be leveraged to enhance the energy efficiency of buildings, which account for a significant portion of carbon emissions in cities. Building automation systems, IoT-enabled sensors, and advanced energy management systems can optimize energy consumption, monitor indoor environmental conditions, and enable intelligent control of heating, cooling, and lighting systems. By utilizing ICTs to enhance buildings' features and operations, cities can move closer to achieving carbon neutrality.

Green ICT for city economic growth:

Green ICT initiatives focus on leveraging ICTs to promote sustainability, connectivity infrastructure, citizen empowerment, and addressing carbon behavioralbehavioural change. For instance, cities can invest in the development of low-carbon or zero-carbon electric grids powered by renewable energy sources, facilitating the transition to clean energy. The application of artificial intelligence (AI) and robotics in waste management can enable automated disassembly and separation of waste, improving recycling rates and reducing landfill contributions. By embracing green ICT solutions, cities can foster economic growth while simultaneously reducing their carbon footprint.

ICT to transform citizen behaviour:

Scientists are more certain than ever that people's actions play a pivotal role in environmental change. Lifestyle changes are needed to minimize the impacts of current environmental problems. People's individual actions can make a significant contribution. Urging people to adopt a more sustainable behaviour can be an integral part of the solution to environmental challenges (Abrahamse, 2019).

ICTs offer opportunities to transform citizen behaviour towards carbon neutrality through the provision of smart services and applications. For example, mobile applications can provide real-time information on sustainable transportation options, energy-efficient practices, and eco-friendly consumption habits. Additionally, cities can implement training programmes and awareness campaigns to educate and empower citizens to adopt sustainable behaviors, such as reducing energy consumption, practicing waste recycling, and utilizing public transportation.

3 Guidelines for cities to achieve carbon Net Zero through digital transformation

As we confront the urgent global challenge of climate change, cities stand at the forefront of sustainable transformation. To achieve carbon Net Zero and secure a greener future, cities must embrace digital solutions and smart practices. This framework outlines key measures, capabilities, and policies that cities can adopt to drive digital transformation and promote environment-friendly behaviours. By harnessing information and communication technologies, integrating renewable energy, optimizing mobility, and fostering circular economy practices, cities can pave the way towards a carbon-neutral pathway. Strengthening collaboration between local, regional, and national governments is crucial in realizing a shared vision of a sustainable, smart and resilient future for all.

1. Embrace Digital Transformation:

   a) Develop a Comprehensive Digital Strategy. Ensure that digital transformation aligns with urban planning, infrastructure and sustainability goals. Adopt International Standards and Interoperability to ensure that all digital systems and platforms can seamlessly integrate and scale over time. Establish clear policies, Key Performance Indicators (KPIs) and service level agreements (SLAs) for digital initiatives focused on carbon reduction. Institute ex ante and ex post impact assessments for digital transformation initiatives with a perspective on carbon emissions.

   b) Establish interoperable platforms and mechanisms for data sharing to enable cross-domain data management.

   c) Preserve security, flexibility, data, and technological sovereignty during city custom digital transformation.

   d) Digitalize Urban Operations including smart water, waste and energy management systems. Use digital twin technology to simulate and optimize city-wide systems for efficiency. Deploy sensors to monitor air quality, water usage and waste, so providing actionable insights. Shift to energy-efficient LED lighting integrated with motion sensors and remote controls.

2. ICT for Energy Efficiency and Carbon Neutrality:

   a) Integrate information and communication technologies (ICT) to achieve zero emissions in energy consumption.

   b) Optimize Energy and Resource Use with the ICT. Integrate renewable energy sources (solar, wind) with IoT-enabled smart grids. Use AI to optimize energy consumption across residential, commercial and public sectors. Implement smart building systems to monitor and reduce energy use with the application of green building standards (e.g., LEED certification).

   c) Promote recycling, re-use and resource optimization through digital tracking and incentives.

d) Integrate Carbon Management Digital Tools to track and report emissions across all city sectors. Partner with digital platforms to invest in verified carbon offset projects. Automate the collection and analysis of emissions data for better decision-making.

3. Harness Renewable Energy Sources:

   a) Deploy renewable energy sources in conjunction with ICT networks to power the city sustainably.

4. Promote Efficient Mobility:

   a) Utilize ICT to optimize mobility, including active mobility, micromobility, electric vehicles (EVs), and EV sharing.

   b) Implement smart multimodal solutions such as Mobility as a Service (MaaS) and automation.

5. Adopt Circular Economy Practices:

   a) Utilize ICT to integrate circular economy principles, creating a closed-loop system that minimizes resource inputs, waste, pollution, and carbon emissions.

6. Encourage Carbon-Related Behavioural Change:

   a) Leverage ICT-based economic growth to promote upskilling and behavioural changes that reduce carbon impact.

   b) Engage Communities and Businesses with mobile apps and digital tools to educate citizens about carbon neutrality efforts and gather feedback. Incentivize sustainable behaviours through gamification and rewards (e.g., reduced taxes or discounts). Encourage local businesses to adopt sustainable practices through shared digital resources such as carbon tracking software.

7. Assure City-Level Capabilities/Competences:

   a) Organizational capabilities: Establish connections with regional and national governments, implement initiatives, and gain political support.

   b) Technical capabilities: Develop capacity, experiment, advise, manage finances, and oversee projects.

   c) Design and monitoring capabilities: Implement strategic and evolutionary evaluation, design initiatives, and monitor key performance indicators (KPIs).

   d) Foster Digital Innovation and R&D with innovation centres to incubate technologies aimed at sustainability. Create virtual replicas of city infrastructure to test carbon reduction scenarios and optimize designs. Collaborate with startups focusing on AI, IoT, and blockchain solutions for sustainability.

8. Promote Environment-Friendly Behaviour:

    a) Encourage behavioural change through:

        1) Climate communication campaigns that address individuals as members of a local community.

        2) Designing interventions that consider psychological and social constraints to positive action.

        3) Fostering socially desirable outcomes by shaping social norms.

9. Coordinated Efforts and Inclusive Policies:

    a) Cities should incentivize and accelerate digital transformation and carbon neutrality initiatives.

    b) National policy makers should design inclusive policies and programmes, with people at their core.

    c) Capacity-building across digitalization and energy sectors is essential.

    d) Ensure timely, robust and transparent access to data.

    e) Promote financial innovation and provide access to finance.

    f) Encourage the development and adoption of international standards and benchmarks.

    g) Facilitate opportunities for sharing and learning among cities.

    h) Implement Regulatory and Incentive Mechanisms to enforce building codes, emissions standards, and renewable energy mandates using digital platforms. Use digital payment systems to manage subsidies and incentives for renewable energy adoption, electric vehicles (EVs), and green buildings. Use blockchain for tamper-proof environmental reporting and compliance

10. Strengthen Cooperation Across Government Levels:

    a) Foster collaboration between local, regional, and national governments to advance equitable energy transitions and achieve shared Net Zero objectives.

    b) Monitor Progress and Scale with digital dashboards to visualize energy savings, emissions reductions, and other KPIs. Use AI and predictive analytics to identify areas for improvement. Ensure that all systems are scalable to accommodate city growth and evolving carbon neutrality goals.

    c) Collaborate with foreign governments and international standards development organizations (SDOs) to monitor advances in sustainable and Net Zero technologies and evolving standards

By implementing these guidelines, cities can play a pivotal role in combating climate change, advancing sustainability, and realizing a carbon Net Zero future.

4 Use cases

In the following subsections, several cases from around the world are analysed (Seto *et al*., 2021) and explained their contribution and alignment to the city Net Zero framework.

City services, transportation and mobility

Micromobility and Alternative E-transit

Micromobility is a widely used term for low-speed modes of transport based on the use of electricity. They are usually personal microvehicles such as e-scooters. Nevertheless, the types of vehicle that are included in the term micromobility differ from country to country. For example, e-bikes are included in this definition in the United States of America (USA) but in Italy, micromobility usually refers to small electric devices, thus excluding e-bikes. The use of this type of vehicle, mainly for short distances, is fostered via new shared mobility services such as bike sharing or e-scooter sharing (Fazio *et al*., 2021).

Micromobility as a general transportation mode presents differences such as availability and usage in each region, country, and even city. In Asia, for instance, e-mopeds are quite popular, as are e-scooters in Europe and the US. In Europe, traditional bikes and e-bikes are quite common. In the US, traditional bikes have started to be used again, as e-bikes gain in popularity. Not surprisingly, given its long history, the bike remains, by far, the dominant mode of transport among city residents. In China, its use is eclipsed only by the e-moped. The Netherlands, Denmark and Germany are leaders in bike use. In Barcelona, micromobility is combined with urban design innovations (like Superblocks) where cars are restricted, which reduce nitrogen dioxide levels by 25 per cent in these areas. In overall micromobility use, city dwellers in China use all modes more often than people in any other country. France leads the European countries in e-scooter use. (Lang *et al*., 2022).

Figure 2: E-Scooters in China

Source: Adobe Images

An e-bike typically "resembles a standard pedal bicycle with the addition of a rechargeable battery and electric motor to assist with propulsion. By providing electric power assistance, e-bikes expand the potential role of the bicycle – especially for commuting and errands – by addressing the limits of trip distance and terrain. E-bikes are used by various individuals to bike farther and to overcome barriers to biking such as trip length, cargo weight, and physical limitations. People are using their e-bikes mainly to commute to work or school and then for local trips" (MacArthur *et al*., 2014).

EV sharing

The EV sharing model is a new transportation mode that characterizes the separation of ownership and use. Its presence not only lowers the use of EVs but also introduces a series of external benefits such as environmental and public infrastructure benefits. Currently, there are two categories of sharing EV: *ride-sourcing EV* and *self-service EV*. Ride-sourcing EV mode is a reformed model of traditional taxi services, while self-service EVs depend more on the rental spots located all over a city, where users should pick up and drop off (park) EVs at specific parking locations. "According to the statistics of the International Energy Agency (IEA), in 2016, China's carbon dioxide emissions in the field of transportation account for 92.1 per cent of total emissions, while private cars account for more than half (Wu *et al*., 2016)". To face this challenge, Chinese authorities have issued a set of regulations that include restrictions on purchasing or driving internal combustion vehicles (ICVs), as well as providing grants to some types of EV. Since 2016, an innovative transportation business model (i.e., sharing EV model) showed up and presents a good developing tendency in China. In the case of Chongqing City (China), the biggest benefits come from the road investment savings, and the saving of parking places. As to the benefits of emissions reduction, the biggest comes from the emission reduction of carbon dioxide (Lefeng *et al*., 2020).

EV sharing has become a developing tendency of car-sharing, and there are many car-sharing operators around the world that have deployed EVs; for example, in France, in Germany, in the USA, and in China (Ren *et al*., 2020). Micromobility devices (including motor scooters, powered two-wheelers, motorcycles, mopeds, bicycles, e-bikes, pedal-assisted bicycles, speed-pedelecs, mobility scooters, standing scooters, and e-scooters) are also available for sharing. "Following 2010, numerous urban regions implemented shared micromobility, utilizing widely available Internet-enabled smartphones or other mobile devices, hastening the proliferation of micromobility devices. Since 2017, China has had the largest micromobility platform. In Japan, a similar robust industry for bike-sharing has developed over the last decade. Since 1980, India has seen a rising number of fatalities caused by motorized two-wheelers, along with the rapid growth of registered two-wheelers" (Zhao *et al*., 2022).

Figure 3: Bollore's Bluecar EVs are pictured using the company's road-side charging stations in Paris

Source: Automotive News Europe

Electric cars and buses

Electric cars are classified in three main categories, namely battery electric vehicles (BEVs), fuel cell hybrid electric vehicles (FCHEVs) and hybrid electric vehicles (HEVs). Vehicle emission problems can be solved using two approaches. The first method is to change the fuel type used (which can be addressed either by increasing the quality of conventional fuel or by using alternative fuel systems). The second method concerns the engine technology (which involves the reduction of in-use vehicle emissions and the new vehicles' emissions standards). Simultaneously, the transport sector can have a positive effect on the reduction of excess fuel consumption. Electric Vehicles (EV) are probably the best choice for reducing emissions from the transport sector (Wilberforce *et al*., 2017). To urge people to use EVs, many countries have implemented preferential policies. EV owners benefit from tax breaks, as well as from reduced insurance premiums, highway tolls and parking fees. The maximum subsidy could be increased to 50 per cent for EVs in Japan, while Korea (Republic of) communicated plans to increase EV market share by improving battery capacity and establishing charging stations in July 2016. Germany, since 2016, has applied a series of measures such as exempting EVs from annual sales tax for 10 years and introducing a direct subsidy for private EV buyers. Since 2008, France has organized a bonus system to motivate her citizens to buy EVs, and the United States of America has granted tax credits for EVs linked to battery capacity. In 2014, more than 37 states set up incentives and tax exemptions for EVs. The Government of the United Kingdom has issued a policy to encourage residents to increase the use of bicycles and electric cars as their means of transportation (Nguyen *et al*., 2020).

Electric buses have a series of advantages over buses equipped with internal combustion engines (ICEs). The electric bus is practically silent, easy to operate and reliable. Electric cars and buses have lower operating costs than buses with internal combustion engines (ICEs). This happens because electric buses do not need frequent regular maintenance due to the lack of consumable materials like motor and transmission oils. Moreover, the use of electric buses will help in decreasing the pollutant emission level, while improving the quality of trips due to low noise and vibration levels inside the vehicles, the availability of services for passengers (USB-charger) and a hundred-per cent low floor without elevation changes (Gabsalikhova *et al*., 2018). For the coming years, several cities are considering e-buses as an increasingly effective alternative as compared with conventional buses. Consequently, in 2020, approximately 600 000 electric buses were on the road globally. In China, 78 000 new electric buses circulated on the roads (up 9 per cent from 2019), while in Europe, electric buses registrations totalled 2 100 in 2020. This increase is due to the electrification goals that were established in several nations. One example is Hungary, which, in 2020, launched a Green Bus Programme, committing to replace half of the conventional bus fleet with electric buses within the following ten years (Rodrigues & Seixas, 2022).

Figure 4: Hungary Green Bus Program

Source: Hungary Today

Building efficiency

Lake water heating and cooling for buildings

In some cities, water from natural sources is utilized to provide heating and cooling for buildings. This system is known as a lake water cooling or heating system.

During the winter months, water is drawn from the deeper, warmer layers of the lake, where the temperature remains relatively constant, typically around 4–6 degrees Celsius (39–43 degrees Fahrenheit). This water is then pumped through a heat exchanger, where its heat is transferred to a closed-loop system containing a heat exchange fluid. The heated fluid is then distributed to buildings for space heating, providing warmth and reducing the need for conventional heating systems.

Conversely, during the warmer months, the system operates in reverse. Cold water is drawn from the lake's surface, which remains cooler than the surrounding air due to its depth and thermal inertia. This cold water is used to cool the heat exchange fluid in the closed-loop system, effectively absorbing excess heat from the buildings' interiors. The heated lake water is then returned to the lake, and the cooled heat exchange fluid continues to circulate and provide cooling to the buildings.

Using lake water for heating and cooling is an energy-efficient and environmentally-friendly approach, as it harnesses the stable thermal properties of large bodies of water. It reduces the reliance on conventional energy sources for heating and cooling purposes, thereby contributing to lower greenhouse gas emissions and a more sustainable urban environment.

A great case example is in Geneva, Switzerland. Lake water is being converted into renewable energy to heat and cool some fifty buildings in Geneva using hydrothermal technology. The implementation of thermal networks, as showcased in the GeniLac project initiated in 2009 in the canton of Geneva, demonstrates a sustainable and eco-friendly solution for heating and cooling buildings. The primary objective of the GeniLac project is to displace traditional oil and gas-powered heating and air conditioning systems with environmentally-friendly water-powered alternatives. Spearheaded by the power company Services Industriels de Genève (SIG), this ambitious undertaking forms a crucial component of the canton of Geneva's comprehensive climate strategy, promoting energy efficiency and reducing greenhouse gas emissions (Huszno, 2021).

Figure 5: Installing the GeniLac pipelines

Source: Huszno, 2021

District heating system for buildings

District heating is a centralized heating system that supplies heat to multiple buildings or facilities through a network of insulated pipes. Instead of individual heating units in each building, district heating uses a central heat source to produce and distribute hot water or steam, which is then circulated through the network to provide heating and sometimes hot water to connected buildings.

Copenhagen, Denmark, is a prime example of an energy-efficient district heating system. The city has implemented an innovative district heating infrastructure that harnesses waste heat from various sources, including power plants, waste incineration and industrial processes. This waste heat, which would otherwise be released into the environment, is captured and utilized to generate hot water for heating purposes.

The advanced technology and infrastructure invested in by Copenhagen allow for the efficient distribution of this captured heat to residential and commercial buildings throughout the city. By using waste heat as a primary heat source, Copenhagen's district heating system has achieved significant reductions in the city's reliance on fossil fuels for heating, contributing to a more sustainable and environmentally-friendly solution (Danish Energy Agency, 2023).

Figure 6: Copenhagen’s Copenhill waste-to-energy plant, designed by Bjarke Ingels Group

Sustainable economic growth

Smart Waste Management

Smart waste management is crucial for cities due to its benefits of efficient resource utilization, environmental sustainability, cost savings, revenue generation, and data-driven decision making. Utilizing technology such as IoT sensors and data analytics, smart waste management optimizes waste collection routes, promotes recycling, and reduces landfill waste. It helps maintain clean public spaces, minimizes environmental impact, and creates new revenue streams through waste-to-energy programmes. Moreover, data insights enable informed decision making, ensuring cities can proactively address waste-related challenges and work towards long-term sustainability goals while building more resilient and livable urban environments.

In San Francisco, USA, the implementation of "Smart Recycling Bins" has revolutionized waste management and recycling practices. These innovative bins are equipped with cutting-edge sensors and data connectivity, allowing for real-time monitoring of their fill levels. The data collected is used to optimize waste collection routes, ensuring that collection trucks are dispatched only when bins are nearing capacity, thus reducing unnecessary trips and minimizing fuel consumption. Additionally, the smart bins contribute to improved recycling rates by encouraging proper waste separation and disposal. With these digital technologies, San Francisco has efficiently streamlined its waste management processes, leading to cost savings, reduced environmental impact, and increased recycling efficiency, ultimately supporting the city's commitment to sustainability and creating a cleaner, greener urban environment.

Figure 7: San Fransico Smart Garbage Bins

Source: Waste 360

Smart City Lighting

Smart lighting can significantly contribute to economic growth and sustainability in a city by offering energy efficiency and cost savings through technologies like LED lighting and motion sensors. Enhanced safety and security from well-lit public areas attract more visitors and residents, supporting local businesses and nightlife economy while promoting sustainable urban development. Smart lighting also acts as a catalyst for broader smart city projects, attracting investments and fostering innovation in related sustainable sectors.

Copenhagen has deployed an intelligent lighting system that uses ICT to adjust street lighting based on real-time traffic data and pedestrian movement. The smart lighting infrastructure saves energy by dimming lights when areas are less busy and brightening them as needed. Additionally, the city employs ICT to optimize traffic flow, reducing congestion and emissions through real-time data analysis and adaptive traffic signal control.

Figure 8: One of the light fixtures embedded with sensors

Source: The New York Times

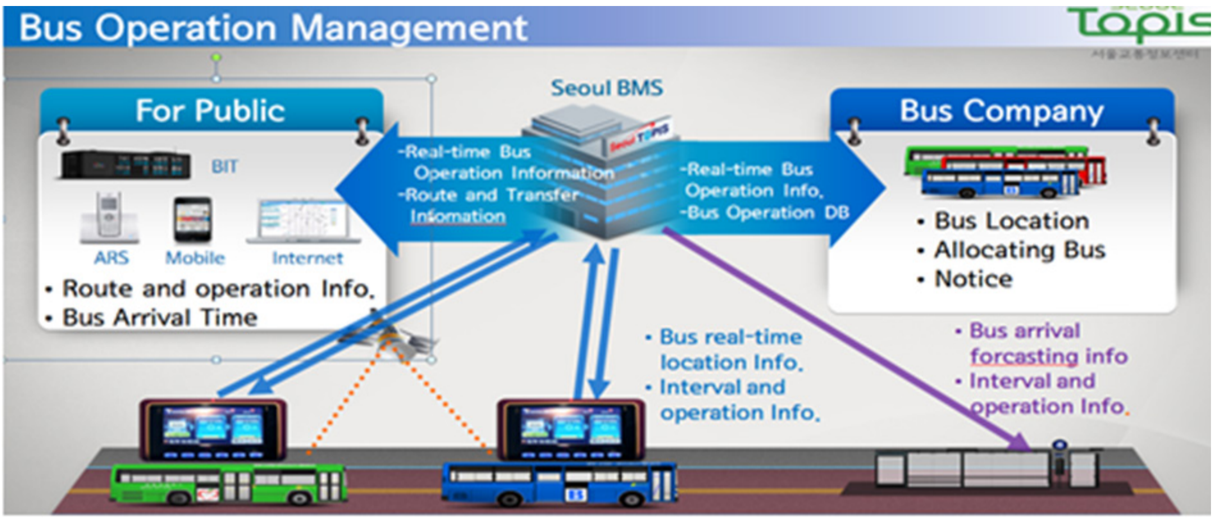
Sustainable citizen behaviour

E-Government and Digital Services

E-government and digital city services offer a powerful toolbox for cities to drive sustainability and work toward Net Zero targets. These technologies empower citizens, improve resource management, and enable data-driven decision-making, ultimately leading to more environmentally-friendly, resilient and prosperous urban environments. E-government platforms and digital services provide a direct and accessible means of engaging citizens in sustainability efforts. Through apps, websites, and digital communication, cities can raise awareness, educate and incentivize residents to adopt eco-friendly behaviours such as using public transport, reducing energy usage, or participating in recycling programmes.

Seoul, Republic of Korea, stands as a prime example of a city utilizing e-government and digital services to drive sustainability. With a focus on creating a smart and eco-friendly urban environment, Seoul has established a robust digital infrastructure that facilitates seamless communication between government departments and agencies. Through initiatives like the "Seoul Transport Operation & Information Service" (TOPIS) app, the city encourages residents to choose public transportation over private vehicles, optimizing traffic flow, and reducing emissions (Ko & Lee 2018).

Figure 9: Seoul South: Seoul, Republic of Korea's TOPIS App



Source: Seoul Solutions 2018

Tallinn, Estonia's e-Tallinn initiative is a prime example of how e-government and digital services can revolutionize administrative processes, drive sustainability, and enhance citizen engagement. The integrated digital platform allows residents to access public services online, including the innovative e-voting system, minimizing paper usage during elections and reducing paper waste significantly. Beyond sustainability benefits, e-Tallinn empowers citizens with easier access to services, leading to higher democratic engagement. Through streamlined administrative processes and improved resource management, the initiative showcases the transformative power of digital technologies in creating a more sustainable and efficient urban environment.

Figure 10: Estonia's E-Tallinn initiative and e-Residency kits

Source: E-Estonia

5 Initiatives

Zero Energy Building Initiative

To achieve in this goal, *Zero Energy Building (ZEB)* is one of the most important pillars. The concept of ZEB was introduced in the early 2000s, and its popularity increased rapidly worldwide; nevertheless, there is still a lack of agreement on its definition. Moreover, ZEB requirements vary by nation. At the technical level, ZEB is equipped with renewable energy systems and generates as much energy as it consumes over a specific period. As technology evolved, so the definition of ZEB extended to residential and public buildings. In 2020, the five biggest economies of APEC (Asia-Pacific Energy Cooperation), which are Canada, China, Japan, Korea (Republic of) and the USA announced a carbon-neutral goal towards 2050/2060, which will significantly affect the building sector. Simultaneous with the APEC ZEB project, several economies have achieved, and published, successful practices and fruitful research outcomes - these include Australia, Canada, Chile, China, Japan, Korea (Republic of), Malaysia, Russia, Singapore and the USA (Zhang *et al*., 2021). To reduce carbon emissions, the Korean Government implemented a series of polices aimed at promoting a sustainable economy. The 2020 promulgated "2050 Carbon Neutral Strategy of the Republic of Korea" introduced the goal of achieving carbon neutrality in all sectors by 2050, while introducing multiple related emission reduction strategies for the building sector. All new public buildings would need to achieve the zero-energy standard by 2020, extending the regulation to private buildings by 2030 (Amoruso *et al*., 2022).

The "100 Climate-neutral Cities by 2030" initiative

This initiative is part of the European Green Deal strategy that aims to make Europe climate neutral by 2050. All 27 European Union (EU) Member States have committed to turning the EU into the first climate neutral continent by 2050. To get there, they committed to reduce emissions by at least 55 per cent by 2030, compared with 1990 levels. The action of European Green Deal suggests the following:[1]

- Transforming our economy and societies. Climate change is the biggest challenge of our times, and it is an opportunity to build a new economic model.
- Making transport sustainable for all. The transition to a greener mobility will offer clean transport even in the most remote areas.
- Leading the third industrial revolution. The green transition presents an opportunity for European industry by creating markets for clean technologies and products.
- Cleaning our energy system. Reducing greenhouse gas emissions by at least 55 per cent by 2030 requires higher shares of renewable energy and greater energy efficiency.

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

- Renovating buildings for greener lifestyles. Renovating our homes and buildings will save energy and tackle energy poverty.
- Working with nature to protect our planet and health. Nature is an important ally in the fight against climate change.
- Boosting global climate action. We can only solve the global threat of climate change by working with our international partners.

The initiative

The initiative "100 climate-neutral cities by 2030 - by and for the citizens" aims to support 100 European cities in their transformation to climate neutrality by 2030. It is an ambitious attempt, in which cities pledge to be transformed for the benefit of Europe's quality of life and sustainability. It aims to promote system innovation across the value chain of city investment, targeting multiple sectors such as governance, transport, energy, construction and recycling, with support from digital technologies. The Mission demands the cooperation of citizens and organizations. The transformation will be based on three principles: 1) a holistic approach to foster innovation and deployment, 2) a matrix of integrated and multilevel governance and 3) a deep and continuous collaboration between all stakeholders.

Its objectives include:

- Build a multilevel and co-creative process formalized in a Climate City Contract that, while adjusted to the realities of each city, will aim at the shared goal of the mission.
- Promote citizens to become agents of change through bottom-up initiatives and innovation and through new forms of governance.
- Help cities access the financial means to achieve the Mission through Horizon Europe, the European Structural and Investment Funds, the Connecting Europe Facility, the Just Transition Fund, the mechanism for Important Project of Common European Interest, InvestEU, the Next Generation EU instrument and other EU funds.
- Foster a just transition, via the implementation of the United Nations Agenda 2030 and its Sustainable Development Goals, to improve citizens' health and wellbeing.
- Bring many co-benefits (e.g., improved air quality, job creation), healthier lifestyles, stimulating the positive effects of new sustainable mobility concepts.
- Identify European, national, regional and local policy gaps, as well as R&I priorities to contribute to the goals of the European Green Deal.
- Support the development of drivers of transition under five key enablers:
  - A model for the transformation of cities to innovation hubs
  - New forms of participative and innovative city governance

- An economic and funding/financing model for climate action
- An "integrated urban planning" model
- Smart systems and data platforms.

- Create synergies with and between existing European climate initiatives and stakeholders such as the Covenant of Mayors, the EIT and its relevant KICs, the Green City Accord, the European Green Capital Cities, the SET-plan and the 100 PEDs initiative, the EIP-SCC and the lighthouse projects, CIVITAS.
- Align with other missions and initiatives that support the Green Deal to ensure complementarity, with the mission on climate adaptation and its work to adapt Europe – and its urban areas – to the actual or expected climate and its effects.
- Collaborate on innovation with the European business to enhance the competitiveness of European industry in the global markets.

For over a decade, European cities have been leading Europe's efforts to implement ambitious climate action. The Mission for climate neutral cities aims to encourage these efforts in two ways: by setting the greenhouse gas reduction target by 2030 at 100 per cent; and by promoting a systemic transformation of cities via the adoption of the "by and for the citizens" way of thinking and working. A participating city should be able to deliver a credible climate strategy for reaching carbon neutrality by 2030. Methodologies such as the "decarbonization pathways" and the "theory of change", as well as the principles of "integrated urban planning" should be instrumental in the creation of a realistic climate strategy and action plan that can be transformative and agile enough given the complexity of reaching carbon neutrality in such a short time.

To address the challenge of climate neutrality and help better deliver EU policies, the Mission proposes a multilevel co-creation process through the introduction of a Climate City Contract. Adapted to the specific realities of each city, a Climate City Contract will include the goal and targets, specify the strategy and the action plan for transition, and identify stakeholders and responsibilities. Ideally, the Contract will be signed by the city/metropolitan government, the European Commission and the respective national or regional authorities.

The title "by and for the citizens" indicates that the involvement of citizens in their different roles as political agents, users, producers, consumers, or visitors is pivotal for the mission's success, as they can take an active role to the transition to climate neutrality. For example, in several remote consultations with the Board organized by cities across Europe, citizens have given priority to mobility, energy, urban infrastructures and buildings, circular economy and behavioural change. The Climate City Contract will, therefore, give citizens an active role and, as a pre-condition, will provide them with new platforms and better resources to design and implement climate actions. It is obvious that a clear political and organizational evolution in this direction is required.

As city populations continue to grow, the demand for efficient services and resources also increases. This growing demand strains essential services such as energy, water and transportation, which are critical for a city's prosperity and sustainability. At the same time, cities are undergoing a digital transition that needs to be managed effectively. The spreading of ICT is essential for urging economic development in cities. European digital policies and initiatives aim to support and accelerate the transition to sustainability for urban areas and communities through digital means. This will involve building high-quality connectivity infrastructure, creating a digital environment that empowers end-users, upholding European values and norms, fostering skill development, and generating long-term growth opportunities across all sectors of the European economy.

Examples of projects that could have a great impact include stability, effectiveness, and safety of low- (zero-) carbon electric grids, automated disassembly and separation of waste using AI and robotics. On top of these processes, ICT can also help prevent significant damage arising from disruptive weather patterns and phenomena, through climate impact modelling for optimal mitigation and adaption. This will allow for a wide collection and better access to the wide range of environmental "big" data and help engage with citizens using digital tools. To this end, the planned creation of common European dataspaces, in particular the Green Deal dataspace, will be an important step towards developing the digital ecosystem of the environment. One of its early deliverables will be the creation of a data ecosystem for climate-neutral and smart communities, which will facilitate the access, share and re-use of locally relevant data (in areas such as mobility, energy, climate and zero pollution) and as such can serve as the underlying digital infrastructure for the cities supported by the EU initiative. Therefore, the initiative will need to be powered by a proper framework and by digital solutions that:

i) allow the management of cross-domain data (interoperable platforms and mechanisms for data sharing); and

ii) also help cities pursue their digital transformation their own way (i.e., by preserving their security and flexibility, as well as their data and technological sovereignty) when adopting technological solutions.

The following initiatives could be of interest to the initiative:

- Future spending under the Digital Europe Programme in Smart Cities and Communities to support the digitalization of urban areas to adopt AI-based services for green purposes.
- Work with Digital Innovation Hubs to help smart cities and communities in their use of advanced digital technologies such as AI.
- Work with the COP-CITIES community to engage smaller cities and support them in scaling up digital solutions.
- Work towards the creation of a smart communities' dataspace with an agreed governance structure and collaboration mechanism to access, share and re-use all kinds of data from different sources with relevance for cities and communities.

Other key areas to be addressed and incentivized to work on new solutions include:

- Energy efficiency, aiming at zero emissions to reach the full potential of energy efficiency - especially in the buildings sector, which accounts for 40 per cent of energy demand.
- Deployment of renewables and use of electricity to fully decarbonize Europe's energy supply - as calculated by the Commission, an electricity supply that is fully decarbonized by 2050 must come approximately 80 per cent from renewable generation.
- An efficient mobility for all, clean, safe and accessible including carbon-free and alternative fuels, promotion of public transport, walking and cycling, smart multimodal solutions such as mobility as a service (MaaS), and automation.
- Integration of the circular economy approach that employs re-use, sharing, repair, refurbishment, remanufacturing and recycling in a close-loop system for minimizing the use of resource inputs and the creation of waste, pollution and carbon emissions.
- Reaping the full benefits of bioeconomy and create essential carbon sinks since global and European assessments confirm that a Net Zero-emissions economy will require increasing amounts of biomass compared with today's consumption.
- Optimizing the carbon footprint of Gigabit society as the latter becomes an increasingly important part of the society and economy.

The implementation

The EU initiative will select cities of all sizes and level of preparedness if they have high ambitions. All cities with 50 000 citizens or more should be welcome to apply to become a Climate Mission City. In Member States with five or fewer cities above 50 000 inhabitants, the threshold of 10 000 should be applied. Carbon neutrality, namely mitigating and offsetting all GHG (in CO_2-eq) within a city, is the target of the mission. The Mission will establish a robust, transparent, yet simple monitoring process to measure and evaluate (HGW) progress towards the Mission goal. Three indicators are proposed:

1. *Scope 1 GHG emissions* for the city within the geographic boundary (mandatory from the beginning of the mission). This indicator will be calculated based on the emissions from buildings, industry, transport, waste treatment (solid waste and wastewater), agriculture and forestry and from other activities.
2. *Scope 2 GHG emissions* for the city (mandatory from the beginning of the mission). This indicator will be calculated based on the emissions from indirect emissions due to production/consumption of grid-supplied electricity within the geographic boundary and indirect emissions due to production/consumption of grid-supplied heat or cold within the geographic boundary.
3. *Scope 3 GHG emissions* for the city (recommended, to be adopted by 2030). This indicator will be calculated based on the emissions from out-of-boundary emissions from the treatment of waste produced within the geographic boundary, out-of-boundary emissions from transmission and distribution of energy consumed within the geographic boundary, out-of-

boundary emissions from transportation of citizens living within the geographic boundary, out-of-boundary emissions from consumption made within the geographic boundary (e.g., food, clothes, furniture, materials) and other indirect emissions.

Three phases can be identified:

1. An early delivery phase in 2020-2022 that will set the foundations of the Mission and of its facilities to help the participating cities
2. The main phase in 2022-2030, during which the main body of cities will implement their strategy towards transformation and climate neutrality
3. The period after 2030 and up to 2050, when it is hoped that the Mission will have created the momentum for a climate-neutral Europe.

Reaching 100 climate-neutral cities by 2030 is the objective identified by the Mission Board for Climate-Neutral and Smart Cities. Cities are the place where decarbonization strategies for energy, transport, buildings, and even industry and agriculture, coexist and intersect. The climate emergency must be tackled within cities and by engaging citizens. Through a multilevel and co-creative process formalized in a Climate City Contract, adjusted to the realities of each city, the Mission is fully anchored on the European Green Deal Strategy to make Europe climate neutral by 2050.[2]

The initiative of "100 climate-neutral cities by 2030 – by and for the citizens" gives a new role to the citizens of the cities that will participate in this Mission, as their involvement is pivotal for the Mission's success. In the consultations with the Board, citizens have given priority to mobility, energy, urban infrastructures/buildings, circular economy, and behavioural change.

2 https://ec.europa.eu/info/publications/100-climate-neutral-cities-2030-and-citizens_en

6 Conclusions

The journey towards carbon Net Zero in cities requires a strategic and comprehensive approach, leveraging the potential of digital transformation. This report has presented guidelines and recommendations for cities to achieve carbon neutrality through the adoption of innovative digital technologies and practices.

Digital transformation provides cities with a powerful toolset to monitor, analyze, and optimize energy consumption, infrastructure and citizen behaviour. By integrating smart solutions into various sectors, cities can significantly reduce greenhouse gas emissions and move towards sustainable development. The guidelines offered in this report emphasize the importance of data-driven decision-making, cross-sector collaboration, and citizen engagement. City leaders must invest in smart technologies that enable real-time data collection and analysis to develop targeted interventions. Furthermore, cooperation between public and private stakeholders is essential to ensure the successful implementation of carbon Net Zero initiatives.

The use cases discussed, ranging from efficient transportation systems to sustainable economic growth, showcase the diverse applications of digital transformation in the pursuit of carbon neutrality. By tailoring these examples to their unique contexts, cities can create tailored action plans that cater to local needs and challenges.

The initiatives highlighted in this report such as the Zero Energy Building Initiative and the "100 Climate-neutral Cities by 2030" campaign, demonstrate the international commitment to combat climate change through digital innovation. Cities should actively participate in such initiatives to benefit from shared knowledge, resources and support.

In conclusion, the path to carbon Net Zero demands transformative change in urban systems, and digital transformation is an indispensable catalyst. By embracing the potential of digital technologies, cities can pave the way for a sustainable and climate-resilient future. Supporting this transformation is not only essential for environmental reasons but also for creating inclusive, vibrant and prosperous cities for generations to come.

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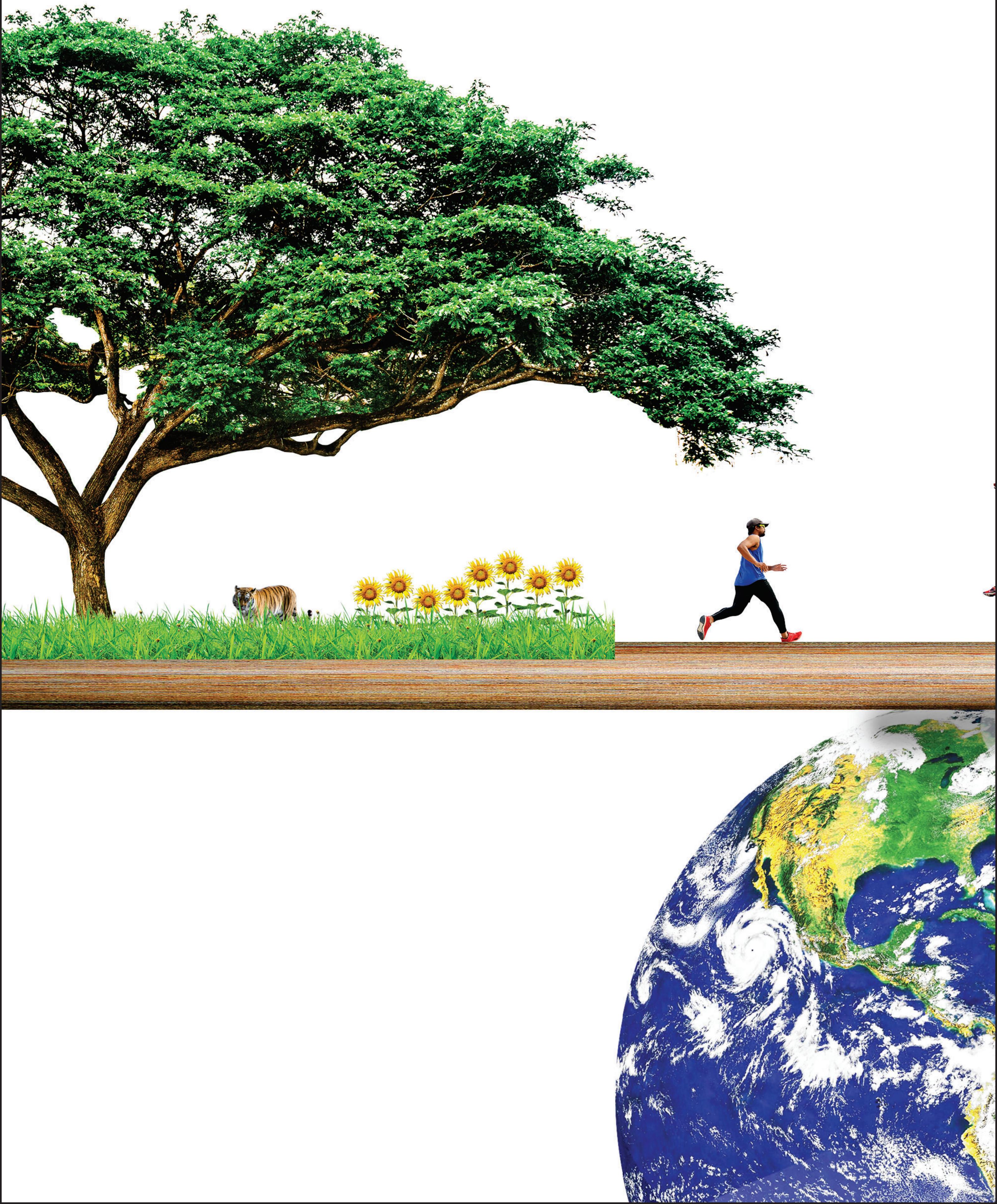

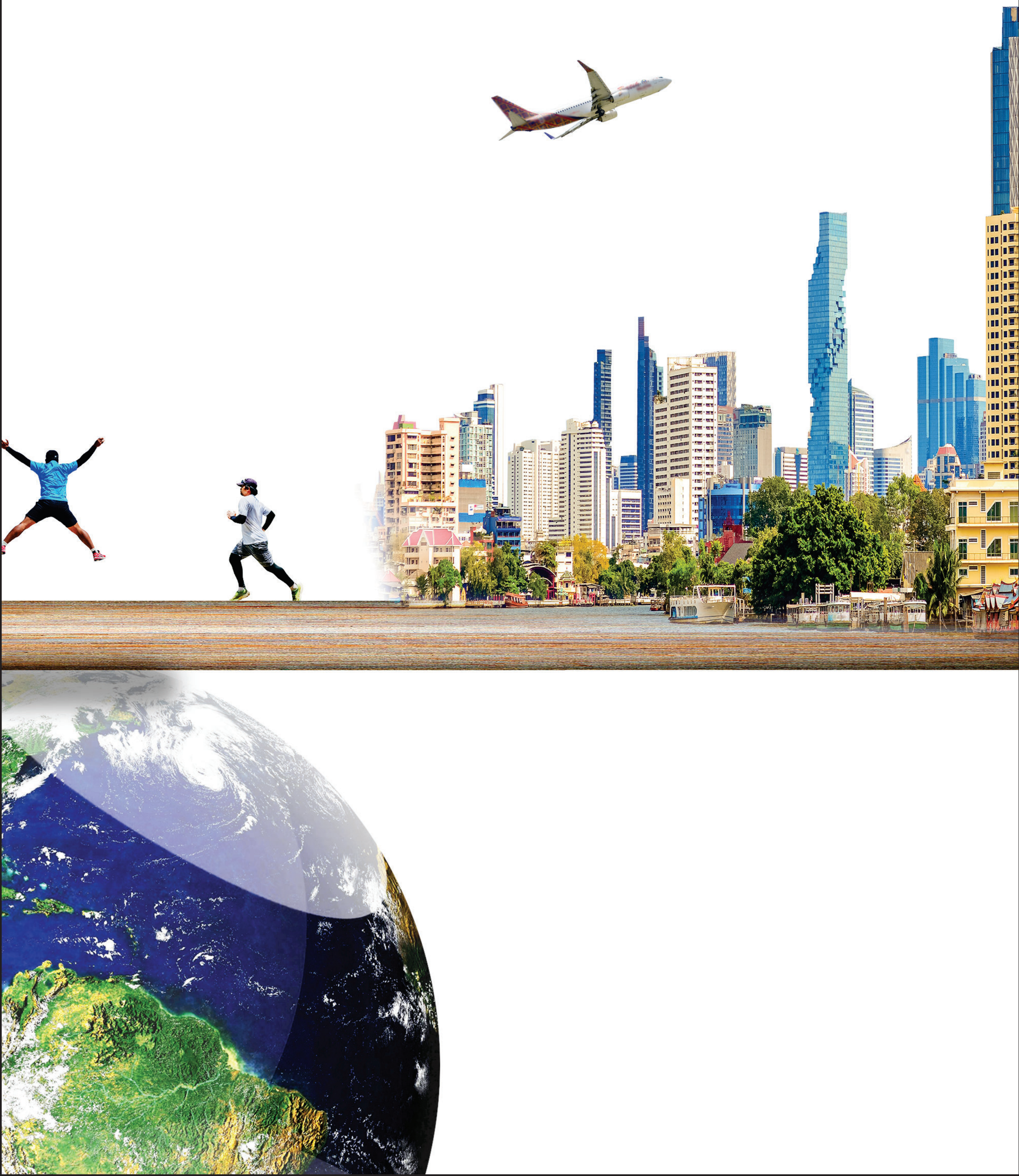

For more information,
please contact: u4ssc@itu.int
Website: https://u4ssc.itu.int/

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