United Nations Commission on Science and Technology for Development
Inter-sessional Panel 2021-2022
17-19 November 2021
Geneva, Switzerland

Issues Paper

on

Science, Technology, and Innovation for Sustainable Urban Development in a Post-COVID World

Unedited Draft

Prepared by the UNCTAD Secretariat[1]

18 November 2021

[1] This draft was prepared by the Science, Technology and Innovation Policy Section of the Division on Technology and Logistics of UNCTAD. Professor Luca Mora (consultant) provided a major input to the report. Contributions from the Governments of Belarus, Belgium, Brazil, Dominican Republic, Egypt, Germany, Islamic Republic of Iran, Kenya, Latvia, Peru, the Philippines, Romania, Russian Federation, South Africa, Switzerland, Thailand, Turkey, and the United Kingdom, as well as from ESCWA, FAO, ITU, UN Habitat, UNIDO, UNOOSA, and UNWTO are gratefully acknowledged.

Table of Contents

INTRODUCTION

The world is far from attaining resource efficient, safe, and inclusive urban areas[2], where anyone can benefit from environmentally friendly and prosperous economies and high-quality public goods and services. The overall impact of COVID-19 has exacerbated existing sustainability challenges, exposing the vulnerability and inefficiencies of urban systems worldwide. However, pre-COVID urban development trends were already picturing deteriorating conditions, especially in developing countries: raising numbers of slum dwellers, whose misfortunes are mainly rooted in enduring cycles of urban poverty; growing levels of air pollution that threaten public health worldwide; urban planning that is unable to manage the complexity of peri-urbanization processes; and increasing levels of exclusion and inequalities, due to an uneven access to basic urban services, which go hand in hand with growing levels of poverty (UN, 2021).

Fostering more sustainable urban futures requires government leaders and other stakeholders to reorganize the functioning of urban sociotechnical systems. Housing, energy, water, education, mobility, healthcare, waste management, telecommunication, economic growth, decent jobs, and justice are all examples of urban sociotechnical systems that serve urban communities. However, under the pressure exerted by exogenous forces – such as urbanization trends, demographic change, natural disasters, climate change, and the decline in national economies – ensuring the sustainable functioning of urban sociotechnical systems have become increasingly difficult. Multiple inefficiencies have propagated, which have pervaded within and across urban systems, preventing urban operations from taking place in a sustainable manner.

In a world in which societies and economies are now primarily based upon science, technology, and innovation (STI) advancements, including digital technologies, significant research and development efforts have been sustained, which have planted global sustainability principles in urban development processes. As a result of these efforts, the world has gained access to a rich variety of STI solutions, both technological and non-technological, to urban sustainability issues (Mora and Deakin, 2019). These innovative solutions help shape the evolutionary patterns of urban sociotechnical systems and contribute to fixing unsustainable urban operations, including economic activities.

To boost sustainable development in urban environments, STI solutions can be adopted to rearrange the configuration of incumbent urban sociotechnical systems and modify their components (Fuenfschilling et al., 2019). Examples of components include physical infrastructure assets, institutional settings, regulations and policies, governance and collaborative mechanisms, market structures, and user behaviors (Frantzeskaki et al., 2017).

This paper builds on the Secretary-General's Report entitled "Science, Technology and Innovation for Sustainable Cities and Peri-Urban Communities" that was presented to the 16th Commission on Science and Technology for Development in 2013. It focuses on the interdependence between urban sustainability and STI. After describing the current

[2] Definitions of urban, peri-urban, and rural areas differ significantly in the literature and among countries. These differences usually relate to minimum population sizes and density, and they make it difficult to agree on universal definitions. In this paper, the terms urban area and its synonyms – such as urban environments, urban settlements, urban communities, urban systems, urban regions, and urban territories – are used interchangeably, and they cover all degree of urbanization and types of urbanized territories, from the more densely populated urban areas of cities and towns to the intermediate and less dense urban areas that create the urban-rural continuum of peri-urban spaces. Peri-urban spaces are composed of both urban and rural areas; they form urban-rural interfaces and may gradually evolve into fully urban territories, but their growth is fragmented and involves relatively sparse and discontinuous land use patterns.

urbanization trends, the status of the global policy discourse on sustainable urban development, and the main urban sustainability challenges that are putting pressure on urban sociotechnical systems worldwide, the paper provides an overview of the contribution that STI practices make towards mitigating some of the most pressing sustainability challenges facing the urban sociotechnical systems. It concludes with recommendations on what policy interventions should be adopted by government leaders and other stakeholders to intensify the production and adoption of STI solutions to urban sustainability challenges.

1. THE IMPERATIVE OF SUSTAINABLE URBAN DEVELOPMENT

The analysis begins with a discussion of the most recent data describing urbanization trends and the status of the global policy discourse on sustainable urban development, which is embedded in some of the main agreements of the post-2015 development agenda. This initial discussion is followed by a detailed overview of the main global challenges that are undermining the sustainability of urban sociotechnical systems. The challenges cover key areas of the green-productive-inclusive triad of sustainable urban development and their overview takes into consideration the effects that the COVID-19 pandemic has brought on urban systems.

1.1. Urbanization trends

We live in a highly urbanized world. In 2017, urban areas were home to more than 4 billion people[3], and this event has become an important milestone in the history of humanity; for the first time, the worldwide share of urban population has outnumbered the rural population (UNDESA, 2018b). The urbanization process is considered as one of the main demographic trends, alongside with population growth, population aging, and international migration.

During the last two centuries, an overall reduction of human fertility levels has been registered almost worldwide. As a result of this trend, the absolute size of the world's population is expected to grow continuously over the next decades, but at a slower pace compared to the pre-1950 scenario, moving from the 7.7 billion recorded in mid-2019 to 8.5 billion in 2030 and almost 10 billion in 2050 (UNDESA, 2019b). Notwithstanding the reduced growth pace, urban areas will continue to expand and absorb most of this future population growth.

Two-thirds of the worldwide population are expected to live in urban areas by 2050 (Baeumler et al., 2021). In 2020, most of the population was still rural only in a few low-income and lower-middle-income countries – mainly located in Central Africa and South Asia. In many middle-income countries across Eastern Europe, East Asia, Africa, and South America, between 50% and 80% of the population was already living in urban environments, and the percentage went above 80% in most high-income countries across Western Europe, the Americas, Australia, Japan and the Middle East (Ritchie and Roser, 2018). Moreover, in addition to being among the most highly urbanized regions in the world, Asia and Africa are also expected to urbanize fastest in the coming decade and to accommodate the largest numbers of new urban dwellers (Baeumler et al., 2021). As a result of these variations within and across regions, dissimilarities appear in urban sustainability implications, which expose the coexistence between local and global dimensions of sustainable urban development.

Moreover, while the population of many urban areas continue to expand, other urban areas are affected by urban shrinkage, a phenomenon that has become global. However, because urban shrinkage and urban population growth are two very localized events, they can manifest together within the same town, city, or macro-region. For example, the most notable and rapid increase in urban population is expected in Africa and Asia, but cases of urban shrinkage have been spotted in some macro regions of Japan, India, China, and Korea (Pallagst et al., 2021; Richardson and Woon Nam, 2014). Shrinking towns and cities – and sometimes neighborhoods (Schenkel, 2015) – are also appearing in Europe and North America (Gao and Ryan, 2020; Richardson and Woon Nam, 2014). For example, urban shrinkage has affected the structural

[3] In producing this estimate, UNDESA has examined urbanization trends in 1,900 urban settlements with 300,000 inhabitants or more.

configuration of cities like Schwedt and Dresden in Germany, Glasgow in Scotland, and Buffalo and Pittsburgh in the United States.

Regionally differentiated patterns also appear when observing the dynamics of population aging. The share of older population – individuals aged 65 years or more – has increased globally over the last three decades, and it is expected to double by 2050 (UNDESA, 2019a). However, global aging remains a more local issue. The uneven distribution of elderly population causes variations in this general prediction; more impact is forecasted in regions like Sub-Saharan Africa, whereas only relatively modest changes are expected in Europe cities (Sivaramakrishnan, 2018).

The global scale and the pace of urbanization trends bring unprecedent challenges, whose implications deeply affect the configuration of urban systems and their functioning.

1.2. Sustainable urban development in the global policy discourse

The global policy framework on sustainable urban development is structured upon five main agreements of the post-2015 development agenda. They are the Sendai Framework for Disaster Risk Reduction, Addis Ababa Action Agenda on Financing for Development, 2030 Agenda for Sustainable Development, the Paris Agreement on Climate Change, and the New Urban Agenda, which was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in 2016.

Reduction and management of disaster risk are key concerns in sustainable urban development discourses. The Sendai Framework focuses on these themes and introduces a roadmap with two fundamental goals: (1) preventing urban and rural communities from being exposed to natural and manmade disasters; (2) enhancing the reliance of the communities that are forced to suffer from the effects of disasters, by strengthening the effectiveness of post-disaster responses. Special importance is given to the need to complement national-level actions with city-level platforms that connect and empower local authorities, whose contribution and coordination are deemed indispensable to build more resilient and disaster-free urban communities. (UN, 2015c).

The Addis Ababa Action Agenda addresses the challenge of financing sustainable development actions. With respect to the urban development, the Action Agenda recognizes the need to strengthen technical and technological capacity, financing, and support for the municipalities and other local authorities, to transform their financing needs for sustainable development into an investment opportunity.

The 2030 Agenda for Sustainable Development introduces the Sustainable Development Goal (SDG) 11, drawing further attention to the importance of positioning urban areas at the forefront of global policy discourses on sustainable development. SDG 11 invites to rethink urban development patterns and to introduce the means that are required to make urban settlements more inclusive, productive, and environmentally friendly (UN, 2015d).

The New Urban Agenda provides comprehensive policy framework for the achievement of SDG ambitions in urban settings, especially the targets related to SDG 11. With the adoption of the New Urban Agenda, countries have committed to ensuring that all citizens can benefit from greener, more inclusive, and more productive urban environments where universal access to opportunities and basic services is guaranteed.

Finally, the global policy framework on sustainable urban development is completed with the Paris Agreement, which strengthens the worldwide response to climate change (UN, 2015b).

Urban areas are among the largest sources of greenhouse gas emissions, and local development actors will play a key role in the arranging the global climate change response.

These five policy documents offer cross-cutting considerations that underpin worldwide efforts to capitalize on the value of urbanization. Moreover, in this global policy discourse lies the opportunity to push for a new STI programs for sustainable urban development, responding to the call for innovative solutions that can help leave no place behind.

1.3. Urban sustainability challenges

This section presents a detailed overview of the main global challenges that are undermining the sustainability of urban sociotechnical systems. The challenges cover key areas of the green-productive-inclusive triad of sustainable urban development and their overview takes into consideration the effects that the COVID-19 pandemic has brought on urban systems.

Table 1. Global urban sustainability challenges: a brief summary

Urban Sustainability Challenges	**Urban Sustainability Dimensions**		
	Green	Productive	Inclusive
Inefficient and polluting urban energy systems	■		■
Unsustainable urban production and consumption patterns	■		■
Urban water scarcity	■		■
Urban traffic congestion and vehicle emissions	■		■
Limited access to decent urban employment opportunities and growing inequalities		■	■
Unaffordable and poor-quality housing	■	■	■
Uneven access to quality education			■
Gender-based inequalities and violence against women and girls		■	■
Defective urban planning practices	■	■	■
Vulnerable healthcare systems			■
Urban violence and insecurity			■
Vulnerability to natural disasters			■

Inefficient and polluting urban energy systems

Urban systems globally consume up to 75% of the world's energy (UN-Habitat et al., 2018), and they are responsible for producing over 50% of the overall greenhouse gasses (GHGs) – a percentage that increases to approximately 80% when indirect GHG emissions are included in the count (UN-Habitat, nd-a). These harmful levels of emissions are correlated with urban energy producion and consumption processes, which are highly dependent on fossil fuels (UNDESA, 2021a); when coal, natural gas, and oil are burned, they release carbon dioxide and other GHGs, which are one of the prime causes of global warming and climate change.

Hidden among the environmental consequences of fossil fuel combustion is also an energy accessibility issue. Between 2010 and 2019, the global access to electricity has increased from

83% to 90%. This progress notwithstanding, in 2019, approximately 760 million people were still lacking access to electricity, and 75% of them were in Sub-Saharan Africa (UN, 2021). However, recent studies show that, in this region, electrification programes have been faster in connecting rural areas rather than urban households, where most of the newly connected customers use very few electricity due to limited appliance uptake and affordability issues (Falchetta et al., 2020).

Finally, it is important to note that public financial flows for renewable energy continue to be concentrated in a few countries, making it difficult for many developing countries and LDCs to sustain urban energy transitions. Sub-Saharan Africa and Latin America have attracted most of the international investments since 2010. However, national-level data shows significant inequalities; between 2010 and 2018, developing countries like Argentina, Nigeria, India, Turkey, and Pakistan received 30% of the total investments, whereas only 20% was directed to the 46 least developed countries (UN, 2021). In addition, the COVID-19 pandemic has caused substantial decline in renewable energy investments – a 34% decrease in the first half of 2020 compared to 2019 (IRENA, 2020).

Unsustainable urban production and consumption patterns

In 2020, the global material footprint – which refers to the raw materials extracted to meet the existing consumption demand – exceeded the growth in population and economic output (UN, 2020h). Should the world continue to follow this consumption trend, with the global population that is expected to reach almost 10 billion by 2050, the equivalent of almost three planets will be required to provide the natural resources needed to sustain current lifestyles (UNEP, 2019c). Most of this ecological footprint is generated in urban areas (UNEP, 2018d). In many Mediterranean countries, for instance, few major urban systems are sufficient to consume the vast majority of the biocapacity of their nation – in some cases, even all of it. Examples of cities include Rome and Naples in Italy, Barcelona and Valencia in Spain, Tunis in Tunisia, Cairo in Egypt, and Athens and Thessaloniki in Greece (GFN, 2015).

Excluding Europe, Northern America, Australia, and New Zealand, all regions of the world experienced a significant rise in domestic material consumption rates over the past two decades, and the material consumption of urban systems is expected to grow from 40 billion tonnes in 2010 to 90 billion tonnes by 2050 (UNEP, 2018d). In developing and least developed regions, this increase is mainly due to late industrialization processes and the outsourcing of material-intensive production, whereas developed countries expose unsustainable lifestyles (UN, 2021).

Plastic and food waste have been emphasized significantly in urban-related material consumption debates (UN, 2020h, 2021). Plastic is one of the most commonplace materials for producing packaging items, such as shopping bags, containers, and drinking bottles, to name a few. Every minute, 1 million plastic drinking bottles are purchased, and 5 trillion single-use plastic bags are thrown away annually (UN, 2021).

However, the global recycling rate remains between 14% and 18% (OECD, 2018c), and cities are responsible for producing an estimated 60% of the plastic that reaches marine waters (WWF, 2020). This recycling issue has also been exacerbated by the COVID-19 pandemic, which has caused a heavy use of plastic goods, especially single-use plastics, such as face masks, personal protective equipment kits, and sanitizer bottles. The overall sale of disposable face coverings has increased from 800 million in 2019 to 166 billion in 2020 (Braich et al., 2020).

The extent of the food waste challenge is as critical as the accumulation of plastic. Food waste represents 44% of the global waste and more than 17% of the global food production may be lost annually. In poorer countries, most food loss happens at the production and distribution stages, whereas most food losses occur at the consumption stage in richer countries. A recent study that compares food waste habits in New York City, Denver and Nashville has estimated that residents trash an average of approximately 3 kilograms of uneaten food weekly (Leigh Hester, 2017).

Electronic waste is an additional challenge, which continues to expand, and is a consequence of the combination between consumerism culture and the easier access to electronic products (WEF, 2019b). Despite highly hazardous substances, which contaminates soil and groundwater, less than 20% of electronic waste is formally recycled and 80% ends in landfill site or is informally recycled (, 2019c). Many landfill sites are homed in developing regions, where they are severely polluting urban spaces. For example, the town of Guiyu and the slum area of Agbogbloshie, which are respectively located in Southern China and the city of Accra, Ghana, have become two of the largest electronic waste recycling dumps in the world, and burning is a regularly applied practice for eliminating the waste, alongside with rudimental and health-threatening dismantling techniques (Adanu et al., 2020; Chai et al., 2020; Minter, 2016).

Urban water scarcity

Urban water scarcity is a key societal challenge. The control and movement of water resources require several core activities to be conducted, which include the replenishment of water reserves, extraction, transport, distribution, and safely treatment and disposal of wastewater. Each activity involves a combination of technologies, management techniques, and human and financial resources whose absence threaten the sustainable and stable supply of clean and fresh water to urban populations (Favre and Oksen, 2020).

For example, more than 60% of urban areas in Sub-Saharan Africa do not have access to water and sanitation services. Moreover, most households connected to municipal piped networks receive water intermittently, and residents that cannot access public supply are forced to rely on self-provision or private vendors, an alternative that costs up to 52 times more than the public service (Mitlin et al., 2019).

Recent studies also estimate that the global urban population facing water scarcity will drastically increase in the following years; between 1.7 and 2.4 billion people will live in water-scarce regions by 2050 (He et al., 2021). This estimate varies between one third to approximately half of the worldwide urban population. Moreover, 292 out of 526 large cities worldwide and 19 megacities are expected to experience perennial or seasonal water scarcity issues by 2050[4]. The megacities are located in Bangladesh, Brazil, China, Egypt, India, Indonesia, Mexico, Pakistan, Peru, Philippines, Russia, Turkey, and United States.

Droughts, climate change, and pollution are among the most critical events that influence the availability of water resources – and hence the adequate supply of clean water for drinking and sanitation purposes (EEA, 2011). Additionally, whilst increasing levels of pollution contaminate surface water and groundwater, affecting human health and the growth prospects of urban and rural economies, population growth and urbanization are increasing the demand, amplifying levels of water stress (Favre and Oksen, 2020). Poorest countries are suffering the most, as they also have a lower coverage of freshwater bodies: 1.4% of land compared to the overall 3.5% of developed countries.

[4] In this study, large cities are urban areas with more than 1 million inhabitants, whereas megacities have a population of more than 10 million inhabitants.

Urban traffic congestion and vehicle emissions

Although transport systems offer numerous benefits to societies, urban mobility hinders some of the greatest obstacles to urban sustainable development. Air pollution, congestion, and limited access to public transportation have become prominent challenges facing many urban areas in developing and developed countries. Among the most relevant causes are: the presence of many transport vehicles that are still heavily dependent on fossil fuel; private ownership of polluting vehicles that is on the rise worldwide; different modes of urban mobility that are forced to share the same, limited urban space, which is not able to accommodate growing levels of urban traffic; access to public transportation that is increasingly unaffordable for poorest groups of urban populations (Gössling, 2020; Nadeau, 2016).

Transport activities are responsible for generating approximately 25% of energy-related carbon emissions from fuel combustion worldwide (UN-Habitat, nd-b), and most of this pollution is coming from urban areas. For example, European cities account for 40% of all carbon emissions of road transport, and they also produce up to 70% of other transport-generated pollutants (EC, 2013). These high levels of harmful emissions have severe health implications on urban residents; they are directly associated with increasing mortality rates and respiratory and cardiovascular diseases (WHO, nd).

Road congestion is particularly common in high-density urban systems, where the presence of vehicles on urban streets is increasing while physical space to support their movement remains insufficient. This urban challenge influences the effectiveness and efficiency of transport systems and road usage; urban economies deteriorate due to limited accessibility, and it creates parking difficulties, longer commuting times, limited mobility of non-motorized transport modes and pedestrians, lower quality of public spaces, higher environmental degradation, and higher levels of stress for drivers and urban residents (Alexopoulos and Wyrowski, 2015).

Limited access to decent urban employment opportunities and growing inequalities

Before the pandemic started, the world had successfully decreased the number of workers suffering from extreme poverty, increased workforce productivity, and decreased unemployment rates, whereas less positive results were associated to employment inequalities, decent work and forced labors rates, the quality of the youth employment environment, and effectiveness of existing labor force protection mechanisms (UN, 2020h). The COVID-19 pandemic has exacerbated all these challenges and erased previous successes, pushing the global economy in a new Great Depression. In 2020, the growth rate of the global real GDP dropped by 4.6% – a sharp contrast with the average growth rate of 2.0% that kept steady every year during the period between 2014 and 2019. This growth reduction is strongly correlated with the notable impact of the pandemic on urban employment landscapes (UN, 2021), and has pushed countries worldwide to introduce drastic measures in their recovery plans.

Pre-COVID data shows the economic power of cities; urban areas were contributing to generating about 80% of global GDP (Estrada et al., 2017) and the impact of the pandemic notwithstanding, they are expected to become the main driving force of the post-COVID economic recovery (The World Bank, 2021a). However, due to substantial differences in the roll-out of vaccines and distribution of state aids, urban areas in developed countries are exposing a general tendency to recover faster than urban settings in least developed countries and developing countries, many of which are lagging behind. For example, as of May 2021, 2.5 million people in the UK were still unemployed – about 50% more than pre-COVID statistics – but fewer people were claiming unemployment benefits in almost all UK cities and large towns. This data suggests the UK urban labor market may be on the recovery track (Magrini, 2021). Conversely, urban unemployment rates in Latin America and the Caribbean

had already reached an average of 10% in 2017 (ECLAC and ILO, 2017) and, as a result of the pandemic, the figure doubled in January 2021 (Llanes, 2021). Similarly in South Africa, the COVID-19 pandemic has exacerbated already high unemployment rates, particularly amongst the youth at 46,3%[5].

This global decline of labor productivity and job opportunities in urban areas indicates a fragile economic system with low resistance to exogenous shocks. One of the main causes of this weakness is the widespread presence of informal working conditions; 1.6 billion informal workers worldwide are left with no or little social protection (Codd and Ferguson, 2020; UNISON, 2021). During the pandemic, informal economies have been severely impacted, especially in developing countries. For example, millions of informal urban workers in India had to move back to rural settlements after losing their jobs. Similarly, in Peru, over 170,000 urban dwellers in poor conditions transferred to the countryside in 2020.

During the COVID-19 pandemic, a number of working hours equivalent to more than 250 million full-time jobs have been lost worldwide and, while the global unemployment rate has grown, already existent gender and age discrepancies in job opportunities have aggravated. In North America and Western Asian, for instance, approximately 11% of the labor force was without a job in 2019, but the unemployment rate of female workers was 6% higher than male workers. Moreover, with a level of unemployment that was 18% higher than adults (UN, 2020h), young people are required to confront higher degrees of uncertainty, as well as the likelihood of greater labor market disruption.

Forced labor, child labor, modern slavery, human trafficking, and high numbers of workplace fatalities and injuries are additional challenges that prevent many urban areas from being a place of inclusive and equitable economic growth. For example, over one million work-related fatalities are reported every year in rural and urban areas – which is equivalent to 5.7% per 100,000 workers – and millions of workers suffer from occupational injuries (ILO, 2019).

Unaffordable and poor-quality housing

Because of existing poverty rates, around a billion urban dwellers are forced to live in informal settlements, which enhance peri-urbanization processes and are mainly located in regions of developing countries. Available statistics show that Eastern and South-Eastern, Central and Southern Asia, and Sub-Saharan Africa account for 80% of the worldwide population living in informal settlements (UN, 2021), where residents experience overcrowded and low-quality housing conditions, forceful evictions, higher levels of vulnerability to disasters, and the lack of access to basic urban services, such as water supply, schools, sanitation, and waste collection.

Considering current urbanization trends, approximately 3 billion people may require quality and affordable housing by 2030 (UN, 2021), augmenting an existing housing deficit that the building sector is incapable to overcome. However, this affordable housing crisis extends beyond developing countries; it also afflicts housing markets in developing economies. House prices are currently three times higher than the median family income in almost all international cities (UCL, 2021), and the most unaffordable housing markets worldwide are spread across all developed regions. Example of cities include Dublin, New York, London, San Francisco, Hong Kong Special Administrative Region of China (HKSAR), Toronto, Paris, and Sydney, just to name a few (URI and FCPP, 2021). The scarce availability of affordable housing

[5] Contribution from the Government of South Africa.

solutions fuels a global housing crisis that contributes to sustaining "urbanization without growth" (Florida, 2015).

To increase infrastructure resilience and improve the sustainability and efficiency of industrial sector activities, including the housing sector, significant global investments have already been made in research and development – US$1.7 trillion in 2020. Most of these investments are focused on the delivery of new products, processes, systems, and services for sustaining the Forth Industrial Revolution and the introduction of digital technologies in industrial sectors to improve their capability to respond to societal needs. However, when comparing country-level financial capacity for research and development efforts, a significant gap emerges between developed and developing countries (UNCTAD, 2020b).

Uneven access to quality education

With a higher density of schools and higher education institutions in urban areas, urban sociotechnical systems for the delivery of education services play a key role in the development of human capital (Van Maarseveen, 2020), an activity that requires municipal governments to connect multi-level governance systems and coordinate with heterogeneous actors.

The COVID-19 pandemic has severely hit urban education systems, causing "the largest disruption to learning in recent history" (UNESCO, 2021b). With a massive closure of schools, universities, and other higher education institutions, education services have been disrupted worldwide, and local development levels have dramatically influenced the ability of countries to respond to the emergency. Lockdowns and other social distancing measures have left more than 1.5 billion children living in urban and rural areas in need for distance education and more than 90% of the world's enrolled students forced out of school (The World Bank, 2016).

Among the consequences of the pandemic, in 2020, urban education provision has not been able to support millions of children and young people, who have fallen behind in their learning and did not reach the minimum reading proficiency level. In addition, millions from pre-primary to tertiary education risk dropping out or not having access to school in the following years due to the current global recession. Therefore, disparities in school completion are likely to worsen, especially among vulnerable and disadvantaged children. Reduced educational opportunities in early years is another consequence of the pandemic, whose negative effect can influence the learning potential of many children for the rest of their lives, while undermining future employment rates (UN, 2020e, 2021).

Moreover, fast-growing urban populations are expected to generate increasing pressure on education provision, especially in more density populated urban areas, where the demand is likely to exacerbate the already insufficient capacity, causing existing infrastructures to expand and consume additional land (Richardson, 2016).

Gender-based inequalities and violence against women and girls

Women and girls who live in urban areas are subject to inequalities. Despite they represent approximately 40% and 50% of the workers and working-age population, respectively (UN, 2020h), their economic position is significantly disadvantaged compared to men. In certain occupations predominated by women, wages are often lower than occupations predominated by men. As a result, the overall gender pay gap stands at 16% and, for women of color, immigrant women, and women with children, the gap is even greater (UN Women, 2020).

Every day, women around the world contribute to sustain the growth of urban environments by delivering a massive amount of unpaid care work, including parenthood. Despite more

substantial working effort, however, women accumulate 50% less wealth than men (UN-Habitat, 2020c), and they are subject to occupational segregation, which prevent them for accessing many urban employment opportunities, including managerial jobs. For example, in 2019, only 28% of managerial positions worldwide were occupied by women and, when compared with the situation in 2000, this figure only shows a 3% increase in a 19-year timeframe (UN, 2020h).

Legal barriers and gaps are among the main cause of this economic inequality, and they are also instrumental in creating occupational segregation and preventing girls and women from having an equal participation in decision making processes within workplaces (Hyland et al., 2019; OECD, 2018b).

Urban areas are also the spaces in which most of technological advancements are produced and implemented. However, during these innovation processes, gender inequality may appear in the form of a technology-related bias. For example, evidence that proves the presence of gender biases in AI and emerging technologies is growing. Facial recognition technologies, web searches, and the speech recognition software enabling AI bots and voice assistants are examples of technological solutions whose levels of performance have been evaluated as higher for men than women (Chin and Robison, 2020; Palmiter Bajorek, 2019) This phenomenon is observed by the European Union Agency for Fundamental Rights, in a report that examines discrimination in data-supported decision making. The report indicates that these different levels of performance could be the result of technology design processes that have been developed by using a too men-centered focus (FRA, 2018).

Moreover, cases have been reported of gender issues in urban planning practices (Pojani et al., 2018), which tend to overlook how girls and women experience the urban environment. Consequently, their needs are not addressed. According to the Handbook for Gender-Inclusive Urban Planning and Design that The World Bank has recently released, most cities in the developed and developing world have been planned by and for men (The World Bank, 2020d).

Strong correlation also exists between urbanization and the gender-based violence and abuses against women and girls (McIlwaine, 2013). All over the world, for many girls and women living in urban environments, experiencing these forms of violence in public or domestic spaces has become an everyday occurrence. Moreover, the data collected after the COVID-19 outbreak confirms that, during the pandemic, all acts of violence against women and girls have intensified in many countries, especially domestic violence cases (UN, 2020a). Many local and national governments still lack efficient protective measures.

Defective urban planning practices

In addition to exposing a limited capability to cope with the urgent need for gender-inclusive urban spaces and addressing the needs of people with disabilities, urban planning practices have also exposed difficulties in regulating the growing demand for land that a fast-urbanizing world is posing – a demand that creates urban sprawl and uncontrolled peri-urbanization processes.

Due to rapid urbanization and the growing unaffordability of basic urban services, many large urban areas in developing and developed countries have expanded their boundaries and economic activities by taking possession of surrounding rural areas, where unregulated patterns of informal settlements and small towns – some of which are newly developed – have rapidly densified. Fragmented around existing urban areas, these new urban entities are regulated by growth dynamics that “contradict the conventional structure theory of urban form” (Kombe, 2005) and generate peri-urban spaces that many local authorities have largely overlooked.

A common reaction among municipal governments has been the attempt to regulate peri-urban areas with traditional urban planning instruments. However, these tools have proven incapable to successfully deal with the complexity that fragmented spatial distribution processes poses to socio-economic and environmental sustainability. The result is an uneven development of between centrally located urban spaces and urban spaces positioned in peri-urban interfaces; compared to populations living in urban centers, many peri-urban residents are exposed to higher levels of vulnerability and poverty, because they have a reduced accessibility to the jobs, housing, and other socio-economic opportunities and services that central areas can offer (OECD, 2020d).

Local planners and authorities struggle to cope with the complexity of peri-urbanization expansions (Ledo Espinoza, 2021), and this issue is documented in many studies that analyze multiple urban settings, such as Sacaba, Bolivia (Ledo Espinoza, 2021), the metropolitan area of Lille, France (Hasiak and Richer, 2021), Dar es Salaam, Tanzania (Kombe, 2005), Jimma and Bahir Dar, Ethiopia (Abebe et al., 2019; Haregeweyn et al., 2012), and African New Towns (Keeton and Nijhuis, 2019). From these studies, a widespread agreement emerges on the need for alternative urban planning tools and strategies and innovative land use governance systems and policies.

Box 1: Promoting urban policy as part of national development: Lesson from Romania[6]

The Ministry of Development, Public Works and Administration is currently setting up the first Urban Policy of Romania. The Urban Policy represents an essential framework for establishing the connection between the dynamics of urbanization, demographic changes and the overall process of national development. A broad array of policy objectives and associated measures were identified for the effective attainment of a) green and resilient b) competitive and productive c) just and inclusive d) well-governed cities.

Building on the logic of the resilient recovery, the Urban Policy of Romania promotes the reconsideration of policy choices that address inequalities and local capacities while emphasizing a green, inclusive recovery. Cities should rebuild based on "a new approach to urban spaces that takes better account of different needs and shifts from a logic of mobility to one of accessibility to basic amenities and services". Key concepts such as the "circular economy", the "localization of the Sustainable Development Goals", "tactical urbanism" and "the 15-min city" are all taken into consideration into the first Urban Policy of Romania to help achieve better quality of life by enhancing economic activity, providing quality living environments, improving job opportunities and well-serviced business locations.

Pursuing sustainable urban development also requires accelerating change on disability inclusion in urban planning practices. Urban areas are facing a global urban accessibility crisis; estimates suggest that one billion people worldwide are living with a disability, however, planning processes often fail to consider the barriers – physical but also technical, environmental, and social – that design choices create for urban residents with disabilities. As a result of this neglected perspective, the capability of persons with disabilities to access urban spaces, their services, and their facilities is severely undermined. Poor planning poses a significant threat to the inclusion of people with disabilities in urban life, leading to increased inequalities, marginalization, and an accentuated risk of poverty (UNDESA, 2015a, 2016).

However, some good examples persist of the inclusion in urban life. In Germany between 2010 and 2014 the German Standard series DIN 18040 has been published. The three standards cover accessibility requirements for publicly accessible buildings, dwellings and public areas. By

[6] Contribution from the Government of Romania.

considering these requirements in every planning process a maximum of inclusion will be reached. Meanwhile parts of the three standards are even implemented into the German building regulations[7]. In the Republic of Belarus, standards for the construction of ramps have been adopted to satisfy the needs of people with disabilities, starting with design. Furthermore, to create a barrier-free environment not only through providing physical facilities but also removing obstacles in the minds of people and their behavior, a national plan is currently being developed to implement the Convention on the Rights of Persons with Disabilities.[8]

Vulnerable healthcare systems

Urban areas play a twofold role in public health. Urban sociotechnical systems provide access to most of the healthcare facilities and services that protect the wellbeing and health of urban populations. However, urban areas also facilitate the spread of infectious diseases (Neiderud, 2015), and peri-urbanization processes may exacerbate this issue (Allen et al., 2017).

Large urban settings, for example, have been the epicenter of the COVID-19 pandemic, which has exposed the fragility and structural issues of their healthcare systems, in addition to boosting existing inequalities, by disproportionately affecting vulnerable people, especially the residents of informal urban settlements and slums. To enhance the sustainability of urban environments, more resilient urban sociotechnical systems for healthcare provision are urgently needed. Restoring all essential healthcare services while continuing to manage the ongoing risk and consequences of COVID-19, for example, has become a key priority for local and national public authorities worldwide.

Shortage of health and care staff is one of the biggest challenges facing many urban areas and their local authorities. In presenting the workforce requirements for universal health coverage, WHO has estimated a gap of around 18 million health workers, with the majority of this personnel that is needed in developing countries (WHO, 2020b) – this data has been released in 2020 and shows a 3.5 million increase compared to the 2016 projections (WHO, 2016). However, given the notable differences in workforce availability, the intensity of the issue tends to change within and across regions (WHO, 2021c). For example, WHO data comparing the density of nursing and midwifery personnel in different geographical areas picture a state of great inequality. The number of workers per 10,000 people of Northern America is more than 150, a figure which is 15 times greater than Sub-Saharan Africa and 8 times greater than Northern Africa and Southern Asia (UN, 2021).

Urban violence and insecurity

About 83 million people in urban areas worldwide have to live with the consequences of armed conflicts, crime, and violence (UN, 2021). For example, murders related to armed conflicts in urban settings have caused more than 20,000 deaths between 2015 and 2017, and this figure escalated to almost 70,000 between 2018 and 2020 (UN, 2020h). In addition, in 2017, approximately 500,000 urban residents were murdered worldwide as a result of other types of crimes (UN, 2020c). Recent statistics show that approximately 54% of these homicides are carried out with firearms (UN, 2020b; UNODC, 2020a), many of which are entering urban spaces due to illicit trafficking (UNODC, nd).

Armed conflicts in cities generally are the consequence of social unrest, unstable political conditions, and corruption, which pose a substantial threat to urban livelihood. Statistics from over 120 countries indicate that, in 2018, the global cost of corruption that took place in urban

[7] Contribution from the Government of Germany
[8] Contribution from the Government of Belarus

areas was approximately $2.6 trillion, with individuals and businesses that paid at least half of this figure in bribes (UNSC, 2018). Additionally, over the last decade, the average bribery rate of low-income countries had remained almost 30% higher than high-income countries (ECOSOC, 2021).

Over 150 million urban citizens are also confronted with forced evictions (Farha, 2020) – involuntary removal from their homes or land without having access to legal and judicial processes (OHCHR, 2021). This problem has been amplified by COVID-19; significantly impoverished living conditions have left millions of urban households without the means for reaching tenure security. For example, 40 million Americans are at risk of eviction, whereas in India, South Africa, Kenya, and Brazil, thousands have lost their homes (Letzing, 2020).

Vulnerability to natural disasters

The sustainable development of many urban areas in developed and developing countries is also constantly threatened by natural disasters; not only pandemics, but also adverse events such as hurricanes, urban floods, earthquakes, and landslides. The direct losses from natural disasters in urban spaces was $2.9 trillion during the period between 1990 and 2017 (UNDRR, 2019).

Beyond economic damages, natural disasters also wreak havoc with urban social stability and dramatically increase urban death tools; "as a result of natural disasters, 1.3 million people were killed and 4.4 billion were injured in the past two decades, while millions were left homeless, displaced or required emergency help" (Gu, 2019). In China, for example, almost 98% of all major cities are vulnerable to urban floods (Normile, 2021), which caused the displacement of about 750,000 people in 2020 (Lew, 2020),. Meanwhile in Peru, people are displaced and lost their job in areas at risk of streams that endanger the population for the occurrence of mudslide and flash flood caused by torrential rains occurring high in the Andean mountains[9].

1.4. The COVID-19 pandemic and sustainable urban development

Urban areas have become the epicenter of the COVID-19 pandemic. Estimates show that 90% of the COVID-19 cases reported worldwide are located in urban settings (UN, 2020d), where the quality of life has been severely damaged by the devastating effects that the pandemic has caused. However, in addition to being home to most of the infected individuals, urban areas have also become the locus of crucial urban sustainability lessons that country leaders, local authorities, and other urban development actors should take into consideration. These lessons combine optimistic notes of encouragement with powerful expressions of criticism that should serve as a forceful warning: much more intense efforts are urgently needed to ensure transitions to more environmentally-sustainable, inclusive, and productive urban communities (OECD, 2021)

The responses of government leaders to the pandemic have introduced drastic social distancing and lockdown measures, which have modified patterns of energy and transport demand worldwide. Although only temporarily, these measures have led to a significant reduction of greenhouse gas emissions (Le Quéré et al., 2020) and some air pollutants (Streiff, 2020) in many urban areas. These indirect effects of the COVID-19 pandemic have demonstrated that a greener urban future is possible. However, other pressing environmental challenges have been exacerbated, showing the need for more innovation in urban sociotechnical systems. For

[9] Contributions from the Government of Peru

example, the intense use of disposable plastics has led to a significant increase of urban plastic pollution and inappropriate waste management practices (Adyel, 2020).

The COVID-19 pandemic has also led to a global economic crisis that has further highlighted the deep fragility of a labor market that is incapable of ensuring well-being and decent work for all. The devastating impact of COVID-19 on national labor markets has generated business closures and jobs losses worldwide, especially in least developed and developing countries. As a result, existing economic inequalities have been exacerbated and the level of poverty has increased, especially in the share of world population where vulnerable families rely on informal economic activities (ILO, 2020a). During the pandemic, wage losses in the informal sector made many informally employed workers worse due to lack of basic financial support that they needed to protect their health and well-being from COVID-19. For example, the economic hardship has pushed millions of informal workers in developing countries out of urban areas due to their impossibility to afford the prevision of basic urban services, including housing (UN-Habitat, 2020c). Moreover, populations who are affected by a higher incidence of extreme poverty will also be the most exposed to the long economic fallout of the pandemic.

For many cities the COVID-19 pandemic has started as a health crisis but has subsequently expanded into "a crisis of urban access, urban equity, urban finance, safety, joblessness, public services, infrastructure and transport" (UN, 2020d). Urban areas have become the physical space in which COVID-19 has worsened existing deep-rooted inequalities caused by gender, age, and place of residence. Example of the higher pressure on economically disadvantaged groups and other vulnerable populations can be perceived when looking at education systems, where adults and children without Internet access have been left behind. Meanwhile, social care systems have left older individuals and those affected by mobility issues isolated, with no opportunities for social interaction, and housing systems with informal settlements have left their residents exposed to a higher risk of virus transmission due to overcrowded and unhealthy leaving conditions.

On the one hand, the pandemic has exposed the incapability of many urban settings to deliver on the expectations of disaster and risk management for urban resilience and sustainability. Many urban sociotechnical systems have fallen under the pressure, leaving people and places behind, and this result clashes with the core principles of inclusivity and social justice that urban sustainable development champion. On the other hand, the pandemic has showcased the pivotal importance that STI systems play in contributing to equip society with the instruments and capabilities required to direct innovation efforts towards improving sustainable urban development and the resilience of urban systems. Scientific knowledge production processes, digital technology adoption, and innovations in organizational and institutional settings have contributed to mitigating the impact of COVID-19, helping many urban sociotechnical systems to continue to function during the crisis.

2. APPLYING SCIENCE, TECHNOLOGY, AND INNOVATION FOR SUSTAINABLE URBAN DEVELOPMENT

STI solutions can mitigate the most pressing urban sustainability challenges and harness the value embedded in the global population growth while ensuring sustainable urbanization processes. Both technological and non-technological innovations have been introduced in developed, developing, and LDCs to sustain positive change in urban sociotechnical systems[10]. The application cases are grouped in twelve main categories, which identify a series of societal needs that urban areas are expected to provide for in a sustainable manner: energy; circularity; water; mobility; work and financial stability; housing; food; education; gender empowerment and equality; urban planning; healthcare; and safety and security. Each category is connected to one of the twelve groups of urban sustainability challenges presented in the previous section (see Table 2).

Table2. Summary of STI solutions to urban sustainability challenges

Urban Sustainability Challenges	Category	STI Solutions
Inefficient and polluting urban energy systems	**Energy**	Biomass energy systems; Solar energy systems; Hydropower energy system; Geothermal energy systems; Wind energy systems; Green hydrogen technology; Energy efficiency in the construction sector
Unsustainable urban production and consumption patterns	**Circularity**	Product-service systems; Matchmaking platforms for exchanging resources; Environmental labelling; Food traceability systems; Food sharing networks and technology; PAYT pricing models; Smart bin solutions; Single-use plastic ban; Circular economy for plastic; Cup-as-a-service subscription models; Data platforms for plastic waste mapping; Digital systems for automatic hazardous waste detection; Robotic systems for waste management; Right-to-repair standards; Urban mining techniques
Urban water scarcity	**Water**	Smart metering infrastructures; Nanotechnological applications for desalination processes; Sensor-based water protection systems; Portable testing kits for real-time quality control; Satellite technology; Mobile applications for waste monitoring
Urban traffic congestion and vehicle emissions	**Mobility**	Low-emission vehicles; Journey planner applications; Real-time traffic management systems; Mobile ticketing; Mobility as a Service; Bike sharing systems; Cycle-to-work schemes
Limited access to decent urban employment opportunities and growing inequalities	**Economic prosperity and financial stability**	Dedicated urban zones for STI development; Digital finance; E-commerce platforms; ICT-related education and training programs; Innovative data management systems; Cash transfer schemes and programs; Smart technologies to fight forced labor and modern slavery
Unaffordable and poor-quality housing	**Housing**	Digitalization of construction operations and manufacturing processes; Digital twin technology in construction; Predictive analytics; Environmentally sound technologies; Smart building solutions
Uneven access to quality education	**Education**	Touch-screen tablet solutions; Speech recognition software; Adaptive learning technology; Augmented reality; Learning platform solutions;

[10] Please note that the analysis does not aim to cover all possible STI solutions to urban sustainability challenges. The objective is to select a comprehensive number of most notable technological and non-technological innovation cases whose collective examination is required to form a sufficiently robust and data-rich environment for supporting: (1) the identification of relevant lessons and practical implications; and (2) the subsequent formulation of policy measures that can maximize existing potentials. In the framework of this analysis, more than one hundred STI-related initiatives have been examined. Moreover, the urban sustainability potential of some innovations has been examined in different application areas. For example, digital twin technology has been analysed in the context of housing provision, as a monitoring tool, and in urban planning practices, where it becomes a digital support tool for enhancing collaborative decision-making.

		Place-based digital education strategies; Digital learning masterplans; Education for sustainable development
Gender-based inequalities and violence against women and girls	**Gender empowerment and equality**	Gender-pay-gap regulations; Compensation management platforms; Anti-violence online services; Awareness-raising measures and education
Defective urban planning practices	**Urban planning**	Spatial group model building; Gamification for digital participation; Digital twin technology for urban planning; Online crowdsourcing platforms
Vulnerable healthcare systems	**Healthcare**	Digital communication channels as early-warning systems; Wearable health devices; Remote clinical services; Crowdfunding platforms; Dashboard solutions
Urban violence and insecurity	**Safety and security**	Crime prevention policy; Gunshot detection technology; Crime mapping tools; Predictive profiling technology
Vulnerability to natural disasters	**Protection from natural disasters**	Disaster data infrastructure; Nature-based solutions

2.1. Energy

Urban sociotechnical systems for energy production and distribution are highly dependent on fossil fuel combustion and a transition to low carbon and sustainable renewable sources is urgently needed, especially considering the steep increase in urban energy demand that an expanding population will progressively cause (Phillips and Smith, 2015). The use of renewable sources to produce energy gained momentum during the last two decades. However, their shares have always remained limited in comparison to fossil fuels. This gap has triggered significant investments is research and development activities, which have resulted in notable technological and non-technological advancements. Examples of STI solutions to unsustainable urban energy systems including solar, wind, hydropower, biomass, and geothermal energy systems that leverage available natural resources and local climate conditions to produce green energy; green hydrogen technology; and energy efficient buildings. Most of these solutions have already been embedded in urban settings, whereas others serve urban areas by providing them with clean energy that is produced outside their administrative boundaries. Offsite renewable energy production, however, may be undermined by potential market and policy-related barriers, and the diffusion of this green energy production model may benefit urban areas at the expense of rural territories. For example, wind farms can generate landscape and visual impacts in rural settings.

Biomass energy systems

Anaerobic digestion technologies or biomass that convert biodegradable waste into methane-rich biogas are commonly diffused worldwide. For example, urban areas in Guatemala use electricity generated from sugarcane biomass – also known as bagasse – which has been an established practice amongst sugarcane producers since 1990. Electricity from bagasse is used to meet the energy needs of local sugar companies and any surplus is sold back to the grid. During the 2017-2018 harvest season, bagasse made it possible to save approximately 4 million tons of carbon emissions (SWESN, 2021e).

In Manouba, a city in north-eastern Tunisia, a family-managed agricultural enterprise developed in 2015 an innovative form of biofuel that can replace firewood and eliminate the dangerous emissions it generates. The small enterprise invented an agroforestry waste

recycling system that extracts organic charcoal and biomass energy out of pear and olive tree waste (Rajab, 2018). A few years later, Rio de Janeiro piloted the first Biomethanisation system in Latin America (Yeung, 2020). Biomethanisation is "a process by which organic material is microbiologically converted under anaerobic conditions to biogas" (Angelidaki et al., 2011). This system processes the organic fraction of urban solid waste via anaerobic digestion to generate energy and to produce organic compost. The pilot project was conducted in 2018 through the collaborative partnership between the Methanum Company and the Federal University of Minas Gerais. The systems tested in Rio de Janeiro could provide meet the daily need for green energy of an urban area with 70,000 inhabitants.

However, despite the value that the newly developed technology can produced, the project did not reach scalability. Research shows that several issues prevented scale up operations from taking place. For example, the digestion process was complicated by the mix of urban waste; materials needed to be divided during the input phase, but waste management systems do not always offer this service. Moreover, building the pumping systems used for introducing and extracting waste required significant levels of financial investment. Finally, legal frameworks, market conditions, and user demand did not offer the appropriate enabling conditions (C40, 2020).

Solar energy systems

Technologies using solar photovoltaic (SPV) systems to produce urban energy are used in many different application contexts, such as buildings and waste management systems. Moreover, ground mounted panels are among the most common applications, together with rooftop and floating installations.

Rooftop SPV installations have increased significantly in recent years and can easily sustain energy production in urbanized territories where energy is not available, or power interruptions and outages occur regularly. Zambia, for example, is a country in which power interruptions were particularly dangerous for urban areas, because they were regularly leaving medical facilities without electricity provision. To mitigate the effects of this issue, UNDP and the Norwegian Government installed rooftop solar panels on Zambia's national medical warehouse, giving them the capability to autonomously produce green energy (Burton and Alers, 2019). Similarly, in Zimbabwe, hospitals and clinics were frequently affected by long term power interruptions. This disruption was forcing healthcare workers to operate under inadequate conditions and to postpone emergency surgeries. As a part of the UNDP's Solar for Health Initiative, 400 healthcare facilities across the country were provided with rooftop SPV systems to steady power supplies and switch from expensive and polluting diesel-fired generators to clean and renewable sources (Burton and Alers, 2019).

Compared to ground mounted and rooftop installations, floating SPV power represents a more recent technology in the solar power industry. The implementation of floating SPV systems has started emerging in 2008 (IRENA, 2021c), mainly in response to an increasing competition for land use, due to an expanding population and a growing demand for agriculture and industry services (Chandran, 2019). Floating SPV systems also eliminate the operational challenges that typically affect land-based SPV systems – site preparation, site decontamination, and shading activities for cooling purposes (Juch and Rogoll, 2019).

Singapore, for example, has recently introduced floating SPV system installations that groups 122,000 panels. This operation is expected to reduce carbon emissions by approximately 32 kilotonnes annually (Lin, 2021). Moreover, in the city of Suzhou, China's Anhui Province, the China Energy Conservation and Environment Protection Group has partnered with Ciel & Terre – a French company specialized in floating SPV panels – to complete a 70MW floating

SPV system. The plant is expected to generate approximately 70,000 MWh of green electricity annually, equivalent to the power consumption of 21,000 households (SWESN, 2021c).

Developing regions host some of the remotest cities and urban areas in the world, whose development is affected by electricity production challenges. The Chullpia case demonstrates that SPV power can help mitigate these challenges, by introducing scalable off-grid solutions. Relevant examples in this applications domain have also surfaced in the Sub-Saharan region, where the number of urban residents without access to clean and affordable electricity continues to remain very high (IEA et al., 2021).

To eliminate gaps in electricity provision, SPV systems have been extensively used in Africa. For example, as part of Egyptian government's sustainable energy strategy 2035, the government is currently constructing 26 new electricity stations near the city of Aswan, with a total capacity of 26,000 MW. Electricity produced through solar energy increased from 0.529 billion KW to 1.465 billion KW between 2018 and 2019 (increasing by 177%) as Egypt inaugurated the Benban Solar Park, the world's largest solar park[11].

To address the energy affordability challenge facing many urban residents, the African company SolarWorks is providing solar home systems and energy services on a pay-as-you-go basis to urban populations in Mozambique and Malawi. SolarWorks produces technology for different needs, from small systems that include lights and mobile-charging capacity, to bigger systems that can provide power to more complex electric equipment, such as televisions, refrigerators, and sewing machines. The company operates using an innovative business model; customers pay small amounts every month using mobile money until they reach the necessary expenditure to own the appliance model (GIZ, 2021c).

Hydropower energy system

Hydropower is an old technological solution, but under the right conditions, it can still provide urban areas with cost-effective and green electricity. As of 2021, for example, Norway produces 99% of electricity from hydropower, while China has the largest hydropower plant in the world, which produces 80 to 100 terawatt-hours per year.

Examples from various countries show that cities can enhance their existing hydropower infrastructure to produce more emission-free energy. For example, the hydropower station on the River Danube in Pfaffenstein, Germany, produces about 40 million kilowatt-hour of green electricity for the City of Regensburg. This amount of energy is sufficient to serve 11,000 households and the electric buses of the city (SWESN, 2021b).

Melbourne is another city where hydropower plants are used to produce green electricity. Melbourne Water, a statutory authority owned by the Government of the State of Victoria, has been introducing mini plants in different parts of the city since 2008 (SWESN, 2021a). These plants generate approximately 69,500 megawatt-hour of power per year, and they save about 75,800 tonnes of carbon emissions (Keller, 2017).

But in addition to large-scale projects, small-scale micro-hydropower solutions have also spread, and they are making a notable difference to urban and rural communities in remote locations. For instance, kinetic hydropower systems have been introduced in canals in Germany, South Africa, the United States, and India (UNIDO, 2019).

[11] Contribution from the Government of Egypt.

Geothermal energy systems

Technologies for geothermal energy production are used for heating, cooling, and generating electricity. Geothermal power plants produce electricity by converting heat sourced from geothermal fluid. However, high or medium temperature resources are needed for ensuring better efficiency (IRENA, 2021a), and these resources are located closely to regions like Iceland, El Salvador, New Zealand, Kenya, and Philippines. Leveraging the predisposition of their natural environment, all these regions are currently using geothermal energy to produce a share of the electricity demand generated by their urban and rural areas. For example, geothermal resources account for nearly 40% of Kenya's power generating capacity (SWESN, 2021d).

Geothermal energy is also used in European cities. As part of the project Decarb City Pipes 2050, for example, the European cities of Bilbao, Bratislava, Dublin, Munich, Rotterdam, Vienna, and Winterthur are coordinating their work in this green energy domain by exchanging experiences and lessons on how geothermal energy can be used to decarbonize building heating systems (EC, 2021a).

Wind energy systems

Wind power is one of the most rapidly accelerating technologies amongst all renewable energy systems. In twenty years, the combination of onshore and offshore wind generation capacity has increased worldwide, from 7.5 gigawatts (GW) to some 564 GW (IRENA, 2019b). The power generated is transmitted and distributed to the industrial, commercial, and residential users in cities. The UK was the third largest generator of wind powered electricity amongst OECD European countries in 2018, after Germany and Spain (BEIS, 2020). Other pioneering countries in the use of wind power for energy production also include China and the United States. In the meantime, France, Korea and Vietnam are increasing their investments (IRENA, 2020).

Land-based wind sites are often located in remote locations, but small wind turbines can also enter into urban areas, on the roofs of residential and commercial buildings, for example. However, the efficiency and environmental sustainability of these roof-mounted turbines is still highly debated, mainly due to the presence of multifaced technical challenges that research and development activities have been attempting to solve. For instance, winds in urban areas are irregular and severely affected by the presence of buildings and other obstacles (Zabarjad Shiraz et al., 2020).

Green hydrogen technology

Green hydrogen is one of the newest members in the family of renewable energy sources. In recent years, countries started to announce their investment plans to investigate how to benefit from green hydrogen production and develop the technologies required to transform hydrogen in a source of clean power. Europe, Chile, Japan, Australia, Germany, Saudi Arabia, and Portugal are some of the countries that are planning extensive investments in green hydrogen technologies (EC, 2020b; UNFCCC, 2021a). However, developments are still more theoretical rather than practical and technological. Current technologies can produce hydrogen for energy production, but the current practices cause excessive amount of carbon monoxide and dioxide. This type of hydrogen is called grey hydrogen (UNFCCC, 2021a).

Green hydrogen is a promising alternative energy source to fossil fuels and studies show that it may enable the development of low- and zero-emission vehicles for urban mobility, such as

buses, cars and long-haul trucks, and also hydrogen trains, hydrogen-powered aerial vehicles, and turbines for grid power (HC, 2020).

Energy efficiency in the construction sector

To improve energy efficiency of new-built and existing constructions, urban areas are introducing smart technology solutions in the design and construction process and non-technological innovations (IRENA, 2021d; UNECE, 2019), such as energy rating systems, performance certification schemes, building and construction codes and standards, solar thermal ordinances, and design for sustainability approaches. These solutions help to firmly embed sustainable development principals in the building and construction sector, while providing supply chain actors with regulatory frameworks that contain local, national, and international sustainability-related expectations (NIDirect, 2021).

In recent years, many developing and developed countries have introduced new regulatory systems or modified their existing schemes. For example, in Romania, new building energy codes have been introduced in 2017, which require new construction and renovations to comply with minimum energy performance standards. Similar restriction have also been introduced in Brazil, where some types of incandescent bulbs have been banned, and the Brazil's National Institute for Standardization has made mandatory the certification of public lighting using LEDs and other efficient lamps (Abergel et al., 2017). Meanwhile, other countries are experimenting with solar thermal ordinances (STOs), which are applied as a part of municipal regulations regarding building technologies. STOs are legal provisions that require a building's minimum share of heating demand to be covered through the installation of solar thermal systems (IRENA, 2021d).

Energy efficient buildings also require investments in innovate materials that offer adequate thermal performance. On this matter, the government of Ukraine launched a State Program on Energy Efficiency in 2016. The program foresees loans to finance the costs for a variety of energy efficient materials and equipment, such as insulation materials, energy efficient windows, and smart energy meters for individual households and condominiums. The total amount of loans issued as of the end of 2017 was over €150 million for 373,000 households. As a result of the measures implemented during the program, 6 billion cubic meters of natural gas were saved (UNECE, 2018).

Thermal insulation is key to attain energy efficient buildings, because heating and cooling operations accounts for approximately 50-60% of their total energy consumption, and many heating and cooling systems are inefficient and still dependent on fossil fuels (IRENA, 2021d). Digital solutions can be used to track these inefficiencies, by monitoring the overall energy performance of buildings and evaluate the performance of single building components (Morán et al., 2016; Rawte, 2017). Monitoring devices such as sensors, smart meters, and real-time energy management systems are some of the most common examples of technologies that can be used for energy monitoring purposes (Grid Edge, 2021; IEA, 2019a). Some of these solutions – such as smart meters and home energy management systems – can also enhance households' engagement with energy efficiency, by making users more conscious of their energy use habits and inducing behavioral change (IEA, 2019b).

Continuous research and development to improve the energy efficiency in the construction sector is equally important. At this front, The Collaborative Laboratory for the Built Environment of the Future (builtcolab.pt) in Portugal is a good example of an effort that aims to develop research, innovation, and knowledge transfer activities, with a view to increasing productivity, competitiveness, and sustainable growth of the Ecosystem of the AEC sector (Architecture, Engineering, and Construction). The Lab is promoting the digital and climatic

transformation of buildings and infrastructures, making them adaptable, intelligent, resilient, and sustainable[12].

2.2. Circularity

Production and consumption patterns have become key priorities for many urban regions of the developed world because they are putting a serious strain on the limited natural resources that the world has to offer. In the last decade, local and national governments, consumers, and producers started to take conscious actions that attempt to bring circularity and behavioral change into urban areas. The STI solutions resulting from these actions mainly focus on decreasing material footprint per capita, preventing excessive waste production, and increasing recycle and reuse of different types of waste. The main categories of waste include plastic, hazardous chemicals and materials, electronic products, food, and municipal solid waste.

Box 2: Bioeconomy, Circular, and Green (BCG) Economy Policy Model in Thailand.[13]

BCG Economy Model Policy is an economic model towards sustainability that combines bioeconomy with circular economy and green economy.

o Bioeconomy focuses on efficient utilization of natural resources along with natural balance protection, by using technological advancement in various disciplinary to increase efficiency and innovation.

o Circular Economy is an economic system that all resources can be restored and re-utilized to avoid resource scarcity.

o Green Economy is an economic development model that concerned balanced development between economy, society, and environment.

This development model emphasizes on inclusive and sustainable development focusing on food and agriculture, health and medicine, bioenergy, biomaterials and biochemicals, and tourism and creative economy. The BCG model will help Thailand to overcome the middle-income trap and the effect of COVID-19 pandemic to improve social inequality by linking knowledge on science, technology, innovation to biodiversity and cultural diversity to build internal strength of the country and distribute benefits to community equally.

Product-service systems to reduce footprints

To reduce the ecological footprint of urban environments and their residents, many companies are spending significant resources on the development of innovative business models. Product-service systems, for example, are circular business models that enable producers to retain the ownership of their products whereas customers only buy its utility. Producers also remain responsible for undertaking maintenance service and repairs. These business models stimulate producers to use production techniques and product designs that extend product lifespan, minimize the use of harmful and toxic resources, and maximize the use of sustainable and durable materials (Vezzoli et al., 2021). For example, CECOLAB in Portugal is working to develops sustainable market solutions in a model of circular economy for strategic value chains on the national level[14].

[12] Contribution from the Government of Portugal
[13] Contribution from the Government of Thailand
[14] Contribution from the Government of Portugal

Matchmaking platforms for exchanging resources

In addition to product-service systems, companies are also adopting business-to-business (B2B) matchmaking platforms for exchanging resources. These platforms allow companies to put their unused products, materials, and waste streams back into the market and help other companies to find resources while reducing waste (EC, 2017a). Excess Materials Exchange is an example of B2B matchmaking platform that enables users to find reuse options for unused materials and waste. During the pilot study, the platform has circulated 18 different materials back to markets, enabling exchanges of excess resource flows between different industries and sectors, and saved significant amount of carbon emissions and energy (EME, 2019).

Environmental labelling

Another way to decelerate the consumption of materials and goods in urban areas is to make customers aware of the environmental cost of their buying habits, by providing them with detailed information. This can be done with environmental labelling and information schemes, which are voluntary methods of environmental performance certification (OECD, 2016a). By adopting labelling and information schemes, for example, organizations can inform their customers about the energy consumed to manufacture a product, offer data on the recyclability of packaging materials, or highlight the absence or presence of certain materials (ISO, 2019).

Eco-labels can be effective tools for communicating and marketing environmental credentials of products, and they are often used in sustainable public procurement to ensure that public organizations purchase best-standard products, for example, in India, Vietnam, Colombia, and Brazil (UNEP, 2019a). However, it is important to note that eco-labels may also be misused to convey inauthentic information about environmental impacts. This practice is known as greenwashing.

Food traceability systems

Food that should feed urban and rural population can easily become waste along its production and distribution journey. Digital traceability and tracking systems can enable earlier detection of inefficiencies along food supply chains. These systems are highly effective; they help reach higher levels of transparency in production processes, prevent food safety issues, and reduce food loss through supply chain optimization (WEF, 2019a). However, price, accessibility to specific technologies, and the uptake of key digital solutions are among the main barriers for implementation, especially in developing regions.

The improvement of locally produced food safety and traceability measures is the core focus of the AMBROSIA project, whose main output is a digital system that helps municipalities tracks points of origin and shipping processes. It also records all transactions, the status of foods during transportation, and environmental conditions (ESA, 2020). The AMBROSIA solution increases the visibility of food along its journey and ensures quality controlled logistics, an activity that helps avoid waste and spoilage. Recent studies show that reductions in the total lead time up to 48 hours may result in a higher quality level upon arrival and less waste (IoT4AGRI Consortium, 2021).

Food sharing networks and technology

Food waste is a growing concern on a global scale. In response to this challenge, innovative solutions have been introduced in urban areas not only to improve the food supply chain but also to convert the waste it produces in other products. Food waste from companies, supermarkets, and hospitality facilities, for example, can be reintroduced as organic waste in other processes (Ellen MacArthur Foundation, 2021).

Online food sharing services like Ollio and FoodCloud, is another innovative example to manage food that would otherwise be wasted. The online platform will help to collect food that can be redistributed among urban and rural residents in need (Harvey et al., 2020). Moreover, unused food can also be managed through redistribution organizations. With the support of the UK Food Reduction Fund, eight redistribution organizations have been able to save 2500 tonnes of food and redirect it to people in need – food that would have ended up in landfills (DEFRA, 2018a).

PAYT pricing models

The COVID-19 pandemic, however, has introduced new challenges in food supply chains and municipal waste management systems. The pandemic has caused increasing amount of mixed waste, a suspension of recycling activities, and lack of proper equipment for waste collectors, including personal protective equipment. Collecting, classifying, and separating the waste are critical activities in waste management systems (Chen et al., 2018; OECD, 2019b). In the Philippines, results of the survey conducted by the Technical Working Group on Anticipatory and Forward Planning, showed that in the first month of pandemic, 35% of the respondents were not able to sell their product which led to wastage of produce and losses for the farmers. Although the government is assuring the people that there is enough food supply, bringing them to the consumers becomes a problem during the early stage of the COVID-19 pandemic[15].

In urban areas, to facilitate the process, some local authorities have introduced pay-as-you-throw (PAYT) pricing models. The objective is to improve municipal waste management by encouraging waste reduction and separation before disposal and making waste producers responsible for collection and treatment (EC, 2017c; OECD, 2019b). PAYT pricing models can be combined with other digital and physical platforms, such as WasteIQ, a platform implemented in Bergen, Norway. The system links with digitized waste management equipment to generate a customized waste pricing model. In Bergen, the combination of the digital platform with data collection processes and new economic incentives has resulted in a 10% reduction of the general waste level (CIRCit Nord, nd).

Smart bin solutions

Municipal waste management can also be improved by introducing networks of compacting bins with built-in sensor solutions, which are connected through a digital platform. The bins automatically upload data on filling levels on the platform, which helps determine when and where waste collection services are needed. Existing bins can also be integrated into these new platform solutions, by equipping them with sensor solutions (OECD, 2020e).

For example, Konya's Selçuklu Municipality in Turkey, started to monitor the garbage containers instantly with the Waste Scada System. The system, which has an environmentally friendly technology, takes its energy from the sun and does not need extra wiring. The system can manage not only the level of waste in the garbage container, but also the medical waste and waste oil collection units. The technology can be easily installed on already used containers, vehicles and other elements without the need to change the existing infrastructure[16].

Single-use plastic ban

To accelerate the transition to zero-plastic waste, countries and industrial sectors have introduced changes in policy, regulatory, and business settings. These changes are helping urban areas to decrease plastic waste production by modifying the consumption patterns of

[15] Contribution from the Government of the Philippines.
[16] Contribution from the Government of Turkey.

single-use plastics and stop their usage. For example, single-user plastic bags have been widely removed in small-scale markets and supermarket chains, where many retailers have introduced biodegradable bags. Plastic shrink wrap have also been replaced with alternative options such as reusable pallet wrappers (Viera et al., 2020).

Circular economy for plastic

Other initiatives include deposit return schemes and reward mechanisms that encourage customers to bring back plastic containers, such as bottles and cans, and innovative cross-sector alliances which provide policy direction. The United Kingdom, for example, is advocating green production and consumption through the UK Plastics Pact initiative – a cross-sector alliance whose objective is to create a circular system that keeps plastic out of the natural environment (WRAP, 2020). To introduce circular economy principles in urban settings, the Government of the United Kingdom has banned the sale of a number of dangerous plastic products, such as microbeads (DEFRA, 2018c), whereas the European Commission has proposed mandatory collection schemes to separate collection of residual waste, especially single-use plastic waste, in full scale by 2050 (PlasticsEurope, 2018). Moreover, to prevent the export of unmanageable plastic waste from developing countries – the main producers of plastic waste – the UN has introduced a legally binding pact that almost every country in the world have signed (Edmond, 2019).

Cup-as-a-service subscription models

Another stream of innovative solutions to plastic pollution includes technology-based platforms and new business models that are helping urban areas to establish stronger collaborations between actors along the supply chain, ranging from consumers, food retailers, utility companies, and recyclers. These solutions act as an intermediate agent between the public and private sector, and they facilitate the creation of sustainable waste management ecosystems for plastic products.

For example, cUPcircle is an award-winning circular economy service that has been piloted in the hospitality sector. cUPcircle proposes to introduce a cup-as-a-service subscription model for cafes and their customers, which are provided with a continuous furniture of reusable cups in place of disposables. The cups are equipped with barcodes. Customers who subscribe to this service receive their beverages in reusable cups in exchange of a deposit. After being used, the cups are collected in smart bins, which recognize the digital profile of customers and refund the deposit. In addition, the cups are collected, cleaned, and redistributed, freeing cafes' staff from the need to manage single-use cups. (UNLEASH, 2018).

Data platforms for plastic waste mapping

Moving to a more international level, in 2019, about fifty major global companies have forged the Alliance to End Plastic Waste (AEPW), a non-profit organization whose objective is to reduce the pressure that plastic waste is creating on society. This commitment of tackling plastic pollution is supported by the implementation of a new data platform. Supported by a technological partner, research and development efforts are being made to establish a digital platform solution that can aggerate and scale the different streams of data that the actors operating in the plastics value chain possess. (IBM, 2020).

Digital systems for automatic hazardous waste detection

STI solutions can also help detect and manage hazardous waste. The ARC-SCAN system, for example, can automatically detect oil spills in open waters, enabling a prompt response. The

system represents an advanced technological solution that combines nautical navigation systems, satellite imagery, and machine learning (ESA, 2019).

Robotic systems for waste management

Additional advanced technologies are also entering into waste sorting operations, with robotics and artificial intelligence that can be used to support hazardous waste identification processes and to improve waste disposal operations (UNGC, 2017a). For example, robot technology and recycling specialists in Denmark and Sweden have been experimenting with new robotic solutions that use vision systems and deep learning to identify items that contain batteries but may pass unnoticed when electronic waste is sorted (Grau et al., 2020).

Research and development in robotics are also producing new generations of robotic systems for locating chemical leaks in industrial sites and cleaning machines powered with artificial intelligence (Amit et al., 2019).

Electronic waste recycle management

The recycling process of electronic waste is extremely complex and poses a serious threat to urban life; electronic objects are composed of an untangled mix of different materials, which are difficult to separate for reuse purposes. Changes in international regulations, for example, have been introduced in Europe, where an eco-design law including Right-to-repair standards have been recently enforced. The primary objectives are to fight against planned obsolescence and facilitate non-proprietary product repair. This new legislation forces manufacturers to ensure the longer-lasting life of their appliances, so that the production of electronic waste can be reduced. Manufacturers are required to provide spare parts for up to ten years and to ensure that the repair can be conducted by third-party professionals (European Parliament, 2020).

Responsible production principles for extending the lifespan of electronic products can also be complemented with new recycling techniques, such as urban mining. Urban mining of electronic waste implies the extraction of the nanometals embedded in discarded electronic applications – largely found in urban settlements – which are in turn reused in manufacturing processes of new products. Research and development in this area focuses attention on technological innovation, new business models, and scale-up for industrial applications. For example, the European project PLATIRUS developed and tested a set of technological solutions for recycling precious metallic elements from secondary waste sources, like electronic waste. These technologies are now ready for industrial use (EC, 2021e).

China has been experimenting with urban mining techniques and technologies for many years, extending the application area beyond electronic waste. The volume of material recovered and reused has been growing significantly since 2006. Moreover, the practice is becoming significantly cost-efficient (Zeng et al., 2018). However, unsupportive regulations, the lack of stable fiscal and taxation policy, and the absence of ad-hoc business models have been listed among the factors that are preventing urban mining from reaching its full potential at the national level (Xiaofei et al., 2017).

To monitor this electronic waste, the International Telecommunication Union (ITU) has published the Global E-waste Monitor 2020, which assessed the quantitative, flows, and the circular economy potential of e-waste. At the same time, ITU has also published a toolkit on Policy Practices for E-waste management which presents tools for fair and economically viable extended producer responsibility in the management of e-waste[17].

[17] Contributions from the International Telecommunication Union.

2.3. Water

Access to clean water in urban areas is hindered by multiple factors, such as the lack of adequate infrastructure, limited water resources, global warming, pollution in water sources, high-water stress due to excessive extraction, and wasteful behavior. However, depending on the regions, different trends surface. On the one hand, urban areas in developing and least developed regions tend to struggle with finding adequate resources to access clean water and lack infrastructure. On the other hand, developing countries are mainly dealing with obsolete infrastructure assets and excessive levels of water consumption. Many technologies and innovative practices are currently available that can help tackle the urban water scarcity challenges. In addition to manual drilling, more advanced solutions include smart water infrastructures, nanotechnological applications, sensor-based water protection systems, portable testing kits for real-time quality control, satellite technology, and mobile apps.

Smart metering infrastructures

Improving water-use efficiency, demand management, and leakage control is one of the most urgent actions in urban contexts (Andersen, 2020), and smart technologies can provide the necessary support; these technologies can trigger behavioral change of urban households by providing them with real-time information and customized feedback (Cominola et al., 2021). For example, the European-funded project SmartH2O has developed a digital platform that uses smart meters to connect different stakeholders, such as water utilities, municipalities, and citizens, helping them to develop and implement more efficient data-driven water management practices and policies. The platform collects and processes real-time water usage data and analyze consumer behavior. This technology has been introduced in Spain and Switzerland, where it has been tested by 40,000 and 400 households, respectively. The results of the pilots show water savings of approximately 20% in Spain and 10% in Switzerland (EC, 2017b). Similarly, Smarter Homes is a company that produces smart metering and automated leakage prevention systems. Their devices have been installed in 40,000 households in India, and they have helped save approximately 35% of water consumption on average (Oliver Viola et al., 2020).

Nanotechnological applications for desalination processes

Water desalination is the process of removing salt from seawater and then filtering it to obtain drinking quality water. Conventional resources like rainfall and river runoff are becoming insufficient to meet current demand for clean water in urban systems. In response to growing needs, several countries are producing additional drinking water by using desalination technologies. As of 2018, there were 16,000 desalination plants in 177 countries (Jones et al., 2019). Nanotechnological applications have been introduced, proving to be more sustainable solution as a good alternative to reverse osmosis, one of the most common methods used in water desalination that cause pollution to sea waters (Favre and Oksen, 2020; WEF, 2018). For example, the European project NAWADES has developed since 2016 nanotechnology-based, self-cleaning membranes for water desalination. The prototypes have been tested at a desalination plant located in the metropolitan areas of Barcelona, Spain (EC, 2016b).

Sensor-based water protection systems

Water quality is becoming one of the main challenges for urban systems, due to the growing discharge of untreated waste water into rivers, lakes, and coastal and the pollution that results from various land use activities. Declining water quality is putting water availability under an

even bigger stress and is affecting economic growth and public health; it causes diseases, reduces ecosystem functions, and undermines food production (Zandaryaa et al., 2015). Protecting water resources, monitoring their quality, and detecting polluted waters that require treatments is essential to ensure continuation in the supply of clean water and food (UNDESA, 2015b).

Digital solutions for water protection can help increase the efficiency and effectiveness of water treatments, enabling real-time water monitoring and the more rapid detection of possible pollutants (EC, 2021a). The project Fiware4Water, for example, has been developing a smart solution platform that builds upon distributed intelligence and combines different types of sensing devices, such as smart meters and water quality sensors, to monitor water quality parameters and enable real-time monitoring. The Fiware4Water platform has been piloted in European cities. In France, the project consortium is collaborating with the utility company that operates the water systems in Cannes. The objective of the collaboration is to channel data into to Fiware4Water platform to monitor water quality in the urban area, forecast water demand based on historical data, and manage leakage control (EC, 2021c).

Box 3: Sensing technology for ensuring ground and surface water quality

Keeping the quality of ground and surface waters under control by using sensing technology is the primary purpose of GEMstat. Included in the GEMS/Water Program of UNEP, GEMstat is a free, global water quality information system that contains millions of data entries sourced from water stations worldwide. The system relies on a voluntary submission scheme that invites countries and their local organizations to share the data that they capture with monitoring networks. GEMStat is currently combining data from water stations positioned in more than 80 countries and covers a timeframe of 93 years, from 1906 to 2020.

In addition to storing the data in the same database, GEMstat produces statistical and graphical analysis of water quality data at different levels of aggregation. By using the platform, anybody can carry out essential data processing tasks in urban areas, which are enabled by a system that help to: visualize and analyze available data; harmonize and standardize monitoring data exchange to improve national and international operations; and enhance data accessibility, transparency, and discovery processes information systems like GEMStat can increase transparency, accountability, and the engagement of countries that experience reporting deficiency, especially developing and least developed countries.

However, for crowdsourcing platforms like GEMStat to be functional and maximize the potential benefits they can produce, innovative training and supportive policy frameworks are required to build capacity. Not all countries can access these online services, mainly due to the lack of adequate systems for gathering water quality data and lack of appropriate knowledge and skills.

Source: UNEP, *The global water quality database GEMStat* (https://gemstat.org/about/).

Portable testing kits for real-time quality control

To address water contamination issues, British Geological Survey (GBS) has developed an innovative approach to the assessment of microbial risks in drinking water; their methodology introduces a real-time assessment that works faster than traditional methods based on fecal indicator organisms. GBS implement on-site testing using portable tryptophan-like fluorescence (TLF) sensors, which provide instantaneous readings. In 2020, this new assessment was tested in Africa. The results of the test show that TLF has proved to be a more

stable and precautionary indicator of microbial risk than fecal indicator organisms (Sorensen, 2020).

Satellite technology

When visible, pollution and contamination in water sources can also be detected by using satellite technology and drones (EC, 2021a; Favre and Oksen, 2020), which can become an economically feasible solutions for obtaining high-resolution images. Sentinel-2, for example, is an Earth observation mission launched by the European Space Agency; its objective is to monitor variability in land surface conditions using two polar-orbiting satellites. Due to its public-domain nature, Sentinel-2 is an open-data project, and its satellites can provide free images. However, in the aerospace industry, research and development activities conducted by private operators have intensified the competition, leading to technological solutions that can provide images with a quality level that is higher than the standard offered by public-funded equipment (Favre and Oksen, 2020).

Mobile applications for waste monitoring

Images are also the main medium for protecting land and water from pollution in the free, easily accessible, and user-friendly mobile services that are emerging in many countries. For example, a project of the Environmental Protection Agency has resulted in a new application that can be download on mobile phones. The service enables citizens to report water and land pollution when they spot it; by taking and sending a photo of the polluted area, citizens can make authorities aware of environmental problems. The application also uses an embedded GPS system that helps authorities locate and investigate the reported areas (EC, 2021a).

2.4. Mobility

Congestion and air pollution are some of most significant mobility-related problems in urban areas globally, where state- and municipal-level interventions are urgently needed. STI solutions to these urban sustainability challenges can be grouped in three main categories: low-emission vehicles; policy, regulations, and financial schemes to incentivize the use of more sustainable transport solutions, such as cycle-to-work programs; and intelligent transportation systems, which include many different types of smart technologies. For example, journey planner applications, real-time traffic management systems using frontier technologies, mobile ticketing, Mobility as a Service (MaaS) systems, and the technological solutions enabling bike sharing systems.

Low-emission vehicles

Electric cars are among the most common examples of low-emission vehicles and the electrification of urban transportation system is growing in both developed and developing countries as a result of combined forces, such as more favorable policy settings, financial incentives, and continuous research and development efforts that are increasing the performance of vehicles while reducing their overall costs.

For example, Basel Agency for Sustainable Energy (BASE), has supported an effort to electrifying the transport system in helping Bogota, Colombia to gain access to nearly 1,500 hybrid busses. This is in line with government strategies to cap the surge of fossil-fuel-based vehicles since hybrid buses were found to save 35% fuel vis-à-vis diesel buses. Since 2013,

BASE has supported similar initiatives in Peru, Argentina, and Costa Rica for technical, financial, and operational analysis and modelling[18].

Box 4: An electric scooter sharing service for sustainable urban mobility

Vehicle sharing services benefit from Global Navigation Satellite System (GNSS) information in order to track the vehicles, which are widely distributed across the city. In the case of "floating sharing", where vehicles are not parked in specific stations, GNSS is the main source of information for users to locate the vehicle. It also enhances security of the system by alerting about unexpected movements and tracking a vehicle in the event of theft.

Adopting this technology, G-MOTIT is a European-funded project that has developed an electric scooter sharing service in order to solve urban mobility problems potentially in major metropolitan areas in Europe[19]. It allows users to reserve a scooter with their smartphone, receive a notification with the position of the assigned vehicle, drive it and drop it off wherever they want. The service aims to enhance vehicle positioning performance by developing and integrating GNSS-based location technology, which is key for the success of the service.

Source: United Nations Office for Outer Space Affairs.

In Belarus, The National Academy of Sciences (NAS), together with other stakeholders has developed a comprehensive program for the development of electric transport for 2021-2025. It includes more than 40 interrelated activities that range from research and development to work on the development of charging infrastructure. Under the Electromobility Europe Program, NAS also supporting planning process and tool for step-by-step conversion of the conventional or mixed bus fleet to 100% electric bus fleet[20].

Electric vehicles have become a critical part of sustainable urban development action. However, large concentrations of obsolete batteries that need to be replaced have created a waste management challenge for urban recycling processes (Harper et al., 2019), whereas charging operations are troubling urban residents, especially in large urban systems. Examples of issues include congestion at refuelling stations during pick hours and long waiting times due to slow recharging processes. In response to these issues, intelligent fast charging solutions are emerging in cities. For example, Amsterdam, Netherlands have been equipped with Flexpower, the largest public smart charging network for electric vehicles in the city. This technology combines faster charging with the use of locally generated renewable electricity and ensure a more efficient use of the electric grid capacity. A total of approximately 500 charging stations have been upgraded and connected to the Flexpower network – approximately 30% of all charging stations for electric cars in the urban area (Pieter Bons et al., 2020).

Journey planner applications

Journey planner applications enhance urban mobility by providing real-time information; urban mobility users can use these mobile applications to plan their journey and receive continuous up-to-date information and advice about the level of traffic in different areas of the city and availability of public transport options at specific times. Moreover, this technology

[18] For more information, see: https://energy-base.org/news/paving-the-way-for-e-mobility-in-latin-america/
[19] For more information, see http://gmotit.pildo.com/
[20] Contributions from the Government of Belarus.

helps incentivize citizens to use public transport solutions more regularly, because they facilitate the planning of their commuting routines.

Aberdeen City Council, in Scotland, launched a journey planner application called GoAbz in late 2020, The application has been developed as a part of the Civitas Portis project, a multi-million research project that aimed to test different sustainable urban mobility solutions in five European port cities. GoAbz assists citizens and tourists to plan their journeys around the city Aberdeen. The application provides information on journey times and costs, and it also enables users to receive suggestions on alternative transport modes - cycling, walking, buses, and trains (Aberdeen City Council, 2020).

Real-time traffic management systems

In Bengaluru, India, the Electronics City Township Authority (ELCITA) and Siemens have developed and tested a real-time traffic management solution that fully automates traffic control and monitoring operations. The system automates operations like vehicle detection, traffic density estimation, identification of traffic accidents, and traffic light control (Chandran, 2018). A real-time traffic management solution is also the core component of the city of Bristol's traffic management operations.

In the Philippines, the government has developed Local Traffic Simulator (LOCALSIM), a microscopic traffic simulation software, designed to be used by road and traffic engineers as a decision support system for traffic management[21]. The UK city uses the platform to manage traffic networks and monitor traffic flows in the urban area. Moreover, the platform facilitates the collaboration with transport providers, improving the quality of public transport services (Bristol City Council, 2017).

Mobile ticketing

Mobile e-ticketing solutions have the potential to boost active travel – cycling – and public transport usage (Sampson et al., 2019). For example, Oyster is a pay-as-you card developed by Transport for London. Citizens and tourists can top up their cards at kiosks and online. The cards can be used to travel on buses, subway, trams, and many other transport solutions. Moreover, as part of their pay-as-you-go scheme, Transport for London also allows city users to pay tickets with contactless credit and debit cards or mobile devices on all transport services in London (TfL, 2021).

Similarly, in 1997, HKSAR has introduced the Octopus smart card system, the first integrated contactless ticketing system for public transport in the world. The Octopus card can be used for travelling, for shopping, and on electronic government platforms (Puhe et al., 2014). The card has achieved wide circulation within the city and can also be linked to other devices, such as smartphones and smart watches. In HKSAR, 98% percent of citizens between 15 and 64 years use Octopus cards, and there are more than 36 million in the city[22].

Finally, an e-ticketing system has also been introduced in Amsterdam. The service is called iAmsterdam and provides visitors with the access to public transports, bike sharing schemes, and the main attractions in the city. Visitors can choose between cards that are valid for a short period of time – between 24 and 120 hours. The iAmsterdam card is also available as a mobile application, which provides information on activities and touristic attractions (Puhe et al., 2014).

[21] Contributions from the Government of the Philippines
[22] Data available at: https://www.octopus.com.hk/en/consumer/octopus-cards/about/index.html

Mobility as a Service

Enabled by technological advancements in smart technology and the widespread diffusion of smart devices among mobility users, urban areas can also integrate various forms of their transport services into a single on-demand service. This multimodal approach to urban mobility is called MaaS, and its main objective is to disincentivize personally owned modes of transportation. Digital transport service platforms are the core of MaaS systems, and they make it possible for users to complete various tasks by using a single service that facilitates access to multimodal transport solutions. For example, MaaS systems can help users to pay tickets for a wide range of public and private transport options and obtain real-time information on their functioning (Enoch, 2018). However, technology is not enough; the collaboration between users, public authorities, and private mobility service providers is another essential component for the success of MaaS applications, where data streams and mobility-related technological systems belonging to different actors are required to connect (Crozet, 2020).

MaaS Madrid is one of the earlier examples of integrated digital transport service platforms, and it has been launched by Madrid City Council (Signor et al., 2019). This technology combines bus services, cableways, and BiciMAD – the bike-share system of the city – in a dedicated mobile application (Arias-Molinares and Carlos García-Palomares, 2020). A similar MaaS platform, which is called Whim, is also used by the city of Helsinki, Finland. Whim integrates information on bike sharing systems, taxis, car sharing services, and conventional rental cars, together with public transport data. The MaaS solution of Helsinki also allows payments to be processed through the mobile application (Cerema, 2020).

Bike sharing systems

As of 2019, 18 million bikes have been shared in urban areas worldwide through 1600 bike sharing systems (Hyatt, 2019), which are becoming increasingly popular. Bike sharing systems generally combine the use of smart cards, mobile applications, automatic docks and stations, and platforms for sourcing real-time information on where bikes can be borrowed or left after being used (ECF, 2013). Cities such as Edinburgh, Bogota, Mexico City, Berlin, Lille, Prague have been using bike sharing schemes for many years and have achieved notable benefits. For example, the bike sharing system in Mexico City has reduced taxi use and private car use of 8% and 5%, respectively, and it has made it possible to save approximately 500 tons of carbon emissions, while helping users to save more than 2,000 days in aggregated travel time (Patel, 2017).

Cycle-to-work schemes

Cycling is one of the most sustainable urban mobility solutions, and it can be incentivized through different programs and initiatives. In many countries, for example, national governments have activated Cycle-to-Work schemes. In the United Kingdom, for example, this scheme allows employees to buy commuter bikes and cycling equipment through their employers, by means of an advantageous loan. After making their purchase, employees repay all costs in small instalments, which are automatically deducted from their monthly salaries. After 12 months the employer will have recovered their costs, while the employee will maintain the ownership of the bike and equipment and will have accumulated approximately 15% in savings through a tax break (DfT, 2019).

The international, non-profit organization World Bicycle Relief has introduced Employee Purchase Programs (EPPs) in developing regions, which have allowed their essential workers to buy off a bicycle over a few months. EEPs have helped purchase more than 600 bikes in Colombia, about 150 in Kenya, and almost 800 for employees located in the peri-urban areas

around major cities in Zimbabwe. During the COVID-19 pandemic, in addition to allowing workers to get to work, the bicycles have contributed to reducing the risk of infections (WBR, 2020).

During the COVID-19 pandemic, many governments have incentivized cycling to reduce infection rates in urban areas, where bikes have become one of the preferred urban transport solutions. This preference, however, has caused a raise in the demand for bicycles globally, putting manufacturers and suppliers under great pressure. Meanwhile, many municipal governments, such as Lima in Peru, have started to redesign their urban infrastructure in the light of an expanding routes for cyclists to improve urban mobility that[23], in many cases, has been largely overlooked for years (Myers et al., 2021).

2.5. Economic prosperity and decent jobs

Limited access to decent work opportunities, growing economic-related inequalities, financial instability among urban populations, forced labor, and modern slavery are pervasive issues facing urban economies across the globe (Nijman and Wei, 2020). Implementing solutions through science, technology, and innovation could help policy makers to foster entrepreneurship, promote economic prosperity, and support financial stability for urban residents. Some STI solutions could be focus on application areas such as: establishment of dedicated urban zone for STI development park, digitalization of financial systems, e-commerce platforms, innovative ICT-related education and training programs, cash transfer schemes and programs, innovative data management systems, and smart technologies to fight forced labor and modern slavery. Under the influence of COVID-19, these solutions have become imperatives for the recovery of urban economies, where an urgent call for smart, sustainable, and human-centric economic prosperity has been raised worldwide.

Dedicated urban zones for STI development

A dedicated zone or area has been developed in several countries to nurture the sustainable development of science, technology, and innovation in urban area that promote job creation and advancing industrialization. This dedicated space is an effort from the government to support local urban innovation ecosystem to facilitate business sector in doing business, to provide access in financing and tax support, and to create more demand for new job opportunities.

In Turkey, the government established Technology Development Zones (TDZs) to provide job opportunities and accelerates the entry of foreign capital into the country that makes advanced technology investments, by increasing the competitiveness of the industry, provides significant contributions to the development of the cities[24]. Furthermore, many support and tax incentives are provided to entrepreneurs in TDZs, which make significant contributions to sustainable urban development. Another example is from the city of Santo Domingo, Dominican Republic with the establishment of Technological Hub Value Proposition[25]. The hub is pivotal to support capacity building, as well as guided spaces that facilitate the creation, incubation and acceleration of technology-based ventures that make intensive use of knowledge. This hub also incubates companies pursuing cutting edge products in 3D printing, virtual reality, drones, block-chain, and biotech, to name a few.

A similar concept has been developed in the city of Nyeri, Kenya with the establishment of Science and Technology Park (STP), in collaboration with Dedan Kimathi University. The STP

[23] Contribution from the Government of Peru
[24] Contributions from the Government of Turkey.
[25] Contributions from the Government of Dominican Republic.

encourage cooperation and synergies between universities, research institutions, and the private sectors to create a favorable environment for innovation, renovation, and training[26]. In Latvia, the government has established three innovation zones in the capital, Riga. The creation of these innovation zones is to help companies, researchers as well as startups to test their innovative smart city products in real-life settings and to cut unnecessary steps in approval procedures necessary for implementation of new products[27].

Another example is the creation of hubs of innovation and entrepreneurship for the transformation of historic urban areas in Lisbon, Portugal[28]. The Hub is part of European Commission program that aims to promote the urban transformation and regeneration of historic urban areas using as main catalyst the innovation and entrepreneurship, while preserving their unique identity social and cultural identity and the environment.

A different approach under the dedicated zone concept has also been developed in Russia through their single industry cities or monocity. Togliatti (or Tolyatti) is a prime example of a monocity, where innovative activities have received active support. It is the place where one of the Russia's largest high technology parks (technopark) is located, the Zhiguly Valley. Technopark's residents enjoy support at all stages of their innovative activities from idea generation through prototype development and all the way to commercialization of the product. The city of Cherepovets, Norilsk, and Magnitogorsk is another example of successful dedicated zone or area that bring forward comprehensive plan for sociotechnical development in their city to facilitate development of industrialization and promote job creation for their citizen[29].

Digital finance

Digital finance brings information technologies in the financial services industry and is an example of a commonly used solution for achieving higher employment and productivity rates in urban environments. It has emerged as a financial initiative to support urban lifestyle in providing electronic financial products and services, ranging from digital banking, peer-to-peer lending, e-trading platform, and digital payment services. Local authorities can use digital finance as a leverage to overcome barriers to economic productivity, entrepreneurship, and employment, and support the financial inclusion of low-income groups that experience financial instability; this technology can enable the distribution of critical financial flows and targeted funds to local companies to support stabilization and recovery in emergency situations, such as the COVID-19 pandemic.

For example, by facilitating the distribution of micro- and nano-credits, digital financial services like mobile money make low-income people become more resilient and help them overcome the barrier that bank accounts and credit checks may pose (Doorly et al., 2007). This detail is incredibly important for sustaining entrepreneurial activities in the developing world, where many people are still unbanked. Therefore, they cannot pass through the formal checks of credit history and scores, and they are classified as too risky by credit reporting agencies.

Another good example is demonstrated by The CloQ app in response to unbanked population but have access to mobile platform in urban areas. Launched in 2018, CloQ is a microcredit mobile app for people whose income is below minimum wage. The app has started by focusing its operations on Brazilian territories and, in the first two years of activity, it has provided access to credit for urban entrepreneurs. CloQ also offers nudges on financial education, to

[26] Contributions from the Government of Kenya
[27] Contributions from the Government of Latvia.
[28] Contributions from the Government of Portugal.
[29] Contributions from the Government of Russian Federation.

sustain improvements in the capability of its users to manage their own financial situation. (CloQ, 2021).

E-commerce platforms

E-commerce platform is a technology that has been proved important for business in boosting sustainable development urban area. Particularly, e-commerce platforms have been helping micro, small and medium-sized enterprises by providing online space to sell product or services and expand their market opportunities, beyond their geographic boundaries. Additionally, given that demand traffics in e-commerce platforms come from urban area, it triggers labor force absorption to support the logistics backbone to cope with whose demand. This relation was amplified during the COVID-19 pandemic era where people switch to e-platform in buying their daily needs due to the mobility restriction to contain the virus outbreak.

For example, UNCDF is collaborating with the main ride-hailing company in Kampala, the capital city of Uganda, to launch a digital platform called SafeBoda. The e-commerce platform for home deliveries amid COVID-19, has helped 18,000 people to keep their jobs, 800 vendors to maintain revenue streams during the lockdown, and thousands of customers to continue to receive deliveries of food and other essential goods.

ICT-related education and training programs

In addition to data-driven decision making and predictive analytics, which are becoming increasingly common, industrial sectors have also been experimenting with the technological advancements that are leading to higher degrees of automation, such as robotic technologies (George and Paul, 2020). Although in certain sectors automation processes may cause a reduction of workers, this technology unleashes productivity gains and can help reduce occupational injuries and fatalities in dangerous urban occupations – for example, construction jobs (Peeters and Schuilenburg, 2018).

Automation is helping create more decent working conditions in many sectors of urban economies, but it also poses a threat to many workers, who experience high levels of technological anxiety because of the risk of being replaced with machines (Mokyr et al., 2015). This risk is of particular relevance in low- and middle-income countries, where many workers who conduct routine and unsophisticated labor-intensive tasks are employed in informal economies (ILO, 2020b) – an uncertain form of employment that leaves employees without the benefits and protections that standard forms of employment offer (UN, 2020f).

In response to this threat to the future of some professions, many national and local authorities have reacted by promoting innovative education and training programs that target young people and aims to increase their ICT skills. These upskilling opportunities are offered to ensure a better alignment between growing markets and education systems: an alignment which is indispensable to leave no one behind and sustain sustainability-oriented system change in urban areas.

For example, European countries can rely on the Digital Opportunity traineeships, a training initiative funded by the European Commission. Between 2018 and 2020, this initiative provided more than 6,000 students with the opportunity to boost their digital skills in fields with a high market demand. Examples of knowledge areas include cybersecurity, big data, quantum technology, machine learning, web design, digital marketing, and software development. (EC, 2019a).

Similarly, in Sub-Saharan Africa, where millions of youths are unemployed or struggle to access the formal economy largely located in urban areas, the global talent network Andela –

supported by the International Finance Corporation – recruited talented young people and trained them to become professional software developers through a four-year placement-based training program (IFC, 2015). Moreover, in South Africa, the Oliver Tambo Research Chairs Initiative Program has builds on existing continental frameworks and intervention geared towards institutional capacity strengthening; the development of high-end skills; recruitment and retention of excellent researchers; and incentives to support research that contributes to socio-economic and transformative development in Africa[30].

Innovative data management systems

Providing financial support and access to job market to people in need requires scoring and assessment tools that ensures financial inclusion, but many local authorities are experiencing difficulties in developing effective systems. Heterogenous data that is generally fragmented across different public information systems and complex multiple-indicator analyses are required to determine who is entitled to receive financial benefits. To overcome this challenge, urban areas can benefit from the use of data management solutions, which can help eliminate silos effects and lack of interoperability, while providing advanced data visualization tools, the use of AI for predictive analysis, big data analytics capability, and more transparent and accountable reporting systems.

In Costa Rica, for example, the national government has developed a data-integrated, cross-agency platform that contains data of potential beneficiaries of all social protection programs financed by the state – more than 3.5 million individuals and approximately 1.2 million households. To develop the platform, information modules and data infrastructures have been standardized to facilitate data integration after collection processes, which are undertaken simultaneously in different public agencies in rural and urban settings (UNDP, 2021).

In Iran, the STI policy makers has developed an innovative platform to help matching private sectors with the city administration to provide services and products for people in urban area. The aim of this platform is to disentangle the complexity of agreement and provide incentive for the private sectors in supporting transition toward urban sustainable development. For example, the platform has been implemented as part of Smart Waste Management Systems in Iran, to make the outsourcing process more transparent and attract the attention of the startups and entrepreneurs to cooperate with the municipality administration[31].

Another example is AI powered UNWTO Jobs Factory, a platform that supports and improves competitiveness regarding job creation and help to leverage human capital development in cities that relied on the tourism sectors. The joint initiative between UNWTO and Hosco, the professional network specially designed for the hospitality industry, allows monitoring current and future skills development, facilitating intelligent labour market data collection, insights, and forecasting to access jobs opportunities[32].

Embedding new platform solutions in legacy systems, however, requires staff to change their existing routines. Despite the improved efficiency that new systems can generate, digital transformation processes can lead to resistance to change and skills gaps. In addition, the promise of transparency, efficiency, and cost-effectiveness that technological solutions for financial inclusion propose is built on scoring algorithms that may give rise to injustice, leading to discrimination (Qureshi, 2020).

[30] Contribution from the Government of Kenya
[31] Contributions from the Government of Iran
[32] Contributions from the United Nations World Tourism Organization. For more information on Job Factory, see: https://www.unwto.org/jobs-factory.

Cash transfer schemes and programs

Many national and local authorities are also supporting the financial inclusion of urban populations by means of innovative cash transfer schemes that do not leverage technological solutions but still ease the financial burden of poorer workers and help them access secure financial services, limiting the widespread adoption of informal loans.

To nudge behavioral change in low-income populations and improve the sustainability of their financial situation, local authorities can also initiate conditional cash transfer programs (CCT) (Ladhani and Sitter, 2020). These programs help provide poor people with money in return for fulfilling specific behavioral conditions. For example, compulsory attendance of children to school, mandatory visits to health centers, and up-to-date vaccination are among the conditions in the Brazilian experience of Bolsa Família (The World Bank, 2020f), a CCT program activated in Brazilian municipalities. Inevitably, however, the delivery and implementation of the CCT program at the urban level needs customization that is geared towards local resources and conditions.

Another example comes from the city of Sabang, in Indonesia which piloted a similar locally funded cash transfer program called, Geunaseh. The objective of this social protection program is to provide poor households with the monthly-based cash assistance they need to meet the health and nutritional needs of children. Geunaseh represents an important experience because it started as a successful pilot project, which was then scaled up, and it has led to important changes in the institutional setting and regulatory framework of the city. The program has been written in law, defining provision and governance mechanisms and the role of the local stakeholders involved in the delivery (UNDESA, 2021b)

Smart technologies to fight forced labor and modern slavery

STI solutions also offer effective technological means to fight against child labor – whose rate has increased from 8.4 million in 2016 to 160 million in 2021 (ILO, 2021) – but also modern slavery, human trafficking and migrant smuggling, which are crucial urban-related phenomena. For example, according to the UK National Crime Agency, these challenges are affecting almost every large town and city in the country (Rudgard, 2017). Remote monitoring tools addressing forced and child labor, for example, uses mobile-phone-based technologies, real-time tracking systems, and other networked technologies to determine the presence of illegal working conditions in a workplace. These technologies can replace in-person social compliance auditing – that COVID-19 has disrupted, leaving global labor without control measures.

To help children in need, in 2018, more than 50% of UNICEF program countries adopted open-source, real-time information platforms at scale, such as the digital messaging platform RapidPro. These tools help track children and provide them with the required support. By means of messaging interactions, local governments attempt to stay closer to children and protect them from exploitation and forced labor attempts (UNICEF, 2019b, 2020a).

Some of these real-time monitoring tools also uses satellite imagery to oversee the movements and loads of boats and web scraping to search for child abuse data that can lead law enforcement agencies to children in need for help. This technology can also be used to stop human trafficking operations (UNICEF, 2020a).

Smart technologies for preventing forced labor can also leverage predictive profiling, facial recognition, and blockchain technology. Predictive profiling via natural language processing and artificial intelligence can be used to evaluate the probability of having messages associated

with forced labor that travel across the Internet (Foy, 2021). Facial recognition algorithms are adopted by law enforcement authorities during web crawling operations, to scan online ads and attempt to prevent or stop forced labor crimes (Simonite, 2019). Finally, blockchain technology allows to constantly monitor global supply chains and identify the presence of illegal operations involving illicit traffic of goods and modern slavery (Boersma and Nolan, 2020). Nevertheless, the application of these technologies requires strong cross-sector coordination, revised institutional arrangements, and new regulatory frameworks that ensure privacy and data are firmly protected (ICAT, 2019).

2.6. Housing

The housing construction sector is responsible for the development of one of the most crucial urban infrastructure assets, but it is severely lagging behind. The Industry 4.0 vision is crucial to ensuring an improved efficiency and sustainability of the sector and the development of more affordable and quality housing solutions, and the progression of this vision is highly dependent on STI efforts. Many countries have positioned the framing of cross-sector partnerships and industrial alliances for research and development at the center of their national development agenda for the housing construction sector, alongside with establishing international standards to facilitate collaborations. In addition, artificial intelligence, machine learning, robotics, digital fabrication, cloud computing, environmentally sound technologies (EST), and smart building solutions have been widely promoted (OECD, 2019a). Policy interventions, changes in institutional and regulatory frameworks, and cost-effective financing instruments are also proliferating, to underpin system-wide transformations in the configuration of existing housing construction practices and routines (UNDESA, 2018a).

Digitalization of construction operations and manufacturing processes

STI solutions for supporting sustainable development in the housing construction sector strongly focus on the digitalization of operations and manufacturing processes. A wider use of digital fabrication techniques, which rely on IT-controlled production environments, can help improve efficiency while increasing production rates. For example, by capitalizing on digital fabrication technologies and offsite manufacturing techniques, in China, a 30-storey hotel and a 57-floor skyscraper have been built in less than 20 days – a record-breaking speed. The use of traditional building techniques would have required more than one-year of on-site construction activities to deliver the same building (Chang et al., 2018; Gao and Low, 2014).

A growing number of factories have been equipped with additive manufacturing technologies – 3D printing. This technology is used frequently during prototype phases (UNDESA, 2018a), but it can also help build new houses. This is the case of the non-profit organization New Story, which is introducing 3D-printed homes in the slum areas of Haiti, Mexico, and Bolivia. Using 3D-printing technology, New Story can produce a 600-square-feet (about 56 square meters) home in only one day, and with an overall cost of $4,000 (Altam and Pompei, 2018). However, it is important to note that these technologies might shorten supply chains, which would in turn affect those regions in which low-cost labor is high. Moreover, intellectual property rights and legal challenges might increase because the copying and sharing of protected designs is likely to become easier (Fan et al., 2020).

The digitalization of the housing construction sector and actualization of the Industry 4.0 vision can truly push sustainable urban development. However, it also exposes digital skills gap that may prevent these technological developments from taking place and being effective (UN, 2019). For example, approximately 70% of the population living in lower-income economies do not possess basic digital skills (UN-Habitat, 2021a). The COVID-19 pandemic has clearly

exposed this skills gap and showcased the magnitude of the effects that they have on sustainable urban development, especially in a crisis condition.

Available studies have shown that the lack of IT qualified construction workers is one of the main factors inhibiting the adoption of more digital fabrication techniques in China, Australia, New Zealand, and the United Kingdom (Chang et al., 2018; Han and Wang, 2018; Mostafa et al., 2020; Pan et al., 2007), where an absence of the necessary training programs has been identified. This condition reflects the current engineering and architecture curricula, which generally tend to focus little attention on modern construction methods and digital technologies, whose deployment implies radical changes in the traditional approaches to design, fabrication, and construction. As a result of this gap, insufficiently qualified workers are trained, who lack the appropriate technology and management experience, and whose employment can compromise the affordability of dwellings – due the incurrence of severe problems such as inferior structural performance, delays, and raising construction safety accidents, which put workers in danger and make production costs arise (Jiang et al., 2018; Polat, 2008).

Digital twin technology in construction

By using digital twin technology, virtual models can be created to predict the functioning of an object before it is executed. This insight can be used to inform decision-making processes in the housing construction sector (ARUP, 2019). Engineers and designers across manufacturing industries are increasingly using this technology to experiment with different design solutions (OECD, 2020b), whereas civil engineers are using digital twins as a supporting tool during design, construction, and monitoring processes of transport infrastructure assets. Moreover, in housing construction, digital twins allow the collection of information during the entire life cycle of a building and help improve maintenance operations, while facilitating data sharing operations (OECD, 2019a).

Predictive analytics

Big data analytics makes it possible to obtain a greater level of product differentiation, which is driven by intelligence, and can better align productive systems with the request of users. Government and manufacturers can use computational models, which combine customer data, purchases data, sales data, and many other information streams, to evaluate the preferences of costumers, and use this knowledge to inform different market segmentations, pricing, and positioning strategies (Tao et al., 2018). By using this data, manufacturers can introduce business model innovations that "leverage shorter distance and time to markets, which in turn are likely to benefit smaller and more responsive businesses" (OECD, 2019a). For example, in south Africa, under the Innovation and Transformative Technologies Framework, the government is working to enable big data in analyzing areas of urgent housing needs; areas that need subsidized housing; areas requiring improve access to infrastructure, amenities, and services, and areas that supports the integration of different housing typologies, land uses and economic development[33].

Higher levels of customization would be beneficial in the housing construction sector. Addressing the diverse housing needs of low-income groups by offering a mix of affordable housing options is key to foster sustainable communities and this cannot result from a one-size-fits-all mentality. Evidence demonstrates the existence of a strong connection between diversity and affordability. Research using US metropolitan statistical data has demonstrated that the rate of foreclosure is higher in urban areas where housing diversity is lower. This

[33] Contributions from the Government of South Africa.

correlation suggests the homogeneity of housing stock can increase the relative value of units, generating a lack of affordable housing (Chakraborty and McMillan, 2018).

Offering a diverse housing stock, however, requires governments and stakeholders in the construction and real estate sectors to better understand the diverse housing needs of heterogeneous residents and use such a knowledge to design affordable housing solutions which are tailored to meet their expectations (Pimentel Walker, 2016). Affordable housing provision should be diversified in terms of types and tenure, hence providing accommodation options to a broader number of residents while creating diverse and vital neighborhoods.

Machine learning models that transform big data in predictive analytics are already in use in the construction sector. For example, they are used to forecast the potential demand for new homes or fluctuations in market values, and the deployment of this technology can be extended to cover additional functions (Grybauskas et al., 2021).

Environmentally sound technologies and smart building solutions

Housing construction actors in developing and developed countries are increasingly harnessing EST and smart technologies in new-built and retrofitting operations. In many cases, EST measures and smart technologies have been adopted to address climate and environmental issues by increasing the use of renewable energy and recycled materials, reducing waste productions and implementing water-efficiency schemes. EST and smart solutions include not only end-of-pipe and monitoring instruments – such as knowledge management systems and building automation solutions – but also environmental impact assessment tools. One example is the creation of EcoSUN Green Village, a pilot project in South Africa which implement EST and smart technologies to address challenges in human settlement (see Box 5). Another example, the World Bank Group has developed a knowledge platform on eco-friendly infrastructure construction to help govern infrastructure projects across countries in Latin America and the Caribbean (Montgomery, 2015). The idea behind the initiative is to have a one-stop shop that calls up technical specialists with different types of expertise to design and plan for sustainable buildings, roads, bridges, ports, power plants, and water supply systems.

Box 5: EcoSUN Green Village, a village for future.[34]

The EcoSUN Green Village, located in the Eastern Cape province, Sarah Baardtman district Kenton-on-Sea, Ekhuphumleni township -under the Local Ndlambe Municipality - is a collaborative pilot project between Department of Science and Innovation, Ndlambe Local Municipality, Nelson Mandela University, Eastern Cape Department of Human Settlement, and the German Ministry of Education and Research.

The objective of the project is to implement innovative technologies to address challenges faced by the human settlement sector, such as water and energy resource scarcity as well as unemployment. The innovative technologies include the application of water recycling (grey water technology), water filtration, renewable energy (solar technology), innovative building materials and sustainable water drainage.

The 1 hectare village includes, 10 houses, Multi-purpose Centre, landscaping for recreational activities, vegetable garden and waste management facility. The intention is to make a village that operates independent of the municipal services, a village that supports the community and generates jobs.

[34] Contribution from the Government of South Africa

The EcoSun Green Village to date has created employment for 22 youth from the area, in the construction of the Multi-purpose Centre and has attracted donors eager to support local economic development. In addition, the German Ministry of Education and Research and the Nelson Mandela University have collaborated in the development of empowering and training the local youth on the operation and maintenance of the innovative and 'green' technology. Further collaborations are to be forged with in the upcoming construction of Sustainable Urban Drainage System and landscaping for the village.

This pilot project has proven that innovative building materials and technology can be implemented with a limited time and accepted by communities, even under challenging conditions brought about by COVID-19.

One of the key priorities of ESTs and smart technology solutions in the housing construction sector is to eliminate low energy efficiency, whose combination with high energy prices increases housing expenses and force a growing number of low-income occupants to live in fuel poverty (Boardman, 1991) – a long-standing issue generating wider social and health inequalities (Pérez-Fargallo et al., 2017; Poortinga et al., 2017). Low-income households living in fuel poverty cannot afford to keep their dwellings at adequate indoor temperatures. As a result of this failure in achieving thermal efficiency, occupants are not protected from outdoor environmental conditions and more exposed to dust mites, mold, and fungal spores, due to reduced ventilation, increased air contamination, and poor hygrothermal conditions (Sharpe et al., 2015). In addition to live without the basic level of energy needed to guarantee their wellbeing, the budget constraints of fuel poor households also affect their capability to invest in retrofitting interventions for improving the energy efficiency of their substandard homes (Tardy and Lee, 2019; Wrigley and Crawford, 2017).

2.7. Education

Schools and higher education institutions are mainly located in urban areas, and they play a key role in human capital development. To ensure the sustainable urban development through quality education, which is an important element of the urban sociotechnical system, the capability of education services to face crisis conditions and accommodate the request of a fast-growing urban population should be enhanced. The COVID-19 pandemic has uncovered both the fragility of the incumbent system and the potential of digital technologies to increase the resiliency needed to avoid disruptions in service provision. Moreover, digital learning solutions can also help improve the quality of learning environments and help education-related organizations and associations to deal with the increasing demand that urbanization processes have been generating and scarcity of spaces, without incurring in the use of additional land for expanding existing facilities.

The urban sociotechnical system for the delivery of education services should also help cultivate a deeper understanding of sustainable urban development principles, because "education and lifelong learning are essential components of everyday city life, so that urban communities can create sustainable and harmonious societies that embody the principles of social justice, ecological resilience, economic productivity, political participation, and cultural vibrancy. Learning to live together sustainably in cities and communities is one of the most important educational challenges of our time" (UNESCO, 2017).

Box 6: Best practices of St. Petersburg[35]

The need to significantly reconsider all scientific and educational activities of the city, caused by the looming threat of the novel coronavirus infection (COVID-19), was the most important characteristic during the pandemic.

The St. Petersburg Committee for Science and Higher Education provides support to scientific and technological activities in the city on the basis of competitions as part of the state program "Economy of Knowledge in St. Petersburg," enacted by St. Petersburg Government Resolution No. 496, dated June 23, 2014. The city boasts a unique system of assistance to local researchers, ranging from senior school students to fully-fledged scholars. The system of contests and competitive selections for prizes or subsidies or grants makes it possible to provide support to research and development initiatives, as well as congress and convention activities, publication of popular-science periodicals in a variety of fields, including humanities, social, technical, natural, and exact sciences.

St. Petersburg gives room to organizations, consolidating knowledge and conducting scientific research in priority fields for the city and the country in general. The city of St. Petersburg is now hosting the world-class scientific and educational center "Artificial Intelligence in Industry" (hereinafter SEC).

The SEC is focused on world-class research and development and new competitive technologies and products for their further commercialization, as well as on the training of personnel to address large-scale scientific and technological challenges in the interests of scientific and technological development in priority fields as set forth in Russian President's Decree No. 490 "On the development of artificial intelligence in the Russian Federation" dated October 10, 2019. The center's mainstreams include machine engineering (intellectual machinery and production sites); metallurgy and mining; electronics; chemistry and material science; telecommunications; oil and gas; power engineering; pharmacology and biotechnology; Smart City technology; and transport and logistics.

Digital solutions for distance education and online learning

Digital solutions for distance education and online learning are many and this apparatus of technological applications has been expanding and evolving over the years. These technologies have been largely used to ensure that quality education at all stages – from early childhood development to vocational and tertiary education, including university levels – is delivered in both rural and urban settings, especially in poorer and remote geographical areas.

Most of these STI solutions rely on the availability of internet-connected devices, whereas other tools can operate partially or completely offline. In addition, these solutions expose different levels of technological advancement: from basic online functions to more complex AI-based operational modes.

Touch-screen tablet solutions

Joint winners of the Global Learning XPRIZE Award, Kitkit School and OneTab are examples of technological solutions whose objective is to help prepare children for primary education. The resources offered by these touch-screen tablet solutions support children to develop the foundations and practice needed to acquire fundamental literacy and mathematical reasoning skills, regardless of their knowledge, skills, and environment (XPRIZE Foundation, 2019).

[35] Contribution from the Government of Russian Federation

The Kitkit School tablet is a learning platform with a suite of interactive educational activities and material – such as creative commons books, videos, and apps – that are designed to stimulate creativity by using the touch-based interface of the tablet. Kitkit School was initially tested through field tests in Africa – in rural and peri-urban areas of Tanzania – and it has now reached more than 270 organizations in 52 countries, with distribution partners located in Tanzania and Uganda. In addition, a Bahasa Indonesian version has been created which is expected to be released for free. Expansion plans are also in progress, aiming to introduce Kitkit School in the Rohingya refugee camp in Bangladesh and the Philippines (GIE, 2021).

Speech recognition software, adaptive learning technology, augmented reality, and platform solutions

More advanced digital solutions are also penetrating in classrooms, regardless of age, where they are helping to enhance the learning experiences of urban residents, including learners with special educational needs and disabilities. Students who struggle with writing and learning-related vision problem, for example, can use speech recognition software technologies, which automatically replace writing with talking and can read texts aloud (Oh and Song, 2021).

Adaptive learning technology is helping to personalize learning plans, to ensure that they better respond to students' learning needs (Di Giacomo et al., 2016; Nagao, 2019). Scalable personalized education can also be supported through AI-based products, such as virtual learning assistants using conversational pedagogy (Florea and Radu, 2019).

Place-based digital education strategies

The COVID-19 pandemic crisis has dramatically accelerated the digitalization process of national education systems, with lockdowns and other social distancing measures that have forced universities and schools to close and shift to remote education solutions. In examining the policy responses to school closures, OECD describes the creation of online learning platforms to support students, their families, and the school workforce as an almost universal reaction in both developed and developing countries (OECD, 2020c).

Recognizing that students do not have the same access to the technology required to engage with online education, some governments have provided vulnerable students with digital devices – such as laptops and tablets – and Internet access, and they have started channeling teaching activities through televisions, phones, and radios. Broadcasting educational content, for example, is one of the solutions adopted by the Ministry of Education of Argentina, where disadvantaged students in urban areas have been delivered notebooks with pre-loaded learning resources(The World Bank, 2020e).

Education for sustainable development

Many of the courses that MOOC platforms offer promotes the diffusion of contents that learners require to develop a sufficient understanding of sustainable development principles. Cultivating a deeper understanding of sustainable development has also become the objective of innovative education programs like Caring for Life (CFL), which has been recently listed among the SDG Good Practices selected by UNDESA. CFL focuses on character education; it targets children, consumers, and professionals with three ad-hoc programs, whose goal is to teach how to live by following a more responsible and sustainable lifestyle. By reinforcing core qualities such as empathy, responsibility, and discerning thinking, the three educational programs enhance the students' kindness and compassion and induce a greater respect for people, animals, and the environment (ACTAsia, 2016, 2021). The results of a 2018 evaluation

study involving 25 Chinese elementary schools show that the exposure to CFL education can help first and second grade students to strengthen their prosocial behavior (Samuels, 2018).

2.8. Gender empowerment and equality

The value of a sustainable urbanization cannot be realized without introducing safeguards against the existing gender-based gaps, prejudice, and discriminations that have spread in urban environments worldwide. Many women and girls across urban regions continue to suffer from these pervasive systemic issues, whose eradication is pushing public and private organizations, as well as representatives of civil society, towards experimenting with different gender-responsive forms of innovations. STI solutions in this application area range from new digital tools to non-technological interventions which aims to support awareness-raising activities, community mobilization actions, educational programs, legal and policy reforms, and changes in institutional settings.

Gender-pay-gap regulations

Wage disparities differ across countries and strongly depend upon local circumstances. No disaggregated data is currently available to determine the global urban-rural spatial variation in the gender wage gap. However, many cities worldwide have become the space in which gender-unequal economy thrives. The relevance of the problem has been recently remarked by London, Los Angeles, Barcelona, Freetown, Mexico City, and Tokyo, whose municipal administrations have decided to launch the first-of-its-kind network of cities in support of gender equity (GLA, 2020).

Recognizing the relevance of gender-based economics issues, to ensure that men and women receive equal pay for equal work, some governments have implemented innovative adjustments to their existing policy and regulatory frameworks, which impact on urban workplaces. For example, the commitment of the New Zealand Government to closing the gender pay gap has resulted in an Amendment to the country's Equal Pay Act 1972, which was approved in 2020. This law introduced a new regulatory framework that allow individual workers and their union representatives to raise pay equity claims with employers. Before establishing this new claim process, the existing gender pay gap legislation of New Zealand was already guaranteeing men and women to be paid equally for the same work, but not for different work with equal value. The Equal Pay Amendment Act added this critical new condition (UN Women, 2020).

A similar legislative framework – Equality Act 2010 – has also been introduced in England and Scotland, but with an important variant that came into effect in 2017. The act requires public, private, and voluntary-sector organizations with 250 or more employees to annually publish a series of pay gap metrics on their own websites and on a dedicated reporting service website created by the central government[36].

Reputational risk may trigger the reaction of employers (Duchini et al., 2020). However, when examining the effectiveness of these new regulatory reforms, the scientific community offers inconclusive evidence of their effectiveness. For example, on the one hand, the pay transparency laws in the US, UK and Denmark have been correlated with a reduction of the gender pay gap (Bennedsen et al., 2020; Duchini et al., 2020; Kim, 2015). On the other hand, statistical analyses of the impact of the Austrian Pay Transparency Law on individual salaries and the gender pay gap have not evidenced discernible effects (Böheim and Gust, 2021; Gulyas et al., 2021).

[36] Gender pay gap reporting system: https://www.equalpayportal.co.uk/gender-pay-gap-reporting/

Compensation management platforms

Making information on gender-friendliness more accessible requires companies that manage urban workplaces to discover pay gaps and find possible solutions. This discovery process depends upon the capability to aggregate the statistics needed for complying with transparency laws. To facilitate this analytical process, digital services have been developed, which use AI-powered budgeting and forecasting tools to provide estimates of gender-based gaps in remuneration processes (Krawcheck, 2017). These next-generation compensation management platforms can also help companies that are not subject to the statutory requirements of transparency laws but have nonetheless decided to ensure equality in compensation by voluntarily tracking salaries across demographic characteristics. This practice is also linked to voluntary gender equality reporting (Dewson et al., 2011).

Anti-violence online services

In many cities around the world, women and girls do not have the required level of safety. "Violence makes up at least 25 to 30 per cent of urban crime and women, especially in developing countries, are twice as likely to be victims of violent aggression (including domestic violence) as men". In addition, studies focusing on the Arab world demonstrated that approximately 70% of this violence occurs in large urban areas (AlSaud, 2020).

In response to this lack of safety in public and private urban spaces, technological-related grassroots innovations are spreading, some of which aim to enhance the capability of women, girls, and other city users to report abuses and help ignite the reaction of public authorities and the public. For example, by leveraging online messaging systems and social media, the crisis-mapping platform designed by the Nairobi-based company Ushahidi has helped to monitor election-related violence in Kenya and many other events across the world in which reports of violence sparked. The platform builds on crowdsourcing principles and geographic information technology; Ushahidi collects reports of violence submitted by eyewitnesses and, after checking their validity, it maps them out, making all data publicly available (Piccolo et al., 2018). The technology developed by Ushahidi can also be used to document acts of violence against girls and women in urban settings, and ad-hoc platform solutions could also be implemented.

Awareness-raising measures and education

Innovative gender-equality measures are also urgently needed to rethink urban safety, whose improvement can drastically change the lives of women and girls and their relationship with urban environments. "Fear of violence affects the everyday lives of women and girls, restricting their freedom and use of the city and public space" (UN Women, 2016). In many developed and developing countries, among the main causes of this anxiety is the presence of social norms that do not sufficiently deplore violence against girls and women, especially sexual harassment.

Supporting a change in the social norms that trivialize gender-based violence and abuses is one of the key objectives of *Safe Cities and Safe Public Spaces*, a UN Women's Global Flagship Program Initiative that sustains an important change of paradigm: complementing the regulatory framework of public institutions with actions that aim to raise awareness among urban actors and providing them with the training they need to become agents of change.

For example, with sexual harassment in Moroccan public transports and streets that has not been legally recognized yet, introducing a training module on prevention methods for ALSA Marrakech drivers – a large network of buses which serve the entire city – has created a possible

safeguard. The training has informed more than 1,500 bus drivers about the procedures that can be adopted to take action against sexual harassment episodes, should they witness abuses in buses and around bus stops. Similarly, taxi drivers have been sensitized on sexual harassment and mobilized (UN Women, 2017b).

Similarly, in Rwanda, a citywide campaign has been launched to prevent sexual harassment on public transportation, and actions have been taken to enhance the capacities of public transport workers to prevent sexual harassment in public spaces. Meanwhile, in Ecuador, education material on gender discrimination and stereotypes has been piloted in some schools of Quito, whereas public service announcements in Indian metro lines and open discussions have been introduced to raise awareness. Finally, Papua New Guinea has launched a multi-channel campaign that has reached thousands of urban residents by combining social media and television networks, radios, and social interactions in schools, churches, and public spaces (UN Women, 2017c).

2.9. Urban planning

To ensure that central urban areas and their peri-urban interfaces provide all residents with equal access to urban services, facilities, and opportunities, local authorities and urban planners can rely on different STI solutions that upgrade urban planning procedures. Their adoption leads to a more detailed understanding of sustainable development issues and more efficient and inclusive decision-making processes. Examples of STI solutions include innovative approaches to participatory and collaborative urban planning, which introduce systems thinking in peri-urban development, and digital support systems. These technologies help leverage collective intelligence and create the open, inclusive, and highly collaborative environments that are required to ensure that urban planning processes take control of peri-urbanization processes and make urban spaces accessible to all people, regardless of gender, age, disability, or any other factors.

Box 7: CITInova Project to improve national capacities for sustainable urban development[37]

The CITinova Project is a good example of a project aimed at improving national capacities in urban planning for the sustainable development of Brazilian cities. The specific objectives of the project are: (a) accelerate the transition of cities towards sustainable urbanization; (b) use technology and innovation to improve the quality of life and well-being of citizens; and (c) avoid the direct emission of 3.8 million tons of CO2.

Funded by Global Environment Fund, implemented by UNEP and executed by Ministry of Science and Innovation of Brazil in partnership with the Brazilian cities of Brasilia and Recife, the project brings many successes story in developing innovative technological solutions and offer methodologies and tools for integrated urban planning and more sustainable cities. One success story is the public and free District Environmental Information System Platform which provides climate projections for the Federal District and Integrated Development Region of the Federal District and Surroundings.

Another success story is the revitalization and urbanization of Capibaribe Park in the city of Recife. The project covers 30 km of the riverbanks, focusing on public spaces for people on cycle paths and pavements, leisure, and contemplation areas. This is helpful to Recife that aims to increase the public green area index from 1.2 m2 per inhabitant to 20 m2 by 2037.

In addition, the CITinova project developed a virtual platform to support and promote integrated and sustainable public management of cities with the development of Sustainable Development Index for Cities. The Index mapped, monitored, and evaluated SDG`s compliance of 770 Brazilian cities. The data and information of the Index also provide inputs for the preparation of the Local Voluntary Report (RVL) and a balance sheet of the progress of cities in fulfilling the 2030 Agenda.

Spatial Group Model Building

To ensure the synergetic growth of interconnected urban, peri-urban, and rural areas, some local authorities are replacing siloed approaches to urban planning with more integrated practices that use system thinking to better address the spatial complexity of urban-rural linkages and maximize existing interdependences. Achieving this objective, however, requires urban analysts and planners to trigger processes of co-design and participatory decision-making that ensure vertical and horizontal coordination. These participatory and collaborative processes help cut across different policy areas, align the interests of heterogeneous actors – urban, peri-urban, and rural residents and other key stakeholders – and define a commonly-agreed set of development goals for a given rural-urban system, ensuring that excepted benefits reach all parties and resource conflicts are minimized (ECOSOC, 2013).

Studies on peri-urban planning and management have led to the definition of new approaches that respond to the specific needs of peri-urban interfaces (Allen, 2003). For example, the city of Christchurch, New Zealand, has contributed to piloting an innovative participatory process called Spatial Group Model Building (SGMB). SGMB helps combine the expectations and knowledge of a wide range of actors into a peri-urban planning processes by inviting them to

[37] Contribution from the Government of Brazil

co-design a group model building – a model that connects the flows, processes, and collaborative relationships among actors within a complex system.

The participatory process is supported with Geographic Information System (GIS) technology, which helps stakeholders visualize the physical space and connect the information of the group model building on digital maps. The process ends with the empirical examination of all information sourced from the participants, whose analysis helps detect and evaluate possible sustainable development paths (Rich et al., 2018). The towns of Lundazi and Monze, Zambia, have adopted SGMB to investigate how East Coast Fever – a disease of cattle and buffalo – oscillate over time and determine context-specific interventions that can mitigate the impact on the local economy (Mumba et al., 2017). SGMB has also been applied in the Indian state of Bihar, the district of Jessore in Bangladesh, and the Tanintharyi region, in Myanmar (Rich et al., 2021).

Gamification for digital participation

Different digital support tools are currently available, that local authorities, urban planners, and other participants of collaborative urban planning processes can use to jointly develop and assess alternative sustainable development strategies. For example, as part of the Block-by-Block initiative, UN-Habitat has introduced Minecraft in the framework of public space planning, where the videogame has become a participatory tool for stimulating the co-production of regeneration projects for neglected public spaces. This Minecraft-based methodology is freely available to all and provide residents of urban areas with access to a virtual environment in which they can collaboratively design, build, and discuss virtual urban landscapes and architectural models that have the potential to improve the quality of existing urban spaces.

After being piloted in Nairobi and Mumbai, the Block by Block methodology for co-created public spaces have been used extensively in urban areas across the world, in particular developing regions, where it has shown a good capability to mobilize community engagement (Imam et al., 2021). A few years after starting the initiative, in an effort to improve the current methodology, UN-Habitat introduced a mixed-reality tool, which has been tested in Stockholm, Sweden and Johannesburg, South Africa; this enhanced version of the Block by Block methodology uses virtual reality to provide users with a lifelike experience (UN-Habitat, 2019a, b).

Digital twin technology for urban planning

Virtual reality can also be used to create urban digital twins – virtual models of entire urban systems – as in the case of Herrenberg, a small city in Germany. The digital twin has been used to collect data describing the emotional responses of citizens, that local authorities are collecting to inform decision-making (Dembski et al., 2020). Similarly, Buildmedia – a company specialized in 3D visualizations of urban infrastructure – has created a digital twin of Wellington City, New Zealand. The digital twin builds on a combination of smart city technologies that connects streams of urban mobility data. This data describes the real-time functioning of the urban infrastructure and provides different types of urban mobility and transportation statistics, including air traffic data. By using the digital twin, local authorities can acquire data for supporting decision marking and collaboratively work on unbuilt developments, which can be integrated as virtual models in the existing built environment of the city (Frearson, 2021).

Online crowdsourcing platforms

Local authorities and planners can also use a low-tech apparatus, such as social media channels and online platforms, which can help stimulate inclusive discussions on planning ideas and better understand the preferences of key actors that are affected by urban planning decisions, including citizens (Afzalan and Muller, 2018). Online platforms that pool crowd-generated data can help generate collective knowledge and awareness around urban planning challenges, and they can also be used to increase the accessibility of urban spaces. For example, "pervasive computing technology can enhance quality of life for those with disabilities by providing access to timely information and helping them to navigate their environment independently" (Rector, 2018).

For example, the German non-profit organization Sozialhelden has developed Wheelmap, an online map for wheelchair accessible places identification[38]. Wheelmap provides information that is generated with a Wikipedia-approach; anyone can access the online map – which is generated by using OpenStreetMap data – and share knowledge on the wheelchair accessibility of the locations they have visited. Users can pick any public place around the world, rate their level of accessibility for individuals with mobility impairments, and upload photographs. The rating uses a simple traffic-light system. As of today, Wheelmap provides data on more than 1.5 million public places and is available in 33 languages. This data helps people with reduced mobility to make informed travel plans and contributes to make owners of wheelchair-inaccessible public places and local authorities aware of existing barriers (Mobasheri et al., 2017).

2.10. Healthcare

The COVID-19 pandemic has temporarily shifted significant attention away from the fight against other epidemics and communicable diseases, but it has further confirmed that scientific research outputs and combinations of technological solutions and innovations in institutional settings, funding mechanisms, and governance systems play a key role in helping healthcare services to limit the spread of infections and enhance the resilience of urban territories (Brem et al., 2021; Kumar et al., 2020; Steen and Brandsen, 2020). A whole range of COVID-19-related interventions clearly illustrated the importance of STI in strengthening the urban sociotechnical system for healthcare provision -- from genome mapping, diagnostics, contact tracing applications and disease monitoring to treatment and vaccine.

Beyond COVID-19, it is predicted that the digitalization of healthcare services, which has been accelerated by the pandemic, will completely change this sector in the next ten years. Remote care and mobile health, including the home monitoring of vital signs and medication adjustments, have already reduced costs and improved safety in healthcare delivery. The application of big data and artificial intelligence are enabling complex clinical decision-making and the identification and reporting of health emergencies. Finally, developing medical and assistive devices and services, such as 3D printing, have revolutionized the manufacture of devices and equipment. Moreover, many of these technological innovations have also exposed a potential for urban sustainability enhancement.

Digital communication channels as early-warning systems

Municipal governments closely work with citizens and act as trusted intermediators during public health emergencies; they provide local communities with risk communication and public health advice that is informed by the guidance offered by national and intergovernmental authorities. Almost everywhere in the world, municipal governments fulfil this duty by using digital communication channels – such as social media platforms, instant messaging apps,

[38] See: https://wheelmap.org

online video-sharing services, digital media, and websites – which have become early warning systems that help urban populations to sustain informed reactions to health-threatening situations.

These technological solutions work as one-stop shops for distributing up-to-date and reliable information about possible virus outbreaks – like the COVID-19 case – and other public health emergencies. However, they can become the main supporting tool of ill-intentioned individuals who support the spread of fake medical news. In response to this challenge, many municipal governments can open ad-hoc myth-buster webpages, whose contents can help dismantle dangerous false beliefs. In addition, they can operate in collaboration with technology companies, who can provide AI-powered factchecking systems and digital tools that can send alerts to social media users who have engaged with posts containing unreliable claims.

Wearable health devices

Studies have also emerged which explore the potential contribution of wearable health devices – activity trackers, smartwatches, and other devices that automatically collect and monitor physiological signals – to supporting behavioral change in urban residents affected by unhealthy lifestyles. Urbanization is a factor that can affect physical activity. For example, research conducted in China and Oman concluded that rural adolescents were less likely to be overweight and obese than those living in urban communities (Machado-Rodrigues et al., 2014). Physical activity measurements are one the most common type of data that commercially available wearable technology offer to its users, and some devices are completing this information with additional features that monitor heart rates, nutrition levels, and psychological wellbeing. All these functions suggest wearable health devices, which are increasing in popularity and diffusion may help improve the health and wellbeing of urban populations. However, the implementation of this technology in clinical settings still remains a challenge: "research suggests that digital health programs incorporating health behaviors models and personalized coaching are the most successful. Yet, knowledge is limited regarding all the factors that may drive successful implementation of wearables into the healthcare environment" (Smuck et al., 2021).

Moreover, empirical evidence is still lacking in relation to the capability of this technology to motivate individuals toward healthier habits by reporting on their health behaviors and physical activity (Patel et al., 2015). A recent report commissioned by the Health Foundation confirms a high interest in exploring this potential, but it also confirms that large-scale studies are needed to shed light on the effective potential of these devices to support the prevention and management of long-term health conditions (Maguire et al., 2021).

Remote clinical services

Remote clinical services can reduce the pressure facing health systems due to fast-growing urban populations. With most of the large medical centers located in urban areas and a growing demand for healthcare services, digitalization can increase the sector capacity while preventing the consumption of additional land – an already scarce resource in many urban contexts. In addition, remote clinical services can help cope with staff shortages by improving the efficiency of resource allocation processes.

Remote clinical services Telemedicine solutions can be associated to different levels of sociotechnical complexity and include, for example, electronic intensive care units, mobile integrated health care solutions, telepresence robots, and AI-powered bots, but also low-tech solutions such video consultations and online chats. However, while these innovations are quite

diffused in developed countries, the presence of digital divides is preventing many developing countries from introducing telemedicine this technology in their urban systems.

For example, telemedicine programs can help save time and offer the means for more focused visits. Therefore, they represent a useful tool for supporting the triage-treatment decision making process. Nevertheless, despite the potential benefits, equitable access may be difficult to ensure in both developed and developing countries. Very similar issues have emerged in applications cases, such as digital divides, patients showing lack of trust and limited digital health literacy, language barriers, data security issues, financing and scale-up challenges, and high infrastructure and maintenance costs. In addition, commercial insurance plans may not provide reimbursement for telemedicine visits to patients.

It is also widely acknowledged that the adoption of telehealth, which change existing routines, requires significant levels of training, cross-sector collaboration, internal coordination, user support protocols, and regulatory structures. Introducing remote clinical services without having the required sociotechnical infrastructure might create severe difficulties and disruption.

Moreover, telemedicine – in the form of telemental health services – can also help provide mental health support to those experiencing psychological problems, such as stress, insomnia, anxiety, depression, and self-destructive behaviors (Zhou et al., 2020). Research exploring the differences in psychiatric disorders between rural and urban populations shown that the probability to incur in mood and anxiety disorders is higher in urban areas. Telemental services can help urban and peri-urban areas to cope with the existing and future demand for psychiatric services (Peen et al., 2010).

Crowdfunding platforms

"Health inequalities in urban areas continue to grow; urban poor frequently experience worse health outcomes than their rural counterparts" (Elsey et al., 2019), while being exposed to the growing financial burden of medical care. To mitigate this financial pressure, some patients and their families – mainly representing vulnerable populations – have turned to crowdfunding platforms – for example, CoFund Health and GoFundMe – and have launched online crowdfunding campaigns (LSE, 2020). This action expresses a desperate need for reducing the financial burdens of illness through personal medical expense fundraising (BBC, 2021; Chakravorty, 2021).

The widespread diffusion of online crowdfunding campaigns, in particular during the COVID-19 pandemic, represents a clear signal of the acute distress of national health systems and the serious difficulties that the world has been experiencing in offering universal health coverage, including financial risk protection and access to quality and affordable essential healthcare services and medicines. However, analyses of crowdfunding responses show that only a minority of individuals tend to be successful (Saleh et al., 2021). These results confirm that crowdfunding platforms may help lessen the gravity of a serious issue that influence urban sustainability, but only in limited occasions and in the short term; deeper and more complex socio-economic transformations are needed to reach long-term and stable urban development results.

In addition, the findings of an investigation into crowdfunding technology adoption conducted by EU DisinfoLab – a non-governmental organization focused on tackling disinformation campaigns – urge caution; crowdfunding platforms can also become the host of several

attempts to monetize disinformation (EUDL, 2020). Risks of fraud may hinder the capacity of crowdfunding platforms to deliver emergency funds via donations (LSE, 2020).

Finally, evidence is also emerging of the inequalities that online crowdfunding campaigns can generate due to "unequally distributed literacies" (Berliner and Kenworthy, 2017). After analyzing more than 175,000 COVID-19 related online campaigns, researchers at University of Washington have concluded that "crowdfunding provides substantially higher benefits in wealthier counties with higher levels of education. People from these areas are more likely to initiate campaigns in response to adverse health and economic impacts of COVID-19, and they also receive more funding compared to people living in areas with lower income and education" (Igra et al., 2021).

Dashboard solutions

To build resilient recovery strategies, national and municipal governments will need to improve current approaches to epidemiological data collection and processing. The COVID-19 pandemic has been a data crisis, which has exposed the serious lack of urban disaggregated data and limited institutional capabilities of urban areas for systematic data collection.

An investigation conducted by *Nature* in August 2020 shows that unjustified political interferences, lack of national leadership, disorganized networks of public-health centers, and lack of efficient data management strategies are among the main factors that prevented many local and national governments from providing citizens with the information they needed to understand how the virus was spreading and react accordingly (Maxmen, 2020).

2.11. Safety and security

Worldwide efforts have been made to sustain urban safety and security, which are primarily based on the use of innovative policy interventions and research and development efforts that are increasing the availability and performance of technological STI solutions. Examples of technologies for urban safety and security enhancement include gunshot detection systems, crime mapping tools, and predictive profiling technology.

Crime prevention policy

To reduce youth homicide, a key issue in Doha, -Qatar, the local government launched the policy program 'Line Up, Live Up', in collaboration with UNODC and sports organizations (UNODC, 2020b). This program aimed to break the chain of violence by inducing behavioral change in new generations. Sports were promoted among at-risk youths to provide them with a means to learn tolerance and respect and to develop the positive behavior that can help them avoid criminal activates and violence in the future (UNOV, 2021).

Gunshot detection technology

Technological solutions for crime prevention have also been implemented. For example, different variations of gunshot detection technology (GDT) – an audio-based analytical tool – are sprouting up. GDT offers automated analyses of urban soundscapes and build upon a network of acoustic sensors to identify the sound of urban gunshots. Data generated from GDTs becomes a source of information on firearm-related crimes, and this information can be relayed to context-aware emergency services (Irvin-Erickson et al., 2017). An advantage of GDT is that the sound analysis can help determine audio patterns (Bello et al., 2018) by collecting and analyzing data on gun use in urban areas. These audio analyses capture spatial-temporal characteristics of gunshots, which help to predict where and when firearm-related crimes are likely to happen in the future. Moreover, this knowledge can also support police forces to

determine the position of gunshots in real-time. GDT uses algorithms that identify particular acoustic frequencies at different points of public transport networks (such as underground routes or bus lanes). This differentiation helps to timely distinguish gunshots from other noises and to compute the spatial coordinates of the location where the crime is taking place (ACOEM, 2020; Anderez et al., 2021).

Crime mapping tools

To enhance the capacity of GDT in crime prevention, visualization of crimes is also required. Technologies that are used for spatial identification of crime hotspots have been implemented in cities worldwide. Crime mapping via GIS analysis, for instance, is an effective measure that local police forces can adopt in urban areas to develop timelines and map locations of crime events, thereby enhancing strategic planning and operational intelligence, such as suspect movement analysis and geographic profiling of criminals.

In central London, police forces use crime mapping to analyze vehicle crime patterns, understand routines and behaviors of criminals, and determine the most probable location where these crimes take place and could happen in the future (Braga et al., 2019). Similar practices are also implemented in cities of the Global South, such as Mexico City wherein heat maps are created by local authorities to identify hotspots prone to violence against women (Royo et al., 2020).

Moreover, researchers at University of Pretoria have showcased the usefulness of crime mapping in the context of African cities by developing a robbery risk model for the city of Tshwane, South Africa. The model is based on the geo-spatial analysis in which commuter nodes and urban public facilities become points of interest. Their study reveal that urban crimes happen more commonly in neighborhoods that are ethnically heterogenous, economically poor, and with high family disruption (Kemp et al., 2021).

Predictive profiling technology

Some innovative solutions for addressing forced evictions in urban areas rely on predictive profiling techniques, in which machine learning algorithms are a key component. A variety of machine learning models can be used to identify city buildings in which tenants are at risk of landlord harassment. New York City is an example of good practice wherein data scientists have developed an-hoc machine learning model. Their model analysis historical canvass data to predict landlord harassment and create risk scores. Local government agencies harness this intelligence to prioritize inspections to high-risk buildings and better organize outreach activates to vulnerable tenants (Ye et al., 2019). Similar risk scores are also available in San Francisco, where the local government consider them when reaching out to urban residents at high risk of eviction by offering rent subsidy and affordable housing schemes (Janeway Bills, 2019).

2.12. Protection from natural disasters

STI solutions contribute to protect urban areas and their populations from natural disasters by empowering and giving a voice to people, including the most vulnerable; extending access to education services; making possible the monitoring of environmental risks; connecting people; and enabling the development of early warning systems[39]. Among available technological

[39] To obtain a more comprehensive understanding of this theme, please see the UNCTAD issues paper on "The role of science, technology and innovation in building resilient communities, including through the contribution of citizen science". The issues paper can be accessed at: https://unctad.org/system/files/official-document/CSTD2019_Issues02_STI_Build.Res.Comm_en.pdf.

innovations are disaster data infrastructure assets and nature-based solutions, whose use has proven effective in helping to increase the level of protection of urban systems from natural disasters.

Disaster data infrastructure

Data analytics capability is also of the utmost importance for urban regions that are facing natural disasters. To develop this capability, many national and local governments are increasing efforts towards building integrated data management systems that pool critical information on urban infrastructure assets. A critical step for building disaster data infrastructures is the integration of heterogenous urban data sources in the same virtual environment, breaking down the silo effect that lack of communication across city agencies within and across urban environments might generate. The integration process facilitates top-level decision-making in urban emergency responses.

For example, after experiencing a series of natural disasters, Latin America and Caribbean cities have decided to invest in developing the capacity for building a data management platform for supporting disaster management, by conducting activities that are helping to connect heterogeneous data on critical infrastructures. This integration process is already helping local governments to model risk in infrastructures like mobility and transportation (Jorisch et al., 2018). In Turkey, the Disaster Management and Decision Support System was developed in order to monitor and manage disaster and emergency processes electronically and to provide decision support to managers[40].

Examples of integrated disaster data management systems are also emerging from private sectors organizations. For instance, the Portiguese company Tecmic and the private non-profit association INOV – Instituto de Novas Tecnologias – have developed the 4Forces platform, which has been tested by using data from the city of Lisbon. The 4Forces platform has showcased the importance of cross-sector data integration, which has allowed to build a virtual model of the city and use this model to evaluate the potential impact of disasters on the urban system (Elvas et al., 2021). The simulation process aims at ensuring rapid decision-making on resources allocation in case of disasters.

Nature-based solutions

When developing disaster risk reduction schemes and practices, city governments can also bring into action nature-based solutions. Nature-based solutions is an umbrella term that groups different types of ecology-based technical solutions, innovative actions, and policies whose objective is to help protect, govern, and recover urban ecosystems, build up their resilience to natural disasters, and protect biodiversity(UNDRR, 2020).

For example, the uMngeni Infrastructure Partnership (UEIP) in South Africa is a cross-sector water catchment program that aims to boost the capacity of urban systems to support water conservation by introducing nature-based solutions. Several demonstration projects have been implemented in cities of the KwaZulu-Natal Province, where nature-based solutions have helped to rehabilitate natural ecosystems, such as river areas and the Midmar Dam, which serve the urban population in the province (Apamaku, 2021). In Switzerland, the government spent 0,6% of its GDP on protection against natural hazards, including the construction of elaborate protective structures to prevent damage. Knowledge regarding the continual intensification of

[40] Contributions from the Government of Turkey

land use is a key prerequisite for minimizing risk, which is why work on analyzing land use risk is currently ongoing[41].

A similar practice in Lahore, Pakistan shows the government that is committed to remedying to the challenges that high-rate air pollution and heat. An urban forest named Liberty Market was planted in the city in 2019. Acting as a nature-based solution, the forest combined ecological engineering and active policy-making to ensure the exclusive use of native species of vegetation for restoring urban forested areas (Arif, 2021; SANBI, nd).

[41] Contributions from the Government of Switzerland

3. POLICY RECOMMENDATIONS

The COVID-19 pandemic has enabled many new forms of innovation for sustainable cities and communities, and it has triggered a level of research, development, and experimentation that countries have struggled to implement during non-crisis conditions. The pace with which local and national government leaders and other stakeholders have reorganized urban sociotechnical systems in many regions, by introducing innovative STI solutions to the challenges imposed by the crisis, have been remarkable, especially when observing the very fast rearrangement of healthcare and education systems. The action necessary at national and international levels is now to seize this innovation momentum and use its transformative power to ensure that urban areas can deliver on their commitment to sustainable urban development. Therefore, the following recommendations are presented making a distinction between the considerations that apply to national governments and those that would be more pertinent for international action.

Adjust pre-COVID priorities and resource allocation strategies

The uncertain investment climate and fragile financial situation of public and private organizations could severely undermine the capability of countries to sustain the innovation momentum and the scope and scale of STI actions for uplifting urban sustainability. Considering only the period between 2020 and 2030, it is estimated that more than $40 trillion will be required to provide funding for the urban infrastructure developments that are needed to enhance the sustainability of cities and towns worldwide and harness the value of sustainable urbanization (UN-Habitat, 2020c).

The negative economic effects of the COVID-19 pandemic have reached public sector organizations; the overall revenue of local authorities is expected to decline between 15% and 25% in 2021, with more drastic effects on developing countries. For example, the revenue losses of African local governments could go up to 60% (UN, 2020d). With such a massive shortfall in public and private budgets, less funds will be available for STI activities oriented toward enhancing urban sustainability.

- Considerations for member States:
    a) Redefine sustainable urban development priorities in the aftermath of the pandemic – in particular the urgent need to invest in STI solutions that can alleviate unemployment and the financial issues of low-income households and smaller firms.
    b) Ensure that priority is given to the STI actions that can ensure value for money and more efficient spending, with a particular focus on activities that can boost urban resilience.
- Considerations for the international community:
    a) Introduce financial measures that can help reinstate the financial stability of private and public sector organizations, especially in developing economies.

Find and share STI solutions for sustainable urban environments

The analysis has uncovered an incredibly data-rich but fragmented knowledge environment; the application of STI in urban contexts has led to the development of many experiences, solutions, and practical knowledge whose potential for innovation is not fully enacted. Cross-country collaborative research efforts are needed to pool and formalize this knowledge and to ensure knowledge transfer. In addition, the sharing of STI practices will also help to raise awareness of the many innovations which are already available and to forge new local and international collaborations, strengthening urban innovation ecosystems worldwide.

- Consideration for member States:
    a) Capture, formalize, and share positive and negative practices, at different stages of development, and experience on the use of STI solutions for urban sustainability enhancement.
- Considerations for the international community:
    a) Support cross-country collaborative research efforts by establishing common strategies for data collection and analysis that can facilitate benchmarking
    b) Establish a virtual environment to facilitate international knowledge transfer and ensure that an international basis of experience is available for all

Cultivate and empower local ecosystems for urban innovation

Developing, testing, and scaling STI solution to urban sustainability challenges requires a cross-sector and multi-stakeholder effort, with strong collaboration among heterogeneous actors and across scales – national governments, local public sector organizations, businesses, third sector organizations, financial institutions, universities and research centers, and civil society. When all these actors operate in concert, urban innovation can flourish.

Governance frameworks supporting local innovation ecosystems for urban innovation are also required to facilitate open innovation processes, international cooperation, and the scaling up of collaborative dynamics, the three elements whose combination has proven indispensable in the fight against COVID-19 (Klingler-Vidra et al., 2021; Park et al., 2021). In this instance, local governments need to adapt swiftly to digital solutions, particularly to step up their efforts and develop new ways to communicate with their citizens in supporting the ecosystem for urban innovation, for example by facilitating citizen participation via online platforms[42].

- Considerations for member States:
    a) Frame an enabling institutional, policy, and regulatory environment that promotes the development of an open innovation culture in urban spaces and facilitates cross-sector and multi-stakeholder collaboration.
    b) Expand incubation services to facilitate the transformation of business-sector research in science, technology, and innovation that actively contribute in solving urban development challenges (e.g., housing, job creation, waste management, etc.)
- Considerations for the international community:
    a) Assist countries, especially in developing regions, in structuring long-term collaborative efforts that extend beyond single-projects and look at multi-year developments.
    b) Enhance capacity-building support to increase the availability of resources for scaling up research development capacity in response to emergency condition.

Protect against the unperceived complexity of urban digital transformations

In building capacity for local urban innovation, actions should also be taken to raise the awareness of the challenges that the unperceived complexity of technology-related development can generate in urban sustainability actions. For example, in leveraging smart cities technologies to improve urban service delivery, their action is guided by a wrongful

[42] Contribution from the government of Belgium.

conceptualization of smart city development processes which led to faulty implementation in both developed countries (Martin et al., 2019) and emerging economies (Fromhold-Eisebith and Eisebith, 2019).

As a result, urban digital transformations can be erroneously conceived as ready-to-implement technological upgrade, rather than an ongoing sociotechnical change process that is firmly anchored to spatial and temporal dimensions and existing sociotechnical arrangements. In this context, preliminary work through feasibility studies to analyze citizen security, mobility flows, risk management, and allocating economic resources would be important before developing the smart city processes[43]. To enhance urban sustainability, technological solutions are more effective when they are conceived taking into account local conditions and supported with complementary changes in existing institutional settings, and a people-centered focus. Otherwise, negative externalities and inefficacies may appear.

- Considerations for member States:
    a) Provide local actors with the knowledge resources necessary to familiarize them with sustainable urban digital transformations and help them develop policy and governance capacity.
    b) Raise awareness among municipal governments and other local stakeholders on the unperceived complexity of technology-related urban development strategies (e.g., smart city) and the importance to integrate local context conditions with people-centered focus in urban sustainability actions.
- Consideration for the international community:
    a) Mobilize resources for supporting more research exploring the non-technological change dimensions of urban digital transformations for urban sustainability.
    b) Develop operational tools that consider the place-based and sociotechnical nature component of technology-related sustainability transitions, to stop the spread of one-size-fits-all mentalities.

Introduce new and more equitable financing mechanisms

More efficient spending is indispensable but insufficient to ensure that the research and development efforts for sustainable urban development receive adequate financial support. The size of the investments requires countries to establish new international mechanisms to support the financing of STI solutions for urban sustainability challenges. These mechanisms are required to overcome existing inequalities in funding provision and ensure the activation of collaborative ventures with heterogenous actors. Without cross-sector collaborative efforts, financing urban development initiatives involving STI solutions has proven complex, especially when technology-related. In addition, to optimize revenue mobilization, countries should strengthen their institutional settings to ensure that public investment management in cities and communities is supported by policy coherence across multiple levels of governance.

- Considerations for member States:
    a) Facilitate cross-sector collaborative ventures with heterogenous actors to increase the financial capacity of cities and urban communities to support the research and development actions required to embrace STI solutions.
    b) Optimize revenue mobilization by prioritizing STI measures that can ensure

[43] For example, the feasibility study of Smart City in Piura, Peru.

value for money and more efficient spending.

c) Strengthen institutional settings to ensure that public investment management in cities and communities is supported by policy coherence across multiple levels of governance.

- Considerations for the international community:

a) Enhance international support by mobilizing additional financial resources for developing countries from multiple sources.

b) Ensure that research and development efforts for sustainable urban development receive adequate financial support in all regions, especially those with highest need.

Rethink urban areas as data infrastructures

The COVID-19 pandemic has raised significant attention on the value of data and the and important role this resource plays in fostering urban sustainability. Lessons from the pandemic have led to important considerations for future STI policy and practice. First, the pandemic has exposed a critical gap in urban disaggregated data, whose elaboration is crucial to obtain a localized knowledge on the functioning of urban sociotechnical systems and prepare appropriate STI solutions. Second, the pandemic has further demonstrated that data fuels STI and, if correctly deployed, it can help increase urban resilience.

In this regard, the rapid and widespread diffusion of smart city technologies and other digital solutions has augmented this potential, by facilitating the continuous creation of massive amounts of new data at unprecedent speed. This data can be used to create fertile environments for STI activities oriented towards delivering sustainable value for cities and urban communities.

- Considerations for member States:

a) Transform existing data governance structures to ensure a more systemic, human-centric, cross-collaborative, and privacy-preserving approach to the management and development of urban data infrastructures.

b) Ensure that data governance structures are supported by cross-sector and multi-stakeholder collaborative ecosystems.

- Considerations for the international community:

a) Mobilize the resources required to increase the international availability of urban disaggregated data to obtain localized knowledge on the functioning of urban sociotechnical systems and prepare appropriate STI solutions

b) Provide countries with guidance on how to best develop effective local and national regulatory frameworks.

Integrate policy settings for sustainable urban development

The complexity of urban sustainability challenges requires multi-sector and multi-level investments and efforts, which build the foundations of the integrated approach to urban sustainability enhancement that the 2030 Agenda for Sustainable Development and New Urban Agenda champion. STI measures have proved effective in supporting integrated sustainable urban development; many solutions can address multiple sustainable urban development goals simultaneously, and they impact on multiple policy sectors. However, to maximize synergies and minimize trade-offs, coordination is needed among policy settings. When sustainable

urban development policy is fragmented among policy areas, their functional logics and actors lack the coordination that is required to acquire a comprehensive understanding of urban sustainability issues – for example, technological upgrades that lack interoperability.

- Considerations for member States:
    a) Help local development actors to embrace the integrated approach to urban sustainability enhancement that the 2030 Agenda for Sustainable Development and the New Urban Agenda champion.
    b) Adjust institutional frameworks to integrate urban sustainability policy settings, horizontally and vertically, and ensure the coordination needed to maximize synergies among STI actions and minimize fragmentation and trade-offs.
- Considerations for the international community:
    a) Ensure a cross-sectoral harmonization of urban sustainability policies across governmental levels, from local to global.

Boost scale-up and spreading operations

The COVID-19 pandemic has demonstrated that organizations need to accelerate the digitalization of urban sociotechnical systems, especially where the delivery of basic services require more resilient operational modes. Cities and urban communities have been experimenting with a growing number of STI measures for increasing this resiliency, to the extent that many urban areas have become living laboratories for the testing and experimentation of urban innovations.

Despite the progress, in many cases, government leaders and other stakeholders struggle to move beyond local pilot phases and ensure that the benefits of a solution – together with the lessons learned during the testing – can be scaled to reach a wider audience. STI studies can help overcome this critical challenge; more research efforts and resources should be allocated to determine the barriers that are inhibiting scale-up, to develop viable strategies that can ensure the mobility of solutions and, when needed, to achieve of the necessary economies of scale and return of investments.

- Considerations for member States:
    a) Assess the sociotechnical factors that hinder or accelerate local scale-up and spreading operations.
    b) Develop evidence-based strategies that can help ensure the mobility of STI solutions within national boundaries.
    c) Encourage local actors to join national and international networks of cooperation in which they can develop a deeper insight into how to manage scale-up and spreading operations.
- Considerations for the international community:
    a) Compile and disseminate good practice on the framing of business models that support the scaling-up and replicability of STI measures with potential for urban sustainability enhancement.
    b) Introduce measures that can help ensure the mobility of STI solutions across regions.

Building capacity around digital mindsets, skills, and technology acceptance.

During the COVID-19 pandemic many have been left behind because existing inequalities have been remarked and amplified. Among these inequalities are digital divides – especially skills and digitally literacy – which have prevented many individuals from accessing the digital services which have replaced ordinary delivery methods. Digital divides also hinder engagement to citizens who are not connected (e.g., older generation, deprived communities, etc), since those people are not sure what benefits are for them in engaging with these technologies[44].

Closing these digital skills and knowledge gaps should be a central theme in all efforts to sustain a truly inclusive sustainable urban development. Measures to increase digital literacy and human skills development are equally important as those for access to infrastructure or internet.

- Considerations for member States:
    a) Build consensus and strengthen collaboration in the field of digital education strategies including by developing national strategic plans.
    b) Increase innovation and investment in digital technology for learning and teaching.
    c) Introduce the training measures required to provide all children, young adults, and adults with a sufficient level of digital literacy and vital digital skills.
    d) Enhance the digital skills of educators by providing them with the knowledge required to effectively introduce digital technologies in learning environments.
    e) Increase access to digital devices and infrastructure for all teaching staff and learners, while ensuring that the use of this technology is embedded in their teaching and learning activities.
- Consideration for the international community:
    a) Strengthen scientific cooperation in the field of digitally enhanced teaching and learning, to provide government leaders and local authorities with more guidance.
    b) Encourage the reframing of national education systems to ensure that digital literacy and digital technologies become a central component of existing and future school curricula, at all levels, from pre-primary schools to universities.

[44] Contributions from the Government of the United Kingdom.

REFERENCES

Abebe, M.S., Derebew, K.T., Gemeda, D.O., 2019. *Exploiting temporal-spatial patterns of informal settlements using GIS and remote sensing technique: a case study of Jimma city, Southwestern Ethiopia*. Environmental Systems Research 8(1).

Aberdeen City Council, 2020. *New journey planning app launched*, Aberdeen City Council, Aberdeen. https://news.aberdeencity.gov.uk/new-journey-planning-app-launched/.

Abergel, T., Dean, B., Dulac, J., 2017. *Towards a zero-emission, efficient, and resilient buildings and construction sector: Global Status Report 2017*, United Nations Environment Programme (UNEP) and International Energy Agency (IEA). https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf.

ACOEM, 2020. *Brochure: Gunshot and Acoustic Threat Detection: Hear Danger before you See Danger*, ACOEM, Richmond, VA. https://www.acoem.com/wp-content/uploads/2020/03/Brochure.-ACOEM-Gunshot-Acoustic-Threat-Detection-brochure-2020.pdf.

ACTAsia, 2016. *Caring for Life Education: Curriculum Framework and Guidelines* ACTAsia. https://issuu.com/actasia/docs/aa-framework-f_online.

ACTAsia, 2021. *ACTAsia invited to speak at UN High Level Political Forum*, ACTAsia. https://www.actasia.org/news/actasia-invited-to-speak-at-un-high-level-political-forum/.

Adanu, S.K., Gbedemah, S.F., Attah, M.K., 2020. *Challenges of adopting sustainable technologies in e-waste management at Agbogbloshie, Ghana*. Heliyon 6(8), e04548.

Adyel, T.M., 2020. *Accumulation of plastic waste during COVID-19*. Science 369(6509), 1314-1315.

Afzalan, N., Muller, B., 2018. *Online Participatory Technologies: Opportunities and Challenges for Enriching Participatory Planning*. Journal of the American Planning Association 84(2), 162-177.

Ahmed, S., Sanghvi, K., Yeo, D., 2020. *Telemedicine takes centre stage during COVID-19 pandemic*. BMJ Innovations 6(4), 252-254.

Alasuutari, H., 2020. *Tackling inequity in education during and after Covid-19*, The World Bank, Washington, DC. https://blogs.worldbank.org/education/tackling-inequity-education-during-and-after-covid-19.

Alexandratos, N., Bruinsma, J., 2012. *World Agriculture Towards 2030/2050: The 2012 Revision*, Food and Agriculture Organization (FAO), Rome. http://www.fao.org/3/ap106e/ap106e.pdf.

Alexopoulos, K., Wyrowski, L., 2015. *Sustainable urban mobility and public transport in UNECE capitals*, United Nations Economic Commission for Europe (UNECE), Geneva. https://unece.org/DAM/trans/main/wp5/publications/Sustainable_Urban_Mobility_and_Public_Transport_FINAL.pdf.

Allen, A., 2003. *Environmental planning and management of the peri-urban interface: perspectives on an emerging field*. Environment and Urbanization 15(1), 135-148.

Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini, C., Di Marco, M., Breit, N., Olival, K.J., Daszak, P., 2017. *Global hotspots and correlates of emerging zoonotic diseases*. Nature Communications 8(1).

Altam, M., Pompei, A., 2018. *3D Printing For Good: How One Nonprofit Is "Printing" Homes for Families in Need*, United Nations Foundation (UNF), New York City, NY. https://unfoundation.org/blog/post/3d-printing-for-good-how-one-nonprofit-is-printing-homes-for-families-in-need/.

Amit, M., Mishra, R.K., Hoang, Q., Galan, A.M., Wang, J., Ng, T.N., 2019. *Point-of-use robotic sensors for simultaneous pressure detection and chemical analysis*. Materials Horizons 6(3), 604-611.

Anderez, D.O., Kanjo, E., Amnwar, A., Johnson, S., Lucy, D., 2021. *The Rise of Technology in Crime Prevention: Opportunities, Challenges and Practitioners Perspectives*, Nottingham Trent University, University College London, and Metropolitan Police, London. https://arxiv.org/pdf/2102.04204.pdf.

Andersen, I., 2020. *Improving Water Resource Management to Address the Climate Emergency*, United Nations Environment Programme (UNEP), Nairobi. https://www.un.org/en/un-chronicle/we-cannot-address-climate-emergency-without-improving-water-resource-management.

Angelidaki, I., Karakashev, D., Batstone, D.J., Plugge, C.M., Stams, A.J., 2011. *Biomethanation and its potential*. Methods in enzymology 494, 327-351.

Apamaku, A.J., 2021. *Nature-based solutions: Cases in African Cities*, Youth4Nature Foundation. https://www.youth4nature.org/blog/nature-based-solutions-cases-in-african-cities.
ARC, 2019. *Government of Senegal to Receive a minimum of US$22m from the African Risk Capacity Insurance Company Limited for Drought*, African Risk Capacity (ARC), Johannesburg. https://www.africanriskcapacity.org/2019/09/05/government-of-senegal-to-receive-a-minimum-of-us22m-from-the-african-risk-capacity-insurance-company-limited-for-drought/.
Arias-Molinares, D., Carlos García-Palomares, J., 2020. *Shared mobility development as key for prompting mobility as a service (MaaS) in urban areas: The case of Madrid*. Case Studies on Transport Policy 8(3), 846-859.
Arif, Y., 2021. *Liberty Market forest: an urban forest in Pakistan*, University of Oxford, Oxford. https://www.naturebasedsolutionsinitiative.org/news/liberty-market-forest-an-urban-forest-in-pakistan/.
ARUP, 2019. *Digital Twin: Towards a Meaningful Framework*, ARUP, London. https://www.arup.com/-/media/arup/files/publications/d/digital-twin-report.pdf.
Ates, H.C., Yetisen, A.K., Güder, F., Dincer, C., 2021. *Wearable devices for the detection of COVID-19*. Nature Electronics 4(1), 13-14.
Baeumler, A., D'Aoust, O., Das, M.B., Gapihan, A., Goga, S., Lakovits, C., Restrepo Cavadid, P., Singh, G., Terraza, H., 2021. *Demographic Trends and Urbanization*, The World Bank, Washington, DC. http://hdl.handle.net/10986/35469.
BBC, 2021. *Indians turn to crowdfunding to pay Covid bills*, BBC News. https://www.bbc.co.uk/news/world-asia-india-57981252.
Begeny, C.T., Ryan, M.K., Moss-Racusin, C.A., Ravetz, G., 2020. *In some professions, women have become well represented, yet gender bias persists—Perpetuated by those who think it is not happening*. Science Advances 6(26), eaba7814.
BEIS, 2020. *Wind powered electricity in the UK*, Government of the United Kingdom - Department for Business, Energy & Industrial Strategy (BEIS). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/875384/Wind_powered_electricity_in_the_UK.pdf.
Bello, J.P., Mydlarz, C., Salamon, J., 2018. *Sound analysis in smart cities*, in: Virtanen, T., Plumbley, M.D., Ellis, D. (Eds.), *Computational Analysis of Sound Scenes and Events*. Springer, Cham, pp. 373-397.
Bennedsen, M., Simintzi, E., Tsoutsoura, M., Wolfenzon, D., 2020. *Do Firms Respond to Gender Pay Gap Transparency?*, National Bureau of Economic Research (NBER), Cambridge, MA. https://www.nber.org/system/files/working_papers/w25435/w25435.pdf.
Berliner, L.S., Kenworthy, N.J., 2017. *Producing a worthy illness: Personal crowdfunding amidst financial crisis*. Social Science & Medicine 187, 233-242.
Bhatt, A., Azcona, G., 2020. *Unpaid care and domestic work: we're not all in the same boat*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://data.unwomen.org/features/unpaid-care-and-domestic-work-were-not-all-same-boat.
Boardman, B., 1991. *Fuel Poverty: From Cold Homes to Affordable Warmth*. Belhaven Press, London.
Boersma, M., Nolan, J., 2020. *Can Blockchain Help Resolve Modern Slavery in Supply Chains?* AIB Insights 20(2).
Böheim, R., Gust, S., 2021. *The Austrian Pay Transparency Law and the Gender Wage Gap*, IZA Institute of Labor Economics, Bonn. https://www.iza.org/publications/dp/14206/the-austrian-pay-transparency-law-and-the-gender-wage-gap.
Braga, A.A., Turchan, B., Papachristos, A.V., Hureau, D.M., 2019. *Hot spots policing of small geographic areas effects on crime*. Campbell Systematic Reviews 15(3), e1046.
Braich, G., Ricciardi, V., Wadhwa, D., Herrera Garci, L.D., 2020. *Managing plastic and food waste for a sustainable future*, in: Pirlea, A.F., Serajuddin, U., Wadhwa, D., Welch, M., Whitby, A. (Eds.), *Atlas of the Sustainable Development Goals 2020: From World Development Indicators*. The World Bank, Washington, DC.
Brekke, K., Arikan, Y., Zimmermann, M., 2016. *Towards the New Urban Agenda: Linking with international processes*, Local Governments for Sustainability (ICLEI), Bonn. https://www.local2030.org/library/252/Towards-the-New-Urban-Agenda-Linking-with-international-processes.pdf.

Brem, A., Viardot, E., Nylund, P.A., 2021. *Implications of the coronavirus (COVID-19) outbreak for innovation: Which technologies will improve our lives?* Technological Forecasting and Social Change 163, 120451.
Brennen, J.S., Simon, F.M., Howard, P.N., Nielsen, R.K., 2020. *Types, Sources, and Claims of COVID-19 Misinformation*, University of Oxford, Osford. https://www.primaonline.it/wp-content/uploads/2020/04/COVID-19_reuters.pdf.
Briggs, B., 2018. *How technology can speed help to malnourished children in the effort to end global hunger*, Microsoft, Redmond, WA. https://news.microsoft.com/transform/app-end-global-hunger/.
Bristol City Council, 2017. *State of the art operations centre opens in Bristol*, Bristol City Council, Bristol. https://news.bristol.gov.uk/news/state-of-the-art-operations-centre-opens-in-bristol-2.
Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., Van Steenbergen, F., Voytenko Palgan, Y., 2016. *Urban living labs: governing urban sustainability transitions*. Current Opinion in Environmental Sustainability 22, 13-17.
Burton, T., Alers, M., 2019. *Solar for Health: Five Ways Solar Power Can Make Universal Healthcare a Reality*, United Nations (UN), New York City, NY. https://www.un.org/en/un-chronicle/solar-health-five-ways-solar-power-can-make-universal-healthcare-reality.
C40, 2020. *Organic Waste to Biogas in Rio de Janeiro's Biomethanisation unit*, C40 Cities (C40). https://www.c40.org/case_studies/rio-biomethanisation-unit.
Calton, B., Abedini, N., Fratkin, M., 2020. *Telemedicine in the Time of Coronavirus*. Journal of Pain and Symptom Management 60(1), e12-e14.
CCJ, 2019. *Model guidelines for sexual offence cases in the Caribbean Region*, Caribbean Court of Justice (CCJ), Port of Spain. https://juristproject.org/wp-content/uploads/2019/08/Model-Guidelines-for-Sexual-Offence-Cases-in-the-Caribbean-Region-For-website.compressed-1.pdf.
Cerema, 2020. *MaaS in Europe: Lessons from the Helsinki, Vienna and Hanover experiments*, Centre for Studies on Risks, the Environment, Mobility and Urban Planning (Cerema), Paris.
Chai, B., Li, X., Liu, H., Lu, G., Dang, Z., Yin, H., 2020. *Bacterial communities on soil microplastic at Guiyu, an E-Waste dismantling zone of China*. Ecotoxicology and Environmental Safety 195, 110521.
Chaisson, C., 2021. *Fossil Fuel Air Pollution Kills One in Five People*, Natural Resources Defense Council (NRDC), New York City, NY. https://www.nrdc.org/stories/fossil-fuel-air-pollution-kills-one-five-people.
Chakraborty, A., McMillan, A., 2018. *Is Housing Diversity Good for Community Stability?: Evidence from the Housing Crisis*. Journal of Planning Education and Research, 0739456X1881078.
Chakravorty, P., 2021. *How crowdfunding is transforming lives*, The Economic Times. https://economictimes.indiatimes.com/small-biz/sme-sector/how-crowdfunding-is-transforming-lives/articleshow/82213708.cms?from=mdr.
Chandran, R., 2019. *Why floating solar panels are on the rise* World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2019/02/in-land-scarce-southeast-asia-solar-panels-float-on-water.
Chandran, T., 2018. *Smart Cities: Reducing Congestion with Deep Learning*, Siemens, Munich. https://new.siemens.com/global/en/company/stories/research-technologies/folder-future-living/reducing-congestion-with-deep-learning.html.
Chang, Y., Li, X., Masanet, E., Zhang, L., Huang, Z., Ries, R., 2018. *Unlocking the green opportunity for prefabricated buildings and construction in China*. Resources, Conservation and Recycling 139, 259-261.
Chauhan, C., Dhir, A., Akram, M.U., Salo, J., 2021. *Food loss and waste in food supply chains. A systematic literature review and framework development approach*. Journal of Cleaner Production 295, 126438.
Chen, F., Luo, Z., Yang, Y., Liu, G.-J., Ma, J., 2018. *Enhancing municipal solid waste recycling through reorganizing waste pickers: A case study in Nanjing, China*. Waste Management & Research 36(9), 767-778.
Chik, H., Xue, M., 2021. *China floods: how Zhengzhou's 'once in a thousand years' rainfall compares*, South China Morning Post. https://www.scmp.com/news/china/science/article/3142157/china-floods-how-zhengzhous-once-thousand-years-rainfall.
Chin, C., Robison, M., 2020. *How AI bots and voice assistants reinforce gender bias*, Brookings Institution, Washington, DC. https://www.brookings.edu/research/how-ai-bots-and-voice-assistants-reinforce-gender-bias/.

Chowdhury, S.R., Sunna, T.C., Ahmed, S., 2021. *Telemedicine is an important aspect of healthcare services amid COVID-19 outbreak: Its barriers in Bangladesh and strategies to overcome*. The International Journal of Health Planning and Management 36(1), 4-12.
CIRCit Nord, nd. *WasteIQ - Smart waste management by pay-as-you-throw*, Technical University of Denmark (DTU), Research Institutes of Sweden (RISE), Norwegian University of Science and Technology (NTNU), Innovation Center Iceland (ICI), and Technology Industries of Finland. https://circitnord.com/inspiration-cases/cecase-49/.
CloQ, 2021. *CloQ - Simplifying Financial Inclusion*, CloQ, Refice. https://sdgs.un.org/partnerships/cloq-simplifying-financial-inclusion.
Codd, F., Ferguson, D., 2020. *The covid-19 outbreak and employment rights*, House of Commons Library, London. https://researchbriefings.files.parliament.uk/documents/CDP-2020-0140/CDP-2020-0140.pdf.
Cominola, A., Giuliani, M., Castelletti, A., Fraternali, P., Gonzalez, S.L.H., Herrero, J.C.G., Novak, J., Rizzoli, A.E., 2021. *Long-term water conservation is fostered by smart meter-based feedback and digital user engagement*. npj Clean Water 4(1).
Cowtribe, 2020. *#ZhuliaIsHere*, Cowtribe, Accra. https://www.cowtribe.com/tribe-blog/.
Crabtree, L., 2018. *Self-organised housing in Australia: housing diversity in an age of market heat*. International Journal of Housing Policy 18(1), 15-34.
Crozet, Y., 2020. *Mobility as a Service: A New Ambition for Public Transport Authorities*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.itf-oecd.org/sites/default/files/docs/maas-ambitions-public-transport-authorities.pdf.
Daun, J., 2019. *Child Participation and Accountability in Save the Children Colombia's Programming*, The Refugee Law Initiative, London. https://rli.sas.ac.uk/sites/default/files/files/RLI%20Child%20participation%20ENG%20FINAL.pdf.
DEFRA, 2018a. *Our waste, our resources: a strategy for England*, Government of the United Kingdom - Department for Environment, Food and Rural Affairs (DEFRA), London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765914/resources-waste-strategy-dec-2018.pdf.
DEFRA, 2018b. *World leading microbeads ban comes into force*, Government of the United Kingdom - Department for Environment, Food & Rural Affairs (DEFRA). https://www.gov.uk/government/news/world-leading-microbeads-ban-comes-into-force.
Dele-Ajayi, O., Fasae, O.D., Okoli, A., 2021. *Teachers' concerns about integrating information and communication technologies in the classrooms*. PLOS ONE 16(5), e0249703.
Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., Yamu, C., 2020. *Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany*. Sustainability 12(6), 2307.
Dewson, S., Gloster, R., Chubb, C., Carta, E., Reilly, P., 2011. *Voluntary Gender Equality Reporting in Organisations with 150 to 249 Employees*, Government of the United Kingdom - Government Equalities Office (GEO), London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/85541/gender-equality-reporting.pdf.
DfT, 2019. *Cycle to work scheme implementation guidance for employers*, Government of the United Kingdom - Department for Transport (DfT), London. https://www.gov.uk/government/publications/cycle-to-work-scheme-implementation-guidance.
Di Giacomo, D., Vincenza, C., Mascio Tania, D., Maria Rosita, C., Daniela, F., Rosella, G., Pierpaolo, V., 2016. *The silent reading supported by adaptive learning technology: Influence in the children outcomes*. Computers in Human Behavior 55, 1125-1130.
Dindar, M., Suorsa, A., Hermes, J., Karppinen, P., Näykki, P., 2021. *Comparing technology acceptance of K-12 teachers with and without prior experience of learning management systems: A Covid-19 pandemic study*. Journal of Computer Assisted Learning.
Doetinchem, O., Xu, K., Carrin, G., 2008. *Conditional cash transfers: what's in it for health?* , World Health Organization (WHO), Geneva. https://www.who.int/health_financing/documents/pb_e_08_1-cct.pdf.
Doorly, M., Martin, J., Moore, A., O'Dowd, A., Kidney, I., Kennedy, P., 2007. *Give Credit to the Poor*, Irish League of Credit Unions Foundation (ILCU) and Concern Worldwide, Dublin. http://www.ubuntu.ie/media/microcredit.pdf.
Doran, P., 2021. *Doing More with Less: Ensuring Sustainable Consumption and Production*, International Institute for Sustainable Development (IISD), Winnipeg. https://www.iisd.org/system/files/2021-08/still-one-earth-sustainable-consumption.pdf.

Duchini, E., Simion, S., Turrell, A., 2020. *Pay Transparency and Cracks in the Glass Ceiling*, University of Warwick, University of Bristol, and King's College London. https://arxiv.org/abs/2006.16099.
EC, 2013. *Urban mobility*, European Commission (EC), Brussels. https://ec.europa.eu/transport/themes/urban/urban_mobility_en.
EC, 2016. *Improving desalination with nanotechnology*, European Commission (EC), Brussels. https://cordis.europa.eu/article/id/157580-improving-desalination-with-nanotechnology.
EC, 2017a. *From waste to wealth: a digital matching platform finds new high-value reuse options for your materials or (waste) products*, European Commission (EC), Brussels. https://circulareconomy.europa.eu/platform/en/good-practices/waste-wealth-digital-matching-platform-finds-new-high-value-reuse-options-your-materials-or-waste-products.
EC, 2017b. *ICT solutions to enhance urban water management*, European Commission (EC), Brussels. https://cordis.europa.eu/article/id/202126-ict-solutions-to-enhance-urban-water-management.
EC, 2017c. *Pay-as-you-throw schemes increase recycling rates*, European Commission (EC), Brussels. https://www.interregeurope.eu/policylearning/news/550/pay-as-you-throw-schemes-increase-recycling-rates/.
EC, 2019. *Digital Opportunity Traineeships initiative exceeds original targets*, European Commission (EC), Brussels. https://digital-strategy.ec.europa.eu/en/news/digital-opportunity-traineeships-initiative-exceeds-original-targets.
EC, 2020. *Questions and answers: A Hydrogen Strategy for a climate neutral Europe*, European Commission (EC), Brussels. https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1257.
EC, 2021a. *Digital Solutions for Zero Pollution*, European Commission (EC), Brussels.
EC, 2021b. *EU support to Promoting Sustainable Health and nutrition Opportunities for Marginalized urban extreme poor Population (PROSHOMON) in Bangladesh*, European Commission (EC), Brussels. https://sdgs.un.org/partnerships/eu-support-promoting-sustainable-health-and-nutrition-opportunities-marginalized-urban.
EC, 2021c. *FIWARE for the Next Generation Internet Services for the WATER sector*, European Commission (EC), Brussels. https://cordis.europa.eu/project/id/821036.
EC, 2021d. *National Reforms in School Education*, European Commission (EC), Brussels. https://eacea.ec.europa.eu/national-policies/eurydice/content/national-reforms-school-education-1_en.
EC, 2021e. *PLATInum group metals Recovery Using Secondary raw materials*, European Commission (EC), Brussels. https://cordis.europa.eu/project/id/730224.
ECF, 2013. *Bike Share Schemes*, European Cyclists Federation (ECF), Brussels. https://ecf.com/what-we-do/urban-mobility/bike-share-schemes-bss.
ECLAC, ILO, 2017. *Employment Situation in Latin America and the Caribbean: The transition of young people from school to the labour market*, United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and International Labour Organization (ILO), Santiago. https://www.cepal.org/en/publications/42251-employment-situation-latin-america-and-caribbean-transition-young-people-school.
ECOSOC, 2013. *Science, technology and innovation for sustainable cities and peri-urban communities*, United Nations Economic and Social Council (ECOSOC), New York City, NY. https://unctad.org/system/files/official-document/ecn162013d2_en.pdf.
ECOSOC, 2021. *Progress towards the Sustainable Development Goals: Report of the Secretary-General*, United Nations Economic and Social Council (ECOSOC), New York City, NY. https://undocs.org/en/E/2021/58.
Edmond, C., 2019. *This is what the world's waste does to people in poorer countries*, World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2019/05/this-is-what-the-world-s-waste-does-to-people-in-poorer-countries/.
EEA, 2011. *Safe water and healthy water services in a changing environment*, European Environment Agency (EEA), København. https://op.europa.eu/en/publication-detail/-/publication/504f4ea4-2087-4fdc-8a3d-b522dc29f622.
Ellen MacArthur Foundation, 2021. *Making new products from urban organic waste streams: De Clique*, Ellen MacArthur Foundation, Cowes. https://declique.nl/en/.
Elvas, L.B., Mataloto, B.M., Martins, A.L., Ferreira, J.C., 2021. *Disaster Management in Smart Cities*. Smart Cities 4(2), 819-839.

EME, 2019. *EME Pilot Report*, Excess Materials Exchange (EME), Amsterdam. https://excessmaterialsexchange-pilot-report.s3.eu-central-1.amazonaws.com/EME+Pilot+Report+compressed.pdf.
Enoch, M., 2018. *Mobility as a Service (MaaS) in the UK: change and its implications*, Government of the United Kingdom - Government Office for Science (GO-Science), London.
Envirofit, nd. *Smarter cooking technology for better living*, Envirofit. https://envirofit.org/.
Erb, D.L., 2019. *Challenges in Affordable Housing Delivery*, Overseas Private Investment Corporation (OPIC), Washington, DC. https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2019/06/Debra-Erb-OPIC-Challenges-in-Affordable-Housing-Delivery.pdf.
ESA, 2017. *Cultivating microalgae using made-for-space formulas*, European Space Agency (ESA), Paris. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Cultivating_microalgae_using_made-for-space_formulas.
ESA, 2019. *ARCtic Sea-ice and CleAN monitoring*, European Space Agency (ESA), Paris. https://business.esa.int/projects/arctic-sea-ice-and-clean-monitoring.
ESA, 2020. *AMBROSIA – Locally Produced Food Safety and Traceability for Municipalities*, European Space Agency (ESA), Paris. https://business.esa.int/projects/ambrosia.
ESCAP, 2021. *A promising recipe to make clean cooking affordable for all*, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok. https://www.unescap.org/blog/promising-recipe-make-clean-cooking-affordable-all#.
Estrada, F., Botzen, W.J.W., Tol, R.S.J., 2017. *A global economic assessment of city policies to reduce climate change impacts*. Nature Climate Change 7(6), 403-406.
EUDL, 2020. *How COVID-19 conspiracists and extremists use crowdfunding platforms to fund their activities*, EU DisinfoLab (EUDL), Brussels. https://www.disinfo.eu/publications/how-covid-19-conspiracists-and-extremists-use-crowdfunding-platforms-to-fund-their-activities/.
European Parliament, 2020. *Parliament wants to grant EU consumers a "right to repair"*, European Parliament, Brussels. https://www.europarl.europa.eu/news/en/press-room/20201120IPR92118/parliament-wants-to-grant-eu-consumers-a-right-to-repair.
Fan, Z., Sotelo, J., Sundareswaran, V., 2020. *3D Printing: A Guide for Decision-Makers*, World Economic Forum (WEF), Cologny. http://www3.weforum.org/docs/WEF_Impacts_3D_Printing_on_Trade_Supply_Chains_Toolkit.pdf.
FAO, 2021a. *Agriculture Investment Support Scheme (Rythu Bandhu), Andhra Pradesh, India*, Food and Agriculture Organization of the United Nations (FAO), Rome. https://sdgs.un.org/partnerships/agriculture-investment-support-scheme-rythu-bandhu-andhra-pradesh-india.
FAO, 2021b. *The State of Food Security and Nutrition in the World 2021*, Food and Agriculture Organisation of the United Nations (FAO), Rome. http://www.fao.org/publications/sofi/2021/en/.
FAO, IFAD, UNICEF, WFP, WHO, 2020. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets.*, Food and Agriculture Organisation of the United Nations (FAO), Rome. http://www.fao.org/3/ca9692en/ca9692en.pdf.
Farha, L., 2020. *COVID-19 Guidance Note: Prohibition of evictions*, Office of the United Nations High Commissioner for Human Rights (OHCHR), Geneva. https://www.ohchr.org/Documents/Issues/Housing/SR_housing_COVID-19_guidance_evictions.pdf.
Favre, L., Oksen, P., 2020. *Innovative Technology in the Water, Sanitation and Hygiene (WASH) Sector*, World Intellectual Property Organization (WIPO), Geneva. https://www.wipo.int/publications/en/details.jsp?id=4497&plang=EN
Florea, A.M., Radu, S., 2019. *Artificial Intelligence and Education*, 22nd International Conference on Control Systems and Computer Science (CSCS). IEEE, Bucharest.
Florida, R., 2015. *The Problem of Urbanization Without Economic Growth*, Bloomberg, New York City, NY. https://www.bloomberg.com/news/articles/2015-06-12/the-problem-of-urbanization-without-economic-growth.
Foy, K., 2021. *Turning technology against human traffickers*, Lincoln Laboratory, Massachusetts Institute of Technology. https://news.mit.edu/2021/turning-technology-against-human-traffickers-0506.

FRA, 2018. *#BigData: Discrimination in data-supported decision making*, European Union Agency for Fundamental Rights (FRA), Vienna. https://fra.europa.eu/sites/default/files/fra_uploads/fra-2018-focus-big-data_en.pdf.
Frantzeskaki, N., Castán Broto, V., Coenen, L., Loorbach, D., 2017. *Urban Sustainability Transitions*. Routledge, New York City, NY.
Frearson, A., 2021. *Digital twins offer "a very powerful way of developing our cities" say experts*, Dezeen. https://www.dezeen.com/2021/07/09/digital-twins-develop-cities-digital-design-architecture/.
Fromhold-Eisebith, M., Eisebith, G., 2019. *What can Smart City policies in emerging economies actually achieve? Conceptual considerations and empirical insights from India*. World Development 123, 104614.
Fuenfschilling, L., Frantzeskaki, N., Coenen, L., 2019. *Urban experimentation & sustainability transitions*. European Planning Studies 27(2), 219-228.
Gao, S., Low, S.P., 2014. *Lean Construction Management: The Toyota Way*. Springer, Chem.
Gao, S., Ryan, B.D., 2020. *Can Neighborhood Planning in Shrinking Cities Achieve Demolition Goals? A Conformance and Performance Evaluation of Neighborhood Action Plans in Youngstown, Ohio*. Journal of Planning Education and Research.
Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., Pavón, J., 2020. *How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis*. Educational Research Review 31, 100334.
George, B., Paul, J., 2020. *Digital Transformation in Business and Society: Theory and Cases*. Springer, Cham.
GFN, 2015. *How can Mediterranean societies thrive in an era of decreasing resources?*, Global Footprint Network (GFN), Geneva. https://www.footprintnetwork.org/content/documents/MED_2015_English.pdf?_ga=2.234325099.647224.1632288080-1095566433.1632288080.
GIE, 2021. *Kitkit School by Enuma*, Global Innovation Exchange (GIE). https://www.globalinnovationexchange.org/innovation/enuma.
Gilbert, C., Gurran, N., 2018. *Planning for Diverse and Affordable Housing Supply? A Survey of 200 Australian Planning Schemes*. Journal of Planning Education and Research, 0739456X1881827.
GIZ, 2021a. *Burundi's first non-diesel IPPGigawatt Global*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn. https://www.get-invest.eu/story/gigawatt-global-burundis-first-non-diesel-ipp/.
GIZ, 2021b. *Powering up Southern Africa's off-grid homesSolarWorks!*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn. https://www.get-invest.eu/story/powering-up-southern-africas-off-grid-homes/.
GIZ, 2021c. *Reaching last-mile communities with tailored solar solutionsUpOwa*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn. https://www.get-invest.eu/story/reaching-last-mile-communities-with-tailored-solar-solutions/.
Goedde, L., McCullough, R., Ooko-Ombaka, A., Pais, G., 2021. *How digital tools can help transform African agri-food systems*, McKinsey & Company, New York City, NY.
Gomber, P., Koch, J.-A., Siering, M., 2017. *Digital Finance and FinTech: current research and future research directions*. Journal of Business Economics 87(5), 537-580.
Gössling, S., 2020. *Why cities need to take road space from cars - and how this could be done*. Journal of Urban Design 25(4), 443-448.
Grau, A., Morel, Y., Puig-Pey, A., Cecchi, F., 2020. *Advances in Robotics Research: From Lab to Market. ECHORD++: Robotic Science Supporting Innovation*. Springer, Cham.
Grid Edge, 2021. *AI for Flexibility*, Grid Edge, Birmingham. https://gridedge.ai/ai-for-flexibility/.
Grybauskas, A., Pilinkienė, V., Stundžienė, A., 2021. *Predictive analytics using Big Data for the real estate market during the COVID-19 pandemic*. Journal of Big Data 8(105), 1-20.
GSMA, 2020. *2020 Mobile Industry Impact Report: Sustainable Development Goals*, GSM Association (GSMA), London. https://www.gsma.com/betterfuture/2020sdgimpactreport/wp-content/uploads/2020/09/2020-Mobile-Industry-Impact-Report-SDGs.pdf?utm_source=better_future_site&utm_medium=search_engine&utm_campaign=2020_SDG_impact_report.
Gu, D., 2019. *Exposure and vulnerability to natural disasters for world's cities*, United Nations Department of Economic and Social Affairs (UNDESA), New York, NY. https://www.un.org/en/development/desa/population/publications/pdf/technical/TP2019-4.pdf.

Gulyas, A., Seitz, S., Sinha, S., 2021. *Does Pay Transparency Affect the Gender Wage Gap? Evidence From Austria*, University of Mannheim and Yale University.
GWEC, 2021. *Global Wind Report 2021*, Global Wind Energy Council (GWEC), Brussels. https://gwec.net/wp-content/uploads/2021/03/GWEC-Global-Wind-Report-2021.pdf.
GWEC, CREIA, 2020. *Beijing Declaration on Wind Energy*, Global Wind Energy Council (GWEC) and Chinese Renewable Energy Industries Association (CREIA), Brissels and Beijing. https://gwec.net/wp-content/uploads/2020/11/Beijing-Declaration-EN.pdf.
Han, Y., Wang, L., 2018. *Identifying barriers to off-site construction using grey DEMATEL approach: Case of China*. Journal of Civil Engineering and Management 24(5), 364-377.
Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., Meshesha, D.T., 2012. *The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia*. Landscape and Urban Planning 106(2), 149-157.
Harvey, J., Smith, A., Goulding, J., Branco Illodo, I., 2020. *Food sharing, redistribution, and waste reduction via mobile applications: A social network analysis*. Industrial Marketing Management 88, 437-448.
Hasiak, S., Richer, C., 2021. *Can rail save a peri-urban way of life? The case of peri-urban cities served by rail services in the metropolitan area of Lille (France)*. European Planning Studies 29(5), 983-1002.
HC, 2020. *Path to hydrogen competitiveness: A cost perspective*, Hydrogen Council (HC), Brussels. https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf.
He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J., Bryan, B.A., 2021. *Future global urban water scarcity and potential solutions*. Nature Communications 12(1).
Hollander, J.E., Carr, B.G., 2020. *Virtually Perfect? Telemedicine for Covid-19*. New England Journal of Medicine 382(18), 1679-1681.
Howarth, B., 2014. *Big data: how predictive analytics is taking over the public sector*, The Guardian. https://www.theguardian.com/technology/2014/jun/13/big-data-how-predictive-analytics-is-taking-over-the-public-sector.
Huang, N., Zhang, J., Burtch, G., Li, X., Chen, P., 2021. *Combating Procrastination on Massive Online Open Courses via Optimal Calls to Action*. Information Systems Research 32(2), 301-317.
Hyatt, A., 2019. *Real-time bikeshare information in Google Maps rolls out to 24 cities*, Google, Mountain View, CA. https://www.blog.google/products/maps/real-time-bikeshare-information-google-map/.
Hyland, M., Djankov, S., Goldberg, P.K., 2019. *Gendered Laws*, The World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/514981576015899984/pdf/Gendered-Laws.pdf.
IBM, 2020. *IBM and The Alliance to End Plastic Waste to Create Data Platform to help track global plastic waste in the environment*, International Business Machines Corporation (IBM), Armonk, NY. https://newsroom.ibm.com/2020-12-15-IBM-and-The-Alliance-to-End-Plastic-Waste-to-Create-Data-Platform-to-help-track-global-plastic-waste-in-the-environment.
ICAT, 2019. *Human trafficking and technology trends challenges and opportunities*, Inter-agency Coordination Group Against Traffking in Persons (ICAT). https://www.un.org/sexualviolenceinconflict/wp-content/uploads/2019/07/report/human-trafficking-and-technology-trends-challenges-and-opportunities/Human-trafficking-and-technology-trends-challenges-and-opportunities-WEB..-1.pdf.
IDA, IFC, 2020. *Impacts of COVID-19 on the Private Sector in Fragile and Conflict-Affected Situations*, International Development Association (IDA) and International Finance Corporation (IFC), Washington, DC. https://openknowledge.worldbank.org/handle/10986/34857.
IEA, 2019a. *Artificial Intelligence for Building Energy Management Systems*, International Energy Agency (IEA), Paris. https://www.iea.org/articles/case-study-artificial-intelligence-for-building-energy-management-systems.
IEA, 2019b. *Behavioural Insights-Driven Customer Engagement*, International Energy Agency (IEA), Paris. https://www.iea.org/articles/case-study-behavioural-insights-driven-customer-engagement.
IEA, 2020. *Wind: Forecast overview*, International Energy Agency (IEA), Paris. https://www.iea.org/reports/renewables-2020/wind.
IEA, IRENA, UN, The World Bank, WHO, 2021. *Tracking SDG 7: The Energy Progress Report 2021*, International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United

Nations (UN), The World Bank, and World Health Organization (WHO), Washington, DC. https://www.irena.org/publications/2021/Jun/Tracking-SDG-7-2021.
IFC, 2015. *Tech Skills Training for African Youth*, International Finance Corporation (IFC), Washington, DC. https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/tech+skills+training+for+african+youth.
Igra, M., Kenworthy, N., Luchsinger, C., Jung, J.-K., 2021. *Crowdfunding as a response to COVID-19: Increasing inequities at a time of crisis*. Social Science & Medicine 282, 114105.
ILO, 2019. *World Employment Social Outlook Trends 2019*, International Labour Organisation (ILO), Geneva. https://www.ilo.org/global/research/global-reports/weso/2019/lang--en/index.htm.
ILO, 2020a. *COVID-19 crisis and the informal economy: Immediate responses and policy challenges* International Labour Organization (ILO), Geneva. https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---travail/documents/briefingnote/wcms_743623.pdf.
ILO, 2020b. *Global Employment Trends for Youth 2020: Technology and the future of jobs*, International Labour Organisation (ILO), Geneva. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_737648.pdf.
ILO, 2021. *Child labour rises to 160 million – first increase in two decades*, International Labour Organisation (ILO), Geneva. https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_800090/lang--en/index.htm.
Imam, A., Lahoud, C., Martinuzzi, C., Gastelum, E., Delaney, J., 2021. *The Block by Block playbook: Using Minecraft as a participatory design tool in urban design and governance*, United Nations Human Settlements Programme (UN-Habitat), Nairobi. https://unhabitat.org/sites/default/files/2021/09/1-bbb_playbook_publication_final.pdf.
IoT4AGRI Consortium, 2021. *Avoid food waste by sensing during transport*, Netherlands Organisation for Applied Scientific Research (TNO), Wageningen Food & Biobased Research (WUR), Van Oers United, Environmental Monitoring Systems (EMS), Purfresh, SmartPort, Het Internet Huis, Euro Pool System, Thermo King. https://smartport.nl/wp-content/uploads/2021/06/Two-pager_IOT4AGRI_SmartPort_TNO_final_220621.pdf.
IRENA, 2016. *Renewable Energy in Cities*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf.
IRENA, 2019. *Renewable Energy Capacity Statistics 2019*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Mar/IRENA_RE_Capacity_Statistics_2019.pdf.
IRENA, 2020. *Global Landscape of Renewable Energy Finance*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://www.irena.org/publications/2020/Nov/Global-Landscape-of-Renewable-Energy-Finance-2020.
IRENA, 2021a. *Geothermal energy*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://www.irena.org/geothermal.
IRENA, 2021b. *Offshore renewables: An action agenda for deployment*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jul/IRENA_G20_Offshore_renewables_2021.pdf.
IRENA, 2021c. *Renewable Energy Policies for Cities: Buildings*, International Renewable Energy Agency (IRENA), Abu Dhabi. https://www.irena.org/publications/2021/May/Policies-for-Cities-Buildings.
Irvin-Erickson, Y., La Vigne, N., Levine, N., Tiry, E., Bieler, S., 2017. *What does gunshot detection technology tell us about gun violence?* Applied geography 86, 262-273.
ISO, 2019. *Environmental labels*, International Organization for Standardization (ISO), Geneva. https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100323.pdf.
ITU, 2018. *Measuring the Information Society Report*, International Telecommunication Union (ITU), Geneva. https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-1-E.pdf.
ITU, 2020. *Digital Skills Insights 2020*, United Nations, New York City, NY. https://academy.itu.int/sites/default/files/media2/file/Digital%20Skills%20Insights%202020.pdf.
Janeway Bills, N., 2019. *Evaluating Evictions to Understand America*, Medium. https://towardsdatascience.com/data-science-of-evictions-874a41f3cc36.

Jiang, L., Li, Z., Li, L., Gao, Y., 2018. *Constraints on the Promotion of Prefabricated Construction in China*. Sustainability 10(7), 2516.
Jones, E., Qadir, M., Van Vliet, M.T.H., Smakhtin, V., Kang, S.-M., 2019. *The state of desalination and brine production: A global outlook*. Science of The Total Environment 657, 1343-1356.
Jorisch, D., Mallin, C., Accurso, M., Zaballos, A.G., Rodríguez, E.I., 2018. *Technology for Climate Action in Latin America and the Caribbean*, Inter-American Development Bank (IDB). https://www.gsma.com/latinamerica/wp-content/uploads/2018/06/Technology-for-Climate-Action-in-Latin-America-and-the-Caribbean.pdf.
Juch, N., Rogoll, M., 2019. *Floating photovoltaics – is floating solar a new trend?*, Rödl & Partner. https://www.roedl.com/insights/renewable-energy/2019-02/floating-photovoltaics.
Keeton, R., Nijhuis, S., 2019. *Spatial challenges in contemporary African New Towns and potentials for alternative planning strategies*. International Planning Studies 24(3-4), 218-234.
Keller, J., 2017. *Melbourne Water's mini hydro-electricity program*, Melbourne Water, Melbourne. https://www.melbournewater.com.au/media/2366.
Kemp, N., Breetzke, G.D., Cooper, A., 2021. *Modeling the risk of robbery in the city of Tshwane, South Africa*. Cartography and Geographic Information Science 48(1), 29-42.
Kim, M., 2015. *Pay Secrecy and the Gender Wage Gap in the United States*. Industrial Relations: A Journal of Economy and Society 54(4), 648-667.
Kimetrica, 2020. *African Risk Capacity: Payout Process Evaluation*, Kimetrica, Nairobi.
Kimetrica, 2021. *Systems and Analytics Support to Digital Transformation for Food Systems Data Sharing and Visualization*, Kimetrica, Nairobi.
Klingler-Vidra, R., Tran, B., Uusikyla, I., 2021. *Vietnam and innovation in COVID-19 testing*. BMJ Innovations 7(Suppl 1), s19-s22.
Kombe, W.J., 2005. *Land use dynamics in peri-urban areas and their implications on the urban growth and form: the case of Dar es Salaam, Tanzania*. Habitat International 29(1), 113-135.
Krawcheck, S., 2017. *How Technology Can Help Close the Gender Gap*, Harvard Business Review. https://hbr.org/2017/01/how-technology-can-help-close-the-gender-gap.
Kumar, A., Gupta, P.K., Srivastava, A., 2020. *A review of modern technologies for tackling COVID-19 pandemic*. Diabetes & Metabolic Syndrome: Clinical Research & Reviews 14(4), 569-573.
Ladhani, S., Sitter, K.C., 2020. *Conditional cash transfers: A critical review*. Development Policy Review 38(1), 28-41.
Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernethy, S., Andrew, R.M., De-Gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G., Friedlingstein, P., Creutzig, F., Peters, G.P., 2020. *Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement*. Nature Climate Change 10(7), 647-653.
Ledo Espinoza, P.J., 2021. *Peri-urbanization in Sacaba, Bolivia: challenges to the traditional urban planning approach*. International Planning Studies 26(3), 286-301.
Leigh Hester, J., 2017. *Just How Much Food Do Cities Squander?*, Wired. https://www.wired.com/story/just-how-much-food-do-cities-squander/.
León, M., 2019. *Floating solar panels restore life to Peruvian soil*, United Nations Development Programme (UNPD), New York City, NY. https://stories.undp.org/floating-solar-panels-restore-life-to-peruvian-soil.
Letzing, J., 2020. *Can we prevent a surge in pandemic-related homelessness?*, World Economic Forum. https://www.weforum.org/agenda/2020/08/can-we-prevent-surge-covid19-pandemic-homelessness-eviction-poverty/.
Lew, L., 2020. *Flooding hits southern China with 14 million affected*, South China Morning Post. https://www.scmp.com/news/china/society/article/3090854/after-coronavirus-flooding-hits-southern-china-14-million.
Libertun de Duren, N.R., Brassiolo, P., Lara, E., Mastellaro, C., Cardona-Papiol, E., Palacios, A., Ma, X., Sven Hallin, M., Mwai, A., Thomas, D., 2020. *Gender Inequalities in Cities*, Inter-American Development Bank (IDB), Washington, DC. https://publications.iadb.org/en/gender-inequalities-cities.
Lin, C., 2021. *Singapore unveils one of the world's biggest floating solar panel farms*, Thomson Reuters. https://www.reuters.com/business/energy/singapore-unveils-one-worlds-biggest-floating-solar-panel-farms-2021-07-14/.
Llanes, M.C., 2021. *Colombia: Effects of covid-19 on employment in January 2021*, Banco Bilbao Vizcaya Argentaria (BBVA), Bilbao. https://www.bbvaresearch.com/en/publicaciones/colombia-effects-of-covid-19-on-employment-in-january-2021/.

LSE, 2020. *Evidence from France: How crowdfunding is being used to support the response to Covid-19*, London School of Economics (LSE), London. https://blogs.lse.ac.uk/europpblog/2020/04/24/evidence-from-france-how-crowdfunding-is-being-used-to-support-the-response-to-covid-19/.
Magrini, E., 2021. *June 2021: What do the latest statistics tell us about the labour market of the UK's largest cities and towns?*, Centre for Cities, London. https://www.centreforcities.org/blog/june-2021-labour-market-update/.
Maguire, D., Honeyman, M., Fenney, D., Jabbal, J., 2021. *Shaping the future of digital technology in health and social care*, The King's Fund, London. https://www.kingsfund.org.uk/publications/future-digital-technology-health-social-care.
Martin, C., Evans, J., Karvonen, A., Paskaleva, K., Yang, D., Linjordet, T., 2019. *Smart-sustainability: A new urban fix?* Sustainable Cities and Society 45, 640-648.
Maxmen, A., 2020. *Why the United States is having a coronavirus data crisis*, Nature. https://www.nature.com/articles/d41586-020-02478-z.
Maxmen, A., 2021. *Massive Google-funded COVID database will track variants and immunity*, Nature. https://www.nature.com/articles/d41586-021-00490-5.
McGreevy, M.P., 2018. *Housing Diversity and Affordability: The Effects of 35 Years of Exclusionary Land Use Regulations on Housing Affordability in Adelaide, South Australia*. Urban Policy and Research 36(3), 336-353.
McIlwaine, C., 2013. *Urbanization and gender-based violence: exploring the paradoxes in the global South*. Environment and Urbanization 25(1), 65-79.
Minter, A., 2016. *The Burning Truth Behind an E-Waste Dump in Africa*, Smithsonian Magazine. https://www.smithsonianmag.com/science-nature/burning-truth-behind-e-waste-dump-africa-180957597/.
Mitlin, D., Beard, V.A., Satterthwaite, D., Du, J., 2019. *Unaffordable and Undrinkable: Rethinking Urban Water Access in the Global South*, World Resources Institute (WRI), Washington, DC. https://files.wri.org/d8/s3fs-public/unaffordable-and-undrinkable_0.pdf.
Mobasheri, A., Deister, J., Dieterich, H., 2017. *Wheelmap: the wheelchair accessibility crowdsourcing platform*. Open Geospatial Data, Software and Standards 2(1).
Mokyr, J., Vickers, C., Ziebarth, N.L., 2015. *The history of technological anxiety and the future of economic growth: Is this time different?* Journal of economic perspectives 29(3), 31-50.
Montgomery, R., 2015. *How can we promote sustainable infrastructure?*, World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2015/11/how-can-we-promote-sustainable-infrastructure/.
Mora, L., Deakin, M., 2019. *Untangling Smart Cities: From utopian dreams to innovation systems for a technology-enabled urban sustainability*. Elsevier, Amsterdam.
Morán, A.J., Profaizer, P., Zapater, M.H., Valdavida, M.A., Bribián, I.Z., 2016. *Information and Communications Technologies (ICTs) for energy efficiency in buildings: Review and analysis of results from EU pilot projects*. Energy and buildings 127, 128-137.
Mostafa, S., Kim, K.P., Tam, V.W.Y., Rahnamayiezekavat, P., 2020. *Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice*. International Journal of Construction Management 20(2), 146-156.
Mumba, C., Skjerve, E., Rich, M., Rich, K.M., 2017. *Application of system dynamics and participatory spatial group model building in animal health: A case study of East Coast Fever interventions in Lundazi and Monze districts of Zambia*. PLOS ONE 12(12), e0189878.
Myers, A., Hall, J., De Vos, L., Kleine-Kalmer, L., 2021. *The Value of Cycling as an Accelerator of Sustainable Development*, United Nations (UN), New York City, NY. https://www.un.org/en/un-chronicle/value-cycling-accelerator-sustainable-development.
Nadeau, C.A., 2016. *Unaffordable Fare: Cost of Public Transportation for Low-Income Commuters Working at Chicago, Illinois, Midway International Airport*. Transportation Research Record: Journal of the Transportation Research Board 2600(1), 69-79.
Nagao, K., 2019. *Artificial Intelligence Accelerates Human Learning: Discussion Data Analytics*. Springer, Singapore.
Neiderud, C.-J., 2015. *How urbanization affects the epidemiology of emerging infectious diseases*. Infection Ecology & Epidemiology 5(1), 27060.
NIDirect, 2021. *What Building Regulations protect*, Government of the United Kingdom - Northern Ireland Direct Government Services (NIDirect) https://www.nidirect.gov.uk/articles/what-building-regulations-protect.
Nijman, J., Wei, Y.D., 2020. *Urban inequalities in the 21st century economy*. Applied Geography 117, 102188.

Normile, D., 2021. *Zhengzhou subway flooding a warning for other major cities*, Science. https://www.science.org/news/2021/07/zhengzhou-subway-flooding-warning-other-major-cities.
Nyaga, J.M., Onyango, C.M., Wetterlind, J., Söderström, M., 2021. *Precision agriculture research in sub-Saharan Africa countries: a systematic map*. Precision Agriculture 22(4), 1217-1236.
OECD, 2016. *Environmental labelling and information schemes*, OECD. https://www.oecd.org/env/policy-persectives-environmental-labelling-and-information-schemes.pdf.
OECD, 2018a. *The Impact of Legal Frameworks on Women's Economic Empowerment around the World: challenges and good practices*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd.org/mena/competitiveness/2107-March-on-Gender-Legal-Framework-Highlights.pdf.
OECD, 2018b. *Improving Plastics Management: Trends, policy responses, and the role of international co-operation and trade: Background Report*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd.org/environment/waste/policy-highlights-improving-plastics-management.pdf.
OECD, 2019a. *OECD SME and Entrepreneurship Outlook 2019*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd.org/industry/smes/SME-Outlook-Highlights-FINAL.pdf.
OECD, 2019b. *Waste Management and the Circular Economy in Selected OECD Countries*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd-ilibrary.org/sites/9789264309395-en/index.html?itemId=/content/publication/9789264309395-en.
OECD, 2020a. *The Digitalisation of Science, Technology and Innovation: Key Developments and Policies*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd-ilibrary.org/sites/ee2a2c2f-en/index.html?itemId=/content/component/ee2a2c2f-en.
OECD, 2020b. *The impact of COVID-19 on student equity and inclusion: Supporting vulnerable students during school closures and school re-openings*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd.org/coronavirus/policy-responses/the-impact-of-covid-19-on-student-equity-and-inclusion-supporting-vulnerable-students-during-school-closures-and-school-re-openings-d593b5c8/.
OECD, 2020c. *Improving Transport Planning for Accessible Cities*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd-ilibrary.org/content/publication/fcb2eae0-en.
OECD, 2020d. *Smart Cities and Inclusive Growth*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd.org/cfe/cities/OECD_Policy_Paper_Smart_Cities_and_Inclusive_Growth.pdf.
OECD, 2021. *OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity*, Organisation for Economic Co-operation and Development (OECD), Paris. https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-innovation-outlook-2021_75f79015-en.
Oh, E.Y., Song, D., 2021. *Developmental research on an interactive application for language speaking practice using speech recognition technology*. Educational Technology Research and Development 69(2), 861-884.
OHCHR, 2021. *Forced Evictions*, Office of the United Nations High Commissioner for Human Rights (OHCHR), Geneva. https://www.ohchr.org/en/issues/housing/pages/forcedevictions.aspx.
Oliver Viola, C., Modak, N., Ferguson, T., 2020. *The future of water: How innovations will advance water sustainability and resilience worldwide*, The World Bank, Washington, DC. https://blogs.worldbank.org/water/future-water-how-innovations-will-advance-water-sustainability-and-resilience-worldwide.
Pallagst, K., Fleschurz, R., Nothof, S., Uemura, T., 2021. *Shrinking cities: Implications for planning cultures?* Urban Studies 58(1), 164-181.
Palmiter Bajorek, J., 2019. *Voice Recognition Still Has Significant Race and Gender Biases*, Harvard Business Review. https://hbr.org/2019/05/voice-recognition-still-has-significant-race-and-gender-biases.
Pan, W., Gibb, A.G.F., Dainty, A.R.J., 2007. *Perspectives of UK housebuilders on the use of offsite modern methods of construction*. Construction Management and Economics 25(2), 183-194.

Park, H., Lee, M., Ahn, J.M., 2021. *Bottom-up solutions in a time of crisis: the case of Covid-19 in South Korea*. R&D Management 51(2), 211-222.
Patel, D., 2017. *What can other cities learn from Mexico City's bike-sharing scheme?*, London School of Economics and Political Science (LSE), London. https://blogs.lse.ac.uk/internationaldevelopment/2017/12/08/what-can-other-cities-learn-from-mexico-citys-bike-sharing-scheme/.
Patel, M.S., Asch, D.A., Volpp, K.G., 2015. *Wearable Devices as Facilitators, Not Drivers, of Health Behavior Change*. JAMA 315(5), 459-460.
Peeters, R., Schuilenburg, M., 2018. *Machine justice: Governing security through the bureaucracy of algorithms*. Information Polity 23(3), 267-280.
Pérez-Fargallo, A., Rubio-Bellido, C., Pulido-Arcas, J.A., Trebilcock, M., 2017. *Development policy in social housing allocation: Fuel poverty potential risk index*. Indoor and Built Environment 26(7), 980-998.
Phillips, L., Smith, P., 2015. *Sustainable Urban Energy Is the Future*, United Nations, New York City, NY. https://www.un.org/en/chronicle/article/sustainable-urban-energy-future.
Piccolo, L.S.G., Roberts, S., Iosif, A., Alani, H., 2018. *Designing Chatbots for Crises: A Case Study Contrasting Potential andReality*, *HCI '18: Proceedings of the 32nd International BCS Human Computer Interaction Conference*. ACM, New York City, NY.
Pimentel Walker, A.P., 2016. *Self-help or public housing? Lessons from co-managed slum upgrading via participatory budget*. Habitat International 55, 58-66.
PlasticsEurope, 2018. *Plastics 2030: PlasticsEurope's Voluntary Commitment to increasing circularity and resource efficiency*, PlasticsEurope, Brussels. https://www.plasticseurope.org/application/files/5115/1966/5994/PlasticsEurope_-_Voluntary_Commitment_FINAL.PDF.
Pojani, D., Wardale, D., Brown, K., 2018. *Sexism and the city: how urban planning has failed women*, The Conversation. https://theconversation.com/sexism-and-the-city-how-urban-planning-has-failed-women-93854.
Polat, G., 2008. *Factors Affecting the Use of Precast Concrete Systems in the United States*. Journal of Construction Engineering and Management 134(3), 169-178.
Poortinga, W., Jones, N., Lannon, S., Jenkins, H., 2017. *Social and health outcomes following upgrades to a national housing standard: a multilevel analysis of a five-wave repeated cross-sectional survey*. BMC Public Health 17(1).
Prislan, K., Slak, B., 2018. *Analysis of the relationship between smart cities, policing and criminal investigation*. Journal of Criminal Justice and Security(4), 389-413.
Puhe, M., Edelmann, M., Reichenbach, M., 2014. *Integrated urban e-ticketing for public transport and touristic sites*, Science and Technology Options Assessment (STOA), Brussels. https://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/513551/IPOL-JOIN_ET(2014)513551_EN.pdf.
Qureshi, S., 2020. *Why data matters for development? Exploring data justice, micro-entrepreneurship, mobile money and financial inclusion*. Information Technology for Development 26(2), 201-213.
Rajab, S., 2018. *Chanouf Farm Biofire*, United Nations (UN), New York City, NY. https://www.un.org/sustainabledevelopment/blog/2018/07/chanouf-farm-biofire/.
Rawte, R., 2017. *The role of ICT in creating intelligent, energy efficient buildings*. Energy Procedia 143, 150-153.
Rector, K., 2018. *Enhancing Accessibility and Engagement for Those with Disabilities*. IEEE Pervasive Computing 17(1), 9-12.
Rende Taylor, L., Shih, E., 2019. *Worker feedback technologies and combatting modern slavery in global supply chains: examining the effectiveness of remediation-oriented and due-diligence-oriented technologies in identifying and addressing forced labour and human trafficking*. Journal of the British Academy 7(s1), 131-165.
Rich, K.M., Berends, J., Cooper, G.S., 2021. *Enriching value chains through maps: reflections from spatial group model building in Myanmar and India*. Development in Practice, 1-7.
Rich, K.M., Rich, M., Dizyee, K., 2018. *Participatory systems approaches for urban and peri-urban agriculture planning: The role of system dynamics and spatial group model building*. Agricultural Systems 160, 110-123.
Richardson, H.W., Woon Nam, C., 2014. *Shrinking Cities: A Global Perspective*. Routledge, Abingdon.

Richter, F., 2021. *COVID-19 has caused a huge amount of lost working hours*, World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2021/02/covid-employment-global-job-loss/.
Ritchie, H., Roser, M., 2018. *Urbanization*, University of Oxford, Oxford. https://ourworldindata.org/urbanization.
Ritter, S., Carlson, R., Sandbothe, M., Fancsali, S.E., 2015. *Carnegie Learning's Adaptive Learning Products*, in: Santos, O.C. (Ed.) *Proceedings of the 8th International Conference on Educational Data Mining*. International Educational Data Mining Society, pp. 633-634.
Royo, M.G., Parikh, P., Belur, J., 2020. *Using heat maps to identify areas prone to violence against women in the public sphere*. Crime Science 9(1), 1-15.
Ruel, M., 2020. *Growing Cities, Growing Food Insecurity: How to Protect the Poor during Rapid Urbanization*, Center for Strategic and International Studies (CSIS), Washington, DC. https://www.csis.org/analysis/growing-cities-growing-food-insecurity-how-protect-poor-during-rapid-urbanization.
Saleh, S.N., Lehmann, C.U., Medford, R.J., 2021. *Early Crowdfunding Response to the COVID-19 Pandemic: Cross-sectional Study*. Journal of Medical Internet Research 23(2), e25429.
Saliba, V., Legido-Quigley, H., Hallik, R., Aaviksoo, A., Car, J., McKee, M., 2012. *Telemedicine across borders: A systematic review of factors that hinder or support implementation*. International Journal of Medical Informatics 81(12), 793-809.
Samberg, L., 2018a. *Food Security's Social Network*, Projedct Syndicate. https://www.project-syndicate.org/commentary/strengthening-social-networks-to-end-global-hunger-by-leah-samberg-2018-03.
Samberg, L., 2018b. *How new technology could help to strengthen global food security*, World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2018/03/food-security-s-social-network/.
Sampson, E., Signor, L., Flachi, M., Hemmings, E., Somma, G., Aifadopoulou, G., Mitsakis, E., Sourlas, V., 2019. *The Role of Intelligent Transport Systems (ITS) in Sustainable Urban Mobility Planning: Make smarter integrated mobility plans and policies*, ERTICO - ITS Europe, Brussels. https://www.eltis.org/sites/default/files/the_role_of_intelligent_transport_systems_its_in_sumps.pdf.
Samuels, W.E., 2018. *Nurturing kindness naturally: A humane education program's effect on the prosocial behavior of first and second graders across China*. International Journal of Educational Research 91, 49-64.
SANBI, nd. *uMngeni Ecological Infrastructure Partnership*, South African National Biodiversity Institute (SANBI), Pretoria. http://biodiversityadvisor.sanbi.org/participation/umngeni-ecological-infrastructure-partnership/.
Satterthwaite, D., McGranahan, G., Tacoli, C., 2010. *Urbanization and its implications for food and farming*. Philosophical Transactions of the Royal Society B: Biological Sciences 365(1554), 2809-2820.
Schenkel, W., 2015. *Regeneration Strategies in Shrinking Urban Neighbourhoods—Dimensions of Interventions in Theory and Practice*. European Planning Studies 23(1), 69-86.
Scottish Government, 2020. *Offshore wind policy statement*, Scottish Government, Edinburgh. https://www.gov.scot/publications/offshore-wind-policy-statement/documents/.
Sharma, Y.S., 2021. *Unemployment rate in urban India at 10.3% in Q3 of 2020-21: NSO*, The Economic Times. https://economictimes.indiatimes.com/news/economy/indicators/unemployment-rate-in-urban-india-dropped-to-10-3-in-third-quarter-of-2020-21-nso/articleshow/86070295.cms.
Sharpe, R.A., Thornton, C.R., Nikolaou, V., Osborne, N.J., 2015. *Fuel poverty increases risk of mould contamination, regardless of adult risk perception & ventilation in social housing properties*. Environment International 79, 115-129.
Signor, L., Karjalainen, P., Kamargianni, M., Matyas, M., Pagoni, I., Stefanelli, T., Galli, G., Malgieri, P., Bousse, Y., Mizaras, V., Aifadopoulou, G., Hoadley, S., De Roeck, M., Kishchenko, K., Geier, T., 2019. *Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning*, ERTICO - ITS Europe, Brussels. https://www.eltis.org/sites/default/files/mobility_as_a_service_maas_and_sustainable_urban_mobility_planning.pdf.
Silveira, L., 2016. *4 technologies helping us to fight corruption*, World Economic Forum (WEF), Cologny. https://www.weforum.org/agenda/2016/04/4-technologies-helping-us-to-fight-corruption/.

Simonite, T., 2019. *How Facial Recognition Is Fighting Child Sex Trafficking*, Wired. https://www.wired.com/story/how-facial-recognition-fighting-child-sex-trafficking/.
Sivaramakrishnan, K., 2018. *As the World Ages: Rethinking a Demographic Crisis*. Harvard University Press, Cambridge, MA.
Sorensen, J., 2020. *Real-time monitoring of faecally contaminated drinking water*, British Geological Survey (BGS), Nottingham. https://www.bgs.ac.uk/news/real-time-detection-of-faecally-contaminated-drinking-water/.
Steen, T., Brandsen, T., 2020. *Coproduction during and after the COVID -19 Pandemic: Will It Last?* Public Administration Review 80(5), 851-855.
Streiff, L., 2020. *NASA Model Reveals How Much COVID-related Pollution Levels Deviated from the Norm*, National Aeronautics and Space Administration (NASA), Washington, DC. https://www.nasa.gov/feature/goddard/2020/nasa-model-reveals-how-much-covid-related-pollution-levels-deviated-from-the-norm.
Sumbaly, R., Shah, H., Culatana, S.C., Luo, E., Szilvasy, G., Manadhata, P., Douze, M., Jegou, H., Miller, M., Xie, Y., Khatkevich, T., Strauss, E., Puri, M., Graham, B., Yalniz, Z., 2020. *Using AI to detect COVID-19 misinformation and exploitative content*, Facebook, Menlo Park, CA. https://ai.facebook.com/blog/using-ai-to-detect-covid-19-misinformation-and-exploitative-content/.
SWESN, 2021a. *Generating Hydropower from Water Supply Systems*, Sustainable Water and Energy Solutions Network (SWESN). https://www.un.org/sites/un2.un.org/files/generating_hydropower_from_water_supply_systems.pdf.
SWESN, 2021b. *Hydropower for CO2-free Electric Buses in Old Town of Regensburg, Germany*, Sustainable Water and Energy Solutions Network (SWESN). https://www.un.org/sites/un2.un.org/files/hydropower_for_co2-free_electric_busesin_old_town_of_regensburg_germany.pdf.
SWESN, 2021c. *Power Generation from Solar Photovoltaic Panels Floating on Water Reservoirs*, Sustainable Water and Energy Solutions Network (SWESN). https://www.un.org/sites/un2.un.org/files/power_generation_from_solar_photovoltaic_panels_floating_on_water_reservoirs.pdf.
SWESN, 2021d. *Sustainable Geothermal Power Generation and Heating of Greenhouses and Spas in Kenya's Rift Valley*, Sustainable Water and Energy Solutions Network (SWESN). https://www.un.org/sites/un2.un.org/files/sustainable_geothermal_power_generation_and_heating_of_greenhouses_and_spas_in_kenyas_rift_valley.pdf.
SWESN, 2021e. *Water, Biomass and Energy Nexus: Electricity Generation from Sugarcane Biomass in Guatemala*, Sustainable Water and Energy Solutions Network (SWESN). https://www.un.org/sites/un2.un.org/files/water_biomass_and_energy_nexus-_electricity_generation_from_sugarcane_biomass_in_guatemala.pdf.
Tao, F., Qi, Q., Liu, A., Kusiak, A., 2018. *Data-driven smart manufacturing*. Journal of Manufacturing Systems 48, 157-169.
Tardy, F., Lee, B., 2019. *Building related energy poverty in developed countries – Past, present, and future from a Canadian perspective*. Energy and Buildings 194, 46-61.
TfL, 2021. *Contactless and mobile pay as you go*, Transport in London (TfL), London. https://tfl.gov.uk/fares/how-to-pay-and-where-to-buy-tickets-and-oyster/pay-as-you-go/contactless-and-mobile-pay-as-you-go.
The World Bank, 2016. *World Development Report 2016: Digital Dividends*. The World Bank, Washington, DC.
The World Bank, 2017. *Multiphase Programmatic Approach*, The World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/203081501525641125/pdf/MPA-07192017.pdf.
The World Bank, 2018. *Reducing Childhood Stunting with a New Adaptive Approach*, The World Bank, Washington, DC. https://www.worldbank.org/en/news/immersive-story/2018/09/28/reducing-childhood-stunting-with-a-new-adaptive-approach.
The World Bank, 2020a. *Distance Learning as a Solution for Education in Africa in the COVID-19 Context Roundtable*, The World Bank, Washington, DC. https://www.worldbank.org/en/events/2020/07/13/distance-learning-as-a-solution-for-education-in-africa-in-the-covid-19-context-roundtable.
The World Bank, 2020b. *Gender-Inclusive Cities: Can Urban Planning Take into Account Women and Minorities?*, The World Bank, Washington, DC. https://www.worldbank.org/en/news/feature/2020/03/07/ciudades-feministas-diseno-urbano-para-mujeres-y-minorias.

The World Bank, 2020c. *How countries are using edtech (including online learning, radio, television, texting) to support access to remote learning during the COVID-19 pandemic*, The World Bank, Washington, DC. https://www.worldbank.org/en/topic/edutech/brief/how-countries-are-using-edtech-to-support-remote-learning-during-the-covid-19-pandemic.
The World Bank, 2020d. *Strengthening Conditional Cash Transfers and the Single Registry in Brazil: A Second-Generation Platform for Service Delivery for the Poor*, The World Bank, Washington, DC. https://www.worldbank.org/en/results/2020/04/22/strengthening-conditional-cash-transfers-and-the-single-registry-in-brazil.
The World Bank, 2021. *Global economic prospects: A World Bank Group flagship report*, The World Bank, Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/35647/9781464816659.pdf.
The World Bank, nd. *Multiphase Programmatic Approach*, The World Bank, Washington, DC. https://www.worldbank.org/en/what-we-do/products-and-services/financing-instruments/multiphase-programmatic-approach.
Thylin, T., Duarte, M.F.N., 2019. *Leveraging blockchain technology in humanitarian settings – opportunities and risks for women and girls*. Gender & Development 27(2), 317-336.
Torosyan, M., 2020. *Safe YOU App: Armenian women use technology to tackle gender-based violence innovation*, The World Bank, Washington, DC. (https://blogs.worldbank.org/europeandcentralasia/safe-you-app-armenian-women-use-technology-tackle-gender-based-violence.
UCL, 2021. *The global housing crisis and the home ownership myth*, University College London (UCL), London. https://www.ucl.ac.uk/bartlett/public-purpose/events/2021/jun/global-housing-crisis-and-home-ownership-myth.
UN, 2015a. *Addis Ababa Action Agenda of the Third International Conference on Financing for Development*, United Nations (UN), New York City, NY. https://sustainabledevelopment.un.org/content/documents/2051AAAA_Outcome.pdf.
UN, 2015b. *Paris Agreement*, United Nations (UN), New York City, NY. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
UN, 2015c. *Sendai Framework for Disaster Risk Reduction 2015–2030*, United Nations (UN), New York City, NY. https://www.undrr.org/implementing-sendai-framework/what-sendai-framework.
UN, 2015d. *Transforming our World: The 2030 Agenda for Sustainable Development*, United Nations (UN), New York City, NY. https://sdgs.un.org/2030agenda.
UN, 2017. *New Urban Agenda*, United Nations (UN), New York City, NY. https://uploads.habitat3.org/hb3/NUA-English.pdf.
UN, 2019. *Closing Digital Gap Vital to Attaining Sustainable Development, Speakers Stress, as Economic and Social Council Opens Forum on Science, Technology, Innovation*, United Nations (UN), New York City, NY. https://www.un.org/press/en/2019/ecosoc6980.doc.htm.
UN, 2020a. *Addressing the Impact of the COVID-19 Pandemic on Violence Against Women and Girls*, United Nations (UN), New York City, NY. https://www.un.org/en/addressing-impact-covid-19-pandemic-violence-against-women-and-girls.
UN, 2020b. *Firearms trafficking, 'enabler and multiplier of violence' worldwide*, United Nations (UN), New York City, NY. https://news.un.org/en/story/2020/07/1068451.
UN, 2020c. *A New Era of Conflict and Violence*, United Nations (UN), New York City, NY. https://www.un.org/sites/un2.un.org/files/un75_conflict_violence.pdf.
UN, 2020d. *Policy Brief on COVID-19 in the Urban World*, United Nations (UN), New York City, NY. https://www.un.org/sites/un2.un.org/files/sg_policy_brief_covid_urban_world_july_2020.pdf.
UN, 2020e. *Policy Brief: Education during Covid-19 and beyond*, United Nations (UN), New York City, NY. https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf.
UN, 2020f. *Rebirthing the Global Economy to Deliver Sustainable Development*, United Nation (UN), New York City, NY. https://www.un.org/en/coronavirus/rebirthing-the-global-economy-to-deliver-sustainable-development-roundtable2.
UN, 2020g. *Shared responsibility, global solidarity: Responding to the socio-economic impacts of COVID-19*, United Nations (UN), New York City, NY. https://unsdg.un.org/sites/default/files/2020-03/SG-Report-Socio-Economic-Impact-of-Covid19.pdf.
UN, 2020h. *The Sustainable Development Goals Report 2020*, United Nations (UN), New York City, NY. https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf.

UN, 2021. *The Sustainable Development Goals Report 2021*, United Nations (UN), New York City, NY. https://unstats.un.org/sdgs/report/2021/.
UN Women, 2015. *A framework to underpin action to prevent violence against women*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/en/what-we-do/ending-violence-against-women/prevention.
UN Women, 2016. *"Fear of violence affects the everyday lives of women and girls" — Lakshmi Puri*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/en/news/stories/2016/3/lakshmi-puri-at-habitat-iii-agenda-and-gender-equality.
UN Women, 2017a. *Buy From Women*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/-/media/headquarters/attachments/sections/library/publications/2017/buy-from-women.pdf?la=en&vs=231.
UN Women, 2017b. *Making stepping out of home safer for women and girls in Marrakech*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/en/news/stories/2017/11/feature-marrakech-safe-cities.
UN Women, 2017c. *Safe Cities and Safe Public Spaces: Global results report*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/-/media/headquarters/attachments/sections/library/publications/2017/safe-cities-and-safe-public-spaces-global-results-report-en.pdf?la=en&vs=45.
UN Women, 2019. *Innovation for gender equality*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/-/media/headquarters/attachments/sections/library/publications/2019/innovation-for-gender-equality-en.pdf?la=en&vs=733.
UN Women, 2020. *Explainer: Everything you need to know about pushing for equal pay*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://www.unwomen.org/en/news/stories/2020/9/explainer-everything-you-need-to-know-about-equal-pay.
UN Women, 2021. *UN Women-WFP blockchain pilot project for cash transfers in refugee camps*, United Nations Entity for Gender Equality and the Empowerment of Women (UN Women), New York City, NY. https://jordan.unwomen.org/en/digital-library/publications/2021/un-women-wfp-blockchain-pilot-project-for-cash-transfers-in-refugee-camps-jordan-case-study.
UN-Habitat, 2019a. *Using mixed reality technology for inclusive and participatory planning*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/using-mixed-reality-technology-for-inclusive-and-participatory-planning.
UN-Habitat, 2019b. *Using mixed reality technology for inclusive and participatory planning - part two*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/using-mixed-reality-technology-for-inclusive-and-participatory-planning-part-two.
UN-Habitat, 2020. *World Cities Report 2020: The Value of Sustainable Urbanization*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf.
UN-Habitat, 2021. *Cities and Pandemics: Towards a more just, green and healthy future*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/sites/default/files/2021/03/cities_and_pandemics-towards_a_more_just_green_and_healthy_future_un-habitat_2021.pdf.
UN-Habitat, nd-a. *Energy*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/topic/energy.
UN-Habitat, nd-b. *Mobility and Transport*, United Nations Human Settlement Programme (UN-Habitat), Nairobi. https://unhabitat.org/topic/mobility-and-transport.
UN-Habitat, UNECE, UNEP, 2018. *Accelerating SDG 7 Achievement: Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum 2018*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://sustainabledevelopment.un.org/content/documents/17557PB14.pdf.
UNCDF, 2019. *Leaving no one behind in the digital era*, United Nations Capital Development Fund (UNCDF), New York City, NY. https://www.uncdf.org/article/4931/global-strategy-leaving-no-one-behind-in-the-digital-era.

UNCDF, 2020. *Harnessing the true power of capital: Unlocking the growth of potential of the last mile*, United Nations Capital Development Fund (UNCDF), New York City, NY. https://www.uncdf.org/Download/AdminFileWithFilename?id=14934&cultureId=127&filename=260721-uncdf-annual-report-2020webpdf.

UNCTAD, 2020. *World Investment Report 2020: International Production Beyond the Pandemic*, United Nations Conference on Trade and Development (UNCTAD), Geneva. https://unctad.org/system/files/official-document/wir2020_en.pdf.

UNDESA, 2015a. *Accessibility and Disability Inclusion in Urban Development*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://www.un.org/disabilities/documents/2015/accessibility-urbandevelopment.pdf.

UNDESA, 2015b. *Action on… Water quality and the protection of ecosystems*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://www.un.org/waterforlifedecade/waterandsustainabledevelopment2015/water_quality.shtml.

UNDESA, 2016. *Good Practices of Accessible Urban Development*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://www.un.org/disabilities/documents/desa/good_practices_in_accessible_urban_development_october2016.pdf.

UNDESA, 2018a. *World Economic and Social Survey 2018: Frontier technologies for sustainable development*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESS2018_ch1_en.pdf.

UNDESA, 2018b. *World Urbanization Prospects: The 2018 Revision*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.

UNDESA, 2019a. *World Population Ageing 2019: Highlights*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY.

UNDESA, 2019b. *World Population Prospects 2019: Highlights*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf.

UNDESA, 2021a. *2021 Energy Statistics Pocketbook*, United Nations Department of Economic and Social Affairs (UNDESA), New York City, NY. https://unstats.un.org/unsd/energystats/pubs/documents/2021pb-web.pdf.

UNDESA, 2021b. *Delivering results for children through a locally funded social protection programme*, United Nations Children's Fund (UNICEF), New York City, NY. https://sdgs.un.org/partnerships/delivering-results-children-through-locally-funded-social-protection-programme.

UNDP, 2021. *Comprehensive cooperation to Costa Rica´s National Information System and Unique Registry of Beneficiaries (SINIRUBE)*, United Nations Development Programme (UNDP), New York CIty, NY. https://sdgs.un.org/partnerships/comprehensive-cooperation-costa-ricas-national-information-system-and-unique-registry.

UNDRR, 2019. *Global assessment report on disaster risk reduction 2019*, United Nations Office for Disaster Risk Reduction (UNDRR), Geneva. https://gar.undrr.org/sites/default/files/reports/2019-05/full_gar_report.pdf.

UNDRR, 2020. *Making Cities Resilient by Integrating Nature-Based Solutions into Urban Planning*, United Nations Office for Disaster Risk Reduction (UNDRR), Geneva. https://www.undrr.org/event/making-cities-resilient-integrating-nature-based-solutions-urban-planning-africa.

UNECE, 2018. *Regional Forum on Sustainable Development for the UNECE Region*, United Nations Economic Commission for Europe (UNECE), Geneva. https://unece.org/fileadmin/DAM/RCM_Website/RFSD_2018_case_studies_compilation.pdf.

UNECE, 2019. *Mapping of Existing Technologies to Enhance Energy Efficiency in Buildings in the UNECE Region*, United Nations Economic Commission for Europe (UNECE), Geneva. https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf.

UNEP, 2018a. *The UN in Nairobi launches bike-sharing scheme*, United Nations Environment Programme (UNEP), Nairobi. https://www.unep.org/news-and-stories/story/un-nairobi-launches-bike-sharing-scheme.

UNEP, 2018b. *The Weight of Cities: Resource Requirements of Future Urbanization*, United Nations Environment Programme (UNEP), New York City, NY. https://www.resourcepanel.org/reports/weight-cities.
UNEP, 2019a. *Consumer Information, including Ecolabeling*, United Nations Environment Programme, Nairobi. https://www.unep.org/es/node/1509.
UNEP, 2019b. *UN report: Time to seize opportunity, tackle challenge of e-waste*, United Nations Environment Programme (UNEP), New York City, NY. https://www.unep.org/news-and-stories/press-release/un-report-time-seize-opportunity-tackle-challenge-e-waste.
UNEP, 2020. *Electric mobility could help clean the air and boost green jobs as part of the COVID-19 recovery in Latin America and the Caribbean*, United Nations Environment Programme (UNEP), Nairobi. https://www.unep.org/news-and-stories/press-release/electric-mobility-could-help-clean-air-and-boost-green-jobs-part.
UNEP, 2021. *Five things to know about desalination*, United Nations Environment Programme (UNEP), Nairobi. https://www.unep.org/news-and-stories/story/five-things-know-about-desalination.
UNESCO, 2020. *Startling digital divides in distance learning emerge*, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. https://en.unesco.org/news/startling-digital-divides-distance-learning-emerge.
UNESCO, 2021. *One year into Covid: prioritizing education recovery to avoid a generational catastrophe*, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. https://unesdoc.unesco.org/ark:/48223/pf0000376984.
UNFCCC, 2019. *Fossil Fuels Are Biggest Part of Global Ecological Footprint*, United Nations Framework Convention on Climate Change (UNFCCC), New York City, NY. https://unfccc.int/news/fossil-fuels-are-biggest-part-of-global-ecological-footprint.
UNFCCC, 2021a. *Can Green Hydrogen Play a Bigger Role in Renewables?*, United Nations Framework Convention on Climate Change (UNFCCC), New York City, NY. https://unfccc.int/blog/can-green-hydrogen-play-a-bigger-role-in-renewables.
UNFCCC, 2021b. *Too Many Cooks*, United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/blog/too-many-cooks.
UNGC, 2017a. *Disruptive technology executive briefs: Next generation robotics*, United Nations Global Compact (UNGC), New York City, NY. http://breakthrough.unglobalcompact.org/site/assets/files/1308/hhw-16-0018-d_n_robots.pdf.
UNGC, 2017b. *Disruptive Technology Executive Briefs: The microbiome*, United Nations Global Compact (UNGC), New York City, NY. http://breakthrough.unglobalcompact.org/site/assets/files/1555/hhw-16-0029-d_c_microbiome.pdf.
UNIC Rio, 2021. *Cooperative recovers sales with e-commerce during the pandemic*, United Nations Information Centre in Rio de Janeiro (UNIC Rio), Rio de Janeiro. https://www.un.org/en/coronavirus/cooperative-recovers-sales-e-commerce-during-pandemic.
UNICEF, 2014. *Sessions with MobiStation*, United Nations Children's Fund (UNICEF), New York City, NY. https://www.unicef.org/innovation/stories/sessions-mobistation.
UNICEF, 2019. *Annual Report 2018: For every child, every right*, United Nations Children's Fund (UNICEF), New York City, NY. https://www.unicef.org/media/55486/file/UNICEF-annual-report-2018%20revised%201.pdf.
UNICEF, 2020. *Accelerating Results for Children with Technology and Digital Innovation*, United Nations Children's Fund (UNICEF), New York City, NY. https://www.unicef.org/reports/accelerating-results-children-technology-and-digital-innovation-2020.
UNIDO, 2019. *World Small Hydropower Development Report 2019: Case Studies*, United Nations Industrial Development Organization (UNIDO), Vienna. https://www.unido.org/sites/default/files/files/2020-05/Technology%2C%20Innovation%20and%20Smart%20Small%20Hydropower.pdf.
UNISON, 2021. *Bargaining over workplace issues during the COVID-19 pandemic* UNISON, London. https://www.unison.org.uk/content/uploads/2021/07/COVID-19-Pandemic-Bargaining-over-workplace-issues-during-the-COVID-19-pandemic-v36.pdf.
UNLEASH, 2017. *Doti Gold*, UNLEASH, Copenhagen. https://unleash.org/solutions/doti-gold/.
UNLEASH, 2018. *Winners of SDG 12: Responsible Supply Chain and Consumption*, UNLEASH, Copenhagen. https://unleash.org/news/winners-sdg-12-responsible-supply-chain-consumption/.

UNODC, 2020a. *Global Study on Firearms Trafficking 2020*, United Nations Office on Drugs and Crime (UNODC), Vienna. https://www.unodc.org/documents/data-and-analysis/Firearms/2020_REPORT_Global_Study_on_Firearms_Trafficking_2020_web.pdf.
UNODC, 2020b. *Line UP, Live Up: Youth crime prevention through sports*, United Nations Office on Drugs and Crime (UNODC), Vienna. https://www.unodc.org/dohadeclaration/topics/crime-prevention-through-sports.html.
UNODC, nd. *A Global Problem: Illicit Trafficking and Misuse of Firearms as a Threat to Global Security*, United Nations Office on Drugs and Crime (UNODC), Vienna. https://www.unodc.org/unodc/en/firearms-protocol/index.html.
UNOV, 2021. *Crime in the community*, United Nations Office at Vienna (UNOV), Vienna. https://unis.unvienna.org/unis/en/events/2020/crime_congress-community.html#.
UNSC, 2018. *Global Cost of Corruption at Least 5 Per Cent of World Gross Domestic Product, Secretary-General Tells Security Council, Citing World Economic Forum Data*, United Nations Security Council (UNSC), New York City, NY. https://www.un.org/press/en/2018/sc13493.doc.htm.
URI, FCPP, 2021. *Demographia International Housing Affordability: 2021 Edition*, Urban Reform Institute (URI) and Frontier Centre for Public Policy (FCPP). https://fcpp.org/wp-content/uploads/Demographia-International-Housing-Affordability-2021.pdf.
Van Maarseveen, R., 2020. *The urban–rural education gap: do cities indeed make us smarter?* Journal of Economic Geography.
Van Nuland, S., Mandzuk, D., Tucker Petrick, K., Cooper, T., 2020. *COVID-19 and its effects on teacher education in Ontario: a complex adaptive systems perspective*. Journal of Education for Teaching 46(4), 442-451.
Vandenberg, P., 2006. *Poverty reduction through small enterprises: Emerging consensus, unresolved issues and ILO activities*, International Labour Organisation (ILO), Geneva. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_093981.pdf.
Vezzoli, C., Ceschin, F., Diehl, J.C., 2021. *Product-Service Systems Development for Sustainability. A New Understanding*, in: Vezzoli, C., Garcia Parra, B., Kohtala, C. (Eds.), *Designing Sustainability for All: The Design of Sustainable Product-Service Systems Applied to Distributed Economies*. Springer, Cham, pp. 1-21.
Viera, J.S.C., Marques, M.R.C., Nazareth, M.C., Jimenez, P.C., Castro, Í.B., 2020. *On replacing single-use plastic with so-called biodegradable ones: The case with straws*. Environmental Science & Policy 106, 177-181.
Watson, S., Moro, A., Reis, V., Baniotopoulos, C., Barth, S., Bartoli, G., Bauer, F., Boelman, E., Bosse, D., Cherubini, A., 2019. *Future emerging technologies in the wind power sector: A European perspective*. Renewable and Sustainable Energy Reviews 113, 109270.
WBR, 2020. *World Bicycle Relief: Impact Report 2020*, World Bicycle Relief (WBR), Chicago, IL. https://worldbicyclerelief.org/wp-content/uploads/2021/05/WBR_2020_Impact-Report_Spread.pdf.
WEF, 2018. *Fourth Industrial Revolution for the Earth Series*, World Economic Forum (WEF), Cologny. www3.weforum.org/docs/ WEF_WR129_Harnessing_4IR_Water_Online.pdf.
WEF, 2019a. *Innovation with a Purpose: Improving Traceability in Food Value Chains through Technology Innovations*, World Economic Forum (WEF), Cologny. http://www3.weforum.org/docs/WEF_Traceability_in_food_value_chains_Digital.pdf.
WEF, 2019b. *A New Circular Vision for Electronics: Time for a Global Reboot*, World Economic Forum (WEF), Cologny. http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf.
Whitelaw, S., Mamas, M.A., Topol, E., Van Spall, H.G.C., 2020. *Applications of digital technology in COVID-19 pandemic planning and response*. The Lancet Digital Health 2(8), e435-e440.
WHO, 2016. *Health workforce requirements for universal health coverage and the Sustainable Development Goals*, World Health Organization (WHO), Geneva. https://apps.who.int/iris/bitstream/handle/10665/250330/9789241511407-?sequence=1.
WHO, 2020a. *COVID-19 disrupting mental health services in most countries, WHO survey*, World Health Organization (WHO), Geneva. https://www.who.int/news/item/05-10-2020-covid-19-disrupting-mental-health-services-in-most-countries-who-survey.
WHO, 2020b. *Global strategy on human resources for health: Workforce 2030*, World Health Organization (WHO), Geneva. https://apps.who.int/iris/rest/bitstreams/1061558/retrieve.

WHO, 2021a. *COVID-19 continues to disrupt essential health services in 90% of countries*, World Health Organization (WHO), Geneva. https://www.who.int/news/item/23-04-2021-covid-19-continues-to-disrupt-essential-health-services-in-90-of-countries.
WHO, 2021b. *The WHO European Healthy Cities Network: a response to the COVID-19 pandemic close to the people*, World Health Organization (WHO), Geneva. https://www.euro.who.int/en/health-topics/environment-and-health/urban-health/who-european-healthy-cities-network/the-who-european-healthy-cities-network-a-response-to-the-covid-19-pandemic-close-to-the-people.
WHO, 2021c. *World Health Statistics 2021*, World Health Organization (WHO), Geneva. https://apps.who.int/iris/bitstream/handle/10665/342703/9789240027053-eng.pdf.
WHO, nd. *Air pollution and climate change*, World Health Organization (WHO), Geneva. https://www.euro.who.int/en/health-topics/environment-and-health/Transport-and-health/data-and-statistics/air-pollution-and-climate-change2.
WJI, 2018. *Introducing Women's Justice Initiative*, Women's Justice Initiative (WJI), Patzún. https://togetherwomenrise.org/wp-content/uploads/2018/02/2018.03-WJI-PPT.pdf.
WJI, 2019. *Dining for Women: Final Progress Report*, Women's Justice Initiative (WJI), Patzún. https://togetherwomenrise.org/wp-content/uploads/2019/05/WJI-FPR.pdf.
Wong, J.C., 2020. *Coronavirus: Facebook will start warning users who engaged with harmful misinformation*, The Guardian. https://www.theguardian.com/technology/2020/apr/16/coronavirus-facebook-misinformation-warning.
WRAP, 2020. *A Roadmap to 2025: The UK Plastics Pact*, Waste and Resources Action Programme (WRAP), Banbury. https://wrap.org.uk/sites/default/files/2021-02/The-UK-Plastics-Pact-Roadmap-2020.pdf.
Wrigley, K., Crawford, R.H., 2017. *Identifying policy solutions for improving the energy efficiency of rental properties*. Energy Policy 108, 369-378.
WWF, 2020. *Cities take lead in the fight against plastic - World Cities Day 2020*, World Wide Fund for Nature (WWF), Gland. https://wwf.panda.org/wwf_news/?1020291/CITIES-TAKE-LEAD-IN-THE-FIGHT-AGAINST-PLASTIC---WORLD-CITIES-DAY-2020.
Xiaofei, S., Yi, Q., Zongguo, W., Lili, L., Guijuan, S., Jinhui, L., 2017. *Research on Urban Mining Development in China*. Strategic Study of Chinese Academy of Engineering 19(4), 97-102.
XPRIZE Foundation, 2019. *$15M Global Learning XPRIZE Culminates with Two Grand Prize Winners*, XPRIZE Foundation, Culver City, CA. https://www.xprize.org/articles/global-learning-xprize-two-grand-prize-winners.
Ye, T., Johnson, R., Fu, S., Copeny, J., Donnelly, B., Freeman, A., Lima, M., Walsh, J., Ghani, R., 2019. *Using machine learning to help vulnerable tenants in new york city*, in: Chen, J., Mankoff, J., Gomes, C. (Eds.), *COMPASS 19: Proceedings of the 2nd ACM SIGCAS Conference on Computing and Sustainable Societies*. ACM Press, New York City, NY, pp. 248-258.
Yeung, P., 2020. *The Brazilian megacity experimenting with eco-friendly waste disposal*, Deutsche Welle. https://www.dw.com/en/the-brazilian-megacity-experimenting-with-eco-friendly-waste-disposal/a-51469344.
Zandaryaa, S., Deregibus, I., An, S., Jean, M.-E., 2015. *International Initiative on Water Quality: promoting scientific research, knowledge sharing, effective technology and policy approaches to improve water quality for sustainable development*, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. https://en.unesco.org/waterquality-iiwq/wq-challenge.
Zarocostas, J., 2020. *How to fight an infodemic*. The Lancet 395(10225), 676.
Zeng, X., Mathews, J.A., Li, J., 2018. *Urban Mining of E-Waste is Becoming More Cost-Effective Than Virgin Mining*. Environmental Science & Technology 52(8), 4835-4841.
Zhou, M., Zhao, J., 2021. *A Review on the Health Effects of Pesticides Based on Host Gut Microbiome and Metabolomics*. Frontiers in Molecular Biosciences 8(9).
Zhou, X., Snoswell, C.L., Harding, L.E., Bambling, M., Edirippulige, S., Bai, X., Smith, A.C., 2020. *The Role of Telehealth in Reducing the Mental Health Burden from COVID-19*. Telemedicine and e-Health 26(4), 377-379.
Zinser, S., Thinyane, H., Ewen, P., Melnyk, L., 2020. *Promise and Limits of Remote Monitoring in Addressing Forced and Child Labour*, United Nations University, Tokyo. https://delta87.org/2020/12/promise-limits-remote-monitoring-addressing-forced-child-labour/.