Chapter 9:

Innovation and Technology: Towards Knowledge-Based Urban Futures

Quick facts

1. Innovation and technology play an increasingly central role in planning for sustainable urban futures.

2. Digitalization and automation are rapidly transforming urban economies.

3. The urgency to decarbonize urban economies is driving the convergence of green and smart technologies.

4. The demand for smart city systems and solutions is estimated to increase annually by 25 per cent, with an overall market value of approximately US$517 billion.

5. Technological advances risk exacerbating existing, and generating new, socioeconomic inequalities.

Policy points

1. The deployment of innovation and technology should be tailored to suit the diversity of the urban context.

2. Cities need to consider the negative environmental externalities when investing in low-carbon, digital and connected technologies.

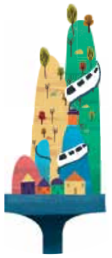
3. Urban economies need to be adequately prepared for the effects of advancing automation and digitalization.

4. To avoid top-down, one-way communication, the deployment of digital tools to address urban challenges needs to be inclusive, collaborative and empowering.

Since the World Cities Report 2020, two major areas of sociotechnical development have continued to accelerate and taken an even more prominent stage in planning for urban futures. The first area is the growing urgency for "unprecedented, aggressive decarbonization."[1] One proposed solution in the fight against global climate change is a series of green technological innovations that harness renewable energy sources, reduce energy consumption and protect other environmental assets. These innovations are key to creating sustainable cities and, as such, will not only significantly reshape urban infrastructure—buildings, transport systems, energy grids, etc.—but also exercise significant influence on urban daily life. The second technological development relates to unparalleled advancements in the digital world. Digitalization encompasses various smart technological innovations that enable ubiquitous computing, big data collection from widespread deployment of sensors and devices, large-scale data analytics, machine learning and autonomous decision-making. These connected and digital technologies find expression in the "smart city," which is now a major paradigm of urban policy and, increasingly, everyday reality. Each of these technological fields is significant on its own but, crucially, it is the confluence of the two that at present creates unique technological momentum with fundamental implications for the way in which future cities are governed and planned.

Cities are not mere bystanders in these technological transformations, but rather are both the setting for and protagonists in how these processes are played out. For one thing, it is predominantly in urban areas that environmental and smart technological innovations will be applied, with city governments and other urban actors expected to implement large-scale infrastructure renewals and building retrofit programmes. For another, the likely disruptive effects of technological innovation, such as rising precarious work and social inequalities, may be particularly pronounced in urban areas and, consequently, require careful assessment and context-specific intervention. Moreover, cities are not only implementors of new technology, but also drivers of innovation: they play an important role in facilitating collaborations among universities, start-up companies, technology firms, social enterpriss, and community groups. They even act as innovators themselves, for example as commissioners of utility services, building owners and land developers.

A key focus of this chapter, therefore, is on the opportunities and responsibilities that cities have in steering and managing these major socio-technical developments to prepare for urban futures. This stewardship requires as much attention to social, cultural and institutional factors as it does to technology itself.



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Consequently, it also requires careful consideration of local conditions and contexts, since the impacts of technological innovations will be felt differently across towns and cities. Throughout, the guiding question should be how to achieve inclusive urban development in the interest of citizens' well-being and environmental protection.

In exploring the role of cities as places of innovation, Section 2 highlights the necessary interplay between technological, social and organizational innovation, and sets out four challenges for innovation in the name of the smart city. Section 3 provides an overview of emergent frontier technologies centring upon the convergence of green and smart technology, and how these may be variously adapted to local contexts. Section 4 takes a closer look at how the combined forces of digitalization and automation are transforming the world of work and how this will likely affect cities. Section 5 examines how cities can respond to both the digital divide and environmental divide arising from technological innovations, which risk creating new, as well as exacerbating existing, urban inequalities. Section 6 turns to the opportunities of connected and digital technologies to enhance participatory governance through more open e-government, civic engagement and community technology making. Section 7 draws attention to the benefits of responsible innovation as a tool for assessing both opportunities and risks of technology. Finally, Section 8 concludes with seven policy lessons for inclusive socio-technical innovations for urban futures.

9.1. Future Cities as Places of Innovation

The role of cities as places of innovation arises from two key urban characteristics. The first relates to the concentration of people and organizations in dense space which creates the conditions for dynamic resource sharing, networking and collaboration. This agglomeration effect has been shown to be critical for enabling and driving innovation (Chapter 4).[2] Consequently, cities play an important role as hosts in providing an enabling environment for innovation. The second characteristic relates to cities' own role as innovators. This is most obvious in relation to the development and improvement of physical infrastructures, including buildings, energy, transport, water, waste, and green and public space. It is also increasingly evident in relation to soft infrastructure, where digital technological systems are key to the delivery of various public services. Urban innovation, however, goes beyond the technological, encompassing essential social and institutional aspects. Furthermore, it requires a context-specific, localized approach.

9.1.1. Combining three innovation perspectives

The thriving cities of the future will likely be ones that recognize and harness opportunities to act as platforms for innovation. Consequently, they will facilitate locally grounded innovation ecosystems by supporting the co-location of research organizations, start-up companies, investors, industries, and business and social enterprises. A 2018 survey showed that committed leadership and dedicated staff support are important enabling factors (Figure 9.1). They will use various instruments, including grants, subsidies, competitions and regulations, to incentivize and steer innovation towards sustainable urban development practices. They may establish innovation districts, living labs or other neighbourhood-scale amenities to provide an enabling environment for creative thinking, design, development and, ultimately, the applications of solutions to societal challenges. Finally, they will tailor innovation to local conditions taking into account, for example, available resources, capacities, and social and cultural practices.

In the present day, however, investment in innovation by city governments is still a relatively new phenomenon and remains a marginal practice according to a 2019 OECD report.[3] Of the surveyed cities, just over half had stated innovation goals and fewer than half had adopted innovation strategies. Those that did were found to approach innovation more holistically and were more open to pursuing change. In response to the findings, 60 mayors from the OECD Champion Mayors for Inclusive Growth Initiative adopted the Athens Road Map, which aimed to provide guidance on increasing cities' innovation capacity and capabilities and, in turn, fostering prosperity and well-being.[4] The initiative emphasizes the importance of pursuing innovation not in narrow technological terms, but with close regard to wider socioeconomic and cultural needs and conditions. As such, it urges cities to invest concurrently in three interlinking types of innovation:

- Technological and digital innovation that contributes to increased well-being in urban areas through smart transformations of public services, ranging from e-government solutions to the use of sensors to address environmental pollution. Participating cities also commit to supporting underserved residents with better access to digital services.

- Social innovation to create better social outcomes through the provision of community services for disadvantaged communities, the creation of targeted employment and activation programmes, and the encouragement of social enterprises and community-building activities.

- Public sector innovation to put the interests of diverse local communities more centre-stage. Recommendations include participatory budgeting, public innovation labs, or citizen-led monitoring to increase engagement of citizens in urban decision-making processes. City governments are equally encouraged to promote public-private partnerships and collaboration between municipalities.

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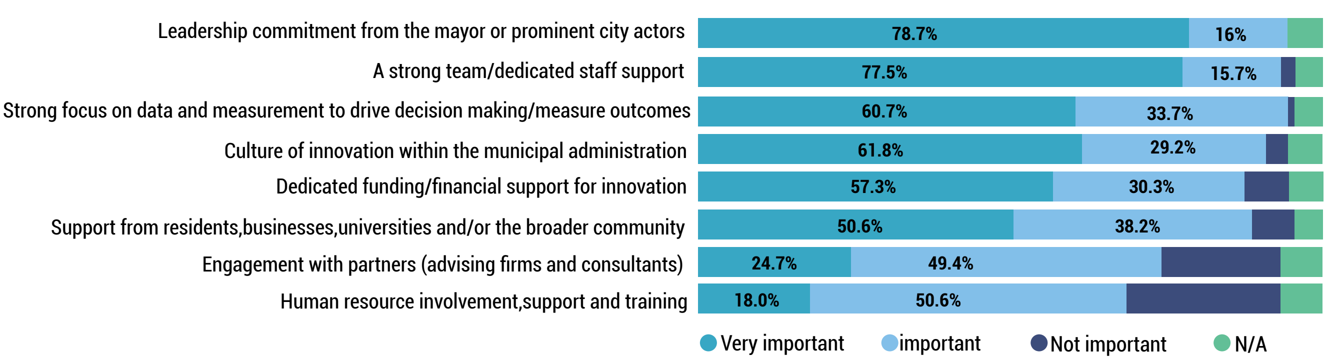
Figure 9.1: Most important practices to support innovation in cities



Source: OECD, 2019.

Smart city technologies © Zapp2Photo/Shutterstock

9.1.2. Localized and inclusive innovation

An important recognition in recent research and policy is the need for localized and inclusive approaches to fostering innovation. This conclusion was reflected in a collection of discussion papers by UN-Habitat on technological innovation for future cities.[5] Similarly, a recent report by OECD called for the broadening of innovation policies for cities and regions.[6] By broadening, the OECD referred to the need to go beyond a conceptually and spatially narrow approach to innovation (concentrated around a few clusters of excellence) and instead support innovation diffusion through the involvement of a broader set of urban actors and better use of local assets. This approach recognizes the heterogeneity of innovation capacities, with implications for how innovation is orchestrated nationally and implemented locally.

Such an approach considers different spatial and territorial dimensions at work.[7] On one hand, developing a city-regional approach is considered important if the aim is to broaden the innovation ecosystem and scale up efficiencies (e.g. shared infrastructures and services). On the other, recent research has focused on the neighbourhood as a useful unit at which to support smaller-scale, adaptive innovation practices with local expertise. This scale makes particular sense where the sustainability transition calls for more decentralized approaches. For example, the Joint Programming Initiative Urban Europe has a programme to plan and deploy 100 positive energy districts and neighborhoods across 20 European countries by 2025. These districts and neighbourhoods will produce more energy than they consume, through combing a diverse range of energy sources and energy transfers (Figure 9.2).[8]

A further direction in recent urban innovation policy and practice is the strategic alignment of innovation activities with grand societal challenges. This concern recognizes that innovation can result in destructive creation that leads to greater inequalities and environmental degradation.[9] Instead, cities are expected to steer innovation towards the sustainability transition and use it to tackle urban challenges, such as environmental pollution and rapid urbanization.

In summary, it is possible to define some qualitative indicators of what kind of innovation policy and practice can be envisaged for future cities. Accordingly, municipal governments would strive to:

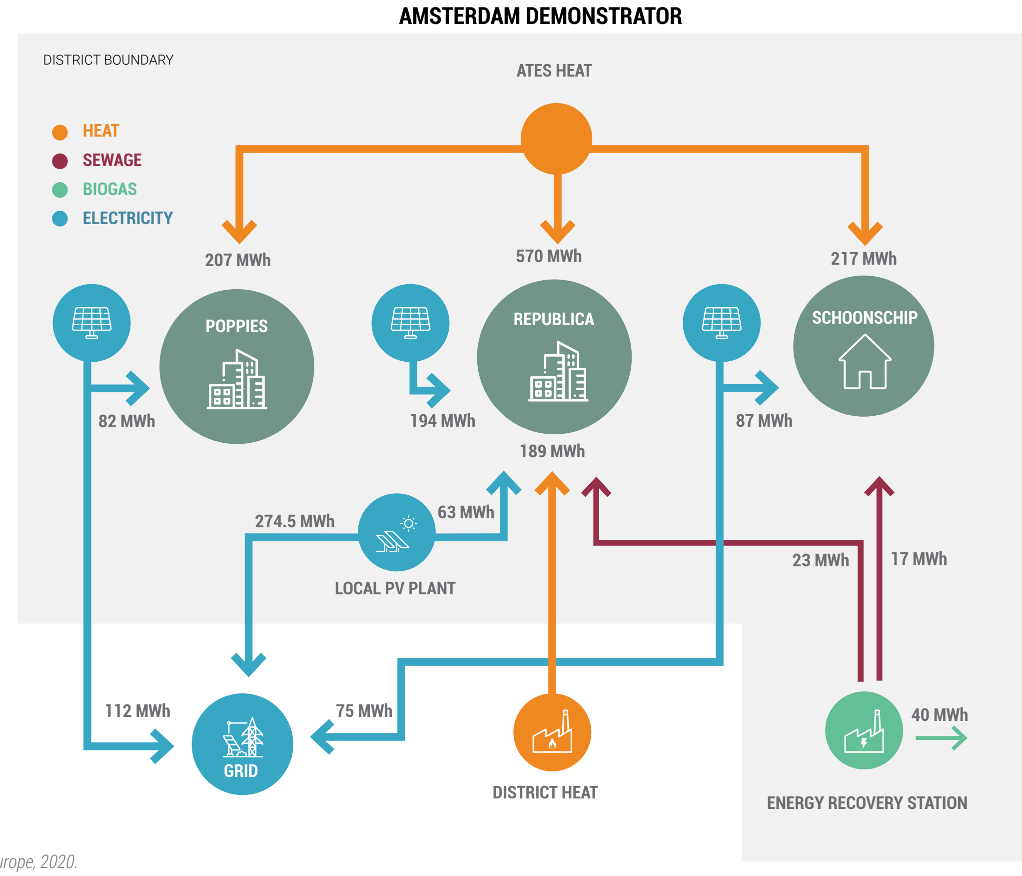
- Align innovation policy and practice with grand societal challenges, including climate change, pollution, poverty, and inequalities as identified in various chapters of this Report

- Support urban agglomeration, and in particular the co-location of complementary resources and organizations, through territorial and socio-economic planning and regulation (see Chapter 6)

- Create a conducive environment for technology and entrepreneurial start-up companies, especially in the green and smart technological sectors

- Facilitate partnerships involving a variety of actors (including intermediaries) within and outside the public sector

Figure 9.2: Diagram showing the flows of energy in a 'positive energy district'



Source: Urban Europe, 2020.

- Support urban experimentation (pilots, incubators, living labs) aimed at addressing societal problems
- Support training and skills development, including upskilling to green jobs and digitalization
- Host or support "future labs" that engage stakeholders and communities in vision-making and scenario-building
- Conduct evaluations of innovation programmes to assess impact and ensure feedback for continuous improvement, learning and capacity building

9.1.3. Four challenges for smart city innovation

The "smart city" has become a globally popular catchphrase and major policy paradigm for technology-driven urban innovation and development. It emerged rapidly from the late 2000s onwards to jockey for local authorities' attention alongside other key urban conceptual paradigms, such as the "compact city," "resilient city" or even the longtime dominant "sustainable city."[10] Within just five years (2015–

Cities are expected to steer innovation towards the sustainability transition and use it to tackle urban challenges

2019), the scientific output on smart cities rose tenfold. This picture of rapid growth is mirrored in the global market, where the demand for smart city systems and solutions is estimated to increase annually by 25 per cent, with an overall market value of approximately US$517 billion.[11] It is further reflected in the popularity of diverse smart city initiatives around the world. According to a recent global survey, 27 cities currently lead the field as smart city champions, followed by numerous others that have launched initiatives under the smart city banner.[12] Of course, having an explicit smart city agenda is not a precondition for cities adopting connected and digital technologies: indeed, some local governments have implemented artificial intelligence (AI) technology without specific reference to smart city.[13]

The "smart city" has become a globally popular catchphrase and major policy paradigm for technology-driven urban innovation and development

Nevertheless, many municipal administrations choose to adopt a smart city agenda, to provide strategic and programmatic direction for urban development. They are often encouraged by national governments that use competitions to entice cities to invest in smart city programmes, as illustrated by India's 100 Smart Cities Mission and the Republic of Korea's Smart Challenge. National and international standards organizations have joined in by issuing indicators and frameworks aimed at guiding cities' work on the ground.[14]

What transpires from many of the recent smart city initiatives is that they place great importance on promoting governance innovation, alongside the more technical rollout of digital technologies such as public Wi-Fi, smart street furniture and open data portals. For example, Amsterdam Smart City styles itself as an "open innovation platform" aimed at connecting people and supporting collaborative approaches to find solutions to urban challenges.[15] Similarly, Melbourne's smart city programme comprises a CityLab, described as a space to prototype new city services with the community, and an annual Open Innovation Competition, which seeks to tap into the creativity and expertise of the community to solve a given city issue (e.g. waste and the circular economy in 2020).[16] In the case of Santiago de Chile's Shared Street for Low-Carbon District initiative, which was spearheaded by an NGO in collaboration with the municipality and the smart cities unit of the Ministry of Transportation, the aim was to combine citizen participation and experimentation to support tactical interventions for more inclusive and sustainable road use.[17] Altogether, rather than starting from a fixed model of the smart city, many recent initiatives emphasize an experimental, open-ended approach to developing solutions to localized urban issues with the involvement of multiple stakeholders.

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Nevertheless, smart city initiatives have faced significant criticism, highlighting the risk of an overly technological approach to innovation without due regard to diverse urban and social contexts. Therefore, cities wishing to implement smart city strategies need to contend with four main challenges.

- **Respect city-specific contexts**, otherwise smart city projects risk being divorced from the reality of ordinary cities if they subscribe to a form of smart urbanism that espouses a clean slate view of a city run on hyper-efficient urban technology.[18] In response, researchers and practitioners have urged a more grounded approach, which situates the smart city within specific locales and socio-political contexts, thereby relating it to the messy reality of urban policy and practice.[19]

- **Adopt a people-centred perspective** to avoid the risk of an overly technocratic approach to how smart city initiatives are conceived and implemented.[20] There is broad acknowledgement that, initially at least, smart city initiatives too often acted in the service of technology and corporate interests aimed at expanding new urban markets for digital technologies. Consequently, a more people-centred approach has been recommended, which emphasizes that smart cities should more explicitly serve the interests of citizens and give them an active role in how these technologies are planned and implemented.[21] However, if such a commitment is to be more than cursory and paternalistic, it requires serious engagement with questions of social justice, the social good and political participation, for example by operating under the right to the city framework.[22]

- **Provincialize smart cities** in order to view the smart city from a different perspective than that of the Global North. The predominant view is problematic when smart city practices developed in Western cities with knowledge-based economies and concentrations of global capital are uncritically assumed to be suitable for, and therefore superimposed on, cities in developing countries. In response, critical scholarship has highlighted the need to provincialize smart cities; that is, to develop more grounded approaches to how smart city discourses and practices can emerge from global peripheries, often in the form of small projects (in contrast to typically large-scale, capital-intensive interventions in the Global North).[23]

- **Ensure environmental sustainability** as there is a major concern that current smart city discourse insufficiently

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engages with environmental sustainability issues. On one hand, smart city initiatives can be criticized for often prioritizing economic goals—expressed, for example, in terms of seizing global marketshare—and, consequently, marginalizing environmental goals.[24] On the other hand, the environmental costs of smart city projects are frequently overlooked, when there is growing evidence that technological innovations may be carbon intensive and environmentally damaging.[25] Recent years have, therefore, seen a shift towards more explicitly aligning the smart city with the goals of the sustainable city.[26]

Overall, the discussion of what innovation policy cities should pursue highlights the importance of a concerted approach that interrelates technological, social and public sector innovation. It further highlights the need for a variegated approach that pays attention to different types of cities and urban contexts, in order to achieve thriving, locally grounded innovation practices. It also underscores the importance of aligning innovation policy with major social policy goals, such as ensuring adequate housing, tackling poverty and improving sanitation. These insights are increasingly recognized in the development and application of emergent urban technologies, as the following section outlines.

9.2. Frontier Technologies for Variegated Urban Futures

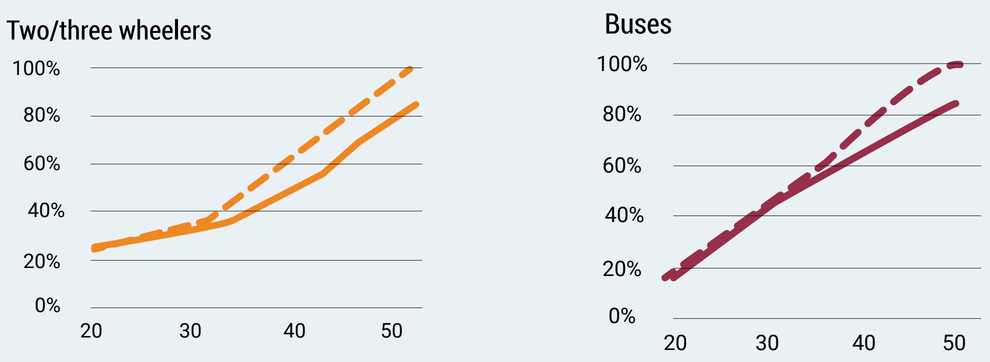
Urban futures will be defined to a significant extent by a series of frontier technologies, particularly relating to the green and smart technology sectors. Frontier technologies are innovations in science, technology, engineering and mathematics which are no longer in the research and development phrase but have yet to see mainstream market penetration and public adoption (Box 9.1). Their application in the urban realm has the potential to reconfigure urban development in radical and disruptive ways. The adoption of frontier technologies is not limited to large, global cities, but is increasingly relevant in lower-tiered cities and even informal settlements. This is because frontier technologies can be designed to be relatively low-cost and suitable for local adaptation. Still, a significant problem remains that some technological innovations, driven by global corporate interests, are either unattainable in resource-poor contexts or in their application exacerbate social inequalities, thus leaving some cities behind. Consequently, urban institutions and stakeholders should be actively involved in deciding how urban technologies are designed and adapted locally in pursuit of sustainable urban development.

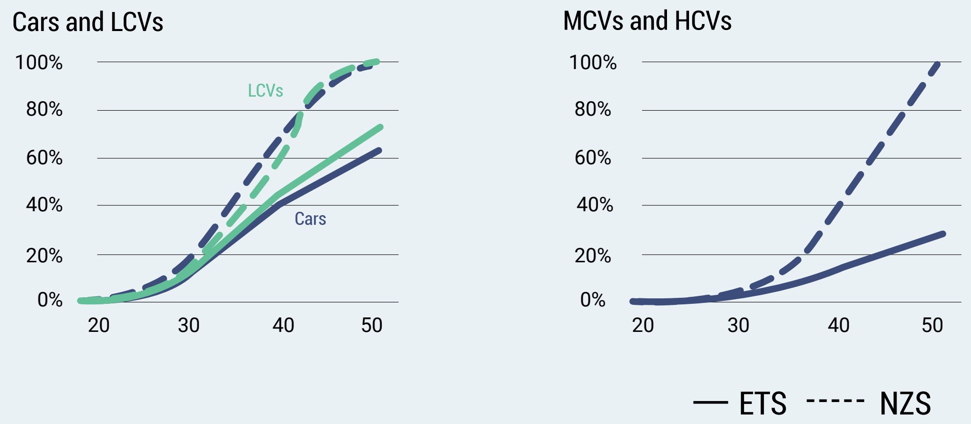
Co-workers at the iHub, a working space for technology entrepreneurs, Nairobi, Kenya. © rvdw images/Shutterstock

Box 9.1: Examples of frontier technologies in urban contexts

- **Artificial intelligence**, or machine learning: Increasingly deployed by municipal governments in the form of virtual agents like chatbots for issuing parking permits and in road traffic management.[27]
- **Blockchain**, or distributed ledger technology: For secure, decentralized exchange of data among network partners. Used by transport operators to deliver shared mobility services, or by city governments to issue residents with digital identifiers for accessing local services.[28]
- **Digital twins**: Virtual representations of urban objects at various scales (building, neighborhood, district, etc.) used as planning tools. Supports diagnostic and prognostic analysis and model-making. Dependent on completeness and accuracy of underlying data known as “digital thread.” [29]
- **3D printing**, or additive manufacturing: Allows for offsite fabrication of building components, thus potentially lowering construction costs of new buildings.[30]
- **Electric vehicle (EV) technology**: With a global target of 60 per cent EV cars by 2030, a rapid uptake is required given the current share of just 4 per cent. (In comparison, EVs already make up 39 per cent of buses.) A key technological challenge is the roll-out of electric charging networks. To date, 15 countries and 31 cities are committed to phasing out the sale of combustion-engine vehicles.[31]
- **Internet of Things (IoT)**: Broad range of applications by embedding a multitude of sensors, smart meters and computer processors in urban infrastructure and objects (buildings, electricity grids, street furniture, water grids, etc.) and connecting these to digital management systems via cloud computing (remote storage and analysis system over the internet)[32].
- **Renewable energy technologies**: Deployed for clean energy production, using various renewable energy sources (solar, wind, hydro, biomass, geothermal). Potential to be applied in tandem, e.g. large bioenergy and waste-to-energy plants with distributed networks of solar panels.[33]
- **Robotics**: Multiple urban applications, including drones for last-mile delivery and connected autonomous vehicles (CAVs). Dependent on 5G/6G technology to deliver high-speed broadband, ultra-reliable connectivity (for low latency) and ability to connect to a multitude of devices simultaneously.[34]

Zero-emission vehicle fleet share outlooks-Economic Transition Scenario (ETS) and Net Zero Scenario (NZS)





Source: BNEF. Note: 'ETS' is Economic Transition Scenario and 'NZS is Net-Zero Scenarion'. 'LCVs, MCVs and HCVs' are light-, medium- and heavy-duty commercial vehicles. 'Zero-emission' includes battery-electric and fuel cell vehicles. All values globals. Some values rounded.

Source: BloombergNEF, 2021.

9.2.1. Converging smart and green technologies

The rise of various green technologies corresponds with the scale and urgency of environmental challenges (Chapter 5). According to the World Energy Outlook only 40 per cent of the CO_2 emission cuts required to reach the 2050 net zero target will be achieved with current measures.[35] Therefore, the uptake of environmental technologies (currently increasing by over 8 per cent annually, as measured by investment) will need to accelerate significantly in the coming years.[36] The decarbonization of energy grids, the electrification of transportation and the application of renewable energy technologies to commercial and domestic buildings are among the most important areas that require innovation and implementation.

For its part, the smart technology sector has grown exponentially based on rapid advancements in digital and connected technologies and their ubiquity in everyday life. The speed with which cities are adopting smart technology is illustrated by strong demand for Internet of Things (IoT) technology, with over 20 per cent annual growth forecast for the coming years.[37] Similarly, blockchain technology is predicted to grow by over 30 per cent in the next few years.[38] AI technologies are increasingly deployed by municipal governments in the form of virtual agents like chatbots.[39] Overall, the market for smart city systems and solutions is estimated to be US$517 billion.[40]

More than their individual contributions, however, it is the convergence of green and smart technologies that creates the basis for major, and potentially disruptive, urban change. For example, the application of IoT and blockchain technologies in combination with renewable energy technologies makes it increasingly technically feasible and financially affordable to set up virtual power plants. These are decentralized, local energy grids that can utilize multiple renewable energy sources and, thus, reduce CO_2 emissions and increase energy resilience. Likewise, modern district heating systems combine renewable technologies (waste heat, heat pumps, thermal storage, etc.) with digital and connected technologies to achieve increased energy efficiency. According to the United Nations Environmental Programme, they are "a secret weapon for climate action and human health," with potential to reduce primary energy consumption by up to 50 per cent compared with conventional systems.[41] Both examples point to the opportunity for small-scale, localized approaches (also known as "off-grid" energy), with technology configured to suit specific local conditions.

A similar technological interplay is required to realize the goals of the circular economy, which seeks to change the prevailing linear production mode (so-called "take-make-dispose") to a closed production cycle where product owners repair, recover, reuse and recycle their goods.[42] Cloud computing and business-to-business matching platforms are enabling technologies to connect waste producers with waste recycling and remanufacturing industries. Blockchain technology can improve the traceability and transparency of

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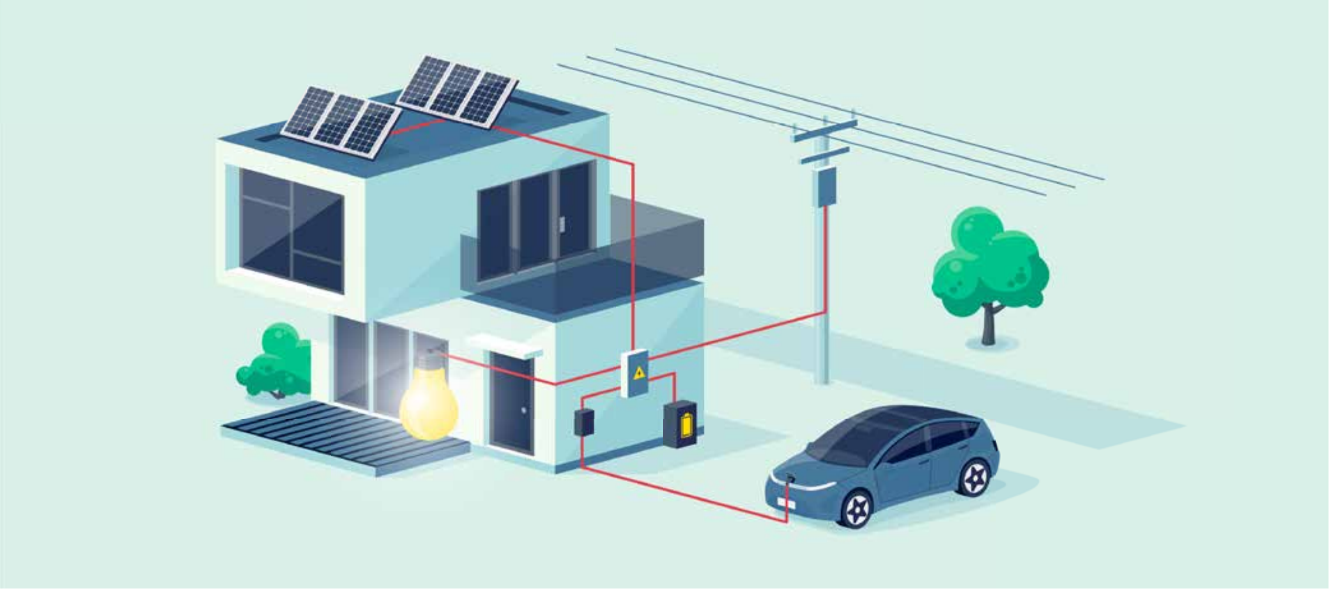


Home electricity scheme with battery energy storage system on modern house photovoltaic solar panels and rechargeable li-ion backup. © Upetovarga/Shutterstock

products by verifying the origins of products and assuring related sustainability claims.

9.2.2. Low-cost applications

The example of virtual power plants demonstrates that frontier technology need not necessarily be unaffordable. Such plants can be designed to allow individual households, groups of residents or neighborhoods to sell surplus electricity to the wider electricity grid, thus generating local income for residents alongside their contribution to decarbonizing the energy system.

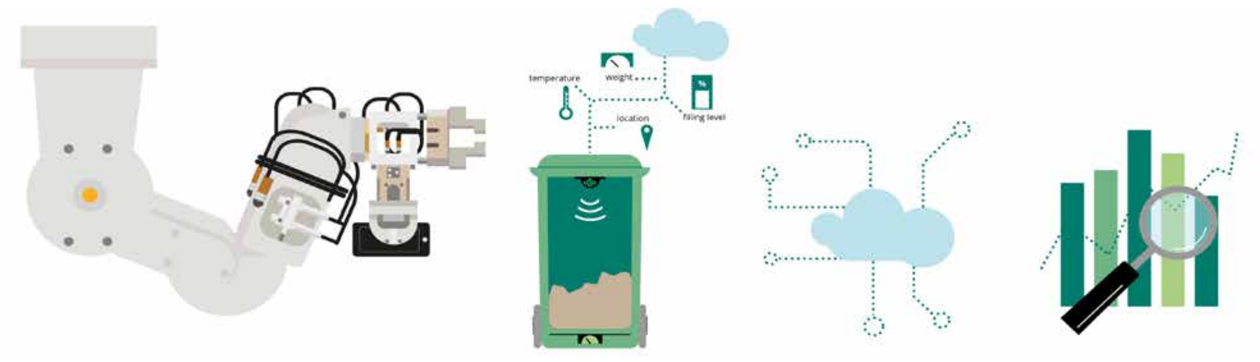
While the costs of new infrastructure development are typically high—and as such may be out of reach for less well-resourced cities—a focus on improving existing infrastructure is often more appropriate and less costly. According to a report by McKinsey on infrastructure options for future cities, even relatively simple and inexpensive digital overlays—such as low-cost automated utility meters and air quality monitors, low-power Wi-Fi communication for intermitted data-streaming, and advancements in solar panel battery technology delivering more power at lower cost—can render existing infrastructure "smart" at affordable prices.[43]

The question of high-versus-low costs also applies to waste management. At the high end, a study by the European Environment Agency argues that the future of waste management will be characterized by the convergence of five technological innovations, namely: (a) robotics that use image recognition for pneumatic sorting; (b) AI and machine learning for waste classification, such as CAV refuse trucks; (c) IoT for sensor-supported waste containers (e.g. smart bins); (d) cloud computing for storing and processing sensor data as well as workflow management; and (e) data analytics to evaluate performance and model alternative options (figure 9.3).[44]

The report, however, acknowledges several potential deterrents: high investment costs, the requirement for advanced digital skills, the prospect of generating additional electronic waste and increasing energy consumption. Echoing this concern, a World Bank report emphasized that appropriate technological solutions to tackling waste may not be the newest or most advanced, depending on context.[45] This is important given that 90 per cent of solid waste is openly dumped or burned in low-income countries, and worldwide 33 per cent of municipal waste is not managed in an environmentally safe way, partly due to the high cost of waste management.[46]

Similarly, the availability of affordable technological solutions to tackle the growing problem of water scarcity and sanitation is a recognized challenge. There are some noteworthy case studies that demonstrate how technology can be applied in resource-poor settings, thus providing clean and affordable water to local communities.[47] Here again, increasingly several technologies interact, with digital overlays adding remote sensing and smart metering capabilities. The trend is towards more small-grid and hybrid-grid water management systems aimed at increasing efficiency and resilience.[48]

Figure 9.3: Five technological innovations that will shape the future of waste management



	ROBOTICS	ARTIFICIAL INTELLIGENCE AND NEURAL NETWORKS	INTERNET OF THINGS	CLOUD COMPUTING	DATA ANALYTICS
PROCESS	Advancements in the pneumatic sorting process as a result of autimation technology allow producing defined waste streams of high purity (over 90%)	Machine learning-using neural networks based on the use of data or examples to solve problems without explicit programming-is used for classification and pattern recognition in the waste management context, improving the efficiency of sorting.	As more and more devices are connected to the internet or other networks,sensor supported containers can collect data and transfer it to central units.	Storing and processing of sensor data and cloud based software solutions make it easy to optimize workflowsw and document failure to collect,failure in sorting or detect waste bins that are not paid for.	Storing and processing of sensor data and cloud based software solutions make it easy to optimize workflowsw and document failure to collect,failure in sorting or detect waste bins that are not paid for.
EXAMPLES	Robots that are able to identify and sort recyclables and critical materials through image recognition/IR scanning/AI vision systems when dismantling used phones/electronics.	Autonomous,self-driving street sweepers,refuse trucks	Smart waste bins with identification systems,weighing systems,level sensors,software for optimizing logistics	Cloud based software for: - Connection,standardizing and optimizing internal procedures. - Real-time order management route planning and optimization,customer self-service,order tracking and evaluation.	- Electronically supported disposition of waste collection vehicles. - Evaluation of sensor data for automated sorting plans. - Control of waste incineration plants - Drone based data collection on landfills.

Source: EEA, 2021b.

9.2.3. Flexible and modular designs

Concomitant with a focus on small-scale, localized approaches, technological innovations are increasingly characterized by flexible and modular designs. A case in point is mobile air quality monitoring, in response to the worldwide problem of urban air pollution which afflicts 9 out of 10 people on a daily basis.[49] The example of Breathe London, a recent pilot study undertaken by the Environmental Defense Fund, demonstrates the feasibility and flexibility of lower-cost and more portable monitoring using sensor pods, as alternative to more costly traditional environmental monitoring technology.[50] The approach is particularly suitable for generating high granularity of data for targeted, hyper-local action, such as dealing with pollution hotspots, and measuring the impacts of intervention. The underlying technological approach has been made available as a blueprint for use in other cities.[51]

Modularity and flexibility are also characteristic of new approaches to urban transportation. Enabled by technological innovations, including electric and connected autonomous vehicles, the future of urban transport will be more multimodal with emphasis on mobility-as-a-service (on-demand ridehailing and car-sharing), micro-mobility (e-scooters, e-bikes and e-light freight vehicles), last-mile and last-minute delivery (drones and robots), and active travel (walking and cycling). This will require both integrated physical infrastructure and interconnected transport management systems. It will also require attention to multiple aims, including reducing air/noise pollution, increasing safety and improving congestion.[52]

9.2.4. On-the-ground partnerships

If a key feature of future urban technologies is small-scale designs and local adaptability, then the need for on-the-ground partnerships becomes apparent. One such example comes from Norway, where 11 towns making up the Rogland region teamed up to upgrade street and park lighting using LED technology.[53] Rather than opting for outsourcing, the project was developed by an industrial company owned by the municipalities, and it is based on an open system design to allow for future IoT functionalities to be added. It resulted in the installation of 18,000 LED lighting poles that are interlinked via a central management system. Elsewhere, the need for cooperation is also critical to achieving more sustainable building design and operations. Buildings contribute an estimated 37 per cent of global CO_2 emissions and account for 36 per cent of global energy consumption.[54] Approximately one-third of emissions stems from construction activities and two-thirds relate to building operations. These sources highlight the importance of applying life-cycle assessment to the building sector: design, planning, construction, operation, renovation and demolition. Apart from environmental technologies (e.g. active and passive solar power; recycled materials for insulation; green roofs), smart technologies are used for building operation as well as to optimize energy efficiency and monitor performance. This essentially requires the active involvement of, and cooperation from, building operations managers and users, whether residents or commercial tenants.

Digital technologies can be used to enhance collaborative planning and decision-making (Chapter 6). Municipal governments and other urban actors have access to growing amounts of large-scale and high-resolution data harvested from diverse sources, including from distributed sensors, closed-circuit television cameras and social media. Digital twin technology is increasingly used in urban design and planning. Geographic digital twins are virtual representations of urban objects at various scales. As digital counterparts of the urban fabric, they can be used as planning tools, by providing diagnostic and prognostic analysis and enabling model-making. The technology, however, is dependent on the completeness and accuracy of the digital thread, the underlying data-driven architecture.

While recognizing the limits of technological sovereignty, city governments have an opportunity to pursue an active role in setting the technological agenda for urban futures. In doing so, the focus should be on supporting technological development and finding technological solutions that are attuned to local conditions, tackle pressing urban challenges, and are socio-economically and culturally inclusive. Cities need to be prepared for, and actively address, technological advances and their likely impacts, such as those arising from automation and digitalization, as the following sections sets out.

9.3. Automation, Digitalization and the Future of Work

According to the World Economic Forum (WEF), by the year 2025, machines will equal humans in terms of time spent on tasks at work.[55] Automation, alongside digitalization and new hybrid forms of work, are expected to transform established modes of labour and employment and, consequently, change urban economies. Digital platforms, for example, create new digital-urban connections with visible impacts on streetscapes and urban trade and services. The COVID-19 pandemic has accelerated these emergent transformations. The WEF report aptly speaks of a "double disruption" confronting the world of work: one caused by connected and digital technologies; the other by the pandemic rupture. City governments, as policymakers, regulators and employers, have a stake in the discussion about how technological innovation should shape the future of work and knowledge-based urban development.

City governments, as policymakers, regulators and employers, have a stake in the discussion about how technological innovation should shape the future of work

9.3.1. Transformations across formal and informal economies

The future of work, in the form of the ubiquitous use of connected and digital technologies, has already arrived for a large proportion of the white-collar workforce.[56] Many public and private sector organizations routinely use cloud computing and big data analytics while consumer-oriented businesses have increasingly embraced e-commerce. Algorithmic management, which relies on data collection and surveillance technology to remotely track and manage workforces, is becoming more commonplace, especially in developed countries.[57]

In emerging and developing countries, the evidence of the impact of digitalization is not yet conclusive, according to the German Agency for International Cooperation (GIZ).[58]

Box 9.2: Digital microwork in an informal settlement in Windhoek

Microwork platforms have attracted growing interest as a promising tool to support work in the informal economy and in areas of high unemployment. They give users access to various short-term Internet-based microtasks, such as transcribing short texts, moderating content and tagging images. Work can be carried out one task at a time from home, thus offering flexibility and remote access. In an experiment on the outskirts of Windhoek, researchers designed a simulation of a range of microtasks for which payment was made.

The aim was to find out what livelihood assets are needed to allow people to pursue microwork, and whether doing so results in improved livelihood outcomes. Volunteers were given training to act as technology mediators so that they themselves could train and support their community. The project concluded that several conditions had to be met for microwork to be a viable option, including: English language skills and digital literacy; physical access to electricity and the Internet; email and bank account ownership; and financial means to pay platform membership fees.

Source: Keskinen et al, 2021.

It cites evidence from five Association of Southeast Asian Nations (ASEAN) countries showing that, in the formal economy, up to 56 per cent of jobs are threatened by digitalization and automation. Corresponding data on the informal economy are more difficult to come by because it is expansive and diversified, encompassing an estimated 2 billion workers across the Global South.[59] Nevertheless, GIZ highlights employment opportunities in the platform economy,[60] and improvements in productivity flowing from technological innovation.

For the G20 intergovernmental forum, digitalization offers an unprecedented opportunity for self-employed individuals as well as small and medium enterprises.[61] Connected and digital technologies can facilitate access to financial services, seen as critical for supporting inclusive and sustainable development. The G20 policy guide highlights the scale of the task, since 1.7 billion adults worldwide lack access to a basic bank or mobile money account. Particularly, women should benefit from digital connectivity, since they make up the largest group across different sectors within the informal economy.

An example of the importance of digital tools for female entrepreneurship is reported in a case study of informal markets in Ghana.[62] There, ICTs, and in particular mobile phones, form an essential part of women's trading practices, providing access to banking services and information on farm pricing, as well as supporting multiple social networks which are central to managing their micro-enterprises. In Namibia, where well over 50 per cent of the work takes place in the informal economy, the benefits of microwork were explored in a community-based experiment in Windhoek (Box 9.2).[63]

Digital labour platforms epitomize the advancing digitalization across formal and informal economies. They exhibit a strong urban dimension: platforms benefit from high population density and spatial proximity between platform users and workers.[64] This dynamic is so significant that captured by the term platform urbanism'.[65] City governments themselves often become involved, for example in an oversight and regulatory capacity to provide licenses to drivers and food safety certificates to restaurants. Indeed, some city governments have participated in legal challenges, for example to force ride-hailing platforms to be treated as transportation companies rather than merely as technology enterprises.[66]

Yet, there are growing concerns that digital labour platforms create a precarious class of underpaid urban workers with little social protection.[67] Research in South-Eastern Asia and Sub-Saharan Africa has shown that platform work can result in irregular worktime, overwork, sleep deprivation, and social isolation, apart from generating low pay.[68] Of particular worry for cities must be the prospect of increased inequality between a growing group of precarious platform workers and a high-income class of residents.[69] These concerns, however, have to be set against the attractiveness—typically emphasized by platform workers themselves—of flexibility, autonomy, additional income and low-entry barriers to urban labour markets.[70]

There are growing concerns that digital labour platforms create a precarious class of underpaid urban workers with little social protection

9.3.2. Advancing automation in cities

Alongside digital transformations, the substitution of human workers with technology is advancing rapidly. In developing countries, two-thirds of jobs could be automated, particularly in formal economies where wages and rates of technological adaptation are high.[71] Similar trends can be observed in developed countries. In the US, up to 47 per cent of employment is estimated to be at risk of automation, particularly affecting jobs in the services and administrative sectors.[72] In the UK, following the example of multinational technology company Amazon, two major national supermarket chains began trialing automation technology in 2021, including camera surveillance and automated billing, that would dispense with retail staff. In municipal service provision, automation plays a growing role. For example, chatbots or virtual agents increasingly replace municipal staff, such as in Helsinki, Finland, where chatbots help process residents' parking permit applications.[73] Another area of application is waste collection based on automated air suction systems and underground pipes.[74] The city of Yavne, Israel, boasts one of the world's most advanced automated waste collection systems, covering homes, schools and public bins.[75] In urban public transport, driverless buses are rapidly becoming common features, such as in Malaga, Spain, and Wuxi, China.[76]

9.3.4. Beyond the pandemic: scenarios for the future of urban work

The COVID-19 pandemic will likely have a lasting effect on the world of work by accelerating automation and digitalization. The need for social distancing hastened the introduction of self-service customer kiosks and the use of service robots in customer interaction areas.[77] Additionally, the pandemic also changed the spatiality of work from the predominant physical mode of work fixed in one place to flexible, hybrid work practices. Despite the difficulty of predicting the winners and losers among cities of the pandemic's long-term effects,[78] it is possible to consider at several scenarios for the future of work and urban development.

In developing countries, two-thirds of jobs could be automated, particularly in formal economies where wages and rates of technological adaptation are high

The double disruption, as described by the World Economic Forum, is likely to continue to reshape the labour market. The International Labour Organization emphasized the likely further increase in inequalities between low- and high-paid workers arising from the type of job losses generated by the pandemic.[79] This will necessarily lead to changes in the mix of occupations and, therefore, require retraining and upskilling.[80] Changes in the retail sector may be particularly pronounced. The high street "retail apocalypse,"[81] already underway before the pandemic, is likely going to make more jobs in large service sectors obsolete. The increase in online retail from 16 per cent of total sales pre-pandemic to 19 per cent globally is likely to accelerate further.[82] The McKinsey Global Institute highlights the need for preparedness for changes in the mix of occupations: it estimates that 25 per cent of workers will need to switch occupations, with jobs in warehousing and transportation increasing, while those in customer-facing sales falling. On their part, digital platforms can be expected to grow and diversify which, while providing work opportunities across developing and developed economies, may add to the precarity of workers.

The COVID-19 pandemic will likely have a lasting effect on the world of work by accelerating automation and digitalization

The enforced lockdowns and subsequent sudden shift to remote working resulted in an abrupt decrease in transportation, coupled with a reduction in air pollution and greenhouse gas emissions (Chapter 6).[83] This led some to predict that new modes of hybrid working will have positive environmental externalities.[84] However, recent evidence points to a rebound effect, as more people switched from public transport to private car use since social distancing is easier to maintain.[85] In addition, growing demand for online shopping and last-mile delivery have led to an increase in road traffic.[86] City administrations, thus, need to analyze how these trends may require investment in sustainable micro-mobility solutions.

As remote and hybrid working practices allow people to live and work at greater distance from urban centers where offices and headquarters are concentrated, smaller cities and suburban areas may benefit relative to larger ones.[87] However, this depends on the availability of suitable infrastructure such as broadband coverage and co-working spaces. Indeed, smaller cities and suburban areas may use the opportunity of the pandemic to invest in urban improvements to increase their attractiveness to footloose remote workers.

Yet, according to a US study, smaller cities may also be expected to experience negative long-term consequences, as they are home to a larger proportion of jobs that can be automated, thus leading to job losses.[88] By the same analysis, large cities may be less affected, given the concentration of highly skilled technical and managerial professions that are less prone to automation. Other research on European and Northern American urban economies predicts a more polarized scenario among large cities, depending on the economic specialization and skillsets of local workforces: cities with higher shares of jobs considered low-skilled (such as in certain service sectors) or high-skilled (for example in biosciences and engineering) may enjoy greater resilience, while those with large medium-skilled workforces (such as in manufacturing or administration) could face high unemployment.[89] The various options for city governments to enhance the attractiveness of locations for businesses and workers include tax incentives and making targeted infrastructure investments.[90]

9.3.5. City-level initiatives to prepare for the future of work

While the implications of the pandemic's double disruption for urban development are yet to crystallize fully, cities would be well advised to prepare urban workers for potential negative impacts. For example, Calgary promotes the reskilling of residents through a dedicated technological skills development programme, in response to the decline of its traditional fossil fuel industries.[91] The government of Singapore offers SkillsFuture, a retraining programme that consists of short modular courses in emerging areas, such as advanced manufacturing, data analytics and urban solutions.[92] Citizens each receive an allowance of SG$500 to sign up for a SkillsFuture course, with more than 431,000 Singaporeans benefitting to date.[93]

Basic income trials are another possible policy intervention, by providing an unconditional monthly income to alleviate the need to engage in precarious and short-term work. For instance, the city of Stockton in the US undertook a two-year trial by offering a selected group of low-income residents a monthly basic income of US$500, which resulted in lower unemployment and improved well-being (Chapter 1).[94] In Madrid, workers have set up platform cooperatives in response to the rise of corporately-owned digital labour platforms. Owned and run by workers, the cooperatives aim to offer better working conditions than established platforms by providing regular pay and paid leave.[95] Despite the uncertainties surrounding the pandemic's long-term effects, cities have several tools at their disposal to manage the economic and social effects of digitalization and automation and to support their citizens' participation in the knowledge-based economy.

9.4. Cities' Responses to Digital and Environmental Divides

The COVID-19 pandemic demonstrated the opportunities afforded by digital technologies which allowed society to adapt quickly to remote online working, education, health care, retail and entertainment. At the same time, the pandemic revealed that a lack of access to smart technology could exacerbate existing socio-economic inequalities. For instance, in New York access to technology emerged as a fundamental determinant of access to health and social care.[96] Residents on lower incomes, from ethnic minorities, the elderly and immigrants, had significantly lower access to broadband and the Internet than the average population, coupled with lower digital literacy.

This is an example of the digital divide, which not only highlights the challenge that some may benefit more from technological innovations than others but, worse, that the introduction of new technology can further entrench existing socio-economic and cultural disparities, as UN-Habitat has repeatedly highlighted.[97] If, therefore, the aim of urban development as stated in the New Urban Agenda[98] is to promote inclusivity and ensure that all inhabitants have access to various urban services, then active steps need to be taken to avoid technological innovations having adverse effects. This similarly applies to environmental technologies, where the risk of "eco-gentrification" and the emergence of a "climate precariat" are well recognized.[99]

Technological divides are not a problem exclusively for cities in the developing world. Cities in the developed world are also confronted with the challenge of addressing digital and environmental divides among their populations. This section seeks to highlight how various cities (and countries) have responded to the challenge with initiatives aimed at making the applications of technological innovations more inclusive.

9.4.1. Approaches to digital inclusion

The digital divide is more than physical access to digital infrastructure, including broadband and the Internet.[100] It encompasses the affordability of smart technology, the skills required for digital literacy, and whether digital engagement translates into new opportunities, such as employment, education, and social and cultural engagement:

- Access consists of two aspects: the availability of digital infrastructures and digital tools and the affordability of using digital services. The former highlights that digital infrastructure may be unevenly distributed across urban space, with gaps in broadband coverage which, therefore, puts underserved communities at a disadvantage. The latter highlights that, even where physical access is available, there may still be a barrier to accessing digital services on cost grounds. Figure 9.4 shows how even in a city like New York, many households are without internet. Expanding the spatial reach of digital infrastructure is seen as the most fundamental requirement to counteract the digital divide.[101] Improving physical access to digital infrastructure alone will not suffice; questions related to affordability, skills development and the productive use of digital tools for economic activity need to be addressed. Still, physical access remains important: in developing countries, in 2018, about 40–42 per cent of people had access to the Internet compared to 70–98 per cent in developed countries.[102]

- Skills: Even if everyone had physical access to digital tools, inequalities would remain if potential users lacked digital literacy to use digital services and create their own content. This is one of the main challenges identified in the UN-Habitat playbook People-Centered Smart City.[103] This framework points to the importance of skills training. Evidence shows significant inequalities concerning digital literacy and skills afflicting particular social groups. For example, research shows that age, income and level of education were important determinants of people's ability to access and use ICTs in Barcelona.[104] In Magelang, Indonesia, the gulf between digital haves and digital have-nots has widened with over one-third of the city's poor having no access to mobile phones. Additionally, they did not have the skills for advanced use, such as logging on, conducting online searches and retrieving information.[105]

- More recent research has focused on the outcomes of computer and Internet use in terms of who is benefitting, and in what way.[106] This research shows that those on the right side of the digital divide (young, male, well-educated, employed) generally report more positive outcomes economically, socially, politically and culturally, and are better at coping with the negative aspects of Internet use, such as cybercrime, disinformation, and online addiction. For those on the wrong side of the divide (older persons, female, those with low-level education and occupation), the situation is reversed. In least-developed countries the uptake of digital technologies for production, rather than mere consumption, still lags significantly behind more developed countries.[107]

Examples of the digital divide from across the world, as well as initiatives that seek to enahnce digital inclusion are presented in Table 9.1. Concerning the former, not only is there compelling evidence of the urban poor being disproportionally affected, as exemplified by the case of Magelang, but there is also a strong gender factor at play: across low- and middle-income countries, women are 20 per cent less likely than men to use mobile Internet, according to the United Nations Conference on Trade and Development (UNCTAD).[108] Research on Indian urban slums revealed in more detail that women in poor settings are disproportionally affected by a lack of Internet access, not owning an access device (mobile phones, computer), and not knowing how to send text messages.[109]

Another study from India highlighted the digital marginalization of elderly people, who experience multiple barriers to using digital services, including difficulty in understanding technical instructions, concerns over cyber security, and a lack of supportive learning environment.[110] A case study of Dar es Salaam found that a change in mobile phone regulations (mandatory registration of SIM cards) disproportionally affected those living in informal settlements by disrupting users' informal financial transaction methods, with detrimental effects on their livelihoods.[111] Elsewhere, research on Internet exclusion in Santiago and Medellín revealed that households who could afford Internet access and had the necessary user skills nevertheless experienced exclusion for want of sufficient digital infrastructure.[112] This study points to network disadvantage that is institutionally generated. Altogether, these studies highlight the complexity of digital exclusion, requiring urban actors to consider multiple levels of intervention to provide redress.

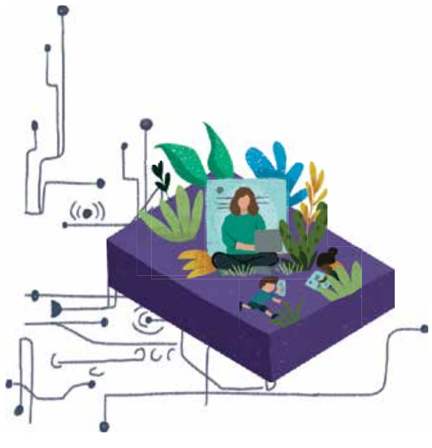
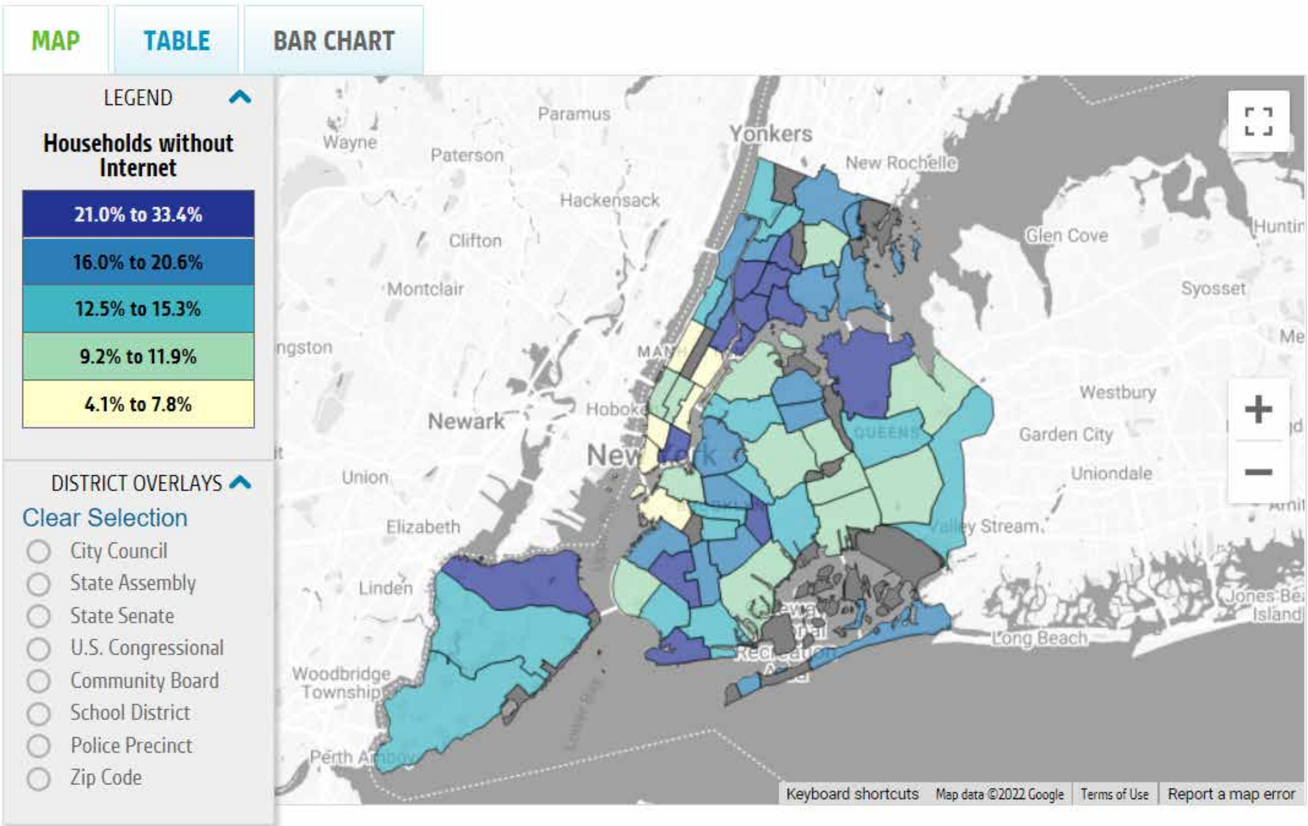


Figure 9.4: Map of New York showing households without internet access: with concentration in the less affluent parts of the Bronx, Queens and Brooklyn



Source: Citizens' Committee for Children of New York, 2019.

Table 9.1: Examples of the digital divide and approaches to digital inclusion

Examples of digital divide	Examples of digital inclusion
Still growing gap between developed and developing countries concerning physical access to the Internet[113]	Nigeria/Senegal/Tanzania: access to, and use of, digital technology to improve labour force participation, thus reducing poverty[114]
Magelang: large proportion of urban poor unable to execute basic tasks on their phones[115]	Johannesburg: short training sessions close to public Wi-Fi points[116]
Indian informal settlements: women less likely to own mobile phones, have Internet access and digital skills than men[117]	Cities Coalition for Digital Rights: a coalition of 45 cities around the world committing to the provision of affordable Internet and improvement of digital literacy of urban dwellers[118]
Santiago and Medellín: sparse Internet access even if households could afford it[119]	Chattanooga, US: citywide Internet coverage provided by the municipality[120]

In terms of the measures to improve digital inclusion, a World Bank study covering Nigeria, Senegal and Tanzania showed that both Internet availability and the use of more sophisticated digital technologies led to more and better jobs for lower-income, lower-skilled people.[121] Labour force participation and wage employment increased significantly after three years in areas where Internet access had been introduced. The importance of skills training was recognized in a smart city project in Johannesburg: in addition to rolling out free Wi-Fi access points near public hospitals, libraries and along public transport routes across the city, 85 trained Jozi Digital Ambassadors were deployed over a three-month period to train and enroll residents in Internet use.

In North America, several cities have sought to overcome the digital divide.[122] For instance, in Chattanooga, US, the city took the lead in installing a citywide fiber network through its own municipal electricity utility company, thus providing affordable gigabit speed to previously underserved communities. During COVID-19, low-income students were granted free Internet access to enable them to participate in online learning. The initiative also helped the city attract new investment, with many tech companies choosing to locate there. Box 9.3 shows how the Toronto is bridging the digital divide, which creates significant barriers for the most vulnerable and marginalized residents in accessing vital services and supports.[123] Apart from these examples, urban actors seeking to access knowledge and guidance on how to facilitate digital inclusion may find the declaration of the Cities Coalition for Digital Rights, agreed between 45 cities, a useful resource.[124]

Box 9.3: Bridging the digital divide in Toronto

All of Toronto has access to some form of Internet coverage, yet not everyone is able to afford quality access due to high prices. As of 2020, 39 per cent of the city's residents did not have Internet speeds that met the standards of the Canadian Radio-television and Telecommunications Commission. This was due to either poor infrastructure or inability to afford quality service. Over one-third of Toronto households indicated that they were able to afford high-quality Internet only at the expense of other purchases like food or clothing. Canada has among the most expensive Internet costs globally; even high-income households tend to spend at least 9 per cent of their income on expenses related to Internet connectivity. Over half of the people surveyed by the Toronto Public Library indicated that the public library was the only source of Internet access.

This digital divide creates significant barriers for Toronto's most vulnerable and marginalized residents in accessing vital services and supports. Residents without consistent internet access cannot access information, resources, supports, educational tools and social platforms to stay connected. Businesses trying to compete in a digital-first world are set back by insufficient Internet access and are unable to have staff effectively work from home.

To address the digital divide and Internet affordability issue, the Toronto undertook several pilot projects:

- 25 residential tower apartments were planned to be connected to free Internet for a year, covering 13,000 residents
- Public Wi-Fi in shelter sites
- Distribution of 400 connectivity kits that include a laptop and an Internet receiver
- Donation of 5000 smartphones to indigenous populations, each with six months of free data and calls
- Free Wi-Fi access expanded in parks and recreational areas

In early 2021, the government concluded that the measures taken were effective, but hardly scalable and not economically sustainable. A more ambitious programme, ConnectTO, was therefore initiated as a city-driven collaborative programme that aims to leverage the use of municipal resources and assets to help bridge the increasing digital divide by expanding access to affordable, high-speed Internet to underserved Toronto residents.

ConnectTO also aims to streamline and update existing city processes to ensure Internet connectivity planning, such as installing public Wi-Fi and laying fibre conduits in existing construction work, is embedded in the planning and execution of various city initiatives moving forward. ConnectTO recommends a phased delivery to effectively build the proper foundation for citywide deployment.

Access to reliable and affordable internet improves socioeconomic opportunities and access to city services for equity-seeking groups and vulnerable populations, nurtures innovation, stimulates Toronto's economic recovery and growth by enabling the digital economy, supports the city's long-term fiscal health by creating valuable city assets, and contributes long-term benefits related to the COVID-19 recovery plan.

Source: UN Habitat, 2021e.; City of Toronto, 2021.

9.4.2. Avoiding eco-gentrification

Eco-gentrification is the process by which urban greening raises property values and drives out existing residents. Like the digital divide, the environmental divide can be considered in terms of the three criteria of access, skills, and outcomes: which urban population groups in which cities have access to environmental technological solutions; whether they have the requisite skills to make use of these; and whether the outcomes such as reduced air pollution, low-carbon infrastructure benefit them equally.

Cities' efforts to mitigate and adapt to climate change can exacerbate processes of exclusion: the climate privileged benefit from low-carbon investments, green infrastructure and amenities; whereas for the climate precariat, climate action may result in rising housing and living costs.[125] Thus, urban climate policies may produce a distinct form of gentrification, with middle- and upper-income residents making choices that afford them access to low-carbon infrastructure and favourable mixed-use neighborhoods.[126] Similar dynamics will be at work between cities, with some disadvantaged by a lack of resources to deploy environmental technologies, and others able to address the climate crisis by using environmental innovation to render their cities more prosperous and livable places. A further problematic dynamic between cities across global regions arises from the shipment of technological waste to far-away places. A case in point is Agboloshie in Accra, one of the world's largest sites of electronic waste dumping, including a growing number of electric vehicle batteries.[127] Low-income residents in that area bear the toxic burden of the low-carbon transition accelerating elsewhere.

Urban actors need to be aware of the convergence of green and smart technological innovations, and how this potentially multiplies technological divides. A study of the social effects of eco-innovation in smart city projects in the city region of Milan shows that certain social groups were not only disadvantaged due to the eco-gentrification effect, but were also excluded due to a lack of digital literacy.[128]

The primary motive for addressing digital, environmental and other divides caused by technological urbanism is evidently to prevent new inequalities from arising and existing ones being further exacerbated. Beyond this, the effort to bridge these divides should yield wider economic, social, and environmental benefits. Enabling digital technology positively enhances labour force participation and, thus, reduces poverty.[129]

9.5. Technological Tools for Inclusive Governance

In a World Bank report on citizen-driven innovation in cities, the term Government 2.0 denotes an advanced mode of municipal government where citizens, developers, city administrations and other actors form partnerships to deliver improved, transparent public services.[130] This thinking reflects a growing trend in policy and practice that emphasizes the benefits of involving citizens and stakeholders in local government. ICT and digital technologies are considered important enablers of more inclusive policy- and decision-making. Consequently, many cities have put in place various e-government initiatives. While some follow a more conventional approach consisting of one-way communication to service users, others pursue more interactive, multi-stakeholder engagement as part of a drive towards participatory e-governance (Chapter 8). Significantly, ICT and digital tools are also increasingly used to create opportunities for public participation beyond municipal government: civic engagement, e-government and newer concepts like "community technology making."

Technology, however, is no panacea: the potential of technology-enabled participation depends on the suitability of technological tools and techniques in particular contexts. Furthermore, public engagement initiatives risk being empty exercises, unless they are properly related to policy and decision processes, and are supported with relevant skills training to allow participants to engage properly.

The potential of technology-enabled participation depends on the suitability of technological tools and techniques in particular contexts

9.5.1. Beyond the basics of e-government

E-government is typically considered at the national level, but its relevance is felt at the municipal level.[131] People often have a invested interest in what happens in their local communities, and local governments deal directly with issues affecting residents' daily lives. Findings from a global survey of 100 cities found that fewer than half had advanced e-government practices, such as deliberative forums, consultations and polls. Instead, most portals heavily relied on social media networks, such as YouTube, Facebook and Twitter.[132] Cities need to embrace a more comprehensive e-government vision and strategy, coupled with sufficient financial investment. A commitment to

Figure 9.5: City dashboard Bandung, Indonesia

Source: City of Bandung, 2022.

the use of open data, and attention to data quality and interoperability, are necessary stepping stones to realizing broader collaboration.[133]

City dashboards showcase the potential of ICT to increase transparency in municipalities. As city administrations gather and process increasing amounts of diverse data on urban environmental and socioeconomic indicators, dashboards help to visualize and organize these data in accessible fashion.[134] Types of data presented include census data, data collected through citizens' mobile phones, and sensor-based measurements of noise or pollution, as exemplified by the city dashboard in Bandung, Indonesia (figure 9.5).[135] Yet, in order to ensure the usefulness of such visualization tools, digital and data literacy of residents needs to be promoted.[136]

There are numerous examples of cities deploying ICT and digital technologies creatively to enable residents and stakeholders to become actively engaged. For instance, the city government of Jakarta introduced QlueMyCity, a map-based integrated reporting and monitoring platform which utilizes citizen participation to identify problems across the city: citizens may report faulty streetlights, clogged drains, waste disposal issues and other infrastructure in need of repair (figure 9.6).[137] The mobile app subsequently displays information on how the problem was resolved, and allows for further feedback.

In the US, a study of public engagement platforms used by local governments identified several approaches to including residents, such as consulting them on proposed decision options, inviting them to make suggestions, and involving them directly in decision-making.[138] Examples include: IdeaScale (Atlanta), which lets participants submit ideas, comment as well as vote on them; and BudgetAllocator (Bayswater), used for participatory budgeting. The study also highlighted the interrelationship between these online platforms and offline consultation and engagement processes used by local governments. Communities that experiment with participatory digital platforms are typically ones that have a pre-existing commitment to, and a track-record of, citizen engagement. Mexico City is further example of the innovative use of technology to realize participatory e-government.[139]

9.5.2. Giving voice through civic engagement

Technology-based methods are also used for engagement activities within communities. One such approach is citizen science, which encourages ordinary people (non-experts) to participate in community-based research on relevant issues. The benefits are twofold: first, tapping into local knowledge, which can inform research and policy by contributing new insights; and second, strengthening the capabilities of individuals and communities. A practical example of citizen science, and the supportive role played by digital technology, stems from the city of Eskilstuna, Sweden (Box 9.4).

Figure 9.6: Screenshots from the QlueMyCity app, which utilizes citizen participation to identify problems across the city

Source: Civic Tech Field Guide, 2021.

Box 9.4: Marginalized youth as citizen scientists in Eskilstuna, Sweden

Eskilstuna is a mid-sized Swedish city home to several neighbourhoods where a majority of residents are foreign-born or have foreign backgrounds as refugees from wartorn countries like Somalia and Syria. In ethnically homogenous Sweden, these communities have struggled to integrate and their youth population have higher rates of criminal activity, including gang affiliation and drug trafficking, that have led these neighbourhoods to be stigmatized in the popular imagination. Researchers enlisted young men in two deprived neighborhoods to serve as citizens scientists, who would use a smartphone app to collect data about their neighbourhood and its residents. The aim was to engage young people to produce local knowledge about the experience and everyday challenges of living in marginalized communities. The rationale was that, as citizen scientists, the participating young people could generate unique knowledge by capturing their surroundings through pictures on their mobile phones and commenting on the significance of certain sites for their neighborhoods, knowledge that external researchers may otherwise not easily access. In turn, this could help overcome the gap between the external perceptions of these neighborhoods and the on-the-ground, lived experience of young people. Insights from this citizen science project were presented to residents and politicians from Eskilstuna's municipality at a public event.

Source: Fell et al, 2021

Citizen science projects are increasingly being used in the implementation and monitoring of the SDGs at the local level. Since the SDG indicators are officially reported at the national level, and municipal governments often do not have the required data to assess progress in achieving the SDGs, citizen science can offer a useful tool for producing localized data. A study of 139 citizen science projects on SDGs in developing countries noted that a strength of the approach is the ability to generate data using a wide range of methods in locations that are inaccessible with other methods.[140] Another strength was the opportunity to involve marginalized and hard-to-reach groups, thereby increasing their representation in datasets. However, there are several challenges, especially in the context of developing countries, such as low literacy levels; language barriers between organizers and participants; insufficient organizational capacity to run citizen science projects effectively; and poor infrastructure to support civic engagement.

Digital tools can enable inclusion and community-building among elderly population groups who often miss out on the benefits of digitalization. One example is the organization of

Digital tools can enable inclusion and community-building among elderly population groups who often miss out on the benefits of digitalization

digital games in Vancouver, where the participation of older citizens in a citywide virtual bowling tournament allowed them to partake in activities which they would otherwise not be able to join. Crucially, the digital game helped them build new social relations that continued after the tournament.[141] Another example of digitally-enabled civic engagement can be found in Berlin, where the grassroots GoVolunteer app facilitates participation in civic and social projects by listing over 1,800 volunteering opportunities.[142]

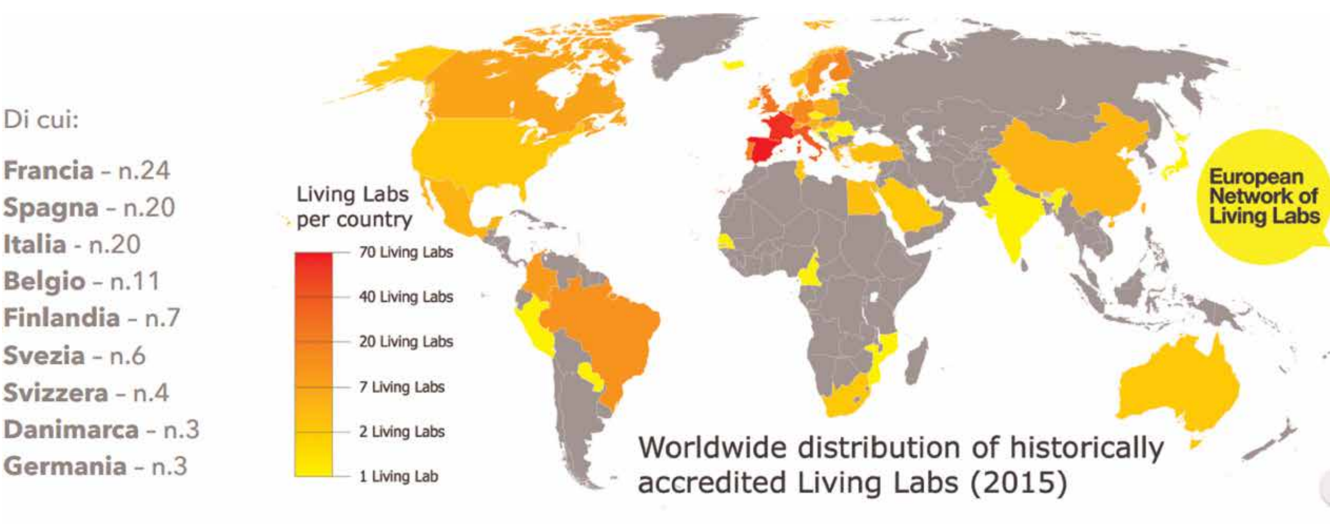
9.5.3. Community technology making

Public participation can also take the form of "community technology making," which involves residents creating their own digital or technological solutions to urban challenges. This concept covers a range of formats, including hackerspaces, makerlabs, hardware incubators and fixer collectives, all of which have in common the aspiration that better urban technologies and environments can be built by their users.[143] One example is Richmond MakerLabs in London, which describes itself as an inclusive "community workshop," and offers access to various technologies, including electronics, 3D printing and laser cutting.[144] "Urban living lab" is an umbrella term used for projects that seek to involve citizens in creating tools and applications. A review of urban living labs in four European cities identified several ways in which participating citizens got involved, including measuring local environmental data, testing smart products and developing technological devices to improve local services.[145] The European Network of Living Labs is the largest partnership of such urban labs and has extend its network globally (see figure 9.7). The study, however, identified as a relative weakness the exclusion of the participants from the wider governance of the smart city initiatives with which the living labs are associated.

A study of civic hackathons in European cities found that, unlike conventional hackathons which mainly cater to high-skilled software developers, these civic versions tend to include a demographically and socially more diverse set of local participants.[146] The main purpose of the hackathons studied was to involve citizens in analysing open data as a basis for informing how their neighbourhoods could be improved.

The question of who gets involved not just in hackathons, but also in other forms of shared technology making is critical, since too often they tend to attract predominantly male participants with pre-existing technical knowledge.[147] In response, some organizers actively seek to include a diverse range of participants, thereby promoting a greater equality of gender, race and class. This also opens up opportunities for alternative visions for, and approaches to, technology making in and hacking of the smart city.

Figure 9.7: Living Labs that are part of the European Network of living labs



Source: Battistoni et al, 2022.

9.6. Towards Responsible Innovation

The preceding sections demonstrate that innovation and technology harbour risks as well as benefits for cities. Frontier technologies often raise complex ethical, legal and planning issues. Automation is a case in point: while connected-and-autonomous vehicles (CAVs) promise to bring benefits to consumers and society at large, there are several technical, ethical, and legal barriers to their adoption in cities.[148] This includes legal challenges and ethical controversy concerning CAVs' independent decision-making on the distribution of harm between passengers and other road users, like pedestrians and cyclists, in the event of traffic accidents. A separate concern is the potential of mass surveillance arising from the technical necessity of continuous location tracking of CAVs. Another example is public unease caused by robots deployed to patrol anti-social behaviour, such as smoking in an unauthorized area or incorrect parking of bicycles, as recently illustrated in Singapore.[149] As discussed earlier, there are concerns that the automation of jobs will lead to a rise in urban unemployment and, consequently, exacerbate inequalities and strain social cohesion.

Cities, therefore, need to anticipate systemic changes and major impacts resulting from technological innovations and, importantly, be proactive about assessing and managing them. This should include addressing environmental externalities, such as resource depletion and habitat loss,

Electric vehicle Charging stations, New Delhi, India © Shutterstock

A responsible innovation approach should involve a wide range of urban stakeholders, including citizens, who can provide essential local knowledge and practice perspectives

as well as carefully considering negative socioeconomic impacts of new technology. To this end, "responsible innovation" offers a promising approach to engage a wide range of stakeholders in assessing the ethical acceptability and societal desirability of technological developments.[150] Responsible innovation has been defined in relation to cities as "a collective commitment of care for the urban futures through responsive stewardship of science, technology and innovation in the present."[151]

Responsible innovation goes beyond technology assessment focused on determining quantifiable risks and social impacts; it equally pays close attention to ethical questions and issues of moral ambiguity.[152] It also pays heed to the possibility of unintended consequences arising from digital technology developed for one purpose subsequently being used for other purposes (for example, if drones designed to monitor traffic were used to track individuals).[153] Consequently, a responsible innovation approach should involve a wide range of urban stakeholders, including citizens, who can provide essential local knowledge and practice perspectives. Such an approach should, therefore, also create spaces for the public scrutiny of the consequences of technological innovations.[154] An example of a collaborative approach to shape the future of urban technology is Flying High, which focused on drones in cities (Box 9.5).

Urban actors can now consult several frameworks for responsible innovation. The Montréal Declaration for Responsible Innovation of Artificial Intelligence, launched in 2018, provides urban actors with a set of underlying ethical principles and practical guidelines for accomplishing digital transitions.[155] Cities could also adopt a "technological sovereignty" approach as used by Barcelona in its Digital City Plan. Based on three principles—the use of free software; the interoperability of systems; and the use of open standards—Barcelona has attempted to lessen the dependence on global technology companies in its provision of digital services.[156] Importantly, responsible innovation raises essential questions about the social and environmental risks of urban frontier technologies and, conversely, how innovation and technology can be deployed inclusively and sustainably.

Box 9.5: Collaborative assessment of future drone technology in the UK

Flying High is an initiative run by the UK's National Endowment for Science, Technology and the Arts since 2017. It brought together city leaders, regulators, public services, businesses and industry in a dialogical process of exploring systemic requirements for integrating drones in cities. Five cities and metropolitan regions—Bradford, London, Preston, Southampton and West Midlands—were engaged to situate the technology assessment within real-world contexts. Among participants, there was strong support for future drone use where this provided clear social benefits, such as medical deliveries, support for fire and rescue services, and the monitoring of traffic incidents. Support for commercial uses, such as parcel delivery, was more muted.

The benefits were set against several significant concerns around safety, security and privacy, with agreement that an appropriate regulatory environment would need to be established to allow autonomous flight in large numbers and over long distances. Furthermore, regulation should be undergirded by a shared societal vision of what is, or is not, acceptable, for example relating to noise pollution, safety and commercialization. Tellingly, the assessment revealed that technology developers and regulators had not previously considered involving cities in the discussion, even though the application of drones is anticipated to be concentrated in urban areas and as flight in low-altitude airspace directly impacts urban environments.

Source: Nesta, 2018.

9.6.1. Mitigating digital risks

Cities need to consider distinct risks that may arise from digital transformations, like security vulnerabilities in smart city technologies.[157] Beyond technological threats, social and ethical challenges require careful consideration. One major concern is that fundamental human rights may be at stake as human activity is increasingly subjected to hyperconnectivity, datafication and algorithmization.[158] Threats to human rights can arise from digital surveillance, the power of dominant digital platforms and the increasing use of AI in decision processes. In response, the notion of "digital rights" has gained traction, in an effort to integrate the smart city and its technologies with ethical principles.[159] Four risks of digitalization are highlighted in Table 9.2, alongside examples of cities' responses.

Table 9.2: Four risks of digitalization, and examples of mitigation measures

Risks	Mitigation measures
Erosion of privacy: As highlighted by the United Nations Human Rights Council, digital innovations risk eroding privacy and related freedoms, including free movement and speech[160].	Hamburg data strategy mandates the anonymization and aggregation of data to ensure the protection of sensitive personal data.[161]
Biases of automated and AI-enabled processes: Software developed by tech firms has been found to discriminate against people of colour, ethnic groups, or religious minorities.[162]	Helsinki has begun to compile its own datasets for training AI-enabled services to avoid reliance on global software developers unfamiliar with the city's demographic composition.[163]
Threat of exclusion: Increasing reliance on algorithms can exclude citizens from decision-making processes, while digital and environmental divides can exclude urban dwellers from the benefits of innovation.	Medellín's smart city initiative Medellín Ciudad Inteligente complements Wi-Fi rollout in public parks and schools with digital literacy training for 10,000 residents per year, prioritizing those living in deprived neighbourhoods.[164]
Data misuse: Data can get processed and analyzed for other purposes than originally intended, such as facial and number plate recognition software used to surveil citizens' movements.	Portland defines and justifies clear targets that data collection shall support and collects only the minimum quantity of data necessary to fulfil those purposes.[165]

The four risks of digitalization may be heightened in developing countries and cities for three related reasons. First, automated and digital solutions designed in developed countries can exacerbate the risks of discrimination, bias and surveillance when the technology is applied in cities in developing countries. [166]Second, low- and middle-income countries may not have the necessary resources and institutions to redress inequalities arising from digital transformations, and to protect marginalized people's rights. Third, due to a comparably weak research and development base and limited resource capacities, they risk becoming technologically dependent on corporations from the Global North.[167] In order to understand the repercussions of digital innovations in cities in emerging economies, digital ethicists have suggested that bespoke impact assessments be carried out where technology developed in the Global North is to be deployed in the Global South.[168] Another recommendation is to trial new tools and processes first in specified districts in emerging cities, before scaling them up to the citywide level.[169]

9.6.2. Addressing environmental risks

The case for low-carbon technologies is by now well-established: they are essential for clean energy generation and for the decarbonization of urban infrastructure systems, such as transportation (Chapter 5). Yet, their associated environmental externalities, as well as potential health risks, should not be overlooked. In encouraging the adoption of low-carbon technologies, urban actors need to be aware of negative impacts and consider how to mitigate these. Several key risks are highlighted below, while Box 9.6 discusses innovative mitigation measures from the circular economy in both high- and low-tech contexts.

- Reliance on critical raw materials: According to the United Nations Environmental Programme's International Resource Panel, an estimated 600 metric tons of metal resources will be needed by 2050 to meet the demands of additional infrastructure and wiring.[170]

- Generation of toxic waste: Arises from both the production of low-carbon technologies such as semiconductors for photovoltaic solar panels, wind turbines and end-of-life decommissioning.[171] Toxic waste management disproportionally affects citizens' health in developing countries.[172]

- Adverse impacts on biodiversity: The electrification of transportation and the rollout of CAVs require new types of infrastructure, such as charging stations and vehicle depots, with the likely loss of habitat and increased urban sprawl.[173] Electrification should rely on electricity from clean sources.[174]

- Energy consumption of smart technology: There is a heightened risk of a rebound effect for ICTs, whereby energy-saving gains are cancelled out by growing consumption patterns.[175] For instance, the annual energy consumption of Bitcoin cryptocurrency is higher than that of Ireland, accounting for 0.5 per cent of global electricity demand in 2018. [176]

Box 9.6: Mitigation measures for environmental risks.

The circular economy offers a possible framework to address some of above-mentioned environmental risks by ensuring the responsible use of resources in cities and promoting sustainable innovation.[177] An example is the Park 20/20 office complex in Amsterdam, where, following the cradle-to-cradle concept, construction materials and green technology can be dismantled and fully repurposed at the end of a building's lifespan.[178] Elsewhere, the Togolese innovation laboratory WoeLab launched the HubCité project in the capital, Lomé, to demonstrate that the circular economy is neither confined to global cities nor contingent on large financial investments. By providing technological equipment and training through two innovation spaces, WoeLab encourages residents to create collaborative hyper-local urban projects and find low-tech solutions to challenges, including waste management and recycling, in their neighbourhoods.[179]

In order to ensure that innovation and technological development are not pursued just for their own sake, but rather in a socially responsible manner to enable sustainable urban development, a key question to ask is to what extent do urban technological innovations result in better outcomes for residents and the environment? Moreover, technology assessment should consider the distribution of benefits and costs to determine whether certain social groups and certain places benefit more, while others bear disproportionate risks.[180] This analysis matters for relations both within cities as well as between cities if the goal of urban technology is to engender equitable and just development.

9.7. Concluding Remarks and Lessons for Policy

The acceleration and convergence of various green and smart technological innovations are being widely witnessed in contemporary urban planning and development and are set to be a dominant force determining our urban futures. City governments and other urban stakeholders have an active role to play in deciding how innovation and technology are adapted in ways that suit specific urban contexts and benefit sustainable development. There are significant opportunities for localized approaches, given the trend towards flexible and modular technological innovations, as exemplified by micro-grid renewable energy systems and community digital platforms. At the same time, cities need to address systemic threats, such as the prospect of rising socioeconomic inequalities caused by automation and digitalization. Altogether, this highlights the need for ongoing social and institutional innovation to accompany technological developments, including investment in skills training and support for community partnerships.

The evidence presented in this chapter prompts seven key lessons for sustainable urban futures. These point to an overarching commitment to the inclusive deployment of technology for the well-being of citizens and the environment and emphasize the agency of cities as hosts, initiators and implementors of innovation and technology.

- City governments should utilize their convening power to foster a thriving innovation ecosystem and support locally embedded socio-technical development. This can be achieved with territorial planning, fiscal incentives and other measures to support the co-location of research organizations, start-ups, industry and social enterprises. Innovation should also be encouraged in the informal sector, mainly in developing countries, by recognizing and supporting informal entrepreneurs within the community.

- Cities embedded within wider regional and national innovation systems, can act as innovators and implement technology to steer sustainable urban development. This relates to both the delivery of public services and the development and management of various urban infrastructures. The example of the Rogland region in Norway, where 11 municipalities jointly developed an integrated LED street and park lighting system using their own industrial company, illustrates cities' role as innovators. It also demonstrates the benefits of cooperation and knowledge exchange among cities.

- The likelihood of new inequalities arising from technological developments, and existing ones becoming more entrenched, requires careful attention and active intervention. There is strong evidence of digital marginalization disproportionally affecting poor people, the undereducated, women and older persons, especially, though not exclusively in developing countries. Digital labour platforms, while offering accessible and flexible work, may expose workers to precarious conditions without some regulatory safety nets. Inequalities can also arise if environmental technologies unevenly benefit certain groups of residents and neighborhoods. Conversely, some urban communities are at greater risk of environmental harm caused by technology.

- Skills development and training have emerged as critical areas of action. This issue partly relates to the workforce in some formal sectors, where digitalization and especially automation are on course to make a growing number of tasks undertaken by humans redundant. Here, the example of Singapore demonstrates the opportunity for retraining and upskilling to allow workers to shift to jobs not at risk of automation. It also relates to the informal economy, where the provision of basic skills training and digital literacy are essential to enable people to use mobile Internet and microwork platforms. The deployment of digital ambassadors or technology mediators can prove useful to achieve strong community participation. Beyond work, digital skills training is essential to allow otherwise disenfranchised groups to benefit from digital services, such as telehealth care.

- Connected and digital technologies offer city governments a range of opportunities to improve openness and actively engage with residents. The evidence shows that e-government is too often used merely for one-way communication, though there are flourishing examples of cites using technology more innovatively, for example with interactive apps and online platforms that allow active citizen participation. Beyond city administrations, technology can be used to strengthen civic engagement and community technology making.

- Cities need to take into account negative environmental externalities when investing in various low carbon and ICT technologies. There is a significant risk of a rebound effect, whereby energy savings achieved by connected and digital technologies are cancelled out by increasing consumption. Additionally, there is particular concern about the energy intensive nature of blockchain technology, which is seen by many as integral to the next generation of smart cities.

- Finally, given the need to weigh benefits and risks of new technology, cities should commit to undertake a robust technology assessment relating to ethical, legal, social and environmental aspects. The example of aerial drones demonstrates both the complexities of issues raised and the importance of cities' involvement in assessing and regulating technological innovations.

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