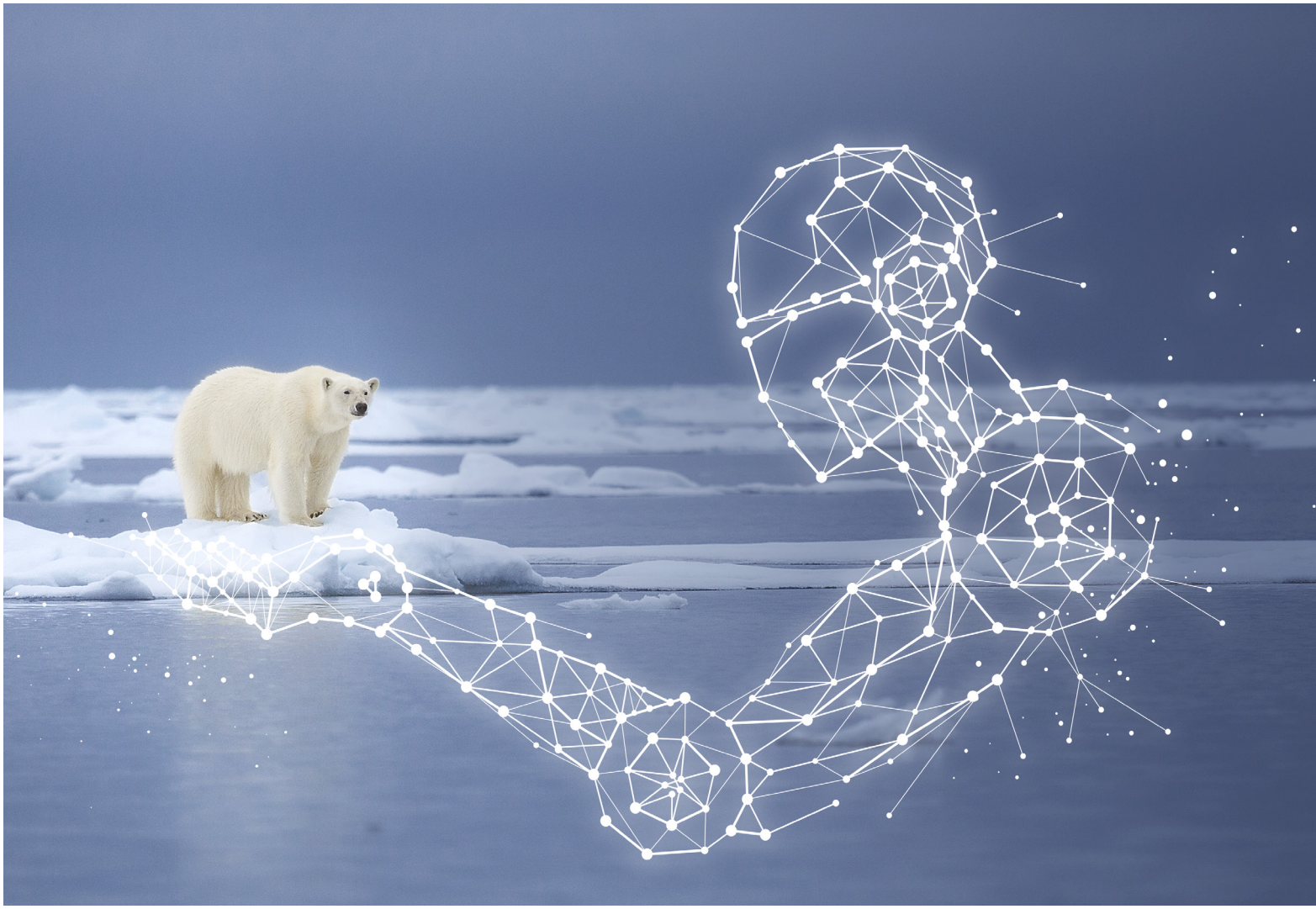
Executive Summary

Frontier technologies to protect the environment and tackle climate change



United Nations Educational, Scientific and Cultural Organization

UN environment
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United Nations Framework Convention on Climate Change

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Frontier technologies to protect the environment and tackle climate change

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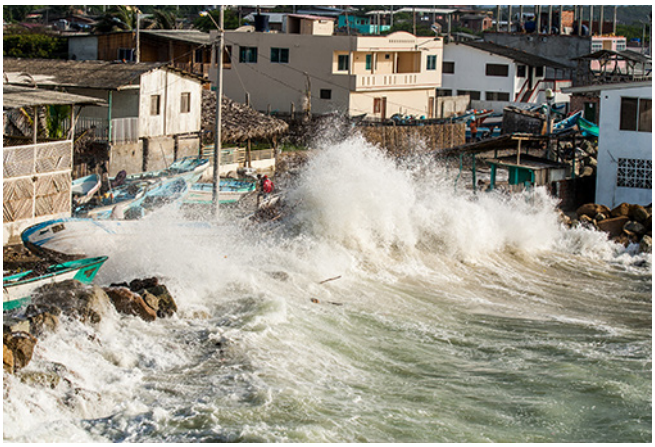
Catastrophic global climate change is not an event waiting to happen, it is the reality facing the world right now, today, and urgent action is needed to tackle it. Cutting-edge frontier technologies such as AI, clean energy, digital twin or robotics can help mitigate and combat these challenges, according to a recent UN report.



Across the planet, rising temperatures caused by global warning are giving rise to more frequent and severe weather-related phenomena such as heat waves, droughts, floods, rising sea levels, wildfires, hurricanes, tropical cyclones and heavy rain and snowfalls. Already vulnerable and poor population groups are likely to be those most affected. Growing urbanization is also set to exacerbate the ramifications of climate change, given that some 70 per cent of energy-related CO2 emissions are traceable back to cities. With high population concentrations, cities are also more at risk from the direct and indirect impacts of climate change, and bear most of their related costs such as dealing with negative health outcomes and population displacements.

Frontier technologies to protect the environment and tackle climate change, the latest report – developed by ITU together with United Nations Economic Commission for Europe (UNECE); United Nations Educational, Scientific and Cultural Organization (UNESCO); UN Environment; United Nations Framework Convention on Climate Change (UNFCCC); United Nations Global Compact; United Nations Industrial Development Organization (UNIDO); United Nations Human Settlements Programme (UN-Habitat); and United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women) – begins by exploring what is changing on our planet, why these changes are taking place, and who is most at risk as a result. It shows that catastrophic global climate change is already clearly underway and that urgent action is needed to help monitor, mitigate and adapt to its effects. Frontier technologies – new, innovative and disruptive technologies – offer tremendous potential for tackling climate change and meeting the goals of United Nations sustainable development goal (SDG) 13 (Climate Action).

The report spotlights eight key emerging technologies, each with the potential to be instrumental in tackling climate change: artificial intelligence (**AI**), Internet of Things (**IoT**), **5G**, **clean energy technology**, **digital twin**, **robotics**, **Space 2.0** technologies, as well as **digitalization and Big Data**.

It also takes us inside the United Nations system, with perspectives from ITU, UNECE, UNESCO, UN Environment, UNFCCC, UN Global Compact, UN Habitat, UNIDO and UN Women. It provides real-life case studies to explore how these innovative technologies are being used in areas as diverse and critical as smart cities, earth monitoring, natural disaster risk reduction, e-waste, and water and electricity management.

Frontier technology highlights

Reducing air pollution, hydrological risk or managing e-waste using AI

Biodiversity and conservation, ocean help, water security, smart cities, clean air and disaster risk are just some of the areas in which AI systems can address climate change. They can perform tasks in areas such as automated detection and monitoring, risk assessment and predictive analysis – improving the accuracy of climate change models, forecasting scenarios, optimizing energy and materials use, consumer awareness and behaviour 'nudging' towards sustainability – for example by helping calculate individual carbon footprints, as well as quality control of data. AI even has the potential to predict cloud formation; by resolving more complicated, smaller-scale atmospheric processes, such as the ones involved in convective cloud formation, it can help reduce this single biggest source of uncertainty in global climate models.

In cities, AI can help with route and traffic optimization, cutting waiting times, enabling better traffic flows, facilitating autonomous and ride-sharing services (in effect cutting the number of vehicles on roads and helping increase driver compliance with environmental regulations).

The report explores the case study of Moscow, where AI powered intelligent traffic control systems help monitor traffic through an extensive network of smart traffic lights, vehicle sensors and CCTV, controlling smart intersections and providing commuters with essential real-time information on traffic, weather and pollution conditions.

Further case studies illustrate the use of AI in quantum computing, potentially offering AI at unprecedented computing speeds. In Japan, AI is already helping to cut natural disaster risk, with a prototype tsunami alert including an automatically launched drone sending alerts using facial recognition software to identify victims. The UNESCO G-WADI (Water and Development Information for Arid Lands – a Global Network) Geoserver application helps manage and mitigate hydrological risk using artificial neural networks to estimate real-time precipitation worldwide, informing emergency planning and flood management, preparing flood or drought information bulletins, and tracking storms.

AI can also be applied to the waste sector, with innovations currently in operation across the globe including smart recycling using robotic waste sorters, intelligent trash cans using AI and IoT-enabled sensors to measure their contents and relay information to waste centres, or even sort the waste and decide what to do with it. It is clear that AI systems can help in many areas, although the report sounds a note of caution as there are still certain limitations that must be addressed in terms of carbon footprint and efficiency in order for AI reach its full potential.

Using IoT for smart energy infrastructure management to help reduce carbon dioxide and greenhouse gas emissions

Thanks to increasingly cost-effective IoT-enabled devices and systems, a multitude of new opportunities for gathering vital data have opened up, with the potential to be used in developed and developing countries alike.

From remote rural areas to the heart of busy cities, IoT sensors busily gather scientific data to help mitigate climate change and promote energy efficiency. The report explores some of the uses of IoT in the urban environment of Dubai, which uses a city-wide IoT network and some 200 000 smart meters to help save water and energy. Its Green Dubai initiative helps cut electricity and water usage, generate clean solar energy and encourage electric vehicle

use. In addition, the Dubai Carbon Abatement Strategy 2021 has specific greenhouse gas reduction targets for each sub-sector.

Combining IoT initiatives with other smart sustainable city initiatives, in addition to having a distinct IoT-related strategy are among the best ways to ensure the technologies are fully leveraged and deployed. Nevertheless, any transition to a fully energy-efficient economy will take time, and will entail fundamental economic and regulatory changes requiring the mobilization of different authorities.

5G for smart water supply management

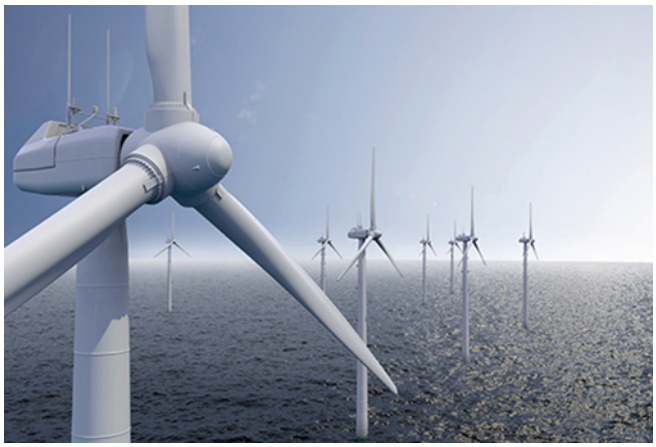
5G technology is the fifth generation of cellular networking technology. It is expected to offer faster speeds, less latency and more coverage, in addition to longer battery life, larger data-transfer capabilities, greater potential for cloud processing and improved overall reliability. In short, as well as increasing connectivity speed, it will also enable more types of devices to be connected, including vehicles, appliances and other IoT devices, across a huge range of different areas.

Taking the vital example of water availability, efficiency and conservation, 5G can enable smart, real-time monitoring of urban water supply systems and decreases in apparent and real water losses. The report examines Singapore's smart water grid and supply management system (WaterWise), which uses hundreds of sensors and data analytic tools to detect leaks and monitor water pressure, flow and quality in the network, helping to reduce unaccounted water loss and improve planning, operations and cost savings via energy optimization.

WaterWiSe relies on a generic wireless sensor network for online monitoring of the city's entire water distribution system, but 5G technology – which Singapore is due to roll out commercially in 2020 – offers value for integrated platforms such as WaterWiSe that are built to monitor in real-time.

Clean energy technology for renewable electricity generation to help reduce fossil fuel consumption

Clean energy technologies (often used synonymously with renewable energy technologies that enable the creation of electricity, heat and fuel from renewable sources such as solar wind or hydro) may have been around for some time, but their design and efficacy has evolved in recent decades. According to the report – which cites International Renewable Energy Agency (IRENA) Renewable Capacity Statistics 2019 – thanks to the growth in the use of solar and wind energy, renewable energy now accounts for a third of global power capacity. Solar, wind and clean battery technologies offer strong potential to address the challenges of climate change by cutting reliance on fossil fuels.



Further research, prototyping, development and deployment of clean energy technologies is needed for them to achieve their full potential. One practical way to do this would be to implement projects at the city level, then scale up to provincial, regional and national levels. Innovation-driven, public-private sector collaboration, on a regional and national level is crucial to help pilot and scale up clean energy projects. Areas of potential growth include offshore wind farming, which is explored in the report through a case study from the 659 MW Walney Extension project in Cumbria, UK. At a pivotal stage of innovation, and ripe for subsidies to help these innovations flourish, the offshore wind farming market offers great potential in terms of new construction prospects – such as deep water floating turbines – to create more cost-effective offshore energy.

Increasing environmental resilience and disaster risk planning with digital twin technology

A digital twin is a virtual model, replica or representation of a physical object, product, service, process, system or geographic location. Essentially a bridge between virtual and physical worlds, it helps analyse data, identifying and mitigating problems before they even occur as well as spotting future opportunities. Digital twin technology has now been extended to include entire systems such as large organizations or even cities.

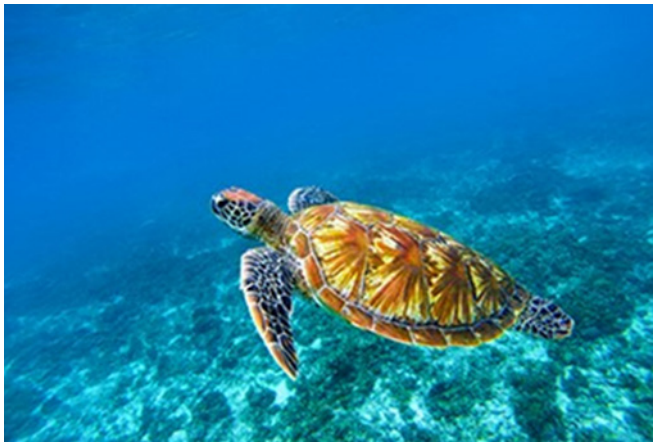
Recreating an entire city digitally involves overlaying a digital 'map' of the city with data from multiple sources – including buildings, infrastructure, flows, environment, and the way the city is used. In terms of climate change and response, digital twinning offers an ideal solution for cities that are growing rapidly in population, size and energy consumption terms and that need efficient management and maintenance of all their systems. Real-time data generated within a city feeds the relevant set of digital twin models to analyse the impacts of, for example, weather-related events to develop and test a set of appropriate action plans.

According to the report, spurred by an extreme rainstorm in 2012, the city of Newcastle, UK has become a frontrunner in the use of digital twin technology, recreating the city digitally to help planners stress-test the city's infrastructure. Sensors all over the city monitor indicators

such as pollution, water quality and biodiversity. It has enabled the city to prepare for future floods, simulating which buildings will be flooded, which infrastructure will need to be closed, and more.

Digital twinning could hold the key to improved disaster response in cities, although to best leverage this technology, cities will still need to define their approach, establish how the project will be managed end to end, facilitate the widespread adoption of the end results and be ready to engage in activities to help combat climate change.

Robotics for monitoring the impacts of climate change underwater, and observing marine life to help protect biodiversity



Programmable, autonomous or semi-autonomous and able to interact with the physical world via sensors and actuators, robots can be invaluable tools in tackling climate change. They can help reduce greenhouse emissions through monitoring and preventing their release, optimize energy consumption through precision manufacturing or eliminate product waste through more efficient use of raw materials. Another major advantage is the ability of robots to reach environments inaccessible to humans, from deep under the sea to high above rainforests.

With marine biodiversity particularly at risk, robotics could be key in helping monitor marine pollution and measure its impacts on marine bio-life. This has been the goal of bio-inspired robots, the 'Venus Swarm,' that have been tested in Venice to survey the MOSE system, which is intended to defend the Venetian Lagoon from high tide. The Swarm technology, consisting of several cooperative and coordinated robotic vehicles, has the potential help protect biodiversity in a host of other areas, too, from obtaining seabed data on acidification, salinity or direction of marine currents to monitoring oil platforms and managing migratory flows.

Monitoring ice sheets, ice caps, predicting sea-level rise and global weather patterns with Space 2.0 technologies

Satellite technology has, over the decades, provided unequivocal evidence of the changes taking place on Earth as a result of climate change. Cutting-edge satellite space 2.0 technologies (the successor to Space 1.0) are now being deployed to help obtain vital data which scientists hope will help improve uncertain forecasts for sea-level rises and better predict and understand global climate patterns.

The report gives a snapshot of NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2), which was launched in 2018. This is a spacecraft with a single major instrument, deploying an industrial size, hyper-precise altimeter, the Advanced Topographic Laser Altimeter System, a powerful green laser split into six beams that pass over the landscape in programmed patterns. Alongside the laser is a special telescope monitoring the beams' reflections, collecting a dozen photons from each laser pulse 10 000 times per second. ICESat-2 helps map the loss of ice in Greenland – an accelerating problem – by providing more precise data on ice cover whether

an ice sheet has risen or fallen, ice sheet elevation and thickness and also examining how it changes over the course of one year.

With higher seas already creating dangerous storm surges exacerbating flooding or coastal erosion from the US Gulf Coast to the Maldives or China, the future effect on communities in Greenland is also uncertain, and so the role of next generation satellites is set to become increasingly important.

Digitalization and Big Data for leapfrogging traditional pathways to help increase agricultural efficiency and food security

Digitalization, as well as the resultant Big Data it generates, will help across a myriad of sectors as diverse as agriculture and transport, enhancing operational and supply chain efficiencies, consolidating information and data from earth observations and making data available to the right stakeholders in order to facilitate innovation.

In agricultural efficiency and food security terms, any digitalization of the agricultural sector could help to increase agricultural production by optimizing inputs such as water, while minimizing undesirable outputs such as CO_2 emissions. The information capital derived from Big Data on (for example) weather, soil moisture, mineral levels or maturity of plants and then transmitted by connected mobile technologies will also alter future jobs within agriculture and the food production chain.

The report cites the case study of Columbia's site-specific agriculture project, which pools data from a multitude of sources including via a phone app for farmers. This local knowledge and site-specific information, when fed into the computer model, enables scientists to refine their advice further, helping farmers pinpoint what, when, where and how to plant.

Enabling frontier technologies to achieve the most far-reaching, beneficial results

As the report demonstrates, the potential of frontier technologies as tools to tackle climate change is clear. And yet, for their rollout and uptake to be as beneficial as possible, some key themes need to be addressed:

- **Buy-in from, and investment by, governments**: Critical to ensuring the progress and spread of frontier technologies, governments have a vital role to play in ensuring cooperation and spurring innovation within the private sector through economic and legislative incentives for R&D in frontier technologies.
- **Engagement with all stakeholders:** A close working relationship between the public and private or business sectors is essential, as is an engagement with academia and citizen stakeholders. Public-private partnerships (PPPs) are needed in order to leverage private sector expertise and infrastructure in data science, cloud computing and AI, to share data and to promote the use of technology for global public goods. Existing partnerships and practitioner communities should be harnessed to ensure that the digital ecosystem for the environment is inclusive and does not overlap with, or duplicate, existing activities.

Non-governmental organizations also need to increase their engagement on this topic, performing a watchdog function.

- **Regulation and cooperation:** An effective regulatory environment and institutional infrastructure is essential. Fostering international cooperation for the exchange of technologies and innovation (particularly between developed countries and the rest of the world), reducing barriers posed by restrictive intellectual property rights mechanisms, and promoting ICT-related standards globally are some key specific ways in which frontier technologies can be leveraged for the benefit of all.
- **Be mindful of their limitations** Frontier technologies can be a contributor to, and part of the solution for climate change, but they do have an environmental impact at each stage of their life cycle due to the energy consumed during their production, distribution and use, and the associated GHG emissions. They need to be used as efficiently as possible in order to fulfil their sustainability potential. Providing this double-edged nature is recognized and accounted for by policy makers, a balance can be achieved wherein their potential in helping to monitor, adapt to and mitigate climate change can be unlocked and optimally leveraged to ensure tangible, measurable progress.
- **Digital leapfrogging can be key**: Leapfrogging, the notion that 'areas which have poorly developed technology or economic bases can move themselves forward rapidly through the adoption of modern systems without going through intermediary steps,'[1]is taking place in many countries. Ethiopia, for example, has moved directly to hydropower to meet its future energy needs, building the Grand Renaissance Dam, which, once completed, will generate 6 000 MW of electricity, over four times Ethiopia's current capacity. Although hydropower, like many other clean energy technologies, is not a new technology, it is certainly a significant disruptor within Ethiopia's energy context, as well as that of other countries nearby, enabling the country to leapfrog over coal as a major traditional energy source, with some potential implications for water supply as well.[2][3]Elsewhere, cities or countries may find themselves leapfrogging even when they have limited capacities to access these technologies, ushering in more renewable cost-effective energy sources, potentially bypassing traditional routes.
- **Disruptive potential can be hindered by affordability and access:** Harnessing the full potential of frontier technologies can be hampered by factors ranging from lack of infrastructure investment and un-modernized public utilities to a lack of appropriate regulations and financial mechanisms and a population lacking the correct digital skills. This gap, in terms of affordability of and access to frontier technologies, can be particularly stark between developed and developing nations. There are ways to minimize this gap by implementing policies aimed at limiting the socio-economic costs of adjustment at the national, regional and city level - thus creating an environment attractive to investors in which innovation can flourish - and by establishing training and learning programmes.
- **Scaling frontier technologies is vital**, in order to maximize impact and lower deployment costs. Most deployments vary significantly in the level of interest, investment, scale and complexity according to geography. Further research, processes and standardization efforts are needed to identify successful-use cases of frontier technologies in the context of climate change and response in order to eventually scale them nationally, regionally and – ultimately – globally.
- **Plan for the future, today.** Even in instances where existing frontier technologies may not yet offer solutions to the complex challenges faced at present, or those that are expected to be faced in the future, the rapid pace of their advancement will likely result in new or more effective frontier technology solutions appearing in future. Therefore, any

1 Leapfrog Soluciones Web. 'Leapfrogging.' Leapfrog Digital Strategies, leapfrog.cl/en/leapfrogging

2 Ramirez, Vanessa Bates. 'Leapfrogging Tech Is Changing Millions of Lives. Here's How.' Singularity Hub, Singularity Education Group, 6 May 2018, singularityhub.com/2018/05/06/leapfrogging-tech-is-changing-millions-of-lives-heres-how/#sm.001u2w1r513ugdrsslu1hejge7x0c

3 Diop, Makhtar. 'Africa Can Enjoy Leapfrog Development.' World Bank, World Bank Group, 11 Oct. 2017, www.worldbank.org/en/news/opinion/2017/10/11/africa-can-enjoy-leapfrog-development

assessment of emerging technology trends and scalable deployment of existing frontier solutions should play a part in any city's resilience strategy over the foreseeable term.

- **Wisely used, frontier technologies offer innovative solutions**: They may be considered frontier or emerging, but **these technologies comprise innovative solutions to meet the needs of the world's population while addressing those of the planet**. Cities and urban regions form the perfect backdrops to test frontier technologies to mitigate the effects of climate change. Continuing innovation must, therefore, be cultivated, nurtured and incentivized by local and national governments alike, in partnership with industry and academia. Many emerging technologies are inter-related, especially to IoT, AI, 5G and Big Data. While the concepts of many of today's emerging technologies have been around for some time, it is now becoming feasible to implement IoT and scalable information systems on larger scales. Ensuring the affordable and wide-scale deployment of these 'enabler' and other connective technologies will assure the further advancement and adoption of other frontier technologies.

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