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Turning digital technology innovation into climate action

GLOBAL GOALS

Turning digital technology innovation into climate action

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Foreword

By Houlin Zhao, Secretary-General, International Telecommunication Union

Today, we are faced with not one but two deep transformations. The first one, driven by emerging technologies such as artificial intelligence, blockchain, the Internet of Things, 5G and many others, is changing how governments, businesses and individuals will act in this new century. As for the second transformation, climate change, it disrupts ecosystems, jeopardizing biodiversity, food and water security and the future of life on our planet.

The question for us is whether humanity can turn this digital revolution into climate action and, most importantly, whether we can do it before it is too late. Already, human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels. It has taken a toll on all of us, including and especially on the least developed countries and Small Island Developing States where investment in digital infrastructure and services is critical. The window of opportunity to keep the world safely from warming above 1.5 °C is closing very fast.

Information and communication technologies (ICTs) offer solutions to monitor, mitigate and adapt to the impacts of climate change. The evidence and case studies presented in this report cover the full range of measures that are being deployed to better understand the Earth's system, reduce greenhouse gas emissions and build resilience to the climate crisis – from using space sensing observation to track deforestation to developing smart grids to accelerate the energy transition to strengthening early warnings systems against the rising number of extreme weather events.

With more and more people coming online, more data being generated and more devices connecting to the network, the digital ecosystem's carbon footprint is growing. It is imperative to monitor this growth closely to weigh the benefits and costs of ICTs. As part of this effort, ITU has recently established a new Focus Group that will provide a global platform to raise awareness of the environmental impacts of artificial intelligence and other frontier technologies, as well as these technologies' ability to contribute to the achievement of the Sustainable Development Goals and the objectives of the Paris Agreement.

As the United Nations specialized agency for ICTs, ITU has been working with the industry to minimize the carbon footprint of ICTs, developing international standards (ITU-T Recommendations), for example, in areas as diverse as smart cities, data centres and e-waste management. We will continue to bring our core competencies of spectrum management and satellite coordination, development of international standards and good policy and best practices to help our government and private sector members and others work together to move towards a lower carbon and more circular economy.

This report will inform the upcoming United Nations Secretary-General's 2019 Climate Action Summit in September in New York. It is a call to action, a testament to the power of technology and the faith in the idea that together we can leverage ICTs to address the existential threat of climate change.

Houlin Zhao,
Secretary-General, ITU

Abbreviations and units

3G	Third-Generation Mobile Communications
4G	Fourth-Generation Mobile Communications
5G	Fifth-Generation Mobile Communications
ACEEE	American Council for an Energy-Efficient Economy
AFOLU	Agriculture, Forestry and Other Land Use
AI	Artificial Intelligence
AOS	Automated System Optimization
AR	Augmented Reality
Art.	Article
BR	Radiocommunication Bureau
BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters Program
BRS	Basel, Rotterdam and Stockholm Conventions
BRT	Belfast Rapid Transit
BT	British Telecom
CCAFS	Climate Change, Agriculture and Food Security Program
CE	Circular Economy
CIS	Climate Information Services
CNES	French National Centre for Space Studies
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
COP	Conference of Parties
DfID	UK Department for International Development
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field(s)
EMG	Environment Management Group
EPR	Extended Producer Responsibility
ESA	European Space Agency
EU	European Union

EWS	Early Warning Systems
FG-AI4EE	Focus Group on Environmental Efficiency for AI and Emerging Technologies
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GIEC	French Intergovernmental Expert Group on Climate Change
GEO	Group on Earth Observations
GeSI	Global e-Sustainability Initiative
GDPS	Global Data Processing System
GHG	Greenhouse Gas
GHGs	Greenhouse Gases
GOS (or WIGOS)	Global Observing System
GPS	Global Positioning System
GSMO	Global Satellite Meteorological Observation
GTS	Global Telecommunication System
HVAC	Heating, Ventilation and Air Conditioning
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
ICTs	Information and Communication Technologies
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISWA	International Solid Waste Associate
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-R	ITU Radiocommunication Sector
ITU-T SG5	Study Group 5
ITU-T SG20	Study Group 20
km2	Square Kilometres

KPIs	Key Performance Indicators
kW	Kilowatts
kWh	Kilowatt-Hour
LAI	Leaf Area Index
LDCs	Least Developed Countries
LIDAR	Light Detection and Ranging technology
LOI	Letter of Intent
M2M	Machine-to-Machine
ML	Machine Learning
NASA	US National Aeronautics and Space Administration
NDCs	Nationally Determined Contributions
NIFC	National Interagency Fire Centre
NLP	Natural-Language Processing
NO2	Nitrogen Dioxide
NOAA	US National Oceanic and Atmospheric Administration
OECD	Organization for Economic Co-operation and Development
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PP	Plenipotentiary Conference
RIC4REC	The Strengthening Community Initiatives for Resilience to Climate Extremes
RFID	Radio-Frequency Identification
SAR	Synthetic Aperture Radar
SARVA	South African Risk and Vulnerability Atlas
SDG	Sustainable Development Goal
SDGs	Sustainable Development Goals
SFEN	French Society of Nuclear Energy
SG	Study Group
SIDS	Small Island Developing States
TSAG	Telecommunication Standardization Advisory Group
TSB	Telecommunication Standardization Bureau
U4SSC	United for Smart Sustainable Cities

UAV	Unmanned Aerial Vehicles
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGC	United Nations Global Compact
UN-Habitat	United Nations Human Settlements Programme
UNIDO	United Nations Industrial Development Organization
UNU	United Nations University
UN Women	United Nations Entity for Gender Equality and the Empowerment of Women
USAID	United States Agency for International Development
VR	Virtual Reality
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WHO	World Health Organization
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
WWW	World Weather Watch

Executive summary

Climate change is threatening to increase vulnerability, undermine economic gains, hinder social and economic development, and worsen access to basic services and the quality of life of citizens all over the world. New findings from the UN show that the Earth is fast approaching the environmental 'tipping point'. Scientists have warned that there is only a short amount of time left for global warming to be kept to a maximum of 1.5°C, beyond which any increase will worsen the risks of climate catastrophes. Moreover, these impacts of climate change may turn into self-reinforcing cycles that affect the young, elderly and other vulnerable individuals the most. Some countries, such as small island developing states (SIDS) and least developed countries (LDCs) are also more vulnerable overall.

Information and communication technologies (ICTs) offer some potential to help address the world's most pressing climate concerns and enable the much-needed shift toward a circular economy (CE). ICTs can be tools for monitoring climate change and for climate change mitigation and adaptation. Because the main output of the ICT sector is information rather than physical goods – a concept sometimes referred to as 'dematerialization" – ICTs can contribute to reducing the emissions and solid waste that emanate from other (non-ICT) sectors of the economy. The higher levels of connectivity that ICTs foster are also leading to societal impacts and an exchange of ideas previously not experienced on this scale and to this extent. Through greater awareness and education, this can have a positive effect on fostering an environmental responsibility mind-set amongst stakeholders, including the ICT sector, policy makers, citizens and academia. This is extremely important as everyone needs to come together to take responsibility for this very complex problem, and to take concerted and timely action.

However, ICTs also consume energy and are, therefore, likely to contribute to global emissions and waste during their production, usage and obsolescence, and they are dependent on the source of the energy being used. For example, technological advancements – and the proliferation of frontier technologies (such as artificial intelligence, the Internet of Things, 5G, digital twins, robotics, etc.), in particular – are contributing to the growing number of data centres and the concern over their energy consumption, which is increasing at an alarming rate. The growing number of ICT- related services is also increasing the environmental footprint of the ICT sector, which calls for action to monitor this trend.

Consequently, the key to successfully leveraging ICTs as part of combatting climate change and its effects is to ensure that the difference between their net benefit and their net cost to the environment is monitored closely. This can be achieved, in part, by remaining mindful of the environmental load of ICTs by tracking their impact and deploying them appropriately in a strategic manner. The development of, and adherence to, international standards for energy-efficient ICTs can help in this regard. E-waste should be reduced through recycling, upcycling, repurposing or otherwise reusing as many components as possible once ICTs have been decommissioned. Eco-design principles that consider the environmental impacts of products to reduce energy and resource consumption through their whole life cycle should be widely employed.

The International Telecommunication Union (ITU) has a strong role to play in encouraging these outcomes by raising awareness and empowering people to make choices (e.g. about the benefits of smart metering for electricity and water consumption), by providing leadership and expertise on ICTs worldwide, and by facilitating greater dialogue and exchange of ideas among different stakeholder groups. Encouraging the responsible use and uptake of ICTs, along with the use of global ICT standards and best practices, the mainstreaming of eco-design principles and taking advantage of environmentally efficient applications of frontier technologies can help to accelerate response to climate change.

Such active measures can help mitigate greenhouse gases, as well as improve public health and working conditions, preserve biological ecosystems and diversity, extreme weather events and continue to contribute to economic prosperity and growth. This report, therefore, takes a comprehensive approach by covering the social impacts of climate change and related ICT-based responses, in addition to those focusing on the reduction of greenhouse gas and carbon footprint impacts.

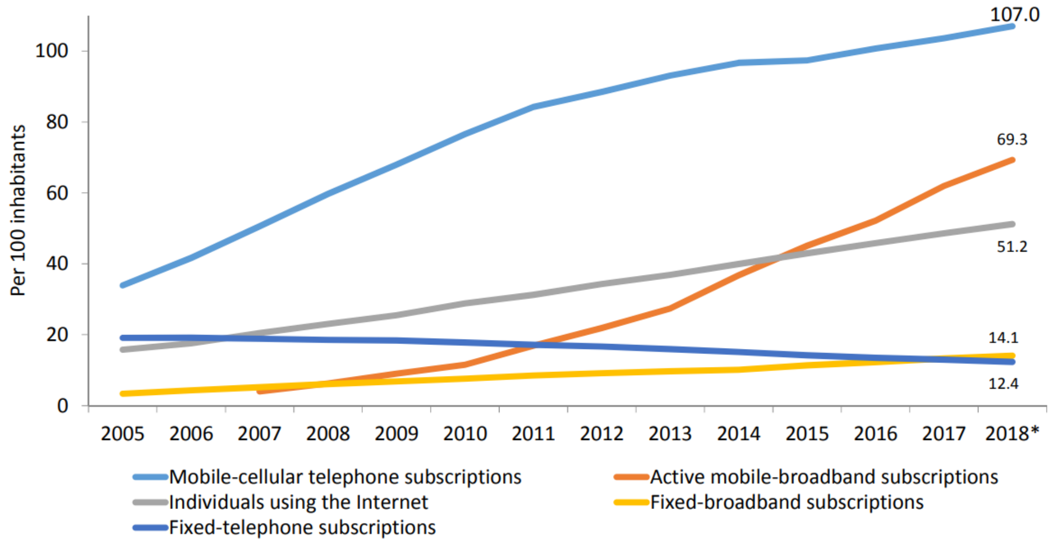
Chapter 1

Chapter 1. People, technology and the climate

Information and Communication Technologies (ICTs), e.g. broadband, computers and wireless communication, have a great capacity to change economies, societies and cultures all over the world. ICTs are inextricably woven into the everyday lives of billions of people and have enabled the digital networks through which ever-increasing volumes of data and information flow at faster and faster speeds. These data are the central bedrock around which new technologies revolve and new modes develop for business, communication and governance, as well as the environment.

ICTs already influence all manner of decisions being taken by 3 billion producers and consumers around the world every day.[1] This influence may increase even further over the coming years. The International Telecommunication Union (ITU), as the United Nations (UN) specialised agency for ICTs, charts the course of such global telecommunication and ICT trends. It has found that by 2019, more than half the world's population is using the Internet and by 2020, more than half the world's households will have access to the Internet.[2] Figure 1 summarizes some key global ICT developments.

Figure 1: Global ICT developments, 2005–2018 (*ITU estimate) [3]



Note: * ITU estimate.

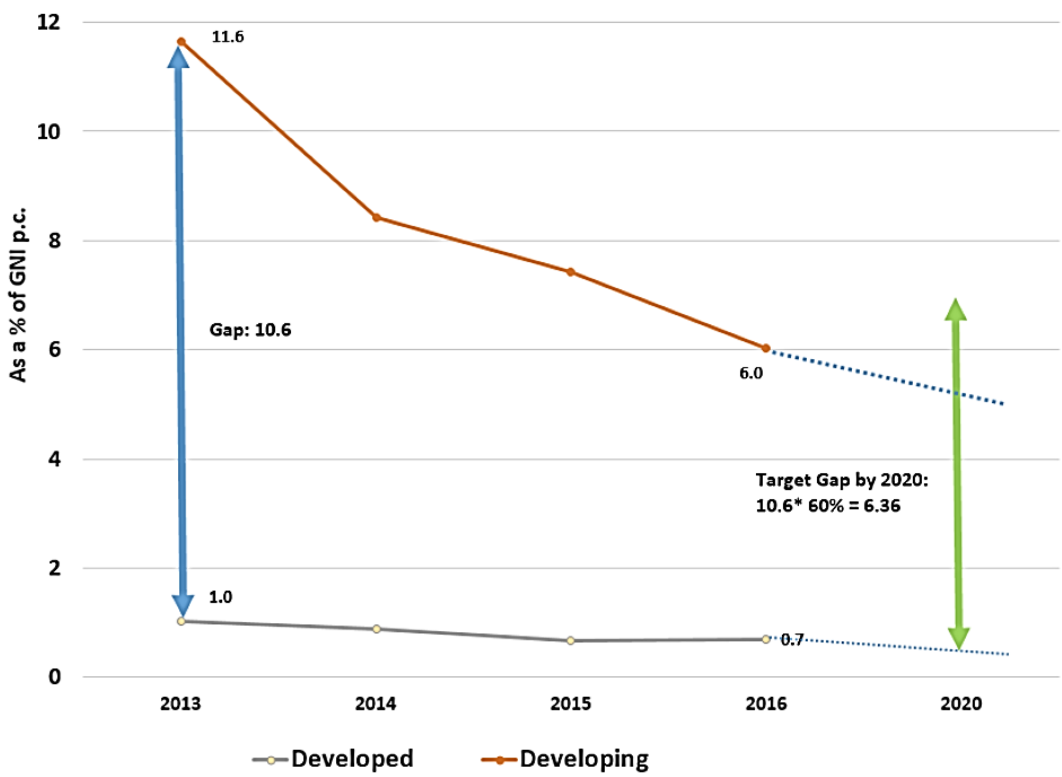
[1] Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

[2] International Telecommunication Union (ITU). 'Measuring the Information Society Report.' Volume 1. 2018, www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-1-E.pdf.

[3] International Telecommunication Union (ITU). 'Measuring the Information Society Report.' Volume 1. 2018, www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-1-E.pdf.

ITU's research also shows that the digital divide between developed and developing countries is shrinking, as investment in ICT networks and services continues to grow while prices fall. This is illustrated in Figure 2, which shows the average price for mobile broadband services falling over time in the least developed countries (LDCs). The increasing affordability of ICTs in general, is expected to continue, which will further ensure their mainstream availability in the remotest locations around the world. With Internet speeds becoming faster and usage limits declining, the world is becoming more connected than ever before.

Figure 2: The tightening affordability gap between developed and developing countries[4]



These increasing levels of connectivity and the increasing use of ICTs globally could, therefore, offer some potential to help address some of the planet's most pressing climate concerns. And while the increased use of ICTs undoubtedly contributes to global warming (as explained in Chapter 2), these technologies can also play a role in monitoring, mitigating, and enhancing and improving climate change adaptation strategies (as detailed in later sections of this report). In particular, since the main output of the ICT sector is information rather than physical goods – a concept sometimes referred to as 'dematerialization" – ICTs can contribute to reducing the emissions and solid waste that emanate from other (non-ICT) sectors of the economy.

There is also potential for continuing to increase the momentum toward environmental conservation and responsibility through the use of ICTs, by helping to disseminate information that shapes responsible discourse and practices. A significant shift needs to occur, especially towards creating a more sustainable and circular economy (CE). Some estimates show that the new services and business models (facilitated by ICTs and digital platforms) that could be developed as a result of more circularity[5] may unleash as much as 1.8 trillion euros of annual benefit by 2030 – or a 7 per cent additional GDP

4 International Telecommunication Union (ITU). 'Draft Report of the Council on the Implementation of the Strategic Plan and Activities of the Union.' Page 6, 19 Mar. 2018. *Also available in Measuring the Information Society Report, 2016

5 Circularity refers to recycling, reuse, upcycling, etc. of technological materials in order to minimize waste and make the most of resources. A circular economy cycles as many materials as possible through a Make-Use-Reuse-Remake-Recycle loop.

increase (relative to the current development scenario) – in Europe alone.[6] Therefore, advocating for responsible consumer behaviour when it comes to the purchase of ICTs, in addition to advocating for CEs, may help curb the overall increase in energy used during the material extraction, material processing, and component manufacturing within ICT production.

Furthermore, as it is an important aspect in the discussion around climate change, this report also covers some of the social impacts of climate change and their ICT-based responses, in addition to those focusing on reduction of greenhouse gases and carbon footprint-related impacts.

Section 1.1 summarizes the various global impacts of climate change and underscores the severity and urgency of the issue.

1.1 Climate change: Trends and impacts

Several causes of climate change exist and are leading to warming of the planet as a result of the release of greenhouse gases (GHGs) – primarily in the form of carbon-based emissions that contribute to the greenhouse effect by retaining more heat from the sun. The average global temperatures increased by 0.85°C between 1880 to 2012, which had an inverse effect on crop yields in the two decades following 1980 alone.[7]

In light of this, the UN Intergovernmental Panel on Climate Change (IPCC) recently issued its starkest warning yet on the consequences of climate inaction and the importance of limiting global warming to 1.5°C.[8] It has confirmed that the Earth is now (on average) already 1°C above pre-industrial levels. The year 2018 has been reported to be the fourth warmest year on record, almost 1°C above temperature levels in the period 1850–1900, as mentioned above. And 2019 is on trend to surpass every year in recorded history.[9]

The following graph from NASA (Figure 3) shows the increase in atmospheric carbon over time. The current warming trend that corresponds to this increase is particularly important, as it is 'proceeding at a rate that is unprecedented over decades to millennia.'[10]

These mounting temperatures have given way to more frequent and severe weather-related phenomena such as heat waves, droughts, floods, wildfires, hurricanes, tropical cyclones and heavy rain and snowfalls. It has been reported that in 2016 alone, the world suffered 772 geophysical, meteorological, hydrological and climatological natural loss events – triple the number suffered in 1980. Already vulnerable and poor population groups are likely to be the most affected by such events.[11]

[6] McKinsey & Company. 'Europe's Circular-Economy Opportunity.' Sep. 2015, www.mckinsey.com/business-functions/sustainability/our-insights/europes-circular-economy-opportunity.

[7] United Nations (UN). 'Climate Change.' www.un.org/en/sections/issues-depth/climate-change/.

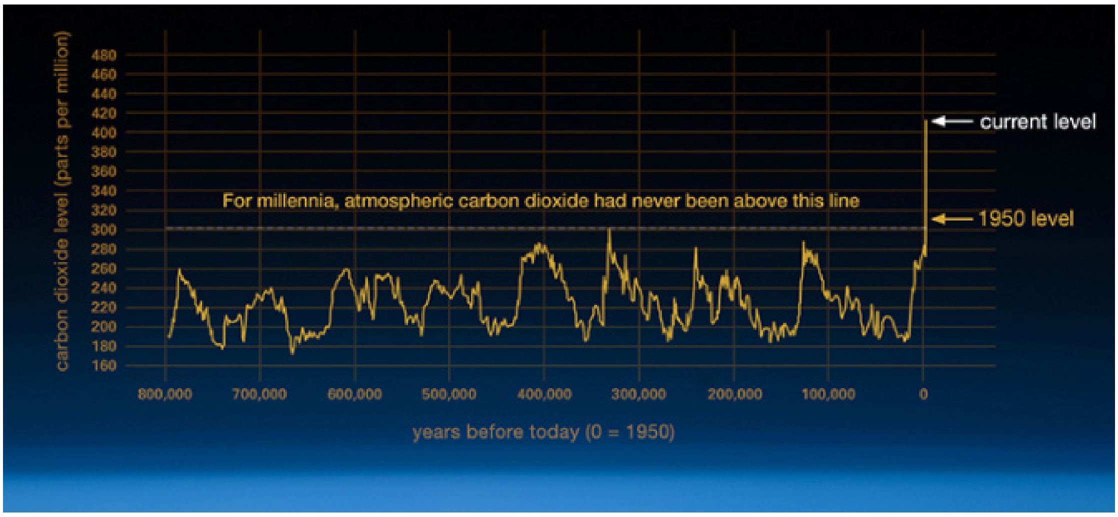
[8] Intergovernmental Panel on Climate Change (IPCC). 'IPCC SPECIAL REPORT: Global Warming of 1.5 ºC.' 2018, www.ipcc.ch/sr15/.

[9] McGrath, Matt. 'Climate Change: Global Impacts "Accelerating"- WMO.' BBC News Services, 28 Mar. 2019, www.bbc.com/news/science-environment-47723577.

[10] National Aeronautics and Space Administration (NASA). 'Evidence." climate.nasa.gov/evidence/.

[11] Paris, Guillaume, and Pierre- Henri Blard. 'Humans Have Derailed the Earth's Climate in Just 160 Years. Here's How.' World Economic Forum (WEF), 27 Mar. 2019, www.weforum.org/agenda/2019/03/how-humans-derailed-the-earths-climate-in-just-160-years/.

Figure 3: Increase in atmospheric carbon with time[12]



Adding to the aforementioned concerns is the fact that while momentum to view the environmental and climate challenges as part of the overall global economic architecture had gained ground after the 2008–2009 global financial crisis[13] – as seen in the formulation of the Paris Agreement (detailed in Box 1) – a decade later, still not enough has been done economically or politically to shift the balance toward sustainability, even though the deteriorating environmental conditions increasingly threaten humanity itself.[14] In a strange paradox, despite worsening climate conditions the political will to fight climate change appears to be fading, according to Mr Antonio Guterres, UN Secretary-General in early 2019.[15]

This is seen in the fact that despite having made promises to make their operations more sustainable, the world's biggest companies have continued to rely on fossil fuels. Research shows that the carbon footprint of the global tech giants is growing particularly fast.[16] This is partly explained by the exponential growth of data centres worldwide.[17] While investment is being made to ensure that the manufacturing and operations of these new data centres will be as environmentally sustainable as possible (e.g. through water efficiency measures, the use of renewable energy and sustainability certifications), it is still unclear what impacts the continued operation, or dismantling, of the old data centres will have on the environment and climate. The fact remains that data centres are consuming vast amounts of electricity and are leaving significant environmental footprints. Unless these data centres begin to move towards utilizing renewable energy sources in their operations, they will remain responsible for a significant portion of global emissions.

The ramifications of climate change are, moreover, likely to be exacerbated by the growing pressure of urbanisation. Today, more than 4 billion people (over half the global population) live in cities and

12 National Aeronautics and Space Administration (NASA). 'Graphic: The Relentless Rise of Carbon Dioxide.' 12 Jun. 2019, climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/.

13 United Nations Conference on Trade and Development (UNCTAD). 'Top Economists Outline Plan for a Global Green New Deal.' 12 Apr. 2019, unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2057&utm_source=CIO%2B-%2BGeneral%2Bpublic&utm_campaign=cbf2294e3c-UNCTAD%2BCSO%2BNewsletter%2B16%2BNovember_COPY_01&utm_medium=email&utm_term=0_3d334fa428-cbf2294e3c-70437777.

14 Pascus, Brian. 'Human Civilization Faces 'Existential Risk' by 2050 According to New Australian Climate Change Report.' CBS News, CBS Interactive Inc., 4 June 2019, www.cbsnews.com/news/new-climate-change-report-human-civilization-at-risk-extinction-by-2050-new-australian-climate/.

15 BBC. 'Political Will to Fight Climate Change Is Fading, Warns UN Chief.' BBC News, BBC News Services, 12 May 2019, www.bbc.com/news/av/world-asia-48244315/political-will-to-fight-climate-change-is-fading-warns-un-chief.

16 Merchant, Brian. Amazon Is Aggressively Pursuing Big Oil as It Stalls Out on Clean Energy. Gizmodo, 8 Apr. 2019, gizmodo.com/amazon-is-aggressively-pursuing-big-oil-as-it-stalls-ou-1833875828?utm_source=gizmodo_newsletter&utm_medium=email&utm_campaign=2019-04-19.

17 Mills, Theadora. 'Enlisting Technologies in the Fight against Climate Change." ITU News, International Telecommunication Union (ITU), 18 Dec. 2018, www.news.itu.int/technologies-fight-against-climate-change/.

urban areas; and this number is expected to grow over the coming years.[18] Over 70 per cent of energy-related CO_2 emissions can be traced back to cities[19], which are responsible for about 75 per cent of all energy consumption.[20]

Cities are also more and more at risk from the direct and indirect impacts of climate change, which means that most of the global costs of adaptation to climate change are likely to be incurred by, and within, cities. These costs will increasingly include those associated with negative health outcomes resulting directly from air pollution in urban areas; currently, approximately 7 million people around the world die every year from exposure to air pollution alone.[21]

Rising sea levels are another impact of climate change that is of particular concern for those living in low-lying urban coastal areas, especially with the global mean sea level reportedly rising 3.7 mm higher in 2018 than the previous year.[22] The resulting risks to transportation, especially in the case of coastal transport infrastructure, pose significant threats to global trade and development. International maritime transport carries over 80 per cent of the volume of world trade and provides access to global markets for all countries, including those that are landlocked.[23]

For small island developing states (SIDS), which are already exposed to major natural hazards, the outlook is particularly alarming. Their critical reliance on coastal transport infrastructure, in particular seaports and airports, worsens their susceptibility to climate change impacts such as rising sea-levels and extreme weather events. These impacts threaten trade and disaster relief efforts, as well as international tourism, which is the crown jewel of economic development in SIDS that requires secure and reliable international transport connections. Yet SIDS and other developing countries have limited capacity to adapt and build the resilience of their transport infrastructure to cope with climate change.[24] The Least Developed Countries (LDCs) are similarly affected and the UN Office for Disaster Risk Reduction estimates that average annual losses in the LDCs in 2017 due to disasters were 8.5 per cent of GDP.[25]

Also at risk are the planet's life-supporting eco-systems themselves.[26] A comprehensive UN study has found that 'nearly one million species risk becoming extinct within decades, while current efforts to conserve the Earth's resources will likely fail without radical action. Although the planet already has specially designed ecosystems to heal itself, there is an urgent need to define how to rapidly identify where the areas of highest concern are, and where the greatest opportunities for restoration lie.'[27]

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18 The World Bank. 'Urban Development: Overview." World Bank Group, 1 Apr. 2019, www.worldbank.org/en/topic/urbandevelopment/overview.

19 C40. "Why Cities?" C40 Cities Climate Leadership Group, Inc., www.c40.org/why_cities.

20 UN-Habitat. "Energy." unhabitat.org/urban-themes/energy/.

21 World Health Organization (WHO). 'Ambient and Household Air Pollution and Health." 12 Jul. 2019, www.who.int/airpollution/data/en/.

22 McGrath, Matt. "Climate Change: Global Impacts 'Accelerating'- WMO." BBC News, BBC News Services, 28 Mar. 2019, www.bbc.com/news/science-environment-47723577.

23 United Nations Conference on Trade and Development (UNCTAD). 'Urgent Need for Climate Adaptation in Transport, Say Experts.' 25 Apr. 2019, unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2063&utm_source=CIO%2B-%2BGeneral%2Bpublic&utm_campaign=d4eace132f-UNCTAD%2BCSO%2BNewsletter%2B16%2BNovember_COPY_01&utm_medium=email&utm_term=0_3d334fa428-d4eace132f-70437777.

24 United Nations Conference on Trade and Development (UNCTAD). 'Urgent Need for Climate Adaptation in Transport, Say Experts.' 25 Apr. 2019, unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2063&utm_source=CIO%2B-%2BGeneral%2Bpublic&utm_campaign=d4eace132f-UNCTAD%2BCSO%2BNewsletter%2B16%2BNovember_COPY_01&utm_medium=email&utm_term=0_3d334fa428-d4eace132f-70437777.

25 General Assembly Economic and Social Council. 'Implementation of the Programme of Action for the Least Developed Countries for the Decade 2011-2020: Report of the Secretary-General.' 2019, unohrlls.org/custom-content/uploads/2019/03/SG-report-on-IPoA-2019-Advance-Unedited.pdf.

26 Watts, Jonathan. 'Human Society under Urgent Threat from Loss of Earth's Natural Life.' The Guardian, Guardian News and Media, 6 May 2019, www.theguardian.com/environment/2019/may/06/human-society-under-urgent-threat-loss-earth-natural-life-un-report?utm_source=Environmental%2BPeacebuilding&utm_campaign=856333aebd-EMAIL_CAMPAIGN_2019_04_11_08_55_COPY_01&utm_medium=email&utm_term=0_7c78b406a1-856333aebd-519355341.

27 MapX. 'Saving Wildlife and Ecosystems Using New Technologies.' 22 May 2019, www.mapx.org/news/newsletters/saving-wildlife-and-ecosystems-using-new-technologies/.

Specifically, the report found that the distribution of 47% of the proportion of terrestrial flightless mammals and 23% of threatened birds may have already been negatively impacted by climate change. Even for global warming of 1.5 to 2°C, the majority of terrestrial species ranges are projected to shrink profoundly.[28]

Rising food insecurity is another issue. Speaking at the launch of a Special Report on Climate Change and Land by the UN Intergovernmental Panel on Climate Change (IPCC) in Geneva, experts highlighted how the rise in global temperatures, linked to increasing pressures on fertile soil, risked jeopardizing food security for the planet.[29]

All this evidence shows that catastrophic global climate change is not an event waiting to happen sometime in the future. It is the reality that the entire world is facing right now. It is, therefore, imperative that countries take urgent and immediate action to address climate change according to the agreed-upon conventions, resolutions and protocols of international instruments such as the ITU's Connect 2030 Agenda and the Paris Agreement, the latter being the UN-coordinated response of Member States to the issue of climate change. The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Any interventions that may help achieve the Agreement's aim should also be utilised, including the use of ICT infrastructure and applications as part of countries' climate change response strategies.

Box 1 below summarises the intended outcomes of the Paris Agreement.[30]

Box 1: The Paris Agreement

The Paris Agreement

At the Conference of Parties (COP-21) in Paris, on 12 December 2015, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C (Art. 2). Additionally, the agreement aims to increase the ability of countries to deal with the impacts of climate change, and make finance flows consistent with a low- GHG emissions and climate-resilient pathway. To reach these ambitious goals, appropriate mobilisation, the provision of financial resources, a new technology framework and enhanced capacity-building will be put in place, thus supporting action by developing countries, and the most vulnerable countries, in line with their own national objectives. The Agreement also provides for an enhanced transparency framework for action and support.

The Paris Agreement requires all Parties to put forward their best efforts through 'nationally determined contributions' (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and their

[28] United Nations Framework Convention on Climate Change (UNFCCC). 'IPBES: Climate Change Is a Key Driver for Species Extinction.' United Nations- Climate Change, 6 May 2019, unfccc.int/news/ipbes-climate-change-is-a-key-driver-for-species-extinction.

[29] United Nations (UN). 'World Food Security Increasingly at Risk Due to 'Unprecedented' Climate Change Impact, New UN Report Warns.' UN News, 8 Aug. 2019, news.un.org/en/story/2019/08/1043921.

[30] United Nations Framework Convention on Climate Change (UNFCCC). 'What Is the Paris Agreement?' unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement.

implementation efforts. There will also be a global stocktake every five years to assess the collective progress towards achieving the purpose of the agreement and to inform further individual actions by Parties. Some of the key aspects of the Agreement are as follows:

- ***Global peaking and 'climate neutrality'*** (Art. 4)
- ***Mitigation*** (Art. 4)
- ***Sinks and reservoirs*** (Art.5)
- ***Voluntary cooperation/Market- and non-market-based approaches*** (Art. 6)
- ***Adaptation*** (Art. 7)
- ***Loss and damage*** (Art. 8)
- ***Finance, technology and capacity-building support*** (Art. 9, 10 and 11)
- ***Transparency*** (Art. 13), ***implementation and compliance*** (Art. 15)
- ***Global Stocktake*** (Art. 14)

The key areas in which ICTs can effectively address climate change are monitoring, mitigation and adaptation. Some examples of ICT-use to address climate change include: remote sensing for monitoring of natural disasters; improved communications to help deal with natural disasters more effectively; and satellite and surface-based remote sensors for long-term environmental observation. These and other examples will be linked within this report.

Chapter 2. Maximising the potential opportunities and minimising the downsides of ICTs

The ICT sector is a contributor to, and a part of, the potential response to climate change. ICTs have an environmental impact at each stage of their life cycle due to the energy consumed during their production, distribution and use. According to some estimates, ICTs alone are directly responsible for 1.4 per cent of global GHG emissions and 3.6 per cent of electricity consumption.[1] The wider ICT ecosystem used about 1 700 terawatt-hours of electricity in 2015, or about 8 per cent of the global total.[2] The use of hazardous substances and scarce and non-renewable resources in production and the generation of e-waste are also part of the environmental load of ICTs.

2.1 The E-Waste Challenge

The growth in Internet of Things (IoT) enabled devices, including the consumer hand-held products that keep us connected, is becoming more widespread as a means of increasing efficiency, lowering costs, saving time and (in some cases) combatting climate change – especially through the localization of the information-renewable energy nexus. Single devices with single or limited functionality are being replaced by devices with multiple functionality. For example, one mobile phone can now be connected to multiple electronics that are wired to different IoT infrastructures. According to British

1 Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

2 Andrae, Anders S.G. 'Total Consumer Power Consumption Forecast.' Huawei, Oct. 2017, www.researchgate.net/publication/320225452_Total_Consumer_Power_Consumption_Forecast.

Telecom (BT), the average UK household will contain 50 connected devices by 2023.[3] [4] The list of possibilities stemming from such connectivity is endless.

However, on the downside, these connected 'Things' require complex and tangible electronics in order to communicate with one another. Furthermore, what is also not visible – and is indeed intangible – is that by 2025, the communications industry could be using 20 per cent of the world's electricity.[5] Globally, this figure translates to an estimated 14 per cent of emissions, which would surpass emissions released from the aviation and shipping sectors.[6] [7] Behind these figures, the expansion of data centres and the need to keep this hidden-support infrastructure cool are major factors in the generation of carbon emissions. Consequently, investment and research in greening data centres is essential.

Almost all smart metering for homes, sensors, actuators, transducers and renewable energy technologies require data centres, complex batteries, servers, control centres, mobile applications and hand-held devices. It is forecasted that in 2023,[8] more than 200 million European households will have smart meters. Although Artificial Intelligence (AI) software optimization and cloud computing, and greater connectivity of ICT devices as part of the IoT is believed, theoretically, to lead to fewer devices (because all services are accessed from fewer devices but with greater multifunctionality), more cloud computing inevitably means more data centres. Furthermore, it is estimated that by 2021, there will be a total of 25 billion connected devices[9] producing an immense volume of data. It is also worth noting that for aesthetic purposes, these devices are predominately housed in casings made of additional materials (such as ceramics, glass and plastics) that eventually end up in several other solid waste streams.

While users are increasingly connecting devices to climate-friendlier renewable means of harnessing energy such as domestic roof-top solar panels, these renewable technologies also eventually become e-waste. Many of these technologies are difficult to recycle, and only a handful of countries have waste legislation for the end-of-life management of solar photovoltaic panels.[10] With little legislation and enforcement in place to cover the environmentally sound management of e-waste, most of the used and end-of-life ICT equipment is managed under rudimentary conditions. It is still unclear whether e-waste management solutions will keep up with the growing number of ICT equipment and components. Indeed, in a report published in 2017, the UN found that 55 billion euros in materials are lost in almost 50 million tonnes of e-waste generated annually.[11]

It is essential that international standards such as the ITU-T Recommendations continue to be developed and implemented, that e-waste management policies reflect the sustainable consumption

[3] Smart Cities Association. 'EE: Average UK Smart Home Will Have 50 Connected Devices by 2023.' smartcitiesassociation.org/index.php/media-corner/news/169-ee-average-uk-smart-home-will-have-50-connected-devices-by-2023.

[4] GOV.UK. 'Smart Meters: Unlocking the Future.' 31 Dec. 2018, www.gov.uk/government/publications/smart-meters-unlocking-the-future/smart-meters-unlocking-the-future.

[5] Climate Home News. 'Tsunami of Data' Could Consume One Fifth of Global Electricity by 2025.' The Guardian, Guardian News and Media, 11 Dec. 2017, www.theguardian.com/environment/2017/dec/11/tsunami-of-data-could-consume-fifth-global-electricity-by-2025.

[6] Andrae, Anders S.G. 'Total Consumer Power Consumption Forecast.' Huawei, Oct. 2017, www.researchgate.net/publication/320225452_Total_Consumer_Power_Consumption_Forecast.

[7] Climate Home News. 'Tsunami of Data' Could Consume One Fifth of Global Electricity by 2025.' The Guardian, Guardian News and Media, 11 Dec. 2017, www.theguardian.com/environment/2017/dec/11/tsunami-of-data-could-consume-fifth-global-electricity-by-2025.

[8] ReportBuyer.com. 'More than 200 Million European Households Will Have Smart Meters in 2023.' PR Newswire Association LLC, 8 Jan. 2018, www.prnewswire.com/news-releases/more-than-200-million-european-households-will-have-smart-meters-in-2023-300578405.html.

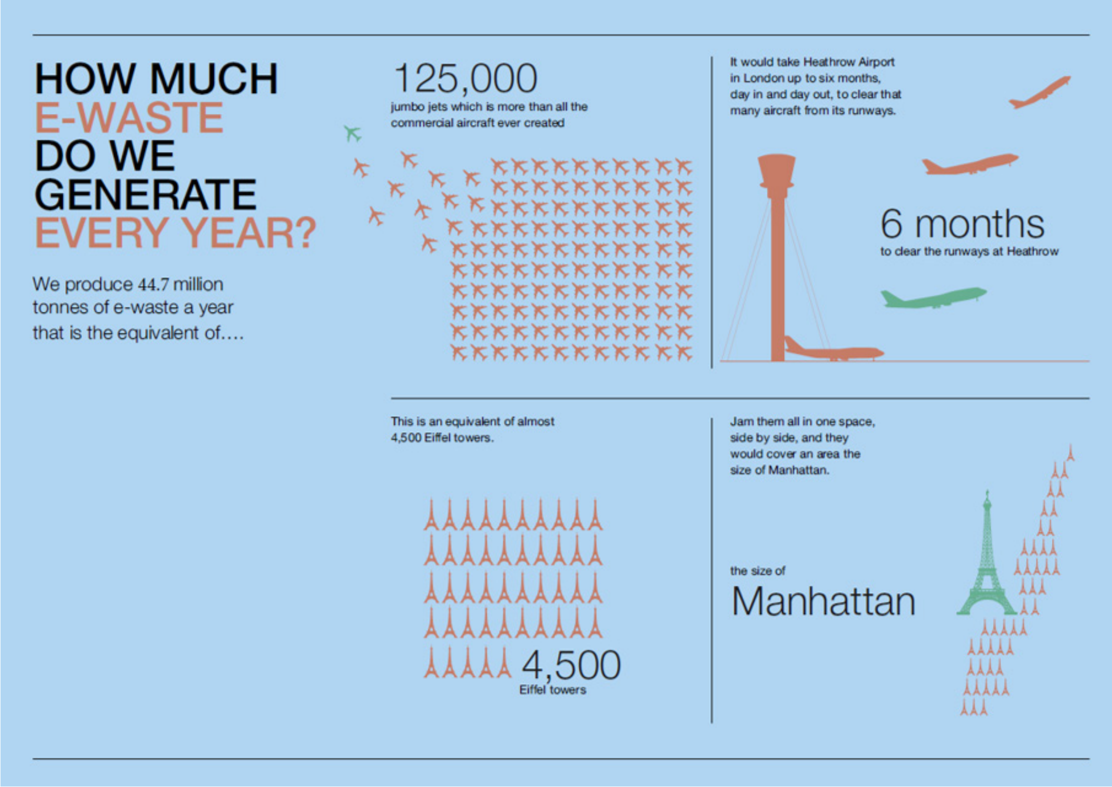
[9] Gartner. 'Gartner Identifies Top 10 Strategic IoT Technologies and Trends.' Gartner, Inc., 7 Nov. 2018, www.gartner.com/en/newsroom/press-releases/2018-11-07-gartner-identifies-top-10-strategic-iot-technologies-and-trends.

[10] Weckend, S., et al. 'End-of-life Management Solar Photovoltaic Panels.' International Renewable Energy Agency (IRENA), IEA, 2016.

[11] Baldé, C.P., et al. 'The Global E-Waste Monitor 2017: Quantities, Flows, and Resources.' International Telecommunication Union (ITU); United Nations University (UNU)-VIE SCYCLE; International Solid Waste Associate (ISWA), 2017, www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf.

and production of ICT equipment, and that governments and industry also consider the negative externalities of using ICT equipment as an accelerator for climate action. Figure 4, taken from the joint UN E-waste Coalition and World Economic Forum report: 'A New Circular Vision for Electronics: Time for a Global Reboot', visualises the amount of e-waste generated every year.

Figure 4: Generation of e-waste each year[12]



The above is supported by reports indicating that ICTs are by now major consumers of energy in:

a) **Manufacturing and production**: It is estimated that one tonne of laptops could emit up to 10 tonnes of carbon dioxide.[13]

b) **Usage:**

- **Growth in the number of consumer devices:** Cisco estimates that nearly 650 million mobile devices and connections were added over 2017.[14] The OECD estimates that a typical OECD household with two children may now have up to ten connected devices on average per household.[15]

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[12] Bel, Garam, et al. 'A New Circular Vision for Electronics: Time for a Global Reboot.' World Economic Forum (WEF); UN E-Waste Coalition; World Business Council for Sustainable Development (WBCSD); World Health Organization (WHO), Jan. 2019, www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf.

[13] Gray, Vanessa. 'Let's Rethink e-Waste, and Pave the Way to a Waste-Free Economy for Electronics.' International Telecommunication Union (ITU), 24 Jan. 2019, news.itu.int/lets-rethink-e-waste-waste-free-economy/.

[14] Cisco. 'Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update.' 2017-2022 White Paper. 18 Feb. 2019, www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.html.

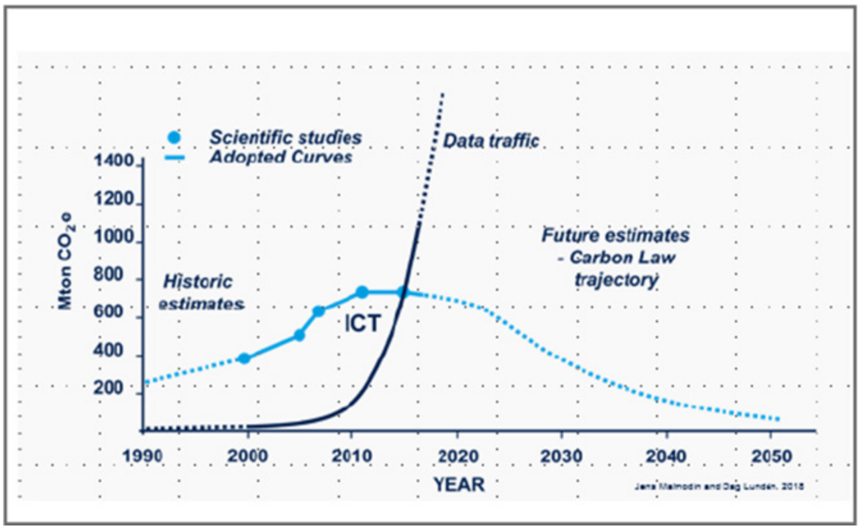
[15] Organisation for Economic Co-operation and Development (OECD). 'OECD Technology Foresight Forum 2014- The Internet of Things.' OECD Conference Centre, 11 Dec. 2014, www.oecd.org/sti/ieconomy/technology-foresight-forum-2014.htm.

- **Data flows:** Cisco estimates that global mobile data traffic grew by 71% in 2017. Global mobile data traffic reached 11.5 Exabytes per month at the end of 2017, up from 6.7 Exabytes per month at the end of 2016.[16]
- **Energy use & energy efficiency across networks:** International standards can help address these concerns by providing common measurement methodologies. ITU has developed a set of methodologies and key performance indicators (KPIs) to assess the environmental impact including measuring carbon footprint, energy performance and efficiency across telecom/ICT networks, goods and services.
- **Data centres:** The number of data centres is increasing rapidly worldwide, with a large number being installed in Scandinavia (e.g. Iceland), where average temperatures are lower. Data centres vary in their energy efficiency and energy sources. For example, Facebook has committed to enough new renewable energy resources to equal 100% of the energy used by every data centre built by Facebook in 2020, and always in the same state or power grid as the data centre itself.[17]

The good news is that some research also shows that ICTs do have the potential to enable up to one-third of the first halving of global GHG emissions by 2030, by enabling efficiencies in lifestyle and in other (non-ICT) sectors of the economy[18] through the provision of digital solutions that can improve energy efficiency, inventory management and business efficiency.[19] Opportunities for environmental load reduction through the use of ICTs include travel substitution, transportation optimization, working environment changes, use of environmental control systems, use of e-business, e-government, and so on.

Figure 5 illustrates this overall projection, followed by Figure 6 that shows projections disaggregated by ICT emissions sources.

Figure 5: Projection for halving of global GHG emissions by 2030[20]



[16] Cisco. 'Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update.' 2017-2022 White Paper. 18 Feb. 2019, www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.html.

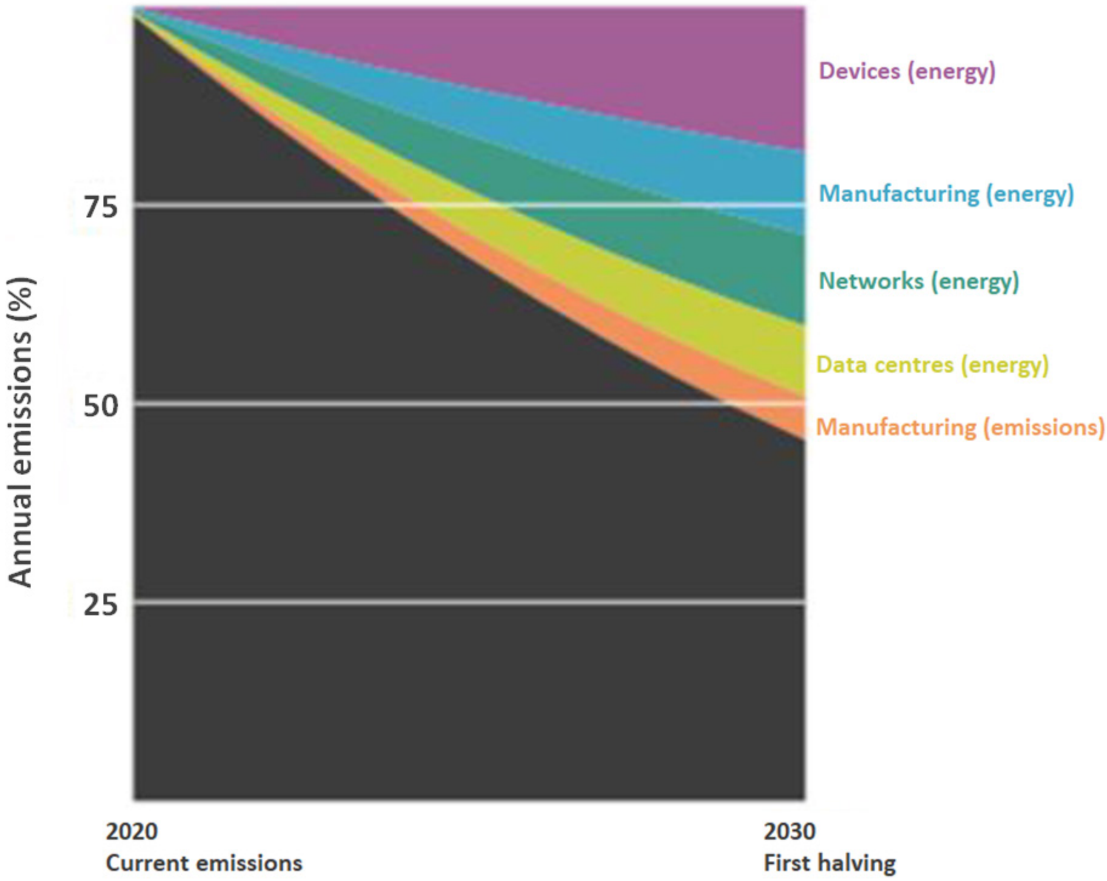
[17] Facebook. 'Sustainable Data Centers.' Facebook Sustainability, Facebook Inc., 24 June 2019, sustainability.fb.com/innovation-for-our-world/sustainable-data-centers/.

[18] Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

[19] Marchi, Beatrice, and Simone Zanoni. 'Supply Chain Management for Improved Energy Efficiency: Review and Opportunities.' 16 Oct. 2017, www.mdpi.com/1996-1073/10/10/1618/pdf.

[20] Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

Figure 6: Projection for halving of global GHG emissions by 2030 - by ICT emissions source[21]



Furthermore, while the 'double-edged" nature of ICTs also manifests through the 'rebound effects'[22] caused by additional impacts from the use of more ICT services (especially as their affordability and availability increases), recent research shows that while initially a higher level of ICT usage correlates to a higher level of carbon dioxide equivalent emissions, this typically plateaus 3 years after ICT usage has reached sufficiently high levels.[23] After this point, increases in the level of ICT usage correlate with lower emissions. Essentially, this may amount to an initial investment and implementation, i.e. adjustment period, after which technologies could be optimized to increase efficiency in use and production, thereby potentially lowering emissions in the ICT sector and in other sectors.[24] This is also identified in other research that shows overall emissions avoided through the use of ICTs over a period of time as being nearly 10 times greater than the emissions generated by deploying it.[25]

ICTs can, therefore, be considered to be accelerators that reflect society. If their 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 in the fight against climate change.

[21] Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

[22] Rebound effects refer to the risk that the potential reductions from indirect emissions-reducing effects could be cancelled out by changes in consumer behaviour – leading to greater energy consumption and, hence, greater emissions.

[23] Hernnäs, Helena. 'What Is the Impact of ICT on CO2 Emissions?' Ericsson, 2018, www.ericsson.com/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2018-09-helena-hernnas-m1-dissertation.pdf.

[24] Hernnäs, Helena. 'ICT Impact on CO2 Emissions – a Macro Perspective." Ericsson, 9 Oct. 2018, www.ericsson.com/en/blog/2018/10/ict-impact-on-co2-emissions--a-macro-perspective.

[25] Hernnäs, Helena. 'What Is the Impact of ICT on CO2 Emissions?' Ericsson, 2018, www.ericsson.com/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2018-09-helena-hernnas-m1-dissertation.pdf.

2.2 Frontier technologies and climate actions

The need to unlock this potential is urgent because if the Paris Agreement targets are to be met, it is estimated that the world economy will have to reduce its carbon dioxide equivalent emissions per dollar of income by 6.3 per cent per year until the year 2100.[26] The good news is that some estimates show that already existing ICT solutions offer the potential to suppress 15 per cent of current emissions[27] – a potential that may grow with strategic and responsible adoption of frontier technologies (as outlined in Box 2).

Box 2: The potential of frontier technologies in addressing climate change

Frontier Technologies to Address Climate Change

Frontier technologies are new, innovative and disruptive technologies that offer some potential to help identify, mitigate and, where possible, reverse the effects of climate change. Leveraging these technologies to engineer new solutions to address climate change represents an opportunity to accelerate efforts to achieve the Paris Agreement, as well as Sustainable Development Goal (SDG) 13.

The global proliferation of ICTs, for example, is part of the rising **Internet of Things (IoT)**, which the ITU has defined in its Recommendation ITU-T Y.2060 as, 'a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies". Big data is also an organic by-product of IoT due to the ability of machines to generate, process and analyse large volumes of data at high speeds.

The cost affordability of IoT-enabled devices and IoT-based systems has the potential to be of particular benefit to developing countries by opening up opportunities for advancement

26 Hernnäs, Helena. 'ICT Impact on CO2 Emissions – a Macro Perspective.' Ericsson, 9 Oct. 2018, www.ericsson.com/en/blog/2018/10/ict-impact-on-co2-emissions--a-macro-perspective.

27 Bergmark, Pernilla. 'Halving Global Emissions by 2030 through Exponential Climate Action and Digital Technologies.' International Telecommunication Union (ITU), 13 May 2019, www.itu.int/en/ITU-T/climatechange/symposia/201905/Documents/3_Pernilla_Bergmark.pdf.

that have previously been widely available mostly in developed countries. IoT is increasingly responsible for connectivity-based service models in areas as diverse as water, sanitation, healthcare, agriculture, education and finance.

Artificial intelligence (AI) in computers and machines autonomously simulates human intelligence processes such as learning, reasoning and self-correction. Today's AI systems generally have three qualities that constitute the essence of artificial intelligence: intentionality, intelligence, and adaptability.

There is potential for AI to be a tool in the effort to decouple economic growth from rising carbon emissions. In the not-too-distant future, many consumer purchases will be automated with algorithms that carry potential to influence consumer behaviour related to GHG emissions. However, there still are certain limitations as regards the carbon footprint of AI and machine learning (ML). These are explored later in this chapter.

Renewable energy technologies remain very relevant in the discussion around climate change. ICTs can facilitate greater adoption – through the integration of automated sensors, data capture, performance measurement or other mechanisms – of renewable energy technologies that enable the creation of electricity, heat and fuel from renewable sources, such as solar, wind, hydro, wave and tidal power, heat-exchange/geothermal and bioenergy.

According to the IPCC, moving towards the use of renewable energy is vital, as it can contribute to social and economic development, energy access, secure energy supply, climate change mitigation, and the reduction of negative environmental and health impacts. This may, in fact, be realizable given that clean energy sources such as solar and wind power are quickly becoming more affordable than conventional sources.

ICTs can also facilitate the adoption of other innovative technologies such as **digital twins** to combat climate change. A digital twin is the virtual representation of a physical object or system across its life cycle. It uses real-time data and other sources to enable learning, reasoning and dynamic recalibration for improved decision making. Within the context of climate change and response, digital twins are an attractive proposition, particularly for urban areas that are rapidly growing in population, size and energy consumption. They are also attractive for those urban areas that, as a consequence, need to ensure the efficient, agile and responsive management and maintenance of all their systems.

Another emerging example is **5G technology**, which is the latest generation of cellular and wireless connectivity that is a key focus of ITU's current work agenda (as detailed in later sections). 5G technology is expected to offer faster speeds and greater coverage, in addition to longer battery life for devices, larger data transfer capabilities and more reliability. It is expected to leave behind a smaller environmental footprint than the current technologies because it will be more directional and efficient, resulting in less energy and power being wasted.

Having arrived at a point when such frontier technologies are being actively and extensively studied to gauge the broader implications, network effects and consequences (both intended and unintended) of rapid innovation, ITU is at the forefront of driving such research and analysis at a global level**. ITU, together with the Basel, Rotterdam and Stockholm Conventions (BRS), 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 (UNGC), United Nations Industrial Development Organization (UNIDO), United Nations Human Settlements Programme (UN-Habitat) and UN-Women will publish a report on the potential of frontier technologies such as artificial intelligence (AI), Internet of Things (IoT), 5G, clean energy technologies, digital twins, robotics, Space 2.0, digitization and Big Data to protect the environment and tackle climate change in urban areas.**

ITU's effort is especially timely, as all these frontier technologies are to a degree interrelated, especially in their integration with, or reliance on, the Internet of Things (IoT), Artificial Intelligence (AI), 5G and Big Data. While the concept of many of today's emerging technologies has been around for some time, it is especially due to IoT and the wider adoption of ICTs that it is now becoming feasible to implement them on larger scales.

Therefore, further researching and guiding the affordable and wide-scale deployment of these 'enabler' and core building-block ICTs will assure further advancement and adoption of other emerging technologies, which may help to engineer innovative climate solutions in the areas of monitoring, adaptation and mitigation.

2.3 The Limitations of AI and ML

As mentioned in Box 2, however, limitations do remain with regard to the carbon footprint of AI and machine learning (ML). [28] [29] [30] AI and ML, like most technology, have the potential to help in the fight against climate change. They can make systems more efficient (e.g. by preventing electricity loss during transmission), enable remote sensing and automatic monitoring (e.g. pinpointing deforestation, gathering data on buildings, and tracking personal energy use), provide fast approximations to time-intensive simulations (e.g. climate models and energy scheduling models) and also have the potential to lead to interpretable or causal models (e.g. for understanding weather patterns, informing policy makers and planning for disasters).

It has been estimated, for instance, that 'using AI for environmental applications could boost the global economy by up to $ 5.2 trillion (USD) in 2030, a 4.4 per cent increase on the business-as-usual scenario, while reducing GHG emissions worldwide by 4 per cent, equivalent to the 2030 annual emissions of Australia, Canada and Japan combined.'[31]

The efficacy of ML and AI will, however, rely on bringing together several factors, including ensuring their effective integration with other technologies and – because they require large amounts of computing power – decarbonisation of the energy system to ensure that AI and ML can fulfil their sustainability potential. This is imperative, as new studies are showing that typical current ML processes can 'emit more than 626 000 pounds of carbon dioxide equivalent (CO_2e) – nearly five times the lifetime emissions of the average American car (and that includes the manufacture of the car itself)'.[32]

Specifically, these studies have examined 'the model training process for natural-language processing (NLP), the subfield of AI that focuses on teaching machines to handle human language. In the last two years, the NLP community has reached several noteworthy performance milestones in machine

28 Rolnick, David, et al. 'Tackling Climate Change with Machine Learning.' ArXiv.org, Cornell University, arxiv.org/pdf/1906.05433.pdf.

29 Scott, Mike. 'AI Will Be A Vital Tool in Making the Global Economy More Sustainable and Efficient- PwC.' Forbes Magazine, Forbes Media LLC, 23 Apr. 2019, www.forbes.com/sites/mikescott/2019/04/23/ai-will-be-a-vital-tool-in-making-the-global-economy-more-sustainable-and-efficient-pwc/#573e61cb4ce7.

30 Hao, Karen. 'Training a Single AI Model Can Emit as Much Carbon as Five Cars in Their Lifetimes.' MIT Technology Review, 7 Jun. 2019, www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/?utm_campaign=site_visitor.unpaid.engagement&utm_source=hs_email&utm_medium=email&utm_content=73608463&_hsenc=p2ANqtz--j9p83piXIm9fiL7riodfQuQX0XOkswkP4qgMHSe_NJI3GIxGsHMPZsEsVt2YyzyC0TqVKV7Zh0by-TudcURQa5bnoKw&_hsmi=73608464.

31 Scott, Mike. 'AI Will Be A Vital Tool in Making the Global Economy More Sustainable and Efficient- PwC.' Forbes, Forbes Magazine, 23 Apr. 2019, www.forbes.com/sites/mikescott/2019/04/23/ai-will-be-a-vital-tool-in-making-the-global-economy-more-sustainable-and-efficient-pwc/#573e61cb4ce7.

32 Hao, Karen. 'Training a Single AI Model Can Emit as Much Carbon as Five Cars in Their Lifetimes.' MIT Technology Review, 7 Jun. 2019, www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/?utm_campaign=site_visitor.unpaid.engagement&utm_source=hs_email&utm_medium=email&utm_content=73608463&_hsenc=p2ANqtz--j9p83piXIm9fiL7riodfQuQX0XOkswkP4qgMHSe_NJI3GIxGsHMPZsEsVt2YyzyC0TqVKV7Zh0by-TudcURQa5bnoKw&_hsmi=73608464.

translation, sentence completion, and other standard benchmarking tasks. OpenAI's infamous GPT-2 model, as one example, excelled at writing convincing fake news articles. But such advances have required training ever larger models on sprawling data sets of sentences scraped from the internet. The approach is computationally expensive – and highly energy intensive." Furthermore, they found that 'the computational and environmental costs of training grew proportionally to model size and then exploded when additional tuning steps were used to increase the model's final accuracy."[33] It is especially important to account for these limitations when considering the deployment of ICTs to address climate change.

The next few chapters detail the existing (and potential) ways that ICTs do help in monitoring, mitigating and adapting to climate change impacts.

[33] Hao, Karen. 'Training a Single AI Model Can Emit as Much Carbon as Five Cars in Their Lifetimes.' MIT Technology Review, 7 Jun. 2019, www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/?utm_campaign=site_visitor.unpaid.engagement&utm_source=hs_email&utm_medium=email&utm_content=73608463&_hsenc=p2ANqtz--j9p83piXIm9fiL7riodfQuQX0XOkswkP4qgMHSe_NJI3GIxGsHMPZsEsVt2YyzyC0TqVKV7Zh0by-TudcURQa5bnoKw&_hsmi=73608464.

Chapter 3. ICTs and climate monitoring

3.1 Using ICTs to monitor the global environment/ecosystem[1]

Information pertaining to climate, weather, cryosphere, precipitation, pollution and disasters is critically important in understanding climate change and its impact on the environment. Monitoring activities are used to provide daily weather forecasts and long-range predictions, to study climate change, for environmental protection and economic development, and for the safety of life and property. Apart from monitoring the climate, tracking deforestation and recording Arctic sea ice loss, Earth observations are also used to obtain pertinent data on natural resources.

Typical ICT systems involved in environment and climate monitoring and data dissemination include:

- weather satellites that track the progress of hurricanes and typhoons;
- weather radars that track the progress of tornadoes, thunderstorms, and the effluent from volcanoes and major forest fires;
- radio-based meteorological aid systems that collect and process weather data; and
- Earth observation satellite systems that obtain environmental information such as atmospheric composition (e.g. CO_2, vapour, ozone concentration), ocean parameters (temperature, surface-level change), soil moisture, vegetation including forest control, agricultural and other data.

All these systems are part of the World Meteorological Organization (WMO) Global Observing System (WIGOS, more commonly referred to as GOS). The GOS is 'the primary source of technical information on the world's atmosphere,' and is 'a composite system of complex methods, techniques and facilities for monitoring and measuring meteorological and environmental parameters.'[2] The GOS detects and forecasts (as well as provides warning for) severe weather phenomena such as local storms, tornadoes, hurricanes, or extra-tropical and tropical cyclones. Through the capture of observational data for agrometeorology, aeronautical meteorology and climatology, the GOS also facilitates study of the climate, global climate change, safety standards, etc. Data from the GOS are used to support environmental programmes everywhere.

The GOS is complemented by the Global Telecommunication System (GTS), which 'provides for the real-time exchange of meteorological observational data, processed products and related information between national, meteorological and hydrological services.'[3]

It is also complemented by the Global Data Processing and Forecasting System, which 'provides processed meteorological products (analysis, warnings, and forecasts) that are generated by a network of World Meteorological Centres and specialized Regional Meteorological Centres.'[4]

Together, these three components form the World Weather Watch (WWW). Figure 7 illustrates the interaction of various components and the main systems within the GOS, followed by Box 3, which explains spaceborne monitoring systems.

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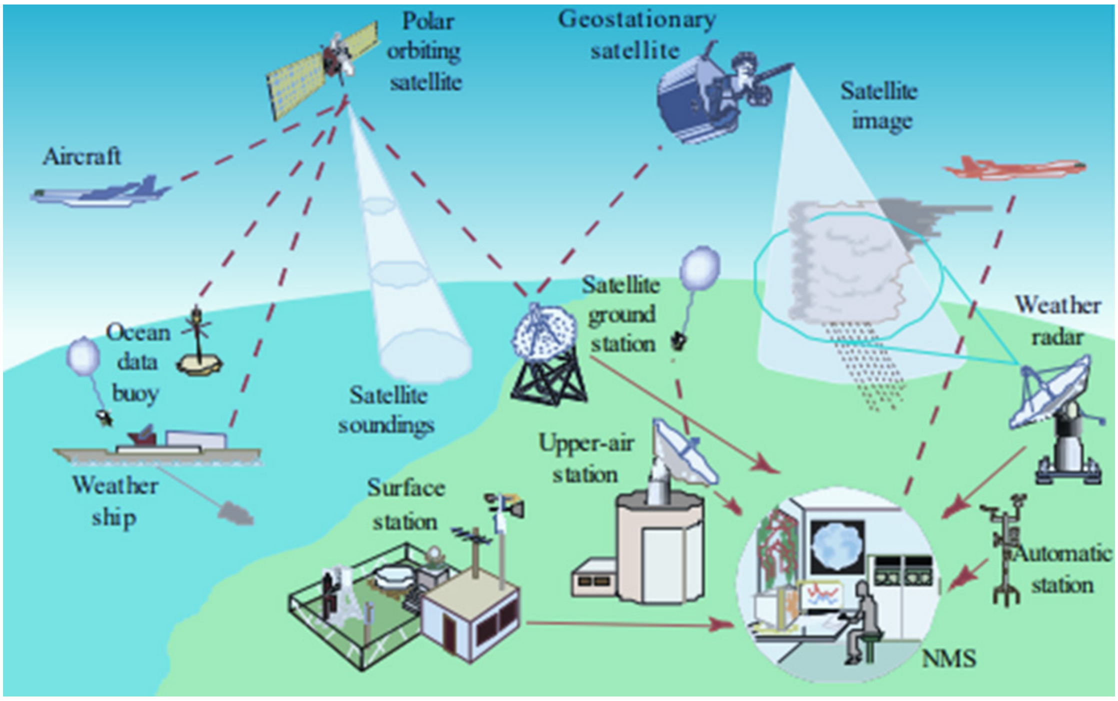
1 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change." International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.

2 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.

3 Ilčev, Stojče Dimov. 'Global Satellite Meteorological Observation (GSMO) Applications.' Volume 2, Springer, 5 Dec. 2018. https://books.google.ca/books?id=9Ld9DwAAQBAJ&dq=real-time+exchange+of+meteorological+observational+data,+processed+products,+and+related+information+between+national,+meteorological+and+hydrological+services&source=gbs_navlinks_s.

4 Ilčev, Stojče Dimov. 'Global Satellite Meteorological Observation (GSMO) Applications.' Volume 2, Springer, 5 Dec. 2018. https://books.google.ca/books?id=9Ld9DwAAQBAJ&dq=real-time+exchange+of+meteorological+observational+data,+processed+products,+and+related+information+between+national,+meteorological+and+hydrological+services&source=gbs_navlinks_s.

Figure 7: Global Observing System (GOS)



Box 3: Space-based Earth monitoring systems[5]

Spaceborne Earth monitoring & observation systems and their crucial impacts

The ITU Radiocommunication Sector (ITU–R) Study Group 7 deals with science services. These include the Earth exploration-satellite and meteorological-satellite services with systems for passive and active spaceborne remote sensing, which enable scientists to obtain important data about the Earth and its atmosphere. The systems used for these purposes have far-reaching effects for everyone on the planet. The data are being used to study and monitor climate change, assist meteorologists in predicting the weather, and monitor a wide variety of natural hazards.

Spaceborne active sensors are instruments that help in this regard by obtaining data through the transmission and reception of radio waves. They are basically radar systems on spaceborne platforms. There are five types of active sensors, each having its own specific purpose. The synthetic aperture radar (SAR) is used to obtain topographical data of the Earth's surface. Altimeters are used to measure the precise height of the ocean surface. Scatterometers are primarily used to determine the wind direction and speed at the ocean surface. Precipitation radars are used to determine rainfall rates and the three-dimensional structure of the rainfall. And cloud profile radars are used to measure cloud cover and structure over the Earth's surface.

Spaceborne passive sensors are very sensitive receivers known as radiometers that measure the electromagnetic energy emitted and scattered by the Earth, and the chemical constituents in its atmosphere. These very sensitive receivers require protection from radio-frequency interference in order to be able to make their requisite measurements. Passive remote sensing instruments operating on Earth observation satellites are looking down at the Earth's surface and atmosphere, and are susceptible to interference from

5 ITU News Magazine. 'Monitoring Our Changing Planet.' International Telecommunication Union (ITU), 2019, www.itu.int/en/itunews/Documents/2019/2019-01/2019_ITUNews01-en.pdf.

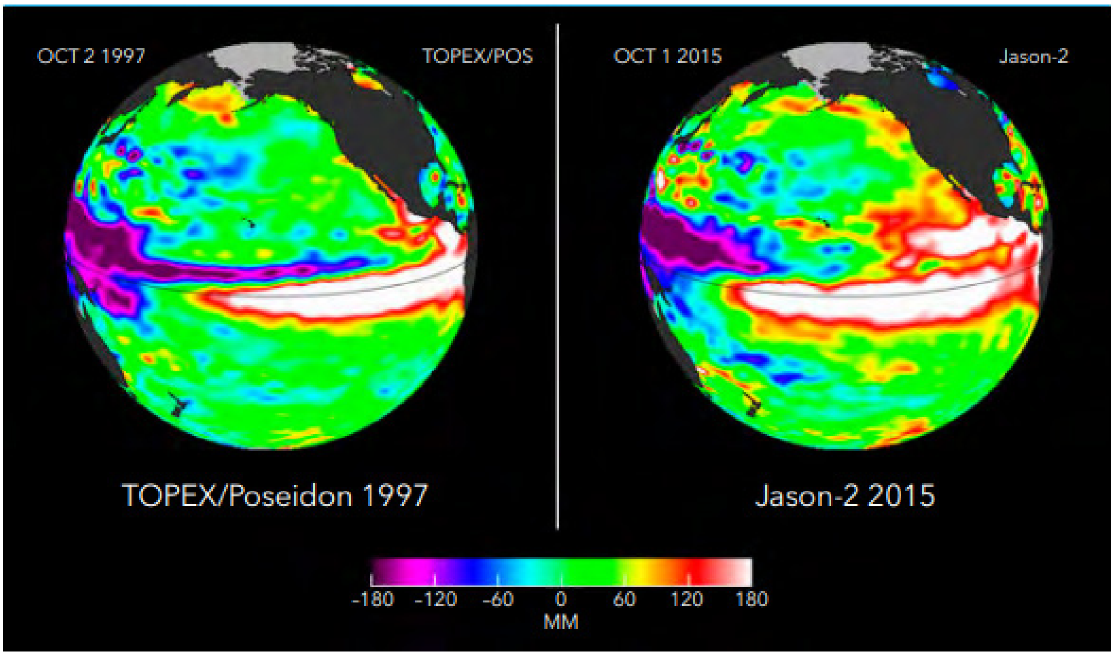
transmitters operating on or near the surface of the Earth. These sensitive receivers can operate successfully only because of the allocation of certain frequency bands to their respective radio services and the regulatory protections afforded to them by many special provisions of the Radio Regulations.

It is important to note that while meteorological and Earth observation satellites are operated by a limited number of countries, the data and data products that result from their operation are distributed and used on a global basis, in particular by national weather services in developed and in developing countries, and by organizations monitoring and studying climate change. Furthermore, data from Earth observation and remote sensing systems are used widely in applications for disaster prediction, monitoring and mitigation. This is crucial, as a United Nations (UN) report has found that **approximately 90 per cent of all disasters are weather-related**.

The continued use of increasingly sophisticated, space-based monitoring technologies has given meteorologists the ability to predict complex El Niño events. Figure 8 shows that it is now possible to predict El Niño from ocean data obtained by satellites; below, a huge anomalous arrival of warm water can be seen off the coast of Peru in 1997 and again in 2015. During 1997, there was a local rise of about 20 cm of the sea level in the equatorial Pacific when the phenomenon was at its height (and as much as 30 centimetres off the coast of Peru).

Another application of space monitoring is early tsunami detection. In the early morning of 26 December 2004, within hours of the big earthquake in the Indian Ocean, two joint NASA/CNES satellites (Topex and Jason-1), ENVISAT (an ESA satellite) and GFO (from NOAA) detected, by chance, the tsunami across the Bay of Bengal. This has led to space agencies now preparing future missions to detect the direction, amplitude and wavelength of surface waves and measure wind speed (CFOSAT); to continue gauging accurate ocean surface topography (JASON-CS / Sentinel 6); and to further study land hydrology and oceanography (SWOT).

Figure 8: El Niño events in 1997 and 2015



An example of the ongoing use of ICTs to monitor the environment can be seen in the monitoring of nitrogen dioxide levels over Northern Italy.[6] [7] [8]

3.2 Using ICTs to monitor food security, water transportation and supply[9]

Climate change can have a profound impact on the quality and availability of water and food. More frequent and severe storms, heat waves, droughts and floods, and worsening air quality will disproportionally impact the poorest countries most severely. Consequently, ICTs are crucially needed to address food security by monitoring food supplies across the world; this includes the mapping of agricultural production and food shortages. The ICTs that can be used for this purpose include:

- satellites, Global Positioning Systems (GPS) and machine-to-machine (M2M) connectivity that supports remote sensing infrastructure, with high-resolution radiometers and moderate-resolution imaging spectrometers used to monitor food and water resources (including sensors and telemetry units that measure and transmit parameters such as air temperature, humidity, leaf wetness and soil moisture over mobile networks to global databases).
- The PCs, mobile devices, servers, mainframes and network databases used for food security mapping, and for the analysis and modelling of the data gleaned through the monitoring efforts.

Monitoring environmental and soil conditions and then using ICTs, including the Internet, to distribute information to farmers and consumers can help make farming more profitable and environmentally sustainable. Monitoring water usage and waste using ICTs can help improve water management and the overall efficiency of its use, thereby providing significant water and cost savings and leading to a more sustainable use of water resources.

Satellite imaging and GPS can be used to monitor the application of fertilizer, in addition to water. This allows for more efficient fertilizer application based on local soil and climate conditions. Furthermore, ICTs can be used to better forecast crop yields and production. This data can then be shared with farmers to enable higher profitability and economic sustainability for them.

An example of the successful use of ICTs to monitor food security can be seen in the monitoring of crop growth in Belgium.[10] [11]

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6 Cornu, Céline. 'Italy's Polluted Po Valley Gasps for Fresh Air.' Phys.org, Science X Network, 28 Feb. 2019, phys.org/news/2019-02-italy-polluted-po-valley-gasps.html.

7 European Space Agency (ESA). 'Nitrogen Dioxide over Northern Italy.' 16 May 2019, www.esa.int/spaceimages/Images/2019/05/Nitrogen_dioxide_over_northern_Italy.

8 Bigi, Alessandro, et al. 'Analysis of the Air Pollution Climate at a Background Site in the Po Valley.' Journal of Environmental Monitoring: JEM, U.S. National Library of Medicine, Feb. 2012, www.ncbi.nlm.nih.gov/pubmed/22170095.

9 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.

10 European Space Agency (ESA). 'Precision Agriculture.' European Space Agency, 17 Dec. 2018, www.esa.int/spaceimages/Images/2018/12/Precision_agriculture.

11 Encyclopedia of the Nations. 'Belgium- Agriculture.' Encyclopedia of the Nations, www.nationsencyclopedia.com/economies/Europe/Belgium-AGRICULTURE.html.

3.3 Using ICTs to monitor deforestation and forest degradation

Each year, land use and tropical deforestation release 1.5 billion tonnes of carbon into the atmosphere, which represents more than 17 per cent of total GHG emissions.[12] Studies have estimated that a temperature rise of 4°C by 2100 would destroy up to 85 per cent of the rainforest.[13]

Tropical forests reduce carbon dioxide flux by acting as large stores of carbon – containing more carbon per unit area than any other land cover. Deforestation releases this carbon into the atmosphere and inadvertently contributes to global emission and climate change. It is estimated that reducing tropical deforestation by 50 per cent over the next century could help prevent 500 billion tonnes of carbon from being released into the atmosphere annually.[14] This reduction in emissions would account for 12 per cent of the total reductions targeted by the IPCC.[15]

ICTs can contribute to reaching this target by monitoring and collecting data on the condition of forests. Satellites that are now able to take images through clouds (and at night) and remote sensing applications are critical for monitoring the health of the world's tropical forests.

An example of the much-needed use of ICTs to monitor deforestation can be seen in the monitoring of the loss of the Amazonian rainforest in Bolivia.[16]

12 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.
13 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.
14 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.
15 Dickerson, Keith, et al. 'Using ICTS to Tackle Climate Change.' International Telecommunication Union (ITU), Nov. 2010, www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000010001PDFE.pdf.
16 European Space Agency (ESA). 'Giving up Forests'. 21 Mar. 2018, www.esa.int/spaceinimages/Images/2018/03/Giving_up_forests.

Chapter 4. ICTs and climate change mitigation

According to the IPCC, climate change mitigation is defined as 'limiting and preventing the emission of greenhouse gas by enhancing activities that remove these gasses from the atmosphere.[1] The primary sources of GHGs can be found in the following sectors: energy, transportation, buildings, industry, waste management, agriculture, and forestry. Accordingly, mitigation actions – including several of the following – can apply to every single one of these sectors:

- **Energy**: The energy supply sector represents the largest contributor of global GHG emissions. Mitigation measures may include: improving energy efficiency; reducing fugitive emissions in fuel extract; switching to renewable energy; and employing carbon dioxide capture and storage technologies.
- **Transportation**: Measures may include: improving vehicle and engine design to improve energy efficiency; reducing the carbon intensity of fuel; and revitalizing city infrastructure to encourage behavioural change.
- **Buildings**: Measures may include: reducing energy requirements in new buildings, retrofitting existing buildings to reduce energy use in heating and cooling, and encouraging lifestyle changes.
- **Industry**: Measures may include: wide-scale upgrading, replacing and deploying best available technologies; improving material use efficiency; encouraging the recycling and re-reuse of materials and products; improving product service efficiency; and enhancing waste use to reduce material demands.
- **Agriculture, forestry and other land use**: Measures may include: reducing deforestation; improving land and livestock management; replacing energy-intensive building materials; and reducing waste in the food supply chain.
- **Human settlements, infrastructure, and spatial planning**: Urban areas account for more than half of global primary energy use and energy-related CO_2. It is difficult to determine the most effective mitigation actions given the complexity of a city. However, some potential mitigation measures may include: implementing effective climate policies; and improving land-use as well as energy policies.

Figure 9 below highlights the allocation of total GHG emissions in 2010. It demonstrates that the energy (indirect emissions) and industry sectors have the largest impacts on climate. They are closely followed by the Road/Transportation sector and the Agriculture, Forestry and Other Land Use (AFOLU) sector. These development trends suggest that reducing energy use in buildings and relieving traffic congestion have potential in reducing GHG emissions in cities.[2]

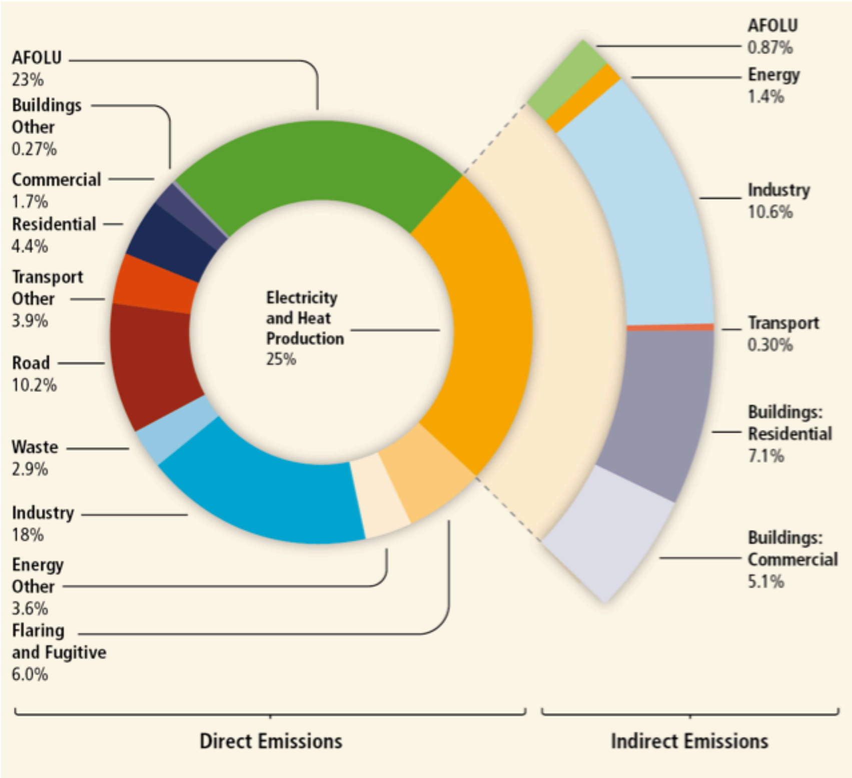
In addition, as indicated previously, the ICT sector itself has also been contributing to global GHG emissions. Being the backbone of digital technologies, ICTs are powered by hundreds and thousands of data centres. It has been shown that data centres are already consuming more than 2 per cent of

[1] Intergovernmental Panel on Climate Change (IPCC). 'AR5 Climate Change 2014: Mitigation of Climate Change.' 2014, www.ipcc.ch/report/ar5/wg3/.

[2] Intergovernmental Panel on Climate Change (IPCC). 'Reports.' https://www.ipcc.ch/reports/.

the world's electricity and are emitting roughly as much emissions as the aviation industry.[3] As the world is moving towards to a digital age, this percentage is expected to continue to grow. It is hoped that some of the largest companies go beyond taking their first steps in adapting renewable energy to power data centres and to lower the carbon emission of these data centres by improving their overall energy efficiency.[4]

Figure 9: Greenhouse gas emission per sector in 2010



This chapter sheds light on the ways in which ICTs may help to accelerate climate mitigation actions, including: improving energy efficiency in buildings; facilitating a pioneer project on data centre management; improving traffic congestion and public transportation in metropolitan areas; and being the key element in operating smart grids.

4.1 Using ICTs to improve the energy efficiency in buildings

Buildings and constructions in cities are responsible for 36 per cent of global final energy use while the industry sector accounts for about 28 per cent of all final energy use.[5] Improving the environmental performance and energy consumption of these sectors has significant potential in reducing the emission of greenhouse gases worldwide.

Smart sensors and IoT applications have the capability to collect, transfer, and analyse a vast amount of data in near real time. When placed in buildings and constructions, they are able to measure

[3] Pearce, Fred. 'Energy Hogs: Can World's Huge Data Centers Be Made More Efficient?' Yale Environment 360 (E360), Yale School of Forestry & Environmental Studies, 3 Apr. 2018, e360.yale.edu/features/energy-hogs-can-huge-data-centers-be-made-more-efficient.

[4] Pearce, Fred. 'Energy Hogs: Can World's Huge Data Centers Be Made More Efficient?' Yale Environment 360 (E360), Yale School of Forestry & Environmental Studies, 3 Apr. 2018, e360.yale.edu/features/energy-hogs-can-huge-data-centers-be-made-more-efficient.

[5] International Energy Agency (IEA). 'Energy Efficiency: Buildings: The global exchange for energy efficiency policies, data and analysis.' 2019, https://www.iea.org/topics/energyefficiency/buildings/

energy use, optimize energy distribution, automate building operations and subsequently improve their overall energy performance.

A smart building may encompass of several smart technologies:[6]

- HVAC – Smart heating, ventilation, and air conditioning (HVAC) systems use sensors to monitor and control building's operations; software programmes will then analyse the collected data. Allowing an HVAC system can limit energy use in unoccupied zones, detect and diagnose faulty events, and optimize energy use during peak energy demand hours.
- Lighting – Smart lighting refers to the use of sensors to optimize the lighting function of a building. This may include incorporating natural daylighting and dimming controls depending on the time of the day. Smart lighting systems can be operated wirelessly and though a digital lighting management platform.
- Automated system optimization (AOS) – AOS uses ICT to collect and analyse building systems' operational and energy performance data. The data will then be used to make anticipatory changes based on external factors such as occupancy patterns, weather forecasts and the utility rate.
- Window shading – a smart wind system manages the amount of solar heat and daylight that enters a building. Windows are then capable of responding to changes in sunlight and temperature, which allows shades to be deployed as necessary or to optimize solar heat gain.

ICTs are being utilized in smart buildings to reduce their energy consumption and the subsequent emissions. Two examples are: 'The Edge' smart building in Amsterdam[7] [8] [9] [10] and the turning of old buildings into smart buildings in Finland.[11]

4.2 Using ICTs to improve data centre management

It is estimated that by 2021, there will be a total of 25 billion connected devices, producing an immense volume of data.[12] As more people are coming online, the Internet of Things (IoT), driverless cars, robots, and other technologies driven by connected devices are becoming major drivers of this growing volume of data. As the volume of data continues to increase, the power consumption of data centres grows in parallel. Reports indicate that data centres are already consuming more than 3 per cent of global electricity.[13] Coupling with the proliferation of frontier technologies, which are also largely data-driven, there is an urgent need to minimize the carbon footprint of data centres and to develop innovative strategies that would support such an endeavour.

The use of renewable energy to power data centres and the reuse of the heat produced by them is one possible way to reduce their potential negative impact on the environment. Advanced DCIM

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6 King, Jennifer, and Christopher Perry. 'Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings.' American Council for an Energy-Efficient Economy (ACEEE), Feb. 2017, aceee.org/sites/default/files/publications/researchreports/a1701.pdf.

7 BREEAM. 'The Edge, Amsterdam.' Building Research Establishment Ltd, 3 Apr. 2018, www.breeam.com/case-studies/offices/the-edge-amsterdam/.

8 Randall, Tom. 'The Smartest Building in the World.' Bloomberg Businessweek, 23 Sept. 2015, www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-building/.

9 Hutt, Rosamond. 'Is This the World's Greenest, Smartest Office Building?' World Economic Forum (WEF), 28 Mar. 2017, www.weforum.org/agenda/2017/03/smart-building-amsterdam-the-edge-sustainability/.

10 van Hooijdonk, Richard. 'The Smartest, Greenest Office Building on Earth – The Edge – Is like a Computer with a Roof.' Richard Van Hooijdonk Blog, 26 Jun. 2018, www.richardvanhooijdonk.com/en/blog/smartest-greenest-building-earth-edge-like-computer-roof/.

11 Smart Cities World. 'Helsinki and Vantaa Make Old Buildings Smart.' 6 June 2019, www.smartcitiesworld.net/news/news/helsinki-and-vantaa-make-old-buildings-smart-4250.

12 Gartner. 'Gartner Identifies Top 10 Strategic IoT Technologies and Trends.' Gartner, Inc., 7 Nov. 2018, www.gartner.com/en/newsroom/press-releases/2018-11-07-gartner-identifies-top-10-strategic-iot-technologies-and-trends.

13 Danilak, Radoslav. 'Why Energy is a Big and Rapidly Growing Problem for Data Centers.' Forbes Magazine, Forbes Media LLC, 15 Dec. 2017, www.forbes.com/sites/forbestechcouncil/2017/12/15/why-energy-is-a-big-and-rapidly-growing-problem-for-data-centers/#61e075255a30.

solutions based on AI technologies, along with the use of additional ICTs, can be used to control a data centre's cooling facilities. These can help improve the data centre's environmental friendliness and efficiency by automatically modulating its cooling levels to optimize the energy consumption of the IT load level and the day/night temperature change.

There is also the possibility to use natural water resources such as marine water, underground water, river water to cool data centres.

Project Natick – an underwater data centre powered by renewable energy – is an example.[14]

4.3 Using ICTs to relieve traffic congestion

Traffic congestion is a major challenge for large cities. Research indicates that around 10 per cent of the global population account for 80 per cent of motorised-passenger kilometres, with OECD countries dominating GHG transport emissions.[15] Growing GDP in developing regions such as Asia has seen growth in the emission levels in those regions as well. In 2010, over 53 per cent of global primary oil consumption was used to meet 94 per cent of the total transport energy demand.[16] Traffic induces air pollution and energy consumption to the detriment of human and environmental health. Therefore, reducing the number of cars on the road is one of the most important pathways to reducing emissions in cities.[17]

ICTs are being used to manage traffic flows in Moscow,[18] as well as in the Belfast Rapid Transit System - the Glider.[19] [20]

4.4 Using smart grids to reduce energy demands and accelerate renewable uptakes

At the centre of climate change mitigation is the reduction of carbon emissions. Renewable energy has played a significant role in this space. Statistics show that the surge in solar and wind energies has pushed renewable energy to account for one-third of the global power capacity in 2018.[21] As the cost of renewable energy continues to decline, the share of renewables is expected to continue to increase.[22]

The increasing uptake of renewable energy is key to reducing the global carbon footprint. The energy sector is known to be the largest emission sector. The demand for energy and associated services is expected to grow as social and economic development continues to evolve. Renewable energy can

14 Roach, John. 'Under the Sea, Microsoft Tests a Datacenter That's Quick to Deploy, Could Provide Internet Connectivity for Years.' Microsoft, 5 Jun. 2018, news.microsoft.com/features/under-the-sea-microsoft-tests-a-datacenter-thats-quick-to-deploy-could-provide-internet-connectivity-for-years/.

15 Saxifrage, Barry. 'Essential Infographics for the Climate-Conscious Traveller.' National Observer, 25 Feb. 2016, www.nationalobserver.com/2016/02/25/analysis/essential-infographics-climate-conscious-traveller.

16 Sims, Ralph, et al. 'Transport.' Intergovernmental Panel on Climate Change (IPCC), 2017, www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf.

17 Sims, Ralph, et al. 'Transport.' Intergovernmental Panel on Climate Change (IPCC), 2017, www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf.

18 Smiciklas, John, and Sahifa Imran. 'Implementing ITU-T International Standards to Shape Smart Sustainable Cities: The Case of Moscow.' International Telecommunication Union (ITU), Nov. 2018, https://www.itu.int/en/publications/Documents/tsb/2018-U4SSC-Case-of-Moscow/mobile/index.html#p=3.

19 Edwards, Mark. 'Belfast Drivers Spent 190 Hours Stuck in Traffic Last Year- Second Worst in UK.' Belfast Telegraph, 12 Feb. 2019, www.belfasttelegraph.co.uk/news/northern-ireland/belfast-drivers-spent-190-hours-stuck-in-traffic-last-year-second-worst-in-uk-37808917.html.

20 Department of Infrastructure, Belfast. 'Belfast Rapid Transit- Glider- Introduction.' www.infrastructure-ni.gov.uk/articles/belfast-rapid-transit-glider-introduction.

21 Dzikiy, Phil. 'Renewable Energy Now Makes up a Third of Global Power Capacity.' Electrek, 3 Apr. 2019, electrek.co/2019/04/03/renewables-third-global-power/.

22 Edenhofer, Ottmar, et al. 'Renewable Energy Sources and Climate Change Mitigation: Summary for Policymakers and Technical Summary.' Intergovernmental Panel on Climate Change (IPCC), 2012, www.ipcc.ch/site/assets/uploads/2018/03/SRREN_FD_SPM_final-1.pdf.

replace fossil fuels, conserve energy and reduce GHG emissions, which, individually and jointly, could represent a significant element in climate change mitigation.[23]

However, studies suggest that the demand for fossil fuels has grown so exponentially that it is compensating for the gain in renewables. In the latest Global Energy & CO_2 Status Report produced by the International Energy Agency (IEA), it is indicated that demand for all fuels, including natural gas, oil, and coal, has increased. Worldwide energy consumption grew by 2.3 per cent in 2018, driven by a robust global economy and higher heating and cooling needs. As a result, CO_2 emissions went up by 1.7 per cent in 2018 despite record renewables growth.[24] In order to achieve a low-carbon economy with high renewable uptake while keeping fossil fuel demands in check, it is imperative to start adopting intelligent power grids that are capable of utilizing data and information to maximize energy efficiency through collecting, distributing and storing renewables. Smart grids are vital in facilitating the transition to renewable energy in a sustainable and reliable manner.

According to IRENA, for a power grid to be smart and capable of accelerating renewable energy deployment, it must be able to overcome the following challenges:[25]

- **Variability** – Renewable energy such as solar and wind are dependent on fluctuating resources. As electricity supply must meet demand at all times, it is imperative that the grid is able to absorb this variability and ensure that electricity is available to meet the demand.
- **Distributed** – Small-scale systems that are privately owned and operated must be recognized by traditional utilities and must be able to connect to the grid. Concerns over safety and grid stability must also be addressed.
- **High initial cost** – Renewable electricity typically has a higher initial cost but lower operating cost compared to fossil-fuelled electricity. Some countries simply cannot invest in renewables that have a high initial cost.

ICTs are the foundational layer of a smart grid. They weave digital intelligence into the power grids, allowing each component to communicate with the others and enable the near real-time collection of information, which then can be sent, shared and analysed in order to maximize efficiency in energy output. For instance, if a photovoltaic system (i.e. a solar power system as shown in Figure 10) is tied to the electricity status of a consumer via a smart grid, when energy output drops (due to clouds or other weather conditions) the grid would be able to intercept and adjust energy output to an acceptable level until weather conditions improve.

Smart grids also benefit distributed renewable generation by providing real-time information on the performance of the system. Smart meters and sensors collect information, including electrical output and voltage. This information is very useful to utility system operators and to consumers in determining optimal energy output in different scenarios, including formulating competitive prices and encouraging renewable uptakes and behavioural changes. Accompanied by the ever-improving energy storage technologies, it is clear that ICTs can play a significant role in reshaping renewable energy into a viable alternative to fossil-fuelled electricity.

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23 Edenhofer, Ottmar, et al. 'Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN): Summary for Policymakers.' Intergovernmental Panel on Climate Change (IPCC), 2011, www.ipcc.ch/site/assets/uploads/2018/03/Summary-for-Policymakers-1.pdf.

24 International Energy Agency (IEA). 'Global Energy & CO2 Status Report." 2018, www.iea.org/geco/.

25 International Renewable Energy Agency (IRENA). 'Smart Grid and Renewables: A Guide for Effective Deployment.' Nov. 2013, www.irena.org/documentdownloads/publications/smart_grids.pdf.

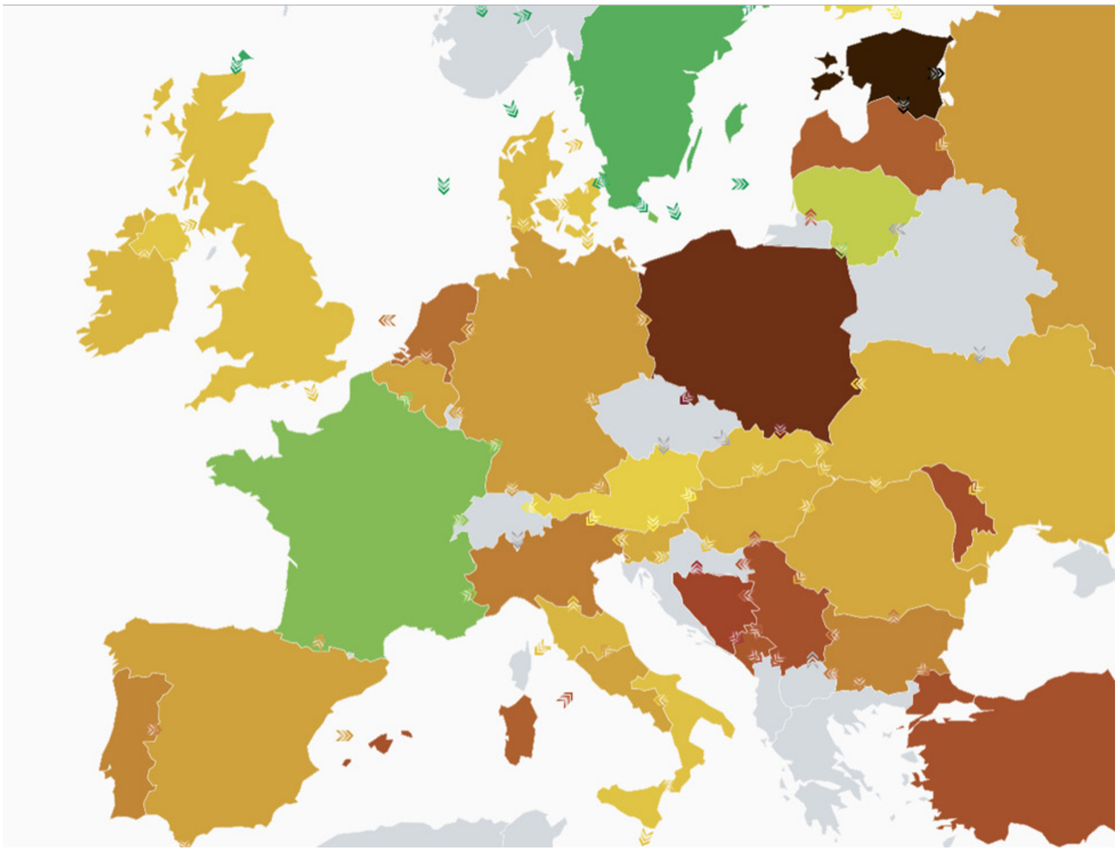
Figure 10: Smart grid in South Africa

However, the efficacy of renewable energy in mitigating climate change must be monitored and studied, as some preliminary findings suggest that not all renewable energy may be as 'clean" as has been hoped (although they are certainly cleaner than fossil fuels). This is partly due to the carbon cost and emissions related to the manufacture, transportation, installation and even maintenance of renewable energy infrastructure. In addition, the carbon footprint of ICT goods and services depends in large part on how and where energy is generated, and whether power is generated from fossil fuels or renewable energy sources. According to the French Intergovernmental Expert Group on Climate Change (GIEC) and figures quoted by the French Society of Nuclear Energy (SFEN) (which consists of industry professionals), carbon-fuelled power stations emit 820g equivalent of CO_2e per kWh of energy, gas-fired power stations emit 490g equivalent of CO_2eper kWh– followed by photovoltaic emitting 41g, hydraulic energy emitting 24g, nuclear power stations emitting 12g and wind-powered stations emitting 11g CO_2e per kWh of energy.[26]

This is reflected in the following Figure 11, which illustrates the National Carbon Intensity of Power Industry Production in Europe in 2018.

[26] Anne Brigaudeau. 'Climat: faut-il sortir du nucléaire pour sauver la planète ? Sept arguments pour comprendre le débat', 9 Jul. 2019, https://www.francetvinfo.fr/societe/nucleaire/climat-faut-il-sortir-du-nucleaire-pour-sauver-la-planete-sept-arguments-pour-comprendre-le-debat_3504835.html.

Figure 11: National Carbon Intensity of Power Industry Production in Europe, Oct. 2018 (Green = low carbon, Red = carbon-intensive.)[27]



Therefore, as also mentioned previously in the context of frontier technologies to combat climate change, the true impact of renewable energy consumption on climate change must be measured and analysed over a meaningful period of time.

To achieve this, ITU established a Focus Group on "Environmental Efficiency for Artificial Intelligence and other Emerging Technologies" (FG-AI4EE) at the ITU-T Study Group 5 meeting in Geneva on May 22, 2019. Box 4 explains the mandate and mechanisms of this Focus Group.

[27] Watson, David. 'Use This Powerful Tool and Avoid Talking Twaddle about Climate.' Medium, Generation Atomic, 24 May 2019, medium.com/generation-atomic/use-this-powerful-tool-and-avoid-talking-twaddle-about-climate-df3958a553dd.

Box 4: FG-AI4EE

The ITU Focus Group on:
"Environmental Efficiency for Artificial Intelligence and other Emerging Technologies"
(FG-AI4EE)

FG-AI4EE will identify the standardization needs to develop a sustainable approach to AI and other emerging technologies including automation, augmented reality, virtual reality, extended reality, smart manufacturing, industry 5.0, cloud/edge computing, nanotechnology, 5G, among others. The focus group will develop technical reports and technical specifications to address the environmental efficiency, as well as water and energy consumption of emerging technologies, and provide guidance to stakeholders on how to operate these technologies in a more environmentally efficient manner to meet the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals.

FG-AI4EE will be an open platform for relevant stakeholders – such as representatives of vertical industries, regulators, policy makers, researchers, engineers, practitioners, entrepreneurs, services providers, platform providers, network operators; international organizations, industry forums and consortia – to share knowledge, best practices and lessons learned in the field.

Chapter 5. ICTs and climate adaptation

As climate change is taking its toll and scientific research suggests that it is time to talk about climate crisis, rather than climate change, it is also "time to start talking less about the technology for preventing global warming and more about the technology we will need to live with it".[1]

Countries with long coastlines, most notably small-island developing states (SIDs), will face the challenges of rising sea levels. According to the IPCC, it is virtually certain that the global sea levels will continue to rise for centuries, beyond the year 2100. Yet even now, island nations such as Tuvalu are already said to be disappearing – literally.[2]

Rising temperatures will have severe impacts on natural and human systems, leading to an increase in the likelihood of droughts, wildfires, extreme rainfalls, floods and severe storms. Among many expected consequences are food insecurity, the spread of infectious diseases and the increasing number of climate refugees around the world. In this context, adaptation strategies and tools, which are defined as adjustments in human and natural systems, in response to actual or expected climate stimuli or their effects, that moderate harm or exploit beneficial opportunities,[3] become as important as mitigation.

ICTs can help attempts to adapt to the impacts of climate change. They are powering a digital innovation that can offer new opportunities for knowledge-sharing and the exchange of information.

Not surprisingly, ICTs are already being deployed to adapt to extreme weather and the impacts of other natural hazards. They make vital climate information available to disaster respondents, who would then be able to deliver early warnings to disaster-stricken areas and vulnerable groups in a timely manner. ICTs can address food insecurity issues and be used in facilitating alternative financing

1 Lichfield, Gideon. "Welcome to Climate Change." MIT Technology Review, 24 Apr. 2019, www.technologyreview.com/s/613350/welcome-to-climate-change/.

2 Roy, Eleanor Ainge. ''One Day We'll Disappear': Tuvalu's Sinking Islands.' The Guardian, 15 May 2019, www.theguardian.com/global-development/2019/may/16/one-day-disappear-tuvalu-sinking-islands-rising-seas-climate-change.

3 Intergovernmental Panel on Climate Change (IPCC). 'AR5 Synthesis Report: Climate Change.' 2014. www.ipcc.ch/report/ar5/syr/.

options. They can also support those affected by climate-related migration and urban infrastructural development. In the agriculture sector, crowdsourcing and the use of drones are helping to gather information and support those who are directly impacted by climate change.

This chapter explores the ways in which ICTs can help in adapting to the impacts of climate change.

5.1 Using ICTs to establish early warning systems (EWS) and enhance disaster management

Heat waves and droughts are two of the primary ways in which most people experience severe climate change. Other consequences of climate change humans are facing include prolonged and intense stormy periods, and record wind speeds and rainfall. As these extreme weather events are becoming more frequent and severe, people are being forced to adapt to these catastrophic changes.

ICTs already play a role in disaster prevention, mitigation, response and recovery. Timely, predictable and effective information are powerful tools for government agencies and other humanitarian actors involved in rescue operations to make informed and timely decisions.

Therefore, having effective ICT networks and infrastructure is critical to disseminating and circulating weather and disaster information. It is with this information that disaster response units and cities can deliver early warnings and alerts to communities that are at risk. Many countries vulnerable to natural hazards are implementing early warning systems to limit the impacts of climate change.

ICTs are being used all over the world in this regard. Some notable examples are found in Peru,[4] [5]the Philippines, [6] [7] Malawi ,[8] California (USA),[9] [10] [11] and Mozambique.[12]

5.2 Using ICTs to enhance food security and support the agricultural sector

A change in the climate means that for the agricultural and agro-pastoral sectors, traditional techniques and knowledge often no longer apply. Human behaviour and more frequent and extreme weather events are leading to changes in the environment that require new solutions, and better information for farmers. ICTs play an important role in this, particularly mobile applications and mobile services, including SMS. Most popular, tech-based adaptation strategies and climate information services are based on traditional mobile technology, since mobile services are used to deliver information to population groups that do not use smartphones or have access to the Internet. Some recent examples

4 Aréstegui, Miguel. 'Intermediate Climate Information Systems for Early Warning Systems.' Practical Action, Jun. 2018.

5 The International Red Cross and Red Crescent Movement 'Early Warning Can Transform Lives.' 17 Oct. 2018, media.ifrc.org/ifrc/2018/10/17/early-warning-can-transform-lives/.

6 Malano, Vicente. 'Philippine Early Warning System." Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), 16 Mar. 2015, www.wmo.int/pages/prog/drr/events/WCDRR-MHEWS/documents/VicenteMalano.pdf.

7 Department of Science and Technology, PAGASA. 'Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)." bagong.pagasa.dost.gov.ph/.

8 The International Red Cross and Red Crescent Movement 'Early Warning Can Transform Lives.' 17 Oct. 2018, media.ifrc.org/ifrc/2018/10/17/early-warning-can-transform-lives/.

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11 Del Real, Jose A. 'Can "Big Data" Help Fight Big Fires? Firefighters Are Betting on It.' The New York Times, 24 June 2019, www.nytimes.com/2019/06/24/us/wildfires-big-data-california.html.

12 Rae, Tej. 'Drones to the Rescue as Cyclone Desmond Storms Mozambique.' Medium, World Food Programme Insight, 24 Jan. 2019, insight.wfp.org/drones-to-the-rescue-as-cyclone-desmond-storms-mozambique-d7f501e40b0f.

can be seen in the use of mobile phones to deliver weather and climate information in Mali,[13] [14] the use of ICTs in smart coffee production in Guatemala ,[15] [16] [17] and the use of ICTs for micro-level drought preparedness in India.[18]

5.3 Using ICTs for climate-related humanitarian action, migration, and refugees

Rapid-onset of disasters such as cyclones, storm surges and other extreme weather events associated with a warming climate, coupled with the slow-onset impacts of sea level change and glacial melt, are adding environmental stressors that are displacing a growing number of people. The consequences of climate change have increased the number of migrants and refugees who are forced to flee their homes in order to survive severe climate conditions.

ICTs can help these highly vulnerable groups to communicate with each other, stay informed on current affairs, keep in touch with family and friends and help give them access to basic services. ICTs also help humanitarian organisations and governments to gather critical information, improve their internal services and better support those in need.

For example, mobile phone data are being used to assess climate change and migration patterns in Bangladesh,[19] and ICTs are being deployed in Rwanda to adapt to the local impacts of climate change.[20]

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13 Kadi, Mohammed. 'The State of Climate Information Services for Agriculture and Food Security in East African Countries.' The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), 2011, ccafs.cgiar .org/sites/default/files/assets/docs/ccafs-wp-05-clim-info-eastafrica.pdf.

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15 Steffens, Gena. 'Changing Climate Forces Desperate Guatemalans to Migrate.' National Geographic, 23 Oct. 2018, www.nationalgeographic.com/environment/2018/10/drought-climate-change-force-guatemalans-migrate-to-us/.

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20 Ntirenganya, Emmanuel. 'How Technology Is Primed to Transform Farming in Rwanda.' The New Times | Rwanda, 9 Nov. 2017, www.newtimes.co.rw/section/read/223291.

Chapter 6. How ITU is expanding its role in climate action

With 193 countries and more than 800 private-sector entities and academic institutions as members, ITU's membership represents a cross-section of the global ICT sector, from the world's largest vendors, manufacturers and telecom operators to small and medium-sized enterprises working with new and emerging technologies, along with leading R&D institutions and academia.

Founded on the principle of international cooperation between governments (Member States) and the private sector (Sector Members, Associates and Academia), ITU is the premier international forum through which different parties can work together to build consensus on using ICTs to tackle a wide range of global issues, including climate change and sustainable development.

The work of ITU contributes significantly to the implementation of multiple international commitments, including the 2030 Agenda and the SDGs, the Paris Agreement and ITU's Connect 2030 Agenda[1] for Global Telecommunication/ICT Development (as seen in Figure 12 below).

Figure 12: The four main goals of the Connect 2030 Agenda

This chapter highlights ITU's role in four particular areas: assessing the environmental impacts of the ICT sector; supporting the transition to smart sustainable cities; supporting the transition to a circular economy (CE); and improving environmental efficiency of frontier technologies.

6.1 Assessing the environmental impacts of the ICT sector

ITU-T Study Group 5 (SG5) on 'Environment, climate change and circular economy' has been working to identify the standardisation requirements for the sustainable use and deployment of ICTs and developing international standards called ITU-T Recommendations on methodologies and guidelines that assess the environmental impacts of different ICT applications. These Recommendations cover specific ICT-related functions, products and services, including, for example: ICT supporting equipment and facilities, installation activities (such as on radio sites), and networks and other services.

[1] The Connect 2030 Agenda is a global agenda adopted by ITU and its member states, aimed at shaping the future of the ICT sector by working towards four distinct goals. Goal 1: Growth – Enable and foster access to and increased use of ICTs; Goal 2: Inclusiveness – Bridge the digital divide and provide broadband for all; Goal 3: Sustainability – Manage challenges resulting from ICT development; and Goal 4: Innovation and Partnership – Lead, improve and adapt to the changing ICT environment

Most recently, ITU-T SG5 has been working to develop a set of international standards (ITU-T Recommendations) that assess the environmental impacts of 5G systems including the electromagnetic compatibility (EMC) aspects, the electromagnetic fields (EMF) aspects, energy efficiency in 5G systems and their resistibility to lightning and power fault events.

A few examples of ITU-T Recommendations are included in Box 5.

Box 5: ITU-T Recommendations

ITU-T Recommendations

ITU-T L.1302 'Assessment of energy efficiency on infrastructure in data centres and telecom centres:' This Recommendation specifies an energy efficiency assessment methodology for data centres and telecom centres, test equipment accuracy requirements, assessment period, assessment conditions and calculation methods. It supports telecom providers and operators to reduce the environmental footprint of data and telecom centres.

ITU-T L.1310 'Energy efficiency metrics and measurement methods for telecommunication equipment:' This Recommendation contains the definition of energy efficiency metrics test procedures, methodologies and measurement profiles required to assess the energy efficiency of telecommunication equipment.

ITU-T L.1320 'Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres:' This Recommendation contains the definition of metrics, test procedures, methodologies and measurement profiles required to assess the energy efficiency of power and cooling equipment of telecommunications and data centres.

ITU-T L.1331 'Assessment of mobile network energy efficiency:' This Recommendation contains metrics and methodologies for assessing the energy efficiency of mobile and operational networks. The networks considered are those whose size and scale could be defined by topologic, geographic or demographic boundaries.

6.2 Supporting the transition to Smart Sustainable Cities

The United for Smart Sustainable Cities (U4SSC) initiative is a United Nations' initiative coordinated by ITU, United Nations Economic Commission for Europe (UNECE) and United Nations Human Settlements Programme (UN-Habitat) along with 14 other UN bodies to achieve SDG 11: 'Make cities and human settlements inclusive, safe, resilient and sustainable".

The U4SSC acts as a global platform that advocates for public policy on using ICTs in facilitating the transition to smart sustainable cities. With inputs and expertise gathered from telecom providers, policymakers, civil society and city stakeholders, the U4SSC has developed technical reports and guidelines that support cities in connecting ICTs to urban sustainable development (see Box 6 below).

Box 6: U4SSC technical reports and guidelines

Left: This online publication provides an overview of how cities can use ICTs to achieve the Sustainable Development Goals (SDGs). It also maps the case studies to the various international agreements as well as to the SDGs.

Middle: This online publication provides a series of case studies on smart governance, smart people and smart economy, which will catapult successful smart city practices into the global spotlight.

Right: This online publication provides a study of the advantages of using ICTs to support the implementation of the SDGs, namely SDG 11, by facilitating the missing linkages that exist between sustainability policies and urban-planning practices through digitally enabled urban actions.

6.2.1 The Key Performance Indicators for Smart Sustainable Cities

To further encourage cities in identifying and exploring the potential of ICTs in addressing the most pressing development issues at the city level, the U4SSC has developed the Key Performance Indicators (KPIs) for Smart Sustainable Cities. The KPIs for SSC support cities primarily in the following ways:

- Functioning as a diagnostic tool for cities to evaluate their current smart strategy and projects, highlighting strengths and areas for improvement that would become future reference points for the city in refining its approach to smart development.
- Evaluating the city's progress in meeting the SDGs at the city level. Each indicator is uniquely connected to different SDGs Targets and Indicators. The results obtained from implementing the KPIs wold highlight how each smart project has helped cities in reaching the targets of the SDGs and to what degree.

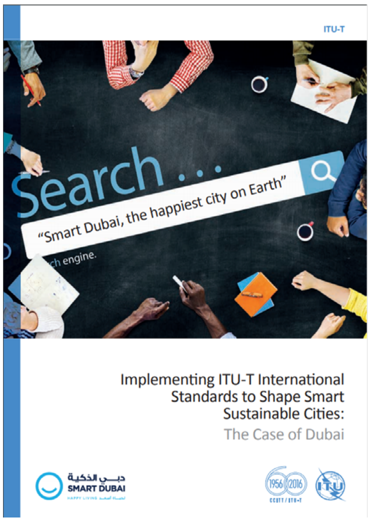
Dubai, Singapore and Moscow are among the 100 cities worldwide that have partnered with the U4SSC in piloting these indicators. Their experiences have redefined and improved the indicators to better reflect the different dimensions of a city. The KPIs for SSC is an ongoing project that constitutes an important part of ITU's effort in supporting the transition to smart sustainable cities worldwide.

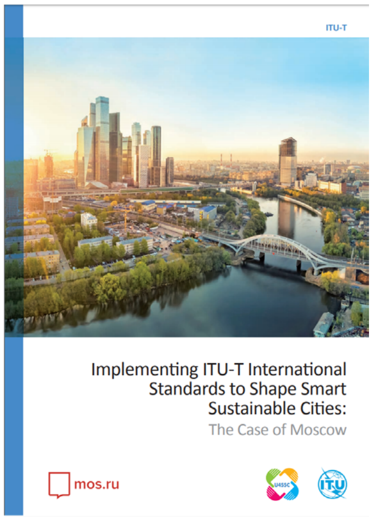
ITU has published case studies that document the experiences of the participating cities in implementing the U4SSC KPIs for SSC, including Dubai, Singapore and Moscow (see Box 7 below).

Each of these case studies highlights the achievement of the participating cities in the areas of ICT proliferation and sustainable development.

In addition, the results gathered from the U4SSC KPIs for SSC are being utilized to develop ITU's Global Smart Sustainable Cities Index, which will be the first international set of coherent metrics on measuring the progress of smart sustainable cities. The purpose of the Index is to benchmark the cities' contributions to sustainability and smartness, as well as their ongoing efforts and progress towards implementing the SDGs. It is expected to be a highly useful tool for cities to further their smart strategies and ambitions, and work is being done to finalize it by later this year.

Box 7: ITU-T Smart Sustainable Cities (SSC) case studies





Left: The case study 'Implementing ITU-T International Standards to Shape Smart Sustainable Cities: The Case of Dubai' details Dubai's ambitious and trailblazing journey towards becoming a smart city, a venture worthy of emulation by other aspiring smart cities around the world.

Middle: The case study 'Implementing ITU-T International Standards to Shape Smart Sustainable Cities: The Case of Singapore' details Singapore's journey towards becoming a smart sustainable city. This case study provides a valuable reference point to other cities pursuing smart city strategies. It also offers valuable guidance to ITU standards developers who are responsible for the refinement of SSC's KPIs.

Right: The case study 'Implementing ITU-T International Standards to Shape Smart Sustainable Cities: The case of Moscow' offers practical insights into the experiences of Moscow in transforming into a smart sustainable city using the KPIs developed by the United for Smart Sustainable Cities initiative (U4SSC), which are based on ITU-T KPIs for SSC Standards. It measures Moscow's progress in reaching the objectives of its smart strategies and meeting the Sustainable Development Goals. The results of this case study provide valuable lessons to other aspiring Smart Sustainable Cities.

6.3 Supporting the transition to a circular economy (CE)

As part of its mandate to minimise the environmental impacts of the ICT sector, ITU-T SG5 has developed a series of international standards that provide ICT producers, designers and cities moving towards to a CE with the relevant tools and guidelines to achieve this. These include:

- ITU-T L.1000 'Universal power adapter and charger solutions for mobile terminals and other hand-held ICT devices': provides high level requirements for a universal power adapter and charger solution that will reduce the number of power adapters and chargers produced and recycled by widening their application to more devices and increasing their lifetime. The solution also aims to reduce energy consumption. The longer life cycle and possibility of avoiding device duplication reduces the demand on raw materials and waste. The universal power adapter and charger solution is designed to serve the vast majority of mobile terminals and other ICT devices.
- ITU-T L.1020 'Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks': suggests approaches of CE for information and communication technology (ICT) goods and networks. It focuses particularly on the next steps in improving circularity in the operators' supply chain. The Recommendation provides a guide on how operators could work with their supply chain to improve CE aspects for ICT goods and networks through a *manifesto* intended to improve the circularity of products through supply chain actions, but it does not provide metrics. The objective of the guide is to provide options to improve circularity and to enable operators and their suppliers to create business models for the promotion of circular networks for an optimum solution that uses all the loops of circularity – from sharing to recycling. Specifically, the *manifesto* calls for the following:
  a. increasing usage rates through sharing or virtualization;
  b. extending the operating life-time of equipment through simplified maintenance and reuse;
  c. the reuse/redistribution of equipment or components on other types of functions or in other countries;
  d. refurbishment and remanufacturing; and
  e. recycling of all materials without using landfills or incineration at the final stage.

- ITU-T L.1021 'Extended producer responsibility – Guidelines for sustainable e-waste management': offers a description of the extended producer responsibility (EPR) system in dealing with e-waste. It expands on the different existing forms of EPR globally, not only in theoretical terms, but also with a practical view on their feasibility, challenges and prerequisites. It presents the definition of the EPR system, in addition to the roles and responsibilities of the different stakeholders and the different types of EPR, as well as how and why they could be used in certain contexts and not in others. The funding mechanism behind every mode and the organizational structure expected to be in place are also presented. Recommendation ITU-T L.1021 concludes with many best practices from the international arena, including developed, developing and emerging economies, as well as the challenges faced in some cases.
- ITU-T L.1030 'E-waste management framework for countries': summarizes the different steps that countries need to adopt in order to put in place an e-waste management system. The different steps of the e-waste management system described in this Recommendation will be further elaborated in future Recommendations. In addition, the Recommendation provides highlights concerning the environmental impact of improper handling of e-waste as well as the economic opportunities that could emerge from the sustainable management of e-waste. Lastly, the Recommendation also defines a set of indicators on correct e-waste management.
- ITU-T L.1031 'Guideline on implementing the e-waste reduction target of the Connect 2020 Agenda': describes a three-step approach as a holistic guideline to address the e-waste reduction target of the Connect 2020 Agenda. The first step consists of guidance on developing an e-waste inventory, which would:
    a. establish the baseline scenario for evaluation and assessment;
    b. classify e-waste based on existing standards;
    c. estimate the amount of e-waste using related metrics and KPIs; and
    d. identify the role of key stakeholders, as well as the flow of e-waste among them.

The information obtained from step 1 is meant to then help the relevant stakeholders/readers to decide their best approaches for steps 2 and 3: the design of e-waste prevention and reduction programmes and the supportive measures required for successfully implementing the Connect 2020 e-waste target. This Recommendation, therefore, is intended to be utilized by the relevant stakeholders to take their first step in addressing Target 3.2 of the Connect 2020 Agenda, which is to reduce waste by 50% by 2020.

- ITU-T L.1100 'Procedure for recycling rare metals in information and communication technology goods': provides information on the recycling procedures of rare metals in information and communication technology (ICT) goods. It also defines a communication format for providing recycling information of rare metals contained in ICT goods, including: the description of the rare metal used in an ICT's production, its recycling procedure (based on the stage of production), and the communication requirements between the ICT producer and recycler.

6.3.1 Building the UN E-waste Coalition

United Nations entities are paving the way for greater collaboration in environmentally sound e-waste management by building the UN E-waste Coalition[2] [3] (as seen in Figure 13 below). The Coalition provides a mechanism for the UN to communicate and raise awareness about the global e-waste challenge in a unified manner, thus increasing outreach. It aims to provide a knowledge hub, to be a one-stop shop for information on e-waste for the general public, governments, the private sector,

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[2] International Telecommunication Union (ITU). "E-Waste Coalition.' www.itu.int/en/ITU-D/Climate-Change/Pages/ewaste/E-waste-Coalition.aspx.

[3] E-Waste Coalition. 'Letter of Intent (the "LOI"): Paving the Way for Coordination and Collaboration on UN System-Wide Support for E-Waste Management.' International Telecommunication Union (ITU), www.itu.int/en/ITU-D/Climate-Change/Documents/2019/FINAL_Letter%20of%20Intent%20-%20E-waste_WSIS_2019.pdf.

civil society, academia and NGOs. As part of its direct support to Member States, through joined up intervention, all UN entities of the Coalition plan to work together in the provision of capacity building and e-waste policy support at the national or regional levels.

In summary, the three core functions of the Coalition's work include: joint advocacy and communication on e-waste; greater knowledge gathering and sharing; and joined-up action at the national level in support of Member States.

All UN entities as Members includes: ITU; United Nations University; Secretariats of the Basel, Rotterdam and Stockholm Conventions; United Nations Industrial Development Organization; United Nations Environment Programme; International Labour Organization; United Nations Human Settlements Programme; International Trade Centre; United Nations Institute for Training and Research; and the World Health Organization.

Figure 13: The three core functions of the UN E-waste Coalition

The Members are currently being coordinated by the Secretariat of the UN Environment Management Group, which originally established a work stream on e-waste in May 2016, in order to increase knowledge sharing and awareness of this topic while aiming to analyse possible coordination efforts at the international level.

In an attempt to engage the diverse array of active stakeholders in the e-waste domain, the Coalition is bringing in partners from all sectors of society. Through the Coalition, the UN entities are working with the private sector, with both upstream and downstream industry, including manufacturers, small and medium-sized enterprises and major recyclers. The Coalition takes a life-cycle approach to its work on e-waste, encompassing all stages of the product life-cycle of electrical and electronic equipment, including obsolete ICT equipment.

In January 2019, the Coalition partnered with the World Economic Forum to publish the report: 'A New Circular Vision for Electronics: Time for a Global Reboot.'[4] [5] This report concluded that society needs to collectively rethink the rules of the game and create a vision around which government, consumers and industry can rally.

The Goals of the UN E-waste Coalition are as follows:

- More countries joining global and regional legal instruments and adhering to standards in the area of e-waste with more effective implementation

[4] International Telecommunication Union (ITU). 'A New Circular Vision for Electronics- Time for a Global Reboot.' www.itu.int/en/ITU-D/Climate-Change/Pages/ewaste/A-New-Circular-Vision-for-Electronics-Time-for-a-Global-Reboot.aspx.

[5] E-waste Coalition. 'A New Circular Vision for Electronics: Time for a Global Reboot.' World Economic Forum (WEF); E-Waste Coalition; World Business Council for Sustainable Development (WBCSD); World Health Organization (WHO); Secretariat of the Environment Management Group (EMG), Jan. 2019, .itu.int/en/ITU-D/Climate-Change/Documents/2019/A-New-Circular-Vision-for-Electronics.pdf.

- Improved national legislation and strengthened enforcement mechanisms in line with international obligations and best practices
- Strengthened national capacity to formulate and implement integrated policies and practical measures to improve e-waste management
- Investments in e-waste management systems and infrastructure promoted
- Transboundary movements are carried out in line with international requirements and illegal traffic of e-waste is prevented or combatted
- Increased awareness and greater engagement of key e-waste stakeholders at the global, regional, national and municipal/local levels
- Better coordinated and more efficient support provided to countries to reduce and manage e-waste in ways that create jobs and business opportunities and that protect e-waste workers, human health and the environment
- Data, statistics and knowledge base strengthened and made more easily accessible to all stakeholders
- Greater impact of the work of the United Nations and its key partners in the area of safe, sustainable and circular e-waste management
- Promote opportunities for non-state actors including industry to become a part of solutions to e-waste challenges
- Promote the implementation of international standards to tackle e-waste and achieve a circular economy

6.4 Improving environmental efficiency of frontier technologies

The disruptive potential of artificial intelligence (AI), Internet of Things (IoT), digitalisation, Big Data, machine learning (ML), robotics, 3D printing, virtual and augmented reality (VR and AR), digital twins, 5G, clean energy technology, Space 2.0, etc., along with other frontier technologies, holds promise for engineering smart innovations and solutions that may help combat climate change.

However, digital infrastructures are increasingly under pressure to cope with the increasing bandwidth and energy demands from these cutting-edge technologies. At the same time, the energy consumption of these frontier technologies continues to grow in parallel. Proper guidelines and benchmarking must be in place to ensure the sustainable use of these new technologies.

To this end, ITU has already taken the first step to identify the energy requirements of frontier technologies.

As explained previously (in Box 4), the Focus Group on ‘Environmental Efficiency for AI and other Emerging Technologies’ (FG-AI4EE) was created in May 2019 to identify the standardization gaps related to the environmental performance of AI and other emerging technologies.

In addition, ITU routinely organizes thematic forums and workshops to gather insights from industrial leaders and sectorial representatives on the latest development of frontier technologies and their developmental trajectories.

Most recently, ITU, along with eight other UN agencies and programmes, organized the 13th Symposium on ‘ICT, Environment and Climate Change” in May 2019 (as seen in Figures 14 and 15). The Symposium bought together panels comprising leaders from the telecom sector, national policymakers, service providers, the civil society, the academia, and UN representatives to discuss the role of frontier technologies in combatting climate change and achieving a circular economy (CE).

As a result of this Symposium, a Call for Action was agreed in which the participants expressed their interested in continuing to engage in global dialogues on examining the disruptive impacts of frontier technologies and evaluating their environmental performance. Given the urgency of tackling climate change, ITU recognizes that it must expand its outreach and build strategic partnerships to support city stakeholders in using ICTs and frontier technologies to combat climate change.

Figure 14: 13th Symposium on 'ICT, Environment and Climate Change'

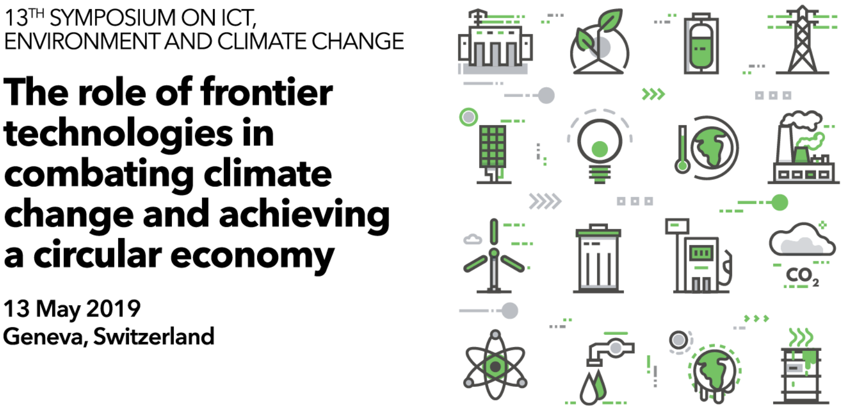

Figure 15: Field experts and other stakeholders at the 13th Symposium on 'ICT, Environment and Climate Change'

Chapter 7. Conclusion

As climate change is taking its toll and scientific research suggests that it is time to talk about climate crisis, rather than climate change, it is also 'time to start talking less about the technology for preventing global warming and more about the technology we will need to live with it'.[1]

Climate change is the single most defining challenge of this century. If not actively addressed at this point in time, its impacts will be irreversible, leading to an uninhabitable planet in the foreseeable future.

ICTs such as satellites, mobile phones and the Internet, in particular, already play a role in addressing some challenges related to climate change. While ICTs are partly responsible for contributing to climate change, they have also shown some potential in monitoring climate change and mitigating and adapting to its impacts. As demonstrated in this report, ICTs can reduce energy consumptions of buildings and are being used to develop future data centres. They are also relieving traffic congestion in urban areas, significantly reducing emissions in cities. ICTs and their ability to collect and analyse in real-time have proven to be key to building responsive early warning systems that would enhance disaster preparedness such as has been the case in Peru and the Philippines. Mobile phones are also making weather information accessible to farmers, allowing them to take adaptive actions to minimise the impacts of climate change.

However, mindfulness is required around the growing challenges regarding disposal of devices and other e-waste (i.e. other electrical and electronic equipment), the environmental impact assessment of ICTs, and other challenges (and opportunities) in the transition to a green and resource-efficient economy. Strategic approaches are needed to successfully deploy ICTs in mitigating climate change through the application of intelligent ICT systems, to enhance the transformational role of ICTs in climate change adaptation and disaster risk reduction, and to recognize the value of ICTs in monitoring deforestation, crop patterns and other environmental phenomena.

Similar mindfulness is required to reduce the downsides of ICT energy consumption through their manufacturing and production, as well as usage (e.g. growth in the number of consumer devices, energy use and energy efficiency across networks, increasing data flows, and the explosion in the number of data centres).

[1] Lichfield, Gideon. 'Welcome to Climate Change.' MIT Technology Review, 24 Apr. 2019, .technologyreview.com/s/613350/welcome-to-climate-change/.

It is also important to note that renewable energy sources are not de facto clean energy sources in terms of carbon footprints, although they are certainly cleaner. In fact, the carbon footprint of ICT goods and services depends in large part on how and where energy is generated and whether power is generated from fossil fuels or renewable energy sources.

While increasing urbanization may intensify pressures on the environment, it also provides opportunities to roll-out new ICT-based solutions. As this can only be achieved with multi-stakeholder and public and private sector partnerships, ITU plays a vital role in providing the platform for such partnerships and close working relationships globally and across sectors. ITU performs extensive work on researching, standardizing and raising awareness about ICTs in the context of climate change and response.

Emerging, i.e. frontier, technologies offer particular promise in accelerating the results of active response to climate change and its effects. The key to their successful use in this regard will be strategic and inclusive deployment that will help developed and developing countries alike to reduce inequalities. This is because the 'value' of an ICT service cannot be measured only in terms of its popularity, consumer convenience or carbon footprint. Many ICT services have important social benefits for poor and vulnerable populations (e.g. the retinal scans and identity authentication of refugees using blockchain, and the value of connectivity in refugee camps as a means of staying in touch with friends and family back home). Also important is scaling them as solutions only once their net effect is that of environmental load reduction and acceleration of response to climate change impacts, as these frontier technologies can also contribute to climate change.

Education and raising awareness of the role and further potential of ICTs in monitoring climate change and mitigating and adapting to its effects is key to unlocking the transformative solutions that can be deployed to ensure a sustainable future.

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International
Telecommunication Union
Place des Nations
CH-1211 Geneva 20
Switzerland

greenstandard@itu.int

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