Resilient pathways: the adaptation of the ICT sector to climate change

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Although this report is based on the experiences and progress being achieved by the ICT sector in the climate change adaptation field, many of the principles and suggested actions could be applied by other sectors.

Additional information and materials relating to this report can be found at:
www.itu.int/itu-t/climatechange

If you would like to provide any additional information, please contact Cristina Bueti at **tsbsg5@itu.int**

Executive Summary

The objectives of this report are to explore the impacts of climate change on the information and communication technology (ICT) sector and the potential for adaptation, including the need for new standards to be developed.

Climate change has risen rapidly up the agenda of international organizations, governments, communities and industry sectors in the past decade, reflecting the growing impact of climatic manifestations at multiple levels. With the potential to become a major disruptive factor in the achievement of economic growth and development over the next fifty years, climate change is playing an increasing role in processes of policy design, strategy implementation, livelihood maintenance and business practices around the globe.

Simultaneously, ICT has been diffusing widely, and redefining the way in which information and knowledge are generated, captured and stored, processed and disseminated among an increasingly inter-connected society.

While the ICT contribution to the abatement of carbon emissions, energy efficiency, monitoring climate-related patterns and events, and implementing adaptive practices (among other climate-related responses) has been explored since the early 2000s, much less is known about the adaptation of the ICT sector itself to climate change impacts.

This report responds to the need of exploring further the effects of climate change on the ICT sector. It aims to raise awareness of the need to design and implement strategies for the sector to better prepare for, respond and adjust to the impacts of short- and long-term climatic manifestations. It gives an overview of the impacts, opportunities and challenges posed by climate change to sector stakeholders; it identifies existing and emerging adaptive measures and provides suggested actions to strengthen the ICT sector's approach to adaptation.

It is intended that this report will assist countries and companies in their efforts to improve resilience to the increasing risks and exploit opportunities posed by climate change. It is also expected that this report will foster new knowledge exchange on this topic, inform the design and implementation of adaptation strategies in the ICT sector, and contribute to further collaboration among ICT and climate change experts and practitioners at the international, national, sectoral and local levels.

The findings and suggested actions identified in this report can be relevant to a wide range of sector stakeholders, including (but not limited to) telecommunications operators, ICT manufacturers and service providers, national governments, stakeholders of other sectors, and international stakeholders such as the International Telecommunication Union (ITU), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and other UN specialized agencies.

This report presents the sector's response to climatic impacts, identifying existing and emerging adaptive strategies, and suggesting areas for future action. The analysis includes examples identified through a survey conducted among key sector stakeholders involved in ICT, environmental sustainability and climate change strategies.

Adaptive approaches involve a sector-wide assessment of the potential risks and vulnerabilities relating to climate impacts, including direct impacts (e.g. flood risks, storm exposure, etc.) and indirect ones (e.g. supply chain disruptions, etc.). It also involves mechanisms to tackle the business opportunities that may emerge with changing climatic conditions (including new standards, business and consumer demands), and to develop the skills and structures required to benefit from new economic possibilities.

This report suggests that the adoption of resilient pathways towards adaptation requires going beyond generic contingency and risk management measures. The ICT sector needs to identify and implement specific actions to manage current threats, responding flexibly and adjusting innovatively to future impacts.

The sector's approach to adaptation could be enhanced by adopting measures that strengthen a set of core resilience attributes, including the sector's robustness, self-organization, learning, redundancy, flexibility and diversity, rapidity and scale.

New standards to foster adaptive action in the sector are discussed. It is intended that this report could act as source of input to standards on the ICT sector and its adaptation to climate change. Examples of a suggested Climate Change Adaptation Risk Assessment Checklist, Adaptation Options and a Climate Change Adaptation Plan are included which could be extended for inclusion in standards.

This report concludes that climate change will cause unavoidable impacts that will affect the ICT sector both directly and indirectly. Within this context, adaptive practices will increasingly become part of the "new normal" for business operations around the world, including those of the ICT sector.

It is expected that this report will contribute to further research on issues, *inter alia*, as novel adaptation strategies, business opportunities emerging from the changing climate, the contributions of the ICT sector's adaptation to the adaptive efforts of other sectors, as well as the need for new enabling standards.

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Adapting the ICT sector to climate change: an ITU perspective

The International Telecommunication Union (ITU) is the specialized agency of the United Nations responsible for information and communication technologies (ICTs). Its membership, comprising 193 governments, over 700 private entities and over 60 academic institutions, has called for ITU to take the lead in engaging the global community (including countries, the UN system and the ICT industry, as well as academia and NGOs) to address climate change through the use of ICTs.

ICTs are deeply embedded in the fabric of our society. They play a critical role in the way in which we network, create and share knowledge, conduct business, access education and government services, among many other uses. And increasingly, ICTs are being integrated into our fight against climate change, by contributing to reduce greenhouse emissions in major industries, supporting adaptation efforts, and helping to build the resilience of communities, industry sectors and countries.

The crucial role played by ICTs in tackling climate change is a message that has emerged strongly at the Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC). We continue to work in close partnership with other organizations in finding innovative ICT-enabled solutions to reduce greenhouse gas (GHG) emissions, and to help stakeholders from the public, the private and the civil society sectors to better prepare for, respond and adapt to the impacts of climate change.

As part of these efforts, ITU is pleased to collaborate with the Global e-Sustainability Initiative (GeSI), encouraging innovative solutions to using ICTs for adaptation and mitigation, and raising awareness on their role towards a more sustainable future.

This report has been jointly prepared by ITU in cooperation with UNFCCC and UNESCO, with the kind support of Deutsche Telekom. It emphasizes the need to adopt resilient pathways of action in order to effectively respond to the challenges posed by climate change. This report provides proposals to foster the adaptation of the ICT sector, and provides concrete examples of the way in which ICT companies are responding to these challenges.

Whilst this report focuses on the ICT sector, many of its principles and findings are also applicable to other sectors of industry.

ITU stands ready to support the dissemination of adaptation knowledge and expertise available in the sector, and to advise other countries or regional organizations on ways to promote the use of ICTs to minimize the industries” environmental impact, reduce emissions, and build resilience to climate change impacts.

Malcolm Johnson
Director, ITU Telecommunication Standardization Bureau

Adapting the ICT sector to climate change: a UNFCCC perspective

Since the United Nations Framework Convention on Climate Change was enacted just over twenty years ago, the world has woken up to the immense challenge of climate change. The effects are undeniable, with years of record heat, increases in extreme weather and obvious links between climate and economic disruption. Climate change is emerging as the greatest challenge of our generation, and leaders of governments and industry are searching for ways to move to sustainable, low-carbon development to minimize its impacts now and into the future, and to grasp the opportunities that emerge from going green.

In this same time period, advances in information and communication technology (ICT) have fundamentally transformed almost every aspect of human existence. It is not enough to simply say we now carry personal computers that are far more powerful than a top-end desktop machine from 20 years ago. We must recognize that ICT advances have changed the very concepts of global connectivity, community and capacity to learn.

We now stand at a crucial moment in history, a crossroads where climate impacts, our capacity to act and the transformative power of ICT meet. And it is up to us to chart a path forward.

That path forward must be low-carbon and high-resilience. We must move on curbing emissions to mitigate climate effects and we must move to adapt to the climate impacts we know are coming. Technology and ICT in particular is a powerful force that can put us squarely on the path to a climate resilient future.

Technology solutions that reduce vulnerability and improve adaptive capacity are available to all economic sectors. ICTs can reduce water consumption, increase efficient electricity distribution, reduce pollution and congestion and increase access to health and education services. Implementing climate-friendly ICTs is a business opportunity that gives companies a competitive edge in terms of risk management, overhead cost and reputation gains. A technology-enabled future shines bright with the prospect of low emissions and high quality of life.

This will not happen unless we work to make it happen. And, I believe there is willingness to work in three key areas: the international process, national governments and the private sector.

Over the last three years, the international community, working within the UNFCCC process, has agreed to remain below two degrees of warming, has agreed to a second commitment period for the Kyoto Protocol, and has agreed to enact a new, universal climate agreement. Meeting these commitments is far easier if the ICT sector is actively involved in formulating responses to climate impacts, identifying adaptive strategies and suggesting future action ripe with potential.

National governments are looking for ways to go low-carbon while continuing to deliver the benefits of growth and development to their populations. The private sector is looking for any competitive advantage in the coming low-carbon economy, while delivering the highest quality goods and services. Achieving these goals is far easier if the ICT sector is actively involved in developing innovative leadership options for governments and industry.

This report is an excellent step towards that active involvement. This report puts the ICT sector on the path to resilience, with positive implications for all sectors, all governments and all people. I applaud the effort of the International Telecommunication Union to develop this report and hope the strategies outlined contribute toward the low-carbon new normal that so many are working so hard to realize.

Christiana Figueres
UNFCCC Executive Secretary

Adapting the ICT sector to climate change: a UNESCO perspective

Climate change is a fact. The world has been experiencing continuing extreme weather events. According to the Intergovernmental Panel on Climate Change (IPCC) report published in 2013 "humans are the dominant cause of global warming since the 1950's".

The World Meteorological Organisation (WMO) maintains that greenhouse gases in the atmosphere have increased throughout the 20th century as a result of the rising use of carbon-based energy and the expansion of the global economy. As this report states climate change is more prominent in the agendas of international organizations, governments, communities and industries. Little by little, the climate change issue is moving from the realm of science into the realm of politics, though much more research needs to be carried out.

Simultaneously, information and communication technologies (ICTs) have redefined how information and knowledge are generated, captured, stored, processed and disseminated in increasingly inter-connected societies. Furthermore, what makes ICTs innovative with regards to climate change is that they are recognized as new approaches to mitigating, monitoring and adapting the impacts of climate change.

However, this report is something different; it shows the need to be well informed about how the ICT sector helps societies to adapt, as well as the need for the sector itself to alter to climate change. If we want ICTs to be part of the solution, the sector must readjust itself to climate change related issues.

Emerging measures are contributing not only to reduce the sector's vulnerability to the impacts of climate change, but also to improve its preparedness and response capacity to the future, and yet uncertain change. Not only can ICTs help to address the risk produced by climate change but also improve the environmental economic performance and green societies.

The UNESCO Climate Change Initiative seeks to reinforce the scientific, mitigation and adaptation capacities of Member States. It brings together four thematic areas: science, education, ecology and ethics to address climate change. These four core programmes have been designed to take advantage of opportunities for synergy among UNESCO's existing capacities and programmes as well as those of other UN agencies and partners. Furthermore, there is a growing awareness of the limitations of single disciplines working on their own and the need for a more holistic, multidisciplinary approach to solving the problem. Policy-makers will need timely and useful information to integrate this knowledge into a much more comprehensive public policy.

In the current setting, UNESCO is working towards the establishment of a Climate Change Consortium with the aim of supporting the professionalization of public and private decision-makers. Within the context of global development, the Consortium will implement a leadership training programme on best practices and comprehensive decision-making on scientific and managerial issues related to sustainable development, its economic and social aspects.

In this sense, by strengthening the interface between science and policy makers, in both the private and the public sector, and by supporting the thinking of scientific concepts relating to sustainability in everyday decision making, well-informed policy makers will be steered to take informed decisions about issues of climate change.

As this report clearly states, the ICT sector will need to face the challenges imposed by this "inconvenient truth": climate change is a reality. This will require a real commitment from the private sector, coherent public policies, strong cooperation from the UN System, oversight from the civil society organizations and knowledge production and sharing from the academic world. The UNESCO Consortium is open to be part of the key debates raised by this report.

We wish you all a very exciting and productive reading!

Dr Jorge Grandi
Director, Regional Bureau for Sciences in Latin America and the Caribbean
UNESCO

Adapting the ICT Sector to climate change: a Deutsche Telekom perspective

DEUTSCHE TELEKOM AG is one of the world’s leading integrated telecommunications companies with almost 150 million mobile customers, around 40 million fixed-network customers, over 17 million broadband customers, around 3 million Internet protocol television (IPTV) customers and 2 million workstation systems marketed. Its products are fixed-network telephony, broadband Internet, IPTV, mobile communications, ICT solutions, cloud services, intelligent networks for health, automotive and energy.

As an international Group with over 232’000 employees and 9’300 trainees operating in around 50 countries worldwide, in Germany, USA and Europe with own infrastructure, Deutsche Telekom is strongly committed to finding innovative solutions to respond to the challenges and the opportunities posed by climate change.

The ICT sector is a key enabler for sustained climate protection. The addition of smart ICT enables GHG reduction in the transport and logistics industry, agriculture, energy and in buildings management. Environmentally-friendly ICT solutions are gaining increasing momentum in the fight against climate change across all industrial sectors. Through dematerialization, ICT provides further reduction of GHG emissions.

Nevertheless, the ICT industry itself has to set an example. ICT companies have to not only exploit opportunities to reduce their own emission, but also to implement effective measures to better cope with and adapt to the increasing effects of climate change.

This report supported by Deutsche Telekom is a contribution to those efforts. The unavoidable impacts of climate change on the ICT sector are identified and innovative responses are proposed to ensure that the infrastructure is resilient and services are maintained under anticipated climate stresses.

Deutsche Telekom continues to demonstrate an exemplary commitment in this field by saving energy and improving energy efficiency, by conducting research, developing and using innovative solutions to adapt to climatic impacts, and by contributing to global partnerships in the fight against climate change.

Furthermore as part of its commitment to climate change, the Board of Management approved in December 2013 a very new absolute climate target for the Group worldwide of reducing 20% of the carbon emissions between 2008 and 2020. This target covers 40 Company subsidiaries in 29 countries where the Company is operating.

Deutsche Telekom is an active member of the Global e-Sustainability Initiative (GeSI), which joined the United Nations' Momentum for Change programme in Warsaw (COP-19) to highlight the role of ICT in tackling climate change and also works closely with ITU.

Luis Neves
Group Sustainability and Climate Change Officer
Deutsche Telekom

Objective

The main objective of this report is to explore the impacts of climate change on the ICT sector and the potential for adaptation, while emphasizing the need for resilient pathways of action, enabling environments and new standards to foster the sector's approach to adaptation.

Introduction

Climate change has risen rapidly up the agenda of international organizations, governments, communities and industry sectors in the past decade, reflecting the growing impact of climatic manifestations at multiple levels[1]. With the potential to become a major disruptive factor in the achievement of economic growth and development over the next fifty years[2], climate change is playing an increasing role in processes of policy design, strategy implementation, livelihood maintenance and business practices around the globe.

Simultaneously, information and communication technologies (ICTs) have been diffusing widely, and redefining the way in which information and knowledge are generated, captured and stored, processed and disseminated among an increasingly interconnected society.

Thus, alongside the growing awareness of both acute (i.e. extreme weather events) and chronic climate effects (i.e. longer-term changes in the environment), ICTs are being increasingly recognized as enablers of innovative approaches to mitigate, monitor and adapt to climate change impacts[3].

However, while ICT contribution to the abatement of carbon emissions, energy efficiency, monitoring climate-related patterns and events, and implementing adaptive practices (among other climate-related responses) has been explored since the early 2000s[4], much less is known about the adaptation of the ICT sector itself to climate change impacts.

This report responds to the need of exploring further the effects of climate change on the ICT sector. It aims to raise awareness of the need to design and implement strategies for the sector to better prepare for, respond and adjust to the impacts of short- and long-term climatic manifestations. It gives an overview of the impacts, opportunities and challenges posed by climate change to sector stakeholders; it identifies existent and emerging adaptive measures, and provides suggested actions to strengthen the ICT sector's approach to adaptation.

This report targets an audience of ICT and climate change strategists and practitioners interested in gaining a better understanding of the challenges and opportunities faced by the sector in regards to climate change. The analysis seeks to highlight the strategic relevance of adopting "climate change resilient pathways", understood as innovative routes of action that are based on a sector-wide, multi-threat (short- and long-term climatic impacts) and multilevel (international, national, sectoral and local) perspectives.

The findings and suggested actions identified in this report can be relevant to a wide range of sector stakeholders, including (but not limited to) telecommunications operators, ICT manufacturers and service

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[1] IPCC. (2007) Fourth Assessment Report (AR4): Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland. http://www.ipcc.ch

[2] EC. (2007) Climate Change and ICT: An Environment of Change, Brussels, Belgium: European Commission (EC) [Online], Available: http://cordis.europa.eu/ictresults

[3] Labelle, R., Rodschat, R. & Vetter, T. (2008), "ICTs for e-Environment: Guidelines for Developing Countries with a Focus on Climate Change", International Telecommunication Union (ITU), Geneva, Switzerland http://www.itu.int/ITU-D/cyb/app/docs/itu-icts-for-e-environment.pdf;

MacLean, D. (2008), "ICTs, Adaptation to Climate Change, and Sustainable Development at the Edges", International Telecommunication Union Symposium on ICTs and Climate Change. London: International Institute for Sustainable Development.

[4] See the ICT and climate change literature trends identified in: Ospina, A. V. & Heeks, R. (2010), "Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study", Centre for Development Informatics, Institute for development Policy and Planning (IDPM), University of Manchester, Manchester, UK. http://www.niccd.org/ScopingStudy.pdf

providers, national governments, stakeholders of other sectors, and international stakeholders such as the International Telecommunication Union (ITU) and the United Nations Framework Convention on Climate Change (UNFCCC).

This report is structured around two main parts. The first part provides an overview of the main challenges and opportunities posed by climate change to the ICT sector. The analysis starts by situating ICT as part of the international climate change policy context, identifying the linkages that exist between adaptation policy processes and sectoral strategies. It then identifies the impacts of climate change on the sector, including key business drivers/opportunities and challenges associated with adaptation.

The second part of this report focuses on the sector's response to climatic impacts, identifying existing and emerging adaptive strategies. The analysis includes practical examples identified through a survey conducted among key sector stakeholders involved in ICT, environmental sustainability and climate change strategies[5] (see Annex 1).

The last section of this report suggests areas for future action to foster adaptive responses and resilient pathways in the ICT sector, including the role of new standards. This report concludes by suggesting next steps based on the sectoral priorities identified throughout the analysis.

It is expected that this report will assist countries and companies in their efforts to improve resilience to the increasing risks and opportunities posed by climate change. It is also expected that this report will foster new knowledge exchange on this topic, inform the design and implementation of adaptation strategies in the ICT sector, and contribute to further collaboration among ICT and climate change experts and practitioners at the international, national, sectoral and local levels.

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[5] The survey was conducted among selected industry stakeholders involved in ICTs, climate change and the environment.

I. The need for climate change adaptation

Climate change is becoming a key defining force for human development in the 21st century. As the ICT sector continues to expand and to permeate economic development and wider social change, the challenges posed by climate change impacts will become increasingly embedded in the way in which business strategies are designed and implemented.

The main impacts of climate change are described in this section.

1.1 The situation today

A growing body of literature evidences the serious effects that climate change (defined in Box 1) has at a global level, particularly in the poorest regions of the world[6]. In spite of the complexity and degree of uncertainty of climate models and projections, data suggest that regional climatic variations and seasonal changes are expected to increase and be manifested in more vulnerable livelihoods and ecosystems, scarcer water resources, heightened food insecurity, new health threats, weakened infrastructure and human habitats, among others[7].

Box 1: A definition of climate change

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change (IPCC) uses a relatively broad definition, referring to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

The IPCC makes a distinction between climate change that is directly attributable to human activities, and climate variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable depending on the context of analysis.

Source: IPCC (2007).

The Working Group I contribution to the IPCC Fifth Assessment Report[8] identifies that:

> *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases have increased" p. 2.*

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6 IPCC. (2001) "Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of the Working Group II to the Third Assessment Report", Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland., http://www.ipcc.ch/.
IPCC. (2007). Ibid.

7 Parry, M. L., Canziani, O. F., Palutikof, J. P., Linden, P. J. v. d. & Hanson, C. E. (eds.) (2007), "Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", Cambridge University Press, Cambridge.

Dumas, J. & Kakabadse, Y. (2008), "Climate Change and Poverty in Latin America and the Caribbean: A Consultation Process", Foundation Futuro Latinoamericano, International Development Research Center (IDRC) and the Department for International Development of the United Kingdom (DFID) Quito, Ecuador.
http://www.ffla.net/images/stories/PDFS/PUBLICACIONES/CCLAC_REPORT.pdf

OXFAM. (2009) "Suffering the Science: Climate Change, People and Poverty", Oxford, UK: Oxford Committee for Famine Relief (OXFAM). http://www.oxfam.org.uk/resources/policy/climate_change/downloads/bp130_suffering_science.pdf

8 IPCC. (2013) "Summary for Policymakers" in: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

The IPCC Fourth Assessment Report (AR4) suggests that greenhouse gas (GHG) emissions have increased by 70% between 1970 and 2004[9], mainly due to the combustion of fossil fuels. Scientific evidence indicates that with the current patterns of economic growth, global GHG emissions will continue to increase over the next few decades.

Climate change is linked to changes in precipitation patterns, rain and drought periods, to an increase in average temperature and the frequency of hot days and hot nights, to an increase in extreme weather events such as intense tropical cyclones, heat-waves and heavy rainfall, to the decrease of mountain glaciers and snow cover areas around the globe, and to changes in seasonality and ecosystem processes, among others[10] (Box 2). These are covered below.

Box 2: Climatic trends

"Many key climate indicators are already moving beyond the patterns of natural variability within which contemporary society and economy have developed and thrived. These indicators include global mean surface temperature, sea-level rise, global ocean temperature, Arctic sea ice extent, ocean acidification, and extreme climatic events. With unabated emissions, many trends in climate will likely accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts".

Source: Richardson et al. (2009), p. 8.

1.1.1 Changes in temperature

The IPCC Fifth Assessment Report indicates that "each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850" (p. 3). Scientific evidence presented in the report also suggests that the average temperature of the earth's surface (land and ocean) show a warming of 0.85%°C over the period 1880 to 2012. Temperature is expected to increase between 1.8°C to 4°C by the year 2100 if no action is taken[11]. Data suggest that even with an increase of 1.8°C, the earth would experience the largest increase in temperature than any century-long trend in the last 10'000 years.

According to the IPCC Fifth Assessment Report, "adaptation and mitigation choices in the near-term will affect the risks of climate change throughout the 21st century (high confidence). Figure 1 illustrates projected warming under a low-emission mitigation scenario and a high-emission scenario, along with observed temperature changes. The benefits of adaptation and mitigation occur over different but overlapping timeframes. Projected global temperature increase over the next few decades is similar across emission scenarios (Figure 1B). During this near-term period, risks will evolve as socioeconomic trends interact with the changing climate. Societal responses, particularly adaptations, will influence near-term outcomes. In the second half of the 21st century and beyond, global temperature increase diverges across emission scenarios (Figure 1B and 1C). For this longer-term period, near-term and longer-term adaptation and mitigation, as well as development pathways, will determine the risks of climate change."

1.1.2 Changes in precipitation

According to the IPCC Fifth Assessment Report, "in many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (medium confidence). Glaciers continue to shrink almost worldwide due to climate change (high confidence), affecting runoff and water resources downstream (medium confidence). Climate change is causing permafrost warming and thawing in high-latitude regions and in high-elevation regions (high confidence)."

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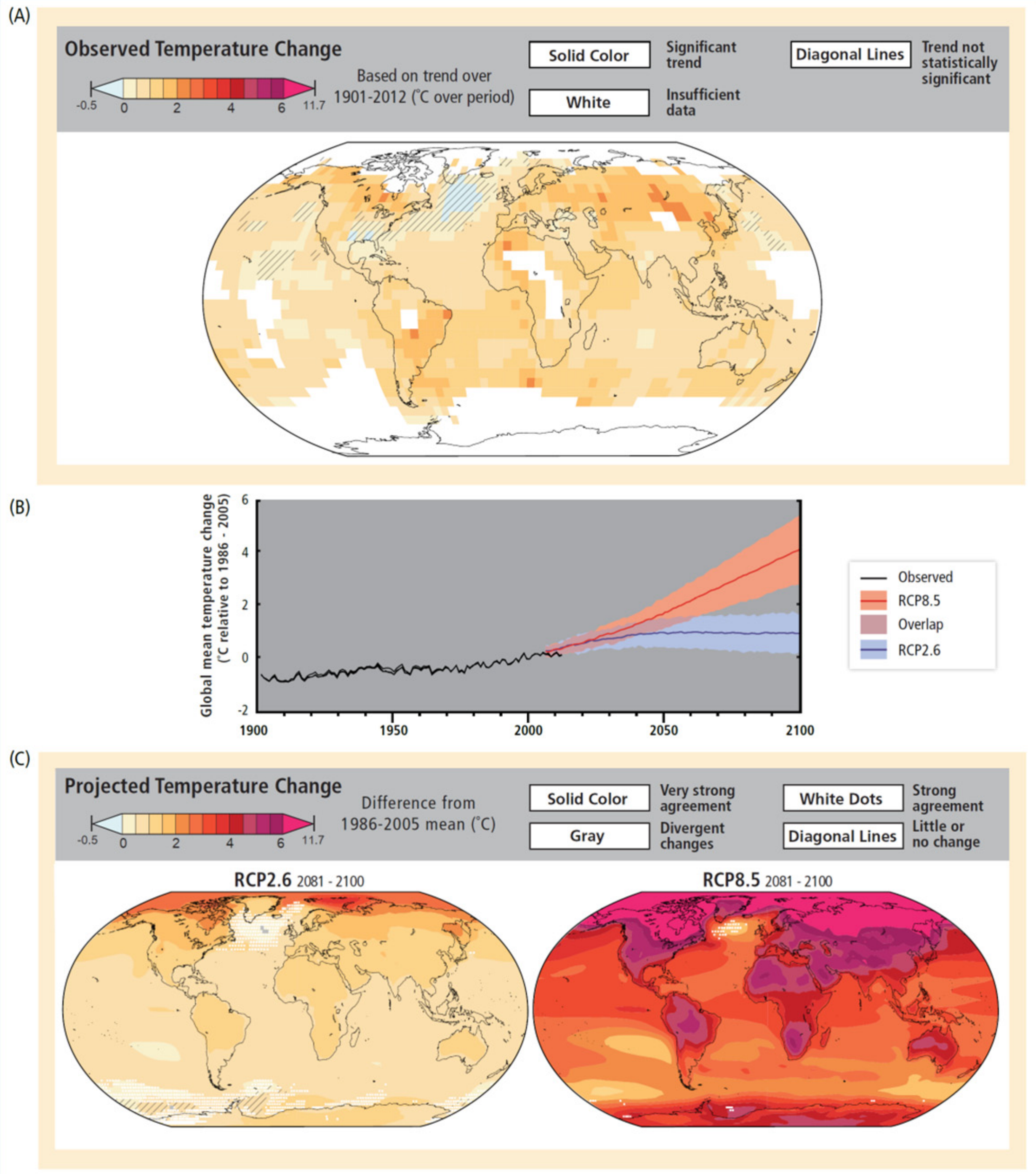
9 Contribution of Working Group III to the Fourth Assessment Report of the IPCC, 2007. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

10 IPCC (2007) "Summary for Policy Makers", in: Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (eds.). Cambridge University Press. Cambridge, U.K.

UNFCCC (2013), Climate Change Adaptation. United Nations Convention on Climate Change, http://unfccc.int/4159.php

11 IPCC 4th Assessment Report, Chapter 11.

Figure 1: Africa-temperature projections for the century



Source: IPCC (2013).

1.1.3 Changes in wind speeds

The IPCC Special Report on "Managing the risks of extreme events and disasters to advance climate change adaptation" (2012)[12] presents evidence on changes in the average wind speed over the century at a height of 10m above the surface. These changes are illustrated in the upper part of Figure 2. The changes shown in grey

[12] IPCC Special Report on "Managing the risks of extreme events and disasters to advance climate change adaptation" http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf

exceed 10% in some areas in both summer and winter. The lower figure shows changes in the 99% percentile where extreme winds are predicted.

Regarding tropical cyclones, the report concludes on page 165 that “It is likely that there has been a poleward shift in the main northern and southern storm tracks during the last 50 years”. More generally, annual wind extremes for coastal locations will typically be highest at mid-latitudes while those expected once every century will be highest in the 10° to 25° latitude tropics.

Figure 2: Projected wind speed changes for 2081-2100

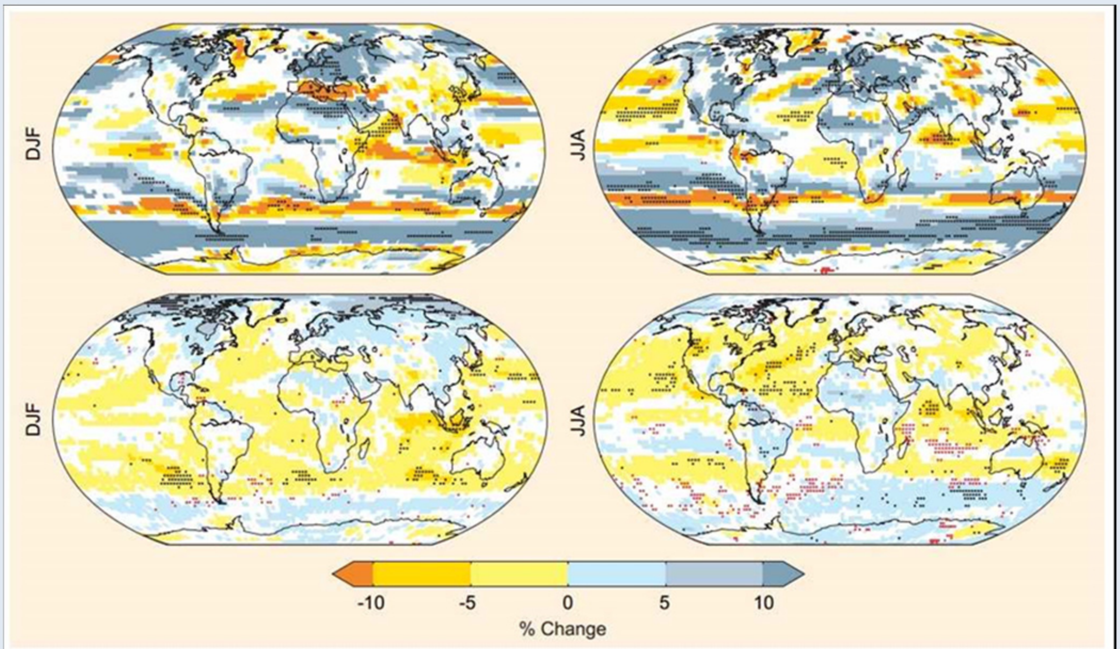


Figure 3-8 | Averaged changes from a 19-member ensemble of CMIP3 GCMs in the mean of the daily averaged 10-m wind speeds (top) and 99th percentile of the daily averaged 10-m wind speeds (bottom) for the period 2081-2100 relative to 1981-2000 (% change) for December to February (left) and June to August (right) plotted only where more than 66% of the models agree on the sign of the change. Black stippling indicates areas where more than 90% of the models agree on the sign of the change. Red stippling indicates areas where more than 66% of models agree on a small change between ±2%. Adapted from McInnes et al. (2011); for more details see Appendix 3.A.

Source: IPCC (2012).

1.1.4 Changes in lightning patterns

The IPCC Fourth Assessment Report states that there is insufficient evidence to determine whether trends exist in lightning. Numerous climate model simulations have shown that lightning activity will increase in a warmer climate[13]. These studies indicate an approximate 10% increase in lightning activity globally for every 1K warming. Optical Satellite Measurements over the period 1999-2008 support this activity[14]. Data can be downloaded or viewed as a movie from the National Aeronautics and Space Administration (NASA)[15]. An interesting animated example showing monthly strikes globally from 1995-2012 can be downloaded from the NASA[16]. However, radio measurements of lightning using the Schumann Resonance method have shown a steady decline over recent

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[13] Colin Price “ Thunderstorms, Lightning and Climate Change, 29th conf on lightning protection, 23-26 June 2008, http://www.iclp-centre.org/pdf/Invited-Lecture-1.pdf

[14] Felix Pereira “A possible relationship between Global Warming and Lightning Activity in India during the period 1998-2009”, http://arxiv.org/ftp/arxiv/papers/1012/1012.3338.pdf

[15] LIS/OTD Gridded Lightning Climatology Data Sets
http://thunder.nsstc.nasa.gov/data/data_lis-otd-climatology.html

[16] NASA: Low Resolution Monthly Time Series (LRMTS)
Data:LIS/OTD 2.5 Degree Low Resolution Monthly Time Series (LRMTS)
Animation: LRMTS_COM_FR_V2.3.2012.mov
ftp://ghrc.nsstc.nasa.gov/pub/lis/climatology/LRMTS/animations/LRMTS_COM_FR_V2.3.2012.mov

years, which has yet to be explained by climatologists[17]. Airborne particles and/or ice particles from aircraft emissions could be seeding rainfall before storms become established.

1.1.5 Changes in humidity

The IPCC Fourth Assessment Synthesis Report does not mention humidity. It is a notable omission and may have been a serious oversight as the NASA points out[18]:

> *"In climate modelling, scientists have assumed that the relative humidity of the atmosphere will stay the same regardless of how the climate changes. In other words, they assume that even though air will be able to hold more moisture as the temperature goes up, proportionally more water vapour will be evaporated from the ocean surface and carried through the atmosphere so that the percentage of water in the air remains constant. Climate models that assume that future relative humidity will remain constant predict greater increases in the Earth's temperature in response to increased carbon dioxide than models that allow relative humidity to change. The constant-relative-humidity assumption places extra water in the equation, which increases the heating."*[19]

1.1.6 Changes in snow and ice

The IPCC Fourth Assessment Synthesis Report does not specifically mention ice storms in the context of climate change but it is mentioned in Reference[20] as "an extreme event with a large spatial scale (as in an ice storm or windstorm) which can have an exaggerated, disruptive impact due to the systemic societal dependence on electricity transmission and distribution networks"[21].

1.2 *Climate change adaptation*

While extreme events have been historically linked to the occurrence of disasters, emerging scientific evidence shows a clear upward trend in the frequency and intensity of disasters from 1950 to 2005, especially from 1980[22], with most of them linked to extreme weather events.

Both acute (i.e. extreme weather events) and chronic climate effects (i.e. longer-term changes in the environment) have differentiated impacts that depend upon the degree of susceptibility and exposure of a given geographic context or business sector[23].

The impacts of acute events or "shocks" (e.g. intense rainstorms or cyclones) usually affect geographically limited areas and require rapid response and relief. Examples include landslides, flooding, disruption of transportation

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17 "Lightning: Principles, Instruments and Applications: Review of Modern lightning", Edited by Hans Dieter Betz, U. Schumann, Pierre Laroche, Springer, 4 Dec. 2008, p. 380. http://books.google.co.uk/books?id=U6lCL0CIolYC&pg=PA380&lpg=PA380&dq=global+lightning+trend+europe+lighting&source=bl&ots=93Fsu0MwuN&sig=YtLSYvDJRRQj9v_StArHDUdWHsc&hl=en&ei=qVidSrrIMoKhjAeSzOmWAg&sa=X&oi=book_result&ct=result&resnum=5#v=onepage&q&f=false

18 NASA, "It's not the heat it's the humidity", NASA Earth Observatory, Accessed September 2013. http://earthobservatory.nasa.gov/Features/WaterVapor/water_vapor3.php

19 NASA, *Ibid*.

20 IPCC Fourth Assessment Report: Climate Change 2007 http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9-5-4-2.html

21 Peters *et al.*, 2006.

22 UN-Habitat (2007), "Enhancing Urban Safety and Security; Global Report on Human Settlements 2007", Earthscan Publications, London, 480 pages.

23 O'Brien, K. & Leichenko, R. (2000), "Double Exposure: Assessing the Impacts of Climate Change Within the Context of Economic Globalization ", Global Environmental Change, 10 (2000): 221-232.

Adger, N. W. (2003), "Adaptation to Climate Change in the Developing World", Progress in Development Studies, 3(3): 179-195.

IISD, IUCN & SEI. (2003) Livelihoods and Climate Change: Combining Disaster Risk Reduction, Natural Resource Management and Climate Change Adaptation in a New Approach to the Reduction of Vulnerability and Poverty. International Institute for Sustainable Development (IISD), The World Conversation Union (IUCN) and Stockholm Environment Institute - Boston Centre (SEI-B), Winnipeg, Canada. http://www.iisd.org/pdf/2003/natres_livelihoods_cc.pdf systems and infrastructure damage, among others. The chronic manifestations of climate change take place over long periods of time, and include effects such sea level rise, melting glaciers or changing oceanic acidity due to atmospheric CO_2 uptake, as well as changes in the variability and intensity of weather cycles and events (e.g. changes in seasonality, temperature and precipitation)[24].

According to UNFCCC[25], it is estimated that the investment and financial flows that will be required to meet adaptation needs could amount to USD 49-171 billion per year by 2030. Thus, beyond the debate around the causes and degree of severity of climate change, there is an increasing scientific consensus about the imminence of its effects, and about the risks that it poses to local livelihoods, ecosystems, businesses and wider socio-economic systems.

Evidence suggests that, given the challenges that developing countries face at the socio-economic, technological and scientific levels, both acute and chronic climate change manifestations will impact them more severely, magnifying poverty and existing development vulnerabilities[26]. These effects are relevant for the ICT sector considering the high interdependence of infrastructure and business sectors that support the global ICT service provision.

A global survey conducted by the Economist Intelligence Unit in 2011 suggests that around nine in every ten firms have suffered climate impacts in the past three years, many of which corresponded to the disruption of supply chains and lost revenue[27].

The impacts of climate change can cause disruptions at multiple levels (from individual organizations and localized geographical areas, to broader interdependent networks and infrastructure, services provided by small to medium enterprises (SME) and large multinational organizations)[28]. These effects will be further explored in section III.

The increasing awareness about climate change impacts has been accompanied by a growing prioritization of actions aimed at adapting to changing climatic conditions and uncertainty. During the last decade, the notion of adaptation (Box 3) has gained considerable momentum, posing new opportunities to moderate, cope with, and take advantage of the opportunities that may emerge with changing climatic conditions.

Box 3: A definition of climate change adaptation

Adaptation to climate change can be defined as the adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential harm or benefit from opportunities associated with climate change.

Source: IPCC (2001).

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[24] Cannon, T. (2010), "Adapting to Climate Change: Applying Concepts in Practice. Climate Change, Disasters and Urban Poverty", Manchester, UK: School of Environment and Development (SED), University of Manchester.

[25] "Report on the analysis of existing and potential investment and financial flows relevant to the development of an effective and appropriate international response to climate change". August 2007, UNFCCC. http://unfccc.int/files/cooperation_and_support/financial_mechanism/financial_mechanism_gef/application/pdf/dialogue_working_paper_8.pdf

[26] IPCC. (2007) *Ibid*.
Kalas, P. P. & Finlay, A. (eds.) (2009), "Planting the Knowledge Seed: Adapting to Climate Change Using ICTs", Building Communication Opportunities (BCO) Alliance.

[27] UKTI, (2011). "Adapting to and Uncertain Climate: A World of Commercial Opportunities", UK Trade & Investment, and The Economist Intelligence Unit.

[28] Horrocks, L., Beckford, J., Hodgson, N., Downing, C., Davey, R. & O'Sullivan, A. (2010), "Adapting the ICT Sector to the Impacts of Climate Change", AEA Group, Oxfordshire, UK.
http://archive.defra.gov.uk/environment/climate/documents/infrastructure-aea-full.pdf

Adaptive measures can take multiple forms according to their timing, source and modality of implementation (e.g. anticipatory or reactive, private or public, and autonomous or planned)[29]. Examples include actions aimed at strengthening local infrastructure in order to withstand the impact of floods and severe rainfall periods, the improvement of productive systems to ensure the continuous flow of inputs during climatic disturbances, or the availability of redundant information channels for early warning and disaster response, among others.

Considering the complexity of climate change impacts and the degree of uncertainty that characterizes this field, the analysis of adaptation strategies cannot be generalized. Instead, a focused perspective is needed. For the purposes of this report, this perspective will be achieved by addressing the case of the ICT sector's adaptation.

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[29] IPCC. (2007). *Ibid*.

II. ICT and climate change adaptation

This section explores the linkages that exist between ICT, climate change adaptation and resilience, providing the contextual basis for subsequent stages of the analysis. The first part of the section will provide an overview of the context within which the adaptation of the ICT sector takes place, emphasizing the progress achieved at the international and sectoral domains. The analysis will then identify the importance of adaptation for the ICT sector, presenting a resilience-based framework that can serve to guide the sector's strategies in this field.

The increasing importance of climate change adaptation has been fostered by an international debate at the highest levels, addressing the mechanisms, measures and policies that should be in place to enable the implementation of adaptive strategies. Alongside this debate, the role of ICT in the climate change adaptation field has grown steadily during the last decade, as recognized in a study led by ITU[30]:

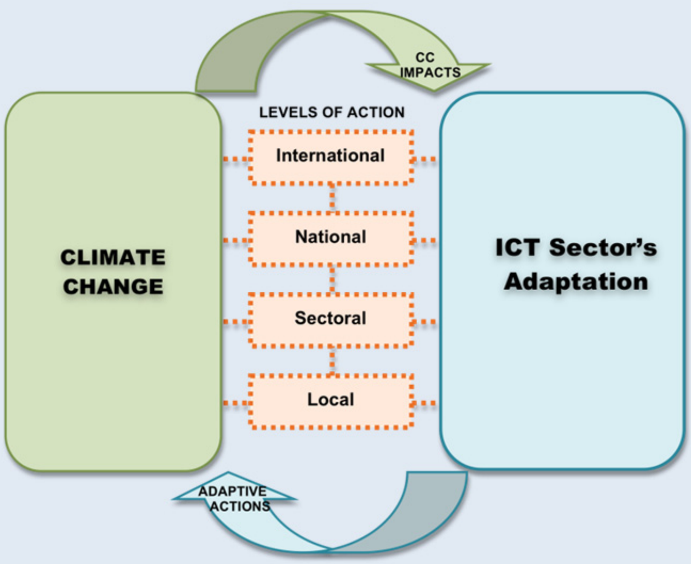
> *"ICTs can assist climate change stakeholders working at the international, national, sectoral and* community *levels to enhance work on different aspects of technologies and know-how for adaptation, as well as on opportunities for their development, diffusion, and transfer" (p. 25).*

The linkages between ICT and climate change adaptation can be found at various levels that are closely interconnected by dynamic feedbacks and interactions (e.g. collaboration between the UNFCCC Secretariat, governments and private sector organizations, between national authorities, regulators and telecommunication providers, between ICT infrastructure and service providers, or between ICT companies and local communities, among others).

The actions undertaken at each of these levels can influence the way in which the ICT sector itself approaches climate change adaptation. For example, international processes and standards (i.e. international level), national ICT initiatives (i.e. national level), multi-sectoral partnerships (i.e. sectoral level), and collaboration between companies and local technology users (i.e. local level) can contribute to shape the design, adoption and implementation of adaptive actions by ICT sector stakeholders.

These dynamic linkages are illustrated in Figure 3.

Figure 3: Levels of action in the ICT sector's adaptation to climate change



[30] Ospina, A.V., Bueti, C., Dickerson, K., & Faulkner, D. (2012), "Information and Communication Technologies (ICTs) and Climate Change Adaptation and Mitigation: The Case of Ghana", International Telecommunication Union (ITU), Geneva, Switzerland, http://www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000020001PDFE.pdf

Recognizing these levels of action can help us gain a better understanding of the context within which the ICT sector's adaptation takes place.

At the international level, the adaptation of the sector is enabled by an active climate change policy domain that dates back to the United Nations Conference on Environment and Development held in 1992 in Rio de Janeiro, Brazil (also known as the 1992 "Earth Summit"). At this point, three intrinsically linked United Nations conventions addressing the interdependent issues of biodiversity, climate change and desertification were established, giving rise to the United Nations Framework Convention on Climate Change (UNFCCC) (Box 4)[31], the United Nations Convention to Combat Desertification (UNCCD) and the United Nations Convention on Biological Diversity (CBD).

Box 4: The United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC entered into force on March 21st 1994. It aims at undertaking actions at the international, regional and national level to reduce GHG emissions (thus mitigating climate change) and to cope with climate change foreseen in the near future. Adaptation plays a pivotal role in the Convention, which requires parties to make provisions to enable adaptation, to cooperate in preparing for adaptation to the impacts of climate change; and to develop and elaborate appropriate and integrated plans related to the relevant sectors. With 194 States and 1 regional economic integration organization (the European Union (EU)), the UNFCCC enjoys near-universal membership.

Source: UNFCCC (2013).

UNFCCC has been linked to a number of key international climate change protocols, agreements and responses to climate change, as summarized in Annex 2. Adaptation, specifically, has been gaining momentum in the international policy domain since the first meeting of the UNFCCC Conference of the Parties (COP) in 1995.

Adaptation began to be widely recognized as a key area for action at the 2001 Marrakesh Accords (COP-7). Collaborative work in the international policy domain was strengthened with the approval of the "*Buenos Aires Programme of Work on Adaptation and Response Measures*" at COP-10 in 2004. Conference parties gathered at COP-12 (2006) agreed the initial list of activities to be undertaken under the "*Nairobi work programme on impacts, vulnerability and adaptation to climate change*" (NWP) (Box 5), a mechanism that fosters collaboration between the private sector and other climate change stakeholders, and that has become a key enabler of adaptation at multiple levels.

Box 5: The Nairobi work programme on impacts, vulnerability and adaptation to climate change (NWP)

The NWP was established as a five-year work programme under the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) to assist all parties, especially least developed countries (LDCs) and small island developing states (SIDS), to improve their understanding and assessment of impacts, vulnerability and adaptation to climate change, and to make informed decisions on practical adaptation actions and measures.

The NWP provides a structured framework for knowledge sharing and collaboration among Parties and organizations. Partners include non-governmental organizations, intergovernmental organizations, community-based organizations, the private sector, institutes and regional centers. They highlight actions being carried out, and pledge further adaptation action in line with the goals and objectives of the NWP as well as in response to calls for action.

Source: UNFCCC (2013).

Following the adoption of the "*Bali Action Plan*"[32] at COP-13 held in Bali, Indonesia (2007), Parties adopted the "*Cancun Adaptation Framework* (CAF)"[33] at the 2010 Climate Change Conference (COP-16) held in Cancun, Mexico. This was an important milestone for adaptation efforts at the international policy domain, as parties affirmed that adaptation goals must be addressed with the same level of priority as mitigation[34].

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31 UNFCCC (2013), Essential Background of the Convention, http://unfccc.int/essential_background/convention/items/6036.php

32 The Bali Action Plan is available at: http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf

33 The Cancun Adaptation Framework is available at: http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=4

34 UNFCCC (2013), Climate Change Adaptation. United Nations Convention on Climate Change, http://unfccc.int/4159.php

Building on these achievements, at the 2012 COP held in Durban, South Africa (COP-17) Parties advanced on the modalities, procedures and composition of a newly formed Adaptation Committee, on activities to be undertaken under the work programme on loss and damage, as well as on modalities and guidelines for a process to enable least developed country Parties to formulate and implement national adaptation plans (NAPs)[35].

Acknowledging the increasing role of ICTs in this field, at COP-17 the UNFCCC Secretariat convened a side event focused on ICTs and climate change adaptation. The efforts of a newly formed collaboration initiated by ITU, the UNFCCC Secretariat and the Global e-Sustainability Initiative (GeSI) started to gain momentum[36], evidencing the growing engagement of the world's leading ICT service providers and vendors on climate change issues.

The role of the ICT sector in the climate change domain was further strengthened with the creation of the private sector initiative (PSI) of NWP under UNFCCC, aimed at catalyzing the involvement of the private sector in the wider adaptation community. With more than 270 private sector organizations (2013), including ICT sector companies, PSI is contributing to a wider knowledge base on sectoral responses and adaptation efforts, new technologies and multi sectoral partnerships with governmental and non-governmental actors[37].

Within the international policy domain, ITU has enabled significant progress in the exploration of ICTs" role towards climate change and the environment, developing technical standards and guidelines needed to foster the adoption of ICTs as part of climate change policies and strategies at various levels.

ITU provides support to Member States in the development of national strategies and capacities needed to promote sustainable development through the effective use of ICT networks, services and applications[38]. Particularly since the publication of the ITU-T Technology Watch Report on *"ICTs and Climate Change"* (2007)[39] and a series of events, publications and standardization activities focused on these issues[40], ITU has become an important referent for ICT sector stakeholders (Annex 3). Through specialized study groups and multi sectoral focus groups, the ITU has contributed to position adaptation as a key priority in the ICT sector's agenda.

Work undertaken by ITU's Study Group 5 (in particular Question 15/5)[41] (Box 6) includes the identification of best practices for countries to enable adaptation to climate change, the ways in which ICT can be used and adapted to more effectively disseminate information on both natural and man-made disasters to communities, as well as the impact of climate change on the ICT sector and the potential for adaptation, among other key issues. Further information about the work of this study group is available in Annex 4.

Box 6: ITU-T Study Group 5 "Environment & Climate Change"

The Study Groups of ITU's Telecommunication Standardization Sector (ITU-T) assemble global experts to develop international standards known as "ITU-T Recommendations", which act as defining elements in the global infrastructure of ICTs.

ITU-T Study Group 5 (SG5) focuses on environment and climate change and includes a specific question on ICTs and adaptation (Question 15/5), aimed at bringing together, developing and disseminating knowledge and research results so that the ICT sector can play its full part in adaptation to climate change.

Source: ITU (2013).

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35 UNFCCC, 2012, http://unfccc.int/4159.php

36 Further information on the Coalition on ICTs and Climate Change is available at: http://www.itu.int/themes/climate/events/cop17/ICTcoalition.html

37 UNFCCC (2013). http://unfccc.int/4623.php

38 http://www.itu.int/themes/climate/docs/report/07_adaptation.html

39 ITU (2007). "ICTs and Climate Change" ITU-T Technology Watch Report #3 http://www.itu.int/oth/T2301000003/en

40 For further references see http://www.itu.int/climate

41 Further information on SG5, Question 15 is available at: http://www.itu.int/en/ITU-T/studygroups/2013-2016/05/Pages/q15.aspx

ITU is also a partner of NWP, and provides support to Member States with its implementation.

Thus, in parallel to the growing importance of climate change adaptation within the international policy domain, the linkages between adaptation and the ICT sector have gained increasing momentum. There is a growing recognition of the sector's role in mitigation, adaptation and monitoring strategies, an increasing engagement of its stakeholders in the achievement of adaptation goals, and a broader awareness of the need for adaptive strategies that respond to the specific priorities of the ICT sector. This international interest is exhibited in Box 7.

Box 7: International recognition of ICTs role in climate change

As part of the COP-19 meeting that took place in Warsaw, Poland, over 30 of the world's leading technology businesses, all members of the Global e-Sustainability Initiative (GeSI), joined the United Nations' Momentum for Change programme in Warsaw to highlight the role of ICT in tackling climate change. Participants recognized the need to harness the potential offered by ICT in the climate change field, and the need to gather the concerted efforts of all involved in the ICT sector in order to achieve transformational change.

An article by Christiana Figueres (Executive Secretary of the United Nations Climate Change secretariat) and Luis Neves (GeSI Chairman/Group Sustainability and Climate Change Officer, Deutsche Telekom) identifies a series of primary steps needed to foster the role of ICTs in the field:

- Concerted action by global policy makers to encourage the implementation of ICT solutions. For example, the SMARTer2020 report provides specific guidance to policymakers on actions they can take to realize significant greenhouse gas reduction.
- Greater involvement by other industries to cooperate with the ICT sector. By making ICT a necessary component of their corporate environmental goals, they will be efficient, sustainable and profitable.
- Support of academics and non-governmental organizations to refer to and implement ICT as part of their work.

As the analysis presented in this report will show, these steps can also contribute to foster the sector's adaptation to climate change impacts (e.g. through an enabling policy environment, increased cross-sectoral collaboration, and further research on the potential of adaptation for ICT companies, among others).

Source: International Business Times (2013).

Efforts conducted at the international policy domain (e.g. as part of the UNFCCC process, and by organizations such as ITU) provide an important enabling environment for ICTs" role in adaptation at the national, sectoral and local levels. International agreements and standards on ICT and climate change, as well as mechanisms for collaboration and knowledge sharing contribute to raise awareness among governments, private sector and civil society stakeholders, to inform policy-making, and to identify innovative measures to mitigate, adapt and monitor climatic impacts with the help of ICT tools.

Having provided a brief overview of the context within which ICT and climate change adaptation converge, the following section will identify the relevance of implementing adaptive strategies for the ICT sector.

2.1 Importance of adaptation for the ICT sector

The analysis conducted up to this point suggests that the linkages between ICT and climate change are multiple and complex. Sources at the intersection of the ICT and the climate change fields have covered extensively the potential of ICT in the abatement of GHG emissions and in the achievement of energy efficiency[42], their role in

[42] Pamlin, D. & Szomolanyi, K. (2005), "Saving the Climate @ the Speed of Light: First Roadmap for Reduced CO2 Emissions in the EU and Beyond", World Wide Fund (WWF) and European Telecommunications Network Operators' Association (ETNO), Brussels, Belgium. http://assets.panda.org/downloads/road_map_speed_of_light_wwf_etno.pdf

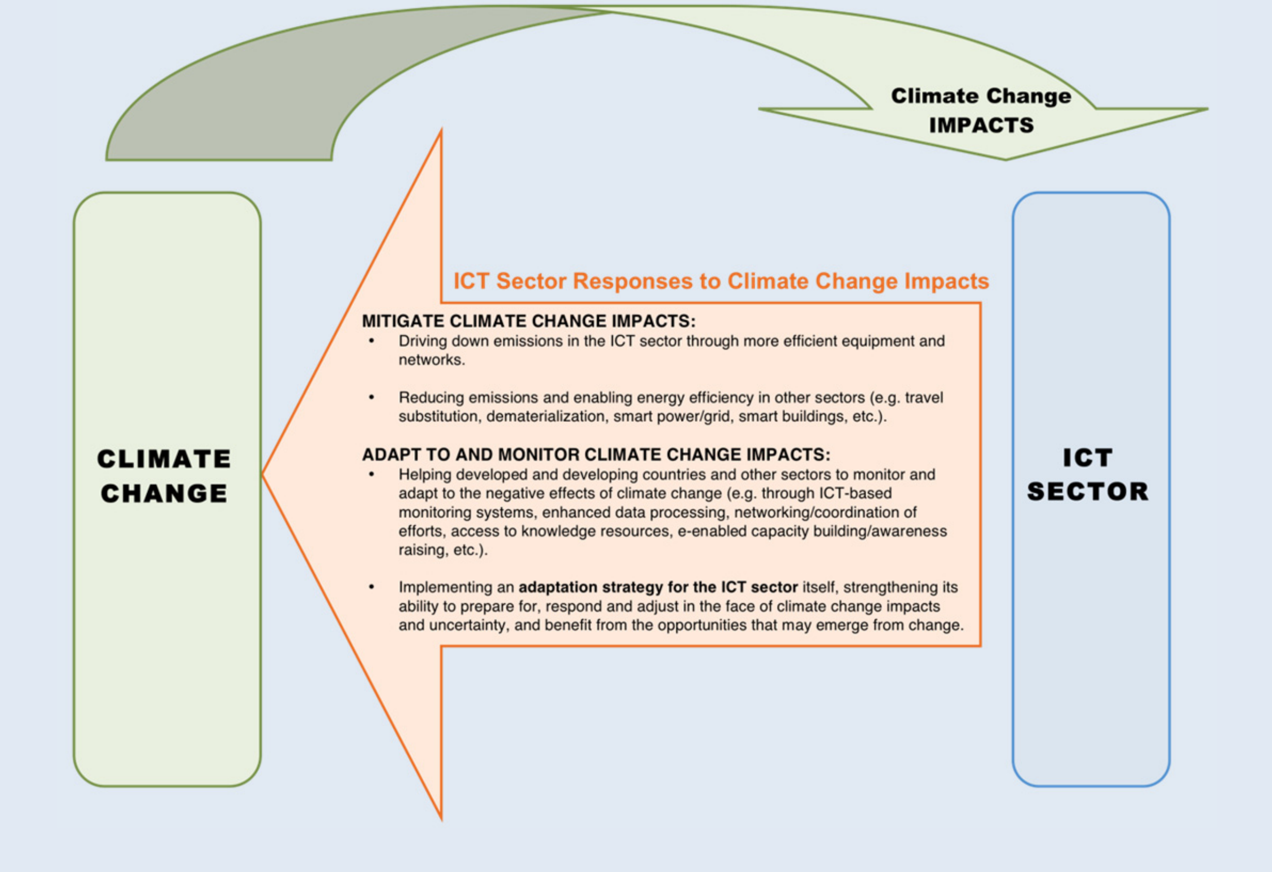
ITU (2008), "ICTs and Climate Change: ITU Background Report", ITU/MIC Japan Symposium on ICTs and Climate Change. Kyoto, 15-16 April 2008: International Telecommunication Union (ITU).

WEF. (2008), "The Contribution of ICT to Climate Change Mitigation", World Economic Forum (WEF), Geneva http://www.unapcict.org/ecohub/resources/the-contribution-of-ict-to-climate-change-mitigation early warning and disaster risk management[43], and increasingly, their contribution to adaptation within vulnerable environments[44]. These explorations suggest that, while emissions generated by the ICT sector represent about 2%-3% of global emissions[45], their positive effects on climate change mitigation, monitoring and adaptation hold a greater potential.

ICT sector responses to climate change involve actions aimed at mitigating its effects (e.g. by driving down emissions in the sector, reducing emissions and fostering energy efficiency in other sectors), monitoring climatic trends (e.g. through ICT-enabled data capture, processing, presentation and dissemination) and adapting to its impacts (e.g. by helping to reduce the vulnerability of various sectors, strengthening networking, decision making and resource access for adaptation)[46].

However, while the role of ICT in these areas is an object of ongoing investigation, much less is known about the adaptive strategies that the ICT sector itself could adopt to better prepare for, respond and adjust to more frequent and intense climatic impacts. These areas of response are summarized in Figure 4.

Figure 4: ICT sector responses to climate change impacts



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43 ITU. (2009), "E-Environment Toolkit and Readiness Index (EERI)", International Telecommunication Union (ITU), Geneva, Switzerland http://www.itu.int/ITU-D/cyb/app/docs/eEnv_Toolkit_draft_for_comments_Dec_09_vf.pdf

44 Akoh, B., Bizikova, L., Parry, J., Creech, H., Karami, J., Echeverria, D., Hammill, A. & Gass, P. (2011), "Africa Transformation-Ready: The Strategic Application of Information and Communication Technologies for Climate Change Adaptation in Africa", International Institute for Sustainable Development (IISD), Prepared for the African Development Bank, the World Bank and the African Union., Winnipeg, Canada. http://siteresources.worldbank.org/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/282822-1346223280837/ClimateChange_Fullreport.pdf

45 Chung, S., Cheon, D., Chang H. (2013), "The case of Korea: The Quantification of GHG Reduction Effects Achieved by ICTs", International Telecommunication Union (ITU). [Online] Available: http://www.itu.int/dms_pub/itu-t/oth/0b/11/T0B110000243301PDFE.pdf

46 Heeks, R. & Ospina, A. V. (2009), "ICTs, Climate Change and Development Overview Model", [Online], Available: http://niccd.wordpress.com/2009/12/14/overview-model-of-icts-climate-change-and-development

As a contribution to this increasingly relevant debate, this report is focused on the latter dimension. Box 8 summarizes some of the key reasons for the integration of adaptation into the strategies and investments of private sector companies, including ICT sector stakeholders.

Box 8: Motivations of private sector companies to integrate adaptation

- "*For economic interest.* Many of their investments in developing countries are at risk, therefore, integrating adaptation planning and measures will make their investments and returns less risky and ultimately more profitable.
- *For their clients" interest.* Without adaptation measures, more development investments in vulnerable countries are not sustainable. In addition to the economic argument, the ethical imperative for sustainable investment and business practice must be considered.
- To support the *interest of their countries of operation.* The private sector must become an active partner in adaptation efforts in developing countries as they can bolster governments, help define and complement effective public adaptation measures, and build public and international support through their influence."

Source: Biagini and Miller (2013) p. 14.

When compared to sectors with "heavy" infrastructure (e.g. energy, water or transportation), the characteristics of the ICT sector provide a degree of inherent adaptability to disruptive events and processes of change, including those linked to climate change. These characteristics include the predominance of smaller infrastructure and shorter lifetimes, reliance on a combined network instead of individual structures, redundancy of service and infrastructure providers, and fast-paced technological change and innovation[47]. Despite these relative advantages, the adoption of an adaptation strategy is an imperative for sector stakeholders.

The impacts of climate change manifestations such as more frequent and intense extreme events, heat-waves, flooding, and sea level rise can have the following disruptive effects on the sector's operations:

- accelerate the degradation of physical assets and ICT infrastructure,
- affect the supply of materials, interrupt transport and logistics,
- disrupt the availability and reliability of ICT services,
- increase operational business costs across the sector,
- reduce revenue, and
- challenge the sector's ability to conduct repairs and recover from the effects of climatic events, among other direct and indirect impacts[48].

In response to these impacts, the adoption of anticipatory adaptation measures is closely linked to the generation of short- and long-term cost savings, to the implementation of novel management strategies to deal with change and take advantage of emerging market opportunities, and to the strengthening of the operational and resource efficiency at multiple levels (e.g. ICT infrastructure and service providers, customers reliant on ICT services).

The magnitude of climate change impacts, coupled with the increasing pervasiveness of the ICT sector in the global networked society and the growing reliance on its services, evidence the urgency of re-thinking and adjusting sectoral processes, practices and structures to reduce the sector's vulnerability to climatic impacts, to improve its responses to short- and long-term effects, and to benefit from business opportunities that may arise with change.

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[47] Horrocks *et al*. (2010). *Ibid*.

[48] Amado, J., Adams, P. (2012), "Value Chain Climate Resilience: A guide to Managing Climate Impacts in Companies and Communities", Partnership for Resilience and Environmental Preparedness (PREP). [Online] Available: http://www.oxfamamerica.org/press/files/prep-value-chain-climate-resilience.pdf

As emerging empirical evidence from adaptation projects supported by climate funds indicates[49]:

> *"Successful private sector engagement in adaptation will catalyse greater and more frequent investments, which could lower the costs, accelerate the replication of climate-resilient technologies and approaches in core development sectors, especially in developing countries" (p. 2).*

According to the UNFCCC website[50], adaptation strategies involve five general components: (a) identifying climatic and non-climatic variables, (b) assessing climate change impacts and areas of vulnerability, (c) planning and formulating adaptive measures, (d) implementing actions to moderate, prepare for or respond to climatic impacts, and (e) monitoring and evaluating the adaptation actions undertaken. The lessons that emerge from monitoring and evaluation (M&E) processes can, in turn, serve as inputs to inform the design or the adjustment of adaptive strategies.

Each of these components needs to be considered as part of the ICT sector's approach to adaptation, and will be addressed in section IV.

2.2 Resilient pathways: An approach to the ICT sector's adaptation

Research conducted at the intersection of ICT and climate change[51] suggests that integrating the notion of resilience can strengthen the sector's approach to adaptation. Acknowledging the availability of multiple interpretations of this concept, Box 9 presents a working definition of resilience that will be used for the purposes of this report.

Box 9: A definition of resilience

Resilience is understood as the ability of a system or a sector to withstand, recover, adapt, and potentially transform in the face of stressors such as those caused by climate change impacts.

Source: Adapted from Ospina and Heeks (2010).

The notion of resilience allows us to take the sector's adaptation efforts one step forward in two ways:

(a) by adopting a broader, system-wide perspective that is not limited to specific actors and specific climatic threats but one that focuses instead on the functioning of the ICT sector as a whole, and

(b) by acknowledging the sector's ability not only to "adjust", but also to occasionally transform in the face of both short- and long-term climatic stressors and emerging opportunities[52]. An example of transformation in the ICT sector is the change from physical to electronic distribution of media (e.g. compact disks/digital versatile disks (CDs/DVDs)), which both reduce costs and GHG emissions.

The exploration of resilience in the climate change literature allows us to identify a series of key attributes that can contribute to the resilience of the ICT sector to climate change impacts.

These attributes refer to the robustness of the sector in the face of extreme climate events and chronic trends, its ability to self-organize and learn, and its redundancy, flexibility and diversity, rapidity of response and scale of interactions[53]. These (non exclusive) attributes are dynamic, interrelated and often overlapping. In practice, several attributes can complement each other, can change over time, and can play a (simultaneous) role in

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49 Biagini B., Miller, A. (2013), "Engaging the Private Sector in Adaptation to Climate Change in Developing Countries: Importance, Status and Challenges", Climate and Development, Vol. 5, Issue 3, pages 242-252.

50 http://unfccc.int/adaptation/items/7006.php#Assessment

51 Ospina, A. V. & Heeks, R. (2010), "Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-Resilience and e-Adaptation", Centre for Development Informatics, Institute for development Policy and Planning (IDPM), University of Manchester, Manchester, UK. http://www.niccd.org/ConceptualPaper.pdf

52 Gallopin, G. C. (2006), "Linkages Between Vulnerability, Resilience and Adaptive Capacity", Global Environmental Change, 16:293-303.

Nelson, D. R., Adger, N. W. & Brown, K. (2007), "Adaptation to Environmental Change: Contributions of a Resilience Framework", Annual Review of Environment and Resources, 32:395-419.
Magis, K. (2009), "Community Resilience: An Indicator of Social Sustainability", Society and Natural Resources, 23:401-416.

53 Ospina, A. V. & Heeks, R. (2010). *Ibid*.

strengthening the sector's approach to adaptation. They can also be adjusted to respond to the specific adaptive needs of the sector in response to a variety of (short- and long-term) climatic threats.

The significance of each attribute for the ICT sector's resilience is summarized in Box 10.

Box 10: Resilient pathways: key ICT sector attributes

- **Robustness** refers to the ability of the ICT sector to maintain its performance in the face of environmental shocks and fluctuations. Includes the ability to spread the risks and effects of climatic disturbances widely, so as to retain overall consistency in the sector's performance.
- **Self-organization** refers to the sector's ability to independently rearrange its functions and processes in the face of an external disturbance in order to withstand, bounce back and adapt to its impacts.
- **Learning** refers to the sector's capacity to gain or create knowledge, and strengthen skills and capacities. It is closely linked to processes of experimentation, discovery and innovation.
- **Redundancy** refers to the extent to which functions, services and components within the sector are substitutable; for example, in the event of disruption or degradation.
- **Flexibility and diversity** refer to the ability of the sector to undertake different courses of action with the determinants at its disposal, while innovating and utilizing the opportunities that may arise from change.
- **Rapidity** refers to the speed at which assets can be accessed or mobilized to achieve the sector's goals in an efficient manner, particularly in the event of shocks.
- **Scale** refers to the breadth of assets that the sector can access in order to effectively overcome, bounce back from or adapt to the effects of disturbances.

Source: Ospina and Heeks (2010).

The integration of resilience attributes as part of the sector's response to climate change can help to strengthen its adaptive capacity, that is its ability to effectively prepare for, respond and adjust to the impacts of extreme events (e.g. cyclones, flooding, heat-waves) and chronic trends (e.g. sea level rise, changes in temperature, shifting seasonality).

The resilience attributes identified in Box 10 are not suggested as a comprehensive list, or as a mechanism to prioritize or categorize adaptation measures. Instead, they are meant to enable and strengthen the sector's overall approach to adaptation by allowing stakeholders (e.g. industry strategists, decision-makers) to consider factors (e.g. long-term robustness, learning, flexibility, etc.) that may have been overlooked from more traditional (i.e. asset-based, short-term/reactive) approaches to adaptation.

The contribution of resilience attributes to the ICT sector's adaptation is twofold. On the one hand, these attributes can help to identify measures or mechanisms that need to be in place to enable/facilitate the implementation of adaptation actions, and therefore, that should be included in the design of adaptation strategies. For example, an effective sectoral response to the impact of extreme events may require collaborative mechanisms in place among ICT operators (which refers to self-organization), the availability of redundant/substitutable services to allow for the continuation of services if base stations fail (which refers to redundancy), as well as flexible management/operational strategies to explore alternative courses of action in the event of climatic shocks (which refers to flexibility).

On the other hand, the integration of these attributes can help strengthen the sector's resilience to short- and long-term climatic impacts. For example, adaptive measures that reinforce or update telecommunication infrastructure can contribute to the long-term robustness of the sector, as well as to the sector's learning (e.g. skills/capacities) by drawing best practices/lessons that can be used in response to future events.

Each of the resilience attributes identified above can be linked to concrete adaptation actions of ICT sector stakeholders; actions that can be taken in anticipation of or in response to climatic stressors. Examples of the linkages that exist between key resilience attributes and potential (adaptive) responses by the ICT sector are provided in Table 1.

Table 1 – Resilient pathways: Linkages between resilience attributes and potential (adaptive) responses by the ICT sector (Source: Adapted from Ospina and Heeks, 2010, and Atomic Energy Agency (AEA), 2010[28])

Resilience attributes	ICT sector's response to climate change
Robustness	• Strengthen the sector's physical assets or the connection between existent assets. This includes investments in flood barriers, cooling systems and more resistant infrastructure, among others. • Review the role of governments, regulators and current market structures in addressing climate risks in the ICT sector, including issues of ownership, and roles and responsibilities in achieving the sector's resilience. • Adopt measures aimed at strengthening the ICT sector structures and organizations so that they are able to continue operating amidst the impact of climatic stress.
Self-organization	• Foster collaborative mechanisms among sector stakeholders in order to address sectoral vulnerabilities at the regional, national and international levels. • Adopt measures to facilitate access to overt resources (financial resources, skills, and technical infrastructure), embedded/social resources (trust, motivation, knowledge) and relevant raw data (Heeks, 1999) required for the sector to self-organize in the face of climatic stressors. • Foster collaborative efforts among the major telecommunications providers aimed at building the business case for companies to address climate risks.
Learning	• Support new research and knowledge on the linkages between ICTs and climate change (including projections, direct and indirect climate risks throughout the ICT supply chain) to increase the sector's awareness and develop the skills required to implement adaptive actions. • Review evidence on the impact of past weather events on ICT infrastructure and service providers, drawing best practices and lessons learned. • Foster experimentation and novelty across the sector, to ensure innovative responses to adjust to new climatic conditions.
Redundancy	• Promote the availability of surplus/interchangeable processes, system interoperability, capacities and response pathways that allow for partial failure of the sectors" services while avoiding complete collapse. • Implement collaborative and multi-sector approaches to foster operational overlaps and multiple sources of support/expertise that can help fill the gaps in times of need, allowing the system to continue to function amidst climatic events. • Foster the functional overlap of contingency/emergency measures to ensure the continuation of ICT services and network operations under climatic stress.
Flexibility and diversity	• Improve the availability of adequate financial mechanisms for rapid access to savings, credit and climate-related insurance to respond to extreme climatic events. • Ensure swift access to information for short-term decision-making and support mobilization in the event of extreme climatic events, including mechanisms for ongoing collaboration with governments, local authorities and emergency-response institutions. • Strengthen the coordination of emergency response services between local authorities and ICT providers.
Scale	• Strengthen cross-sectoral and multilevel collaboration, including access to broader networks of support (e.g. governments, regulators, telecommunication providers, other market players), thus enabling access to resources that may not otherwise be available. • Provide mechanisms for ICT infrastructure and service providers to access assets (e.g. financial, human) at the regional, national or international levels, in order to cope with and recover from climatic disturbances. • Foster cross-government collaboration to explore interdependency issues.

The examples provided in Table 1 are not intended to be comprehensive, but are aimed at illustrating the relevance of resilience and the potential of resilience attributes to strengthen the ICT sector's adaptation to climate change impacts.

Summary

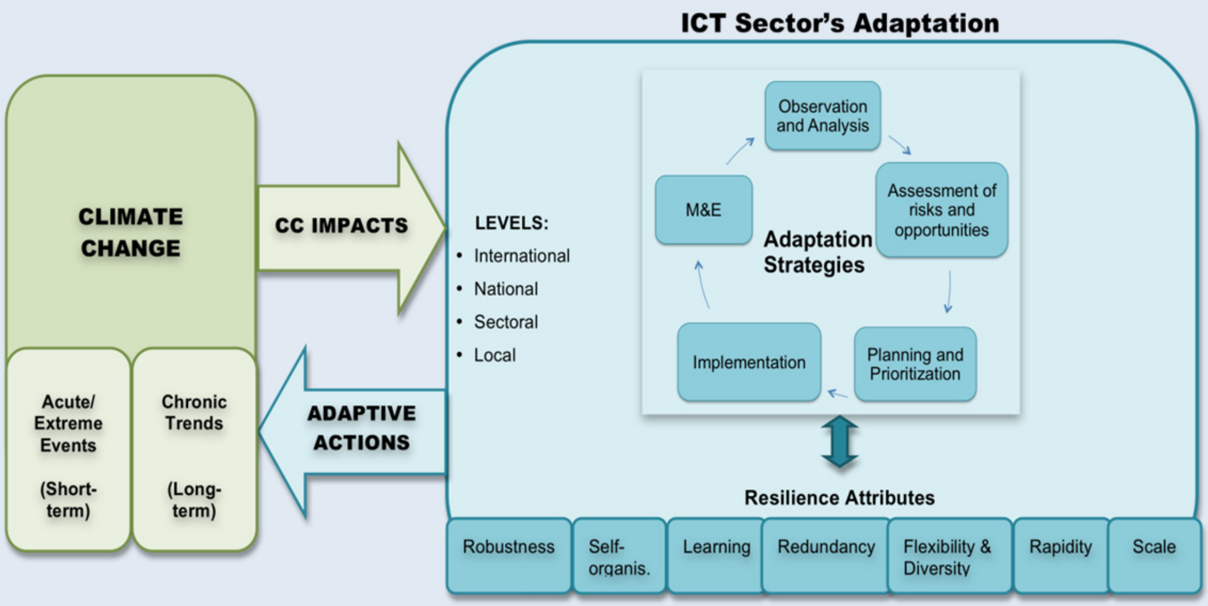
The analysis conducted thus far has suggested several key points for understanding the ICT sector's adaptation to climate change. It has established that climate change constitutes a serious threat to the sector, as both acute and chronic impacts can disrupt the efficiency, operational and cost structure of infrastructure and service providers, and affect negatively millions of users that rely on highly diffused ICT services around the globe.

It has also established the importance of adopting a coherent approach to adaptation by doing three things: (a) considering both the short- and the long-term effects of climate change (i.e. extreme events and chronic impacts), (b) designing an articulated adaptation strategy (including the observation and analysis of impacts, trends and projections, the assessment of risks and opportunities to the sector across its value chain, the planning and prioritization of adaptive measures, and the mechanisms for their implementation, monitoring and evaluation)[54], and by (c) integrating actions at the international, national, sectoral and local levels.

The analysis has also established the relevance of integrating the notion of "resilience" as part of the ICT sector's approach to adaptation.

As reflected in Table 1, addressing the resilience attributes (robustness, self-organization, learning, redundancy, flexibility, diversity, rapidity and scale) can help strengthen the sector's capacity to adjust and adapt to climate change impacts, and can inform the design and implement adaptation strategies (i.e. the observation, assessment, planning, implementation and M&E of adaptive actions). In turn, the adoption of these strategies can strengthen the sector's resilience to climate change stressors. The linkages between these factors are illustrated in the "ICT sector's adaptation framework: Resilient pathways" (Figure 5).

Figure 5: ICT sector's adaptation framework: Resilient pathways



Source: Adapted from Ospina and Heeks (2010).

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[54] Amado, J., Adams, P. (2012). *Ibid*.

This framework suggests that the ICT sector's adaptation involves the design of strategies that are strengthened by resilience attributes, and that take place at various levels in response to both acute and chronic climate change impacts. The interaction between these components can provide the basis for "resilient pathways" in the ICT sector's approach to climate change adaptation.

Based on the acknowledgement of these "resilient pathways" of action, the following section will examine in greater detail the impacts of climate change on the ICT sector, as well as the opportunities and challenges associated with the sector's adaptation. The analysis of these issues will provide the basis upon which existing and emerging adaptation measures will be identified (section IV) and areas for future suggested actions (section V).

III. Climate change impacts, challenges and opportunities for the ICT sector

In the Fourth and Fifth Assessment Reports (2007, 2013), IPCC presents evidence which indicates that many natural systems are being affected by regional climate changes, particularly temperature increases. While the impacts of these trends will diverge among geographic regions, systems and sectors, emerging studies[55] have identified the potential susceptibility of the ICT sector to short- and long-term climate change manifestations, including increased frequency and intensity of extreme events, temperature increases, changes in precipitation regimes and sea level rise, among others.

Given the high level of interdependence of the sector (e.g. in terms of international partners, providers, suppliers and users), climate change impacts are expected to generate both challenges and opportunities across the ICT sector's supply chain.

The first part of this section will present an overview of the potential impacts of climate change and their effects on the ICT sector. The second part will identify the opportunities and challenges involved in the adoption of adaptation strategies by sector stakeholders. It is expected that this analysis will highlight the importance of adaptation for the ICT sector, fostering novel coping strategies, adjustments and potential transformations in the face of climatic impacts.

3.1 Climate change impacts on the ICT sector

The impacts of climate change on the ICT sector can be the result of both acute manifestations (e.g. short-term extreme events such as cyclones and intense rainfall and flooding) and chronic trends (e.g. long-term changes in temperature, seasonality and sea level rise), which affect ICT operations, logistics and supply chains in a variety of ways. For example, extreme climatic shocks, such as the 2011 floods in Thailand, have the potential to reduce the growth domestic product (GDP) of a country by several percent, decimate jobs, and ultimately disrupt the supply chains of the ICT sector, among other disruptive effects[56].

From the impacts of climatic disruptions on the supply of raw materials and the availability and safety of industry personnel, to the degradation of ICT networks and infrastructure, climate change can potentially undermine the availability, reliability and quality of ICT services, ultimately affecting business costs. However, climate change impacts also have the potential to create new market opportunities and to generate cost reductions, and can act as drivers of sectoral innovation and change.

Building on the notion of resilience presented in the previous section, the key potential impacts of climate change on the ICT sector are summarized in Figure 7.

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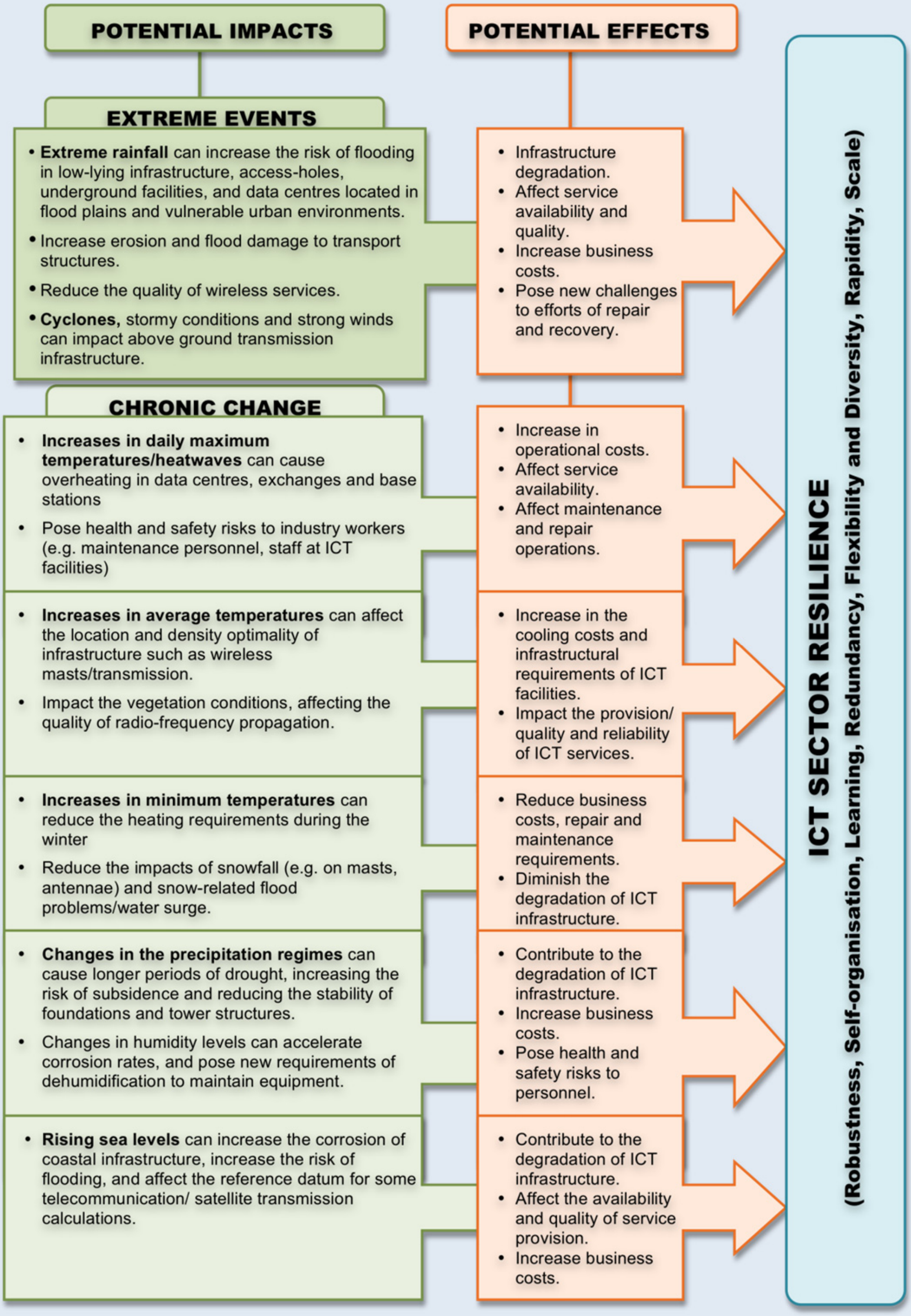
55 Crawford, M., and Seidel, S.(2013), "Weathering the Storm: Building Business Resilience to Climate Change", Center for Climate and Energy Solutions (C2ES). http://www.c2es.org/docUploads/business-resilience-report-07-2013-final.pdf
AEA (2010*) Ibid*., UKTI (2011), *Ibid*.

56 World Bank Global Facility for Disaster Reduction and Recovery, 2012. Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning. Bangkok, Thailand. http://www.gfdrr.org/sites/gfdrr.org/files/publication/Thai_Flood_2011_2.pdf

Figure 6: Potential climate change impacts and effects on the ICT sector



Source: Adapted from AEA[27] (2010).

The examples included in Figure 6 suggest that climate change manifestations have a wide range of potential effects that ultimately impact upon the ICT sector's resilience.

The following points illustrate the linkages between potential climate change impacts and the sector's resilience:

- The occurrence of extreme events (in the short-term) or temperature increases (in the long-term) can affect infrastructure such as data centres (e.g. causing operational and service disruptions, infrastructure damages, increase in operational costs), thus weakening the sector's *robustness* (i.e. its ability to maintain its performance in the face of shocks and fluctuations). Considering the increasing role of data centres in the global networked economy, these disruptions can have wider effects across multiple sectors (e.g. disrupt the availability of electronic commerce).
- An increase in the frequency and intensity of climate-related disruptions may foster the emergence of new partnerships and forms of collaboration between large multinational ICT providers, small and medium enterprises (SMEs), governments and ICT service users, improving the sector's ability to rearrange its functions and processes in the face of external disturbances (i.e. fostering *self-organization*).
- Climate-induced changes can inspire a new wave of research and development (R&D) in the industry, strengthening the adaptability of sector stakeholders to change and uncertainty through *learning* and innovation.
- Wireless transmissions can be affected by temperature increases (e.g. reduced signal range), by precipitation (e.g. weakened quality and reliability of the service), and by changes in the physical environment (e.g. building construction, foliage density), which can affect the sectors" *redundancy* (i.e. substitutability of functions and services in the event of climatic disruptions).
- Climate change impacts can also accelerate the rate of technology change and innovation in the sector in order to tackle consumer and market niches that were not available before (e.g. development of new devices and applications), contributing to the sector's *flexibility and diversity* (i.e. ability to undertake different courses of action, innovate and benefit from emerging opportunities).
- Extreme events can limit the access of industry workers to conduct repairs or restore operations, affecting the *rapidity* of the sector's response to climatic shocks (i.e. the speed at which assets are accessed or mobilized).
- Changing climatic trends may affect the availability of pine supplies required for telegraph poles, while severe weather events can disrupt the international shipment of ICT components and materials in affected areas, contributing to undermine the *scale* at which the sectors" supply chain operates, and potentially, its ability to maintain its performance (i.e. robustness).

The identification of climate change impacts on the sector is evidence that adaptation is crucial to ensure the sector's ability to withstand, recover and thrive in the face of climatic effects, future change and uncertainty.

The following section will identify specific opportunities and challenges faced by the sector in the climate change field.

3.2 Opportunities and challenges of the ICT sector's adaptation

Having recognized that the impacts of climate change generate challenges but also potential opportunities for the ICT sector, this section identifies (a) the key drivers that enable and (b) the factors that hinder the ICT sector's adaptation:

a. Opportunities: Emerging business drivers

The following factors constitute drivers for the adoption of adaptation measures by ICT sector stakeholders:

- Benefit from emerging business opportunities by creating new products and services that help individuals, businesses, cities and governments cope with the impacts of climate change (e.g. climate-friendly technologies, ICT-enabled regional weather and climate networks for real-time observation, mobile phone applications based on climate-related services, novel ICT-enabled early warning, tools for urban planning and visualization in vulnerable areas, mobile-based access to weather forecasts, equipment and smart networks to monitor and manage climate-related impacts, applications to monitor water stress, among others)[57].

- Improve the sector's response and preparedness for short- and long-term risks to operations, logistics and supply chains.
- Strengthen corporate social responsibility programmes and companies" reputation through the adoption of adaptation strategies that offer social advantages and benefits at the community/user level, particularly in developing countries.
- Reduce operational costs and improve efficiency through measures aimed at withstanding, recovering and adjusting to short- and long-term climatic impacts.
- Minimize potential disruptions in the provision of ICT services.
- Strengthen the sector's ability to do business in a variety of conditions, including changing demand for goods/services and future uncertainty.
- Strengthen the risk reduction approach of ICT companies, including the identification of long-term risks for physical operations and climate proofing the ICT supply chain.

b. Challenges: Factors hindering the adoption of adaptation

The following factors can potentially hinder the adoption of adaptation measures by ICT sector stakeholders:

- Lack of awareness about potential climate change impacts and adaptation options among ICT providers and users. This includes lack of climate change impact assessments that are relevant for the location and time horizon of businesses.
- Shortage of the knowledge and skills required for implementing adaptive measures throughout the supply chain.
- Lack of awareness about potential business opportunities linked to adaptation, including adaptation-related products and services.
- Sectoral emphasis on the short-term impacts of extreme events, failing to address the long-term effects and unforeseen risks associated with climate change.
- Limited evidence-base assessing recent experiences of weather events in the sector, and therefore, an underdeveloped "business case" for providers (and customers) to invest in adaptation[58].
- Increasing interdependence of ICT services" provision around the globe, which poses new challenges for the implementation of coherent/articulated adaptive strategies.
- Limited access to the funding required for the implementation of adaptive measures, especially in the case of SMEs.
- Shortage of public-private partnerships that promote private sector responses to climate change.

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[57] UKTI (2011). *Ibid*.
KPMG, 2012. "Climate Change Adaptation in the Private Sector", UNFCCC Private Sector Initiative.
http://unfccc.int/files/adaptation/nairobi_work_programme/private_sector_initiative/application/pdf/kpmg_psi_database_report.pdf

[58] AEA (2010), *Ibid*.

Illustrating the scope of these opportunities and challenges for the resilience of the ICT sector, the Partnership for Resilience and Environmental Preparedness (PREP) stated:

> *"A new business imperative is emerging. Reducing greenhouse gas (GHG) emissions continues to be critical to avoid unmanageable climate change, but businesses must also build their resilience to unavoidable and ongoing climate change by managing climate-related impacts that threaten their value chains, while planning for nascent market opportunities. (…) By bringing climate change into their risk calculations, companies can reduce costs, strengthen contingency plans, and capitalize on business opportunities, building resilience in business and communities alike".* Amado and Adams (2012), p. 6.

Having identified the key impacts of climate change on the ICT sector, the relevance of undertaking adaptation actions, and the opportunities and challenges associated with that approach, the analysis will now explore the current and emerging adaptation measures adopted by the ICT sector.

IV. The sector's response: current strategies and the way forward

As indicated in section 3.1, adaptation strategies arise from an examination of the risks to the sector posed by both acute weather events (e.g. short-term extreme events such as cyclones and intense rainfall and flooding) and chronic trends (e.g. long-term changes in temperature, seasonality and sea level rise). Before discussing the strategies, today's situation, the risks and associated impacts on the ICT sector will be described, followed by the identification of opportunities for the ICT sector arising from these impacts.

4.1 The situation today

The ICT sector has evolved over the past century to operate over a range of environmental conditions including tolerance to extreme weather events. Much of this has been done using historic climate records for the region in which the ICT will operate, without consideration of climate change. Devices are therefore designed to operate within specified ranges of temperature, humidity, etc.

When devices operate outside their specified environmental conditions, they are at risk of failure. Failure can also occur due to wear-out or ageing mechanisms, such as electro-migration, which goes beyond the scope of this report. Electronic devices generally have a design lifetime in the range of 2-13 years[59]. Failure of a component generally results in maintenance work to replace the failed item. However, some parts of the network are designed to cope with failure of a single component, after which the system continues to operate but an alarm signal is sent to indicate that remedial work is needed. Resilience is built-in by replicating parts of the network so that alternative paths can be brought into use. The most common environmental specifications and resilience mechanisms will be set out in this section.

The ICT sector includes infrastructure such as: telephone switching centres, outside plant, data centres, base stations and user terminals including handsets. Most electronic devices are well protected from the weather and are in benign environments such as buildings which are safe for human occupation. Every component used in ICT is specified to operate within agreed environmental limits. Separate temperature ranges are specified for use in commercial buildings, industrial buildings, military applications and aerospace.

Electronic devices are normally adequately protected from the weather and are designed to operate over the design life within specified environmental limits.

An electrical system with no redundancy fails when any one component in the transmission path fails. This may be estimated by summing the failure rate of the individual components which is typically of the order of 1 failure in 10 billion (10^9) hours (1 FIT). A system of 1000 components, each with a reliability of 1 FIT, would therefore be expected to fail once in approximately 100 years.

4.1.1 Resilience in telecommunication networks

Telecommunication systems carry lifeline services to whole communities or populations and need to have a high reliability. Resilience of telecommunication networks is an important topic for national governments[60]. Reliability is agreed by national regulators and operators, and is usually quoted in terms of availability[61]. Trunk networks with exchanges carrying traffic from a thousand or more users normally have alternate paths so that a failure in one point of the network does not cause a complete system failure. Automatic alarms indicate when repair work is needed. The access network, including a telephone exchange or a mobile base station, normally does not include redundant connections to the user and it is therefore this part of the network (lowest level of Figure 7) that has the lowest reliability.

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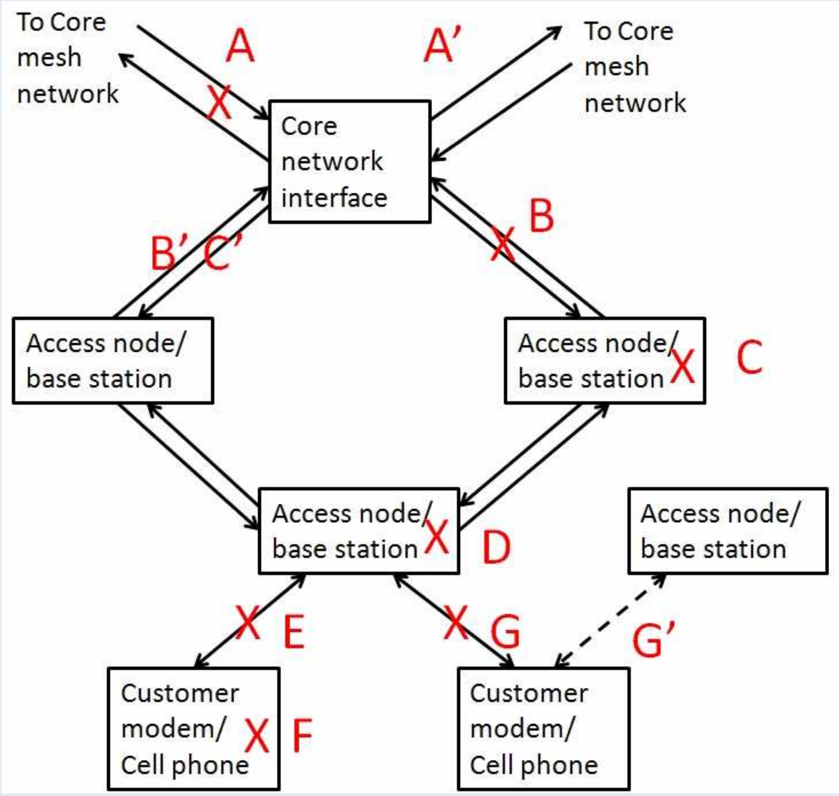
59 BT Group plc Annual Report & Form 20-F 2013, page 111. http://www.btplc.com/Sharesandperformance/Annualreportandreview/pdf/2013_BT_Annual_Report.pdf

60 Enhancing the resilience of communications https://www.gov.uk/telecoms-resilience

61 For an example see: http://stakeholders.ofcom.org.uk/market-data-research/market-data/consumer-experience-reports/bce/

Figure 7: Resilient network design



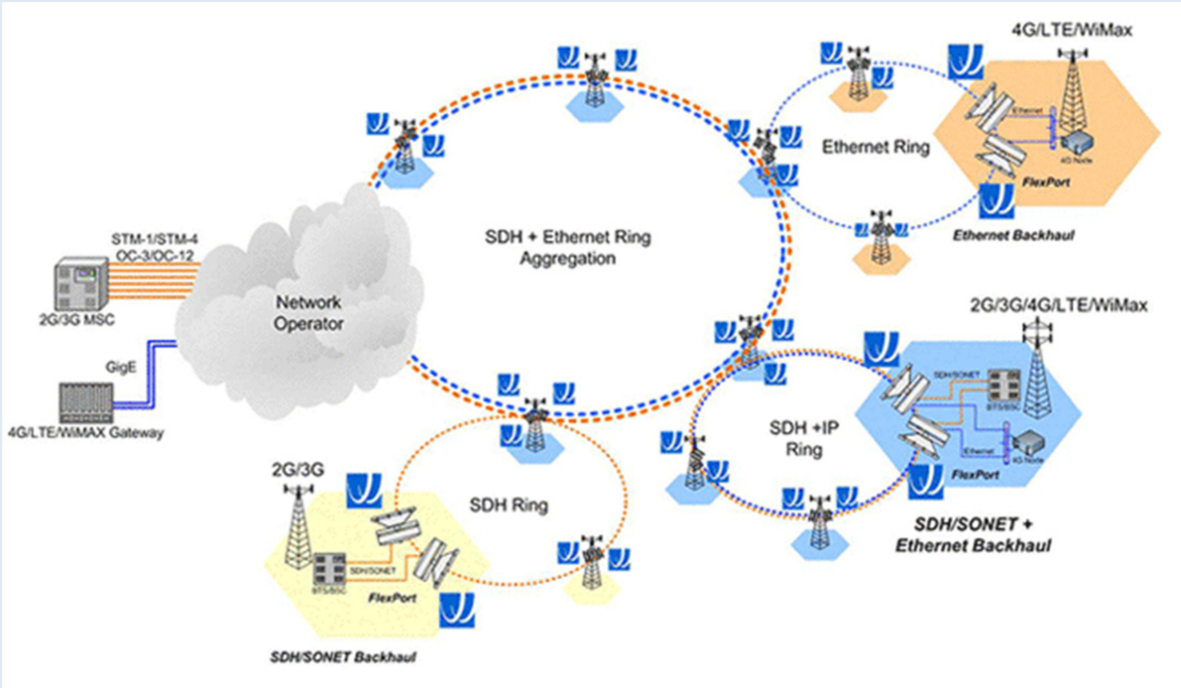
The network design above illustrates common practice for resilient network design both for fixed telecommunications and cellular network types. The core network is shown at the top of the figure and is connected to a fully meshed set of core network switches which include international gateways. The meshed core network is inherently resilient against single and some multiple failures. Examples of customer nodes are shown at the bottom of the figure. The access and backhaul network is at the centre. This forms a bi-directional ring which may be looped back at any node in the event of a path or node failure. Once looped-back, it becomes a single "folded ring". A number of failure/resilience modes are shown with the letters A-F.

- In case A, the network is protected against a single point of failure by path A'. When path A fails, path A' takes over the traffic.
- In case of a break at B, loop back is applied to the remaining three links so that traffic is routed via B'.
- In case of a failure at node C (e.g. power), loop back is applied to the remaining two links so that traffic is routed via C'.
- Cases DEF represent a single point of failure so no protection is available from the service provider at that level.
- In case G the customer has an alternative access network which allows continuity of service via another access node, a cellular base station or a satellite terminal via link G'.

It can be seen that the network has a number of features which mean that the network has some resilience to extreme climate events, disasters or technology failure. Other resilience features include backup power via batteries and/or a generator at the access node or cellular base station. It is generally left to the customer to provide backup power for cell phones and computer equipment on the customer's premises. Fixed line telephony is powered by the battery in the central office and is therefore protected against loss of electricity at the customer end. Additional measures are brought into play to protect calls to emergency services. Traffic to broadcast radio and television (TV) transmitters is also protected when routed over core and protected backhaul networks.

A mobile network topology is shown in Figure 8[62]. This uses synchronous digital hierarchy (SDH) rings for backhaul of voice and data services (2G, 3G and 4G) and Ethernet rings for 4G upgrades to a serving area.

Figure 8: Mobile network topology



Source: Bridge Wave Communications.[63]

The Internet protocol (IP) used for data transmission includes a facility for seeking an alternate path in the event of failure of the primary path through the network but the self-recovery time can be up to three minutes[64].

The following sections examine whether additional steps are needed to ensure robustness and resilience in the face of climate change by examining the risks to the ICT sector from a range of climate impacts.

4.2 Risks from short-term extreme events

The effects of climate change are becoming more apparent. Extreme weather events stress the telecommunications infrastructure more severely and more frequently than in the past and new installations need to be increasingly robust to withstand climate stress. Design limits such as the ability to withstand 70 m/s (252 km/hr) wind speed,[65] will be encountered more frequently. Existing design limits should therefore be questioned and raised, if necessary, both for new-build and for possible remedial work. Chronic and long-term

[62] Flexport “Scalable, future-proof backhaul for today's 3G networks and simple migration to next generation 4G Networks” http://www.bridgewave.com/products/flexport.cfm

[63] Bridge Wave Communications “Scalable, future-proof backhaul for today's 3G networks and simple migration to next generation 4G Networks”
http://www.bridgewave.com/products/flexport.cfm

[64] Achim Autenrieth, “Fault Tolerance and Resilience Issues in IP-Based Networks”
http://www.google.co.uk/url?sa=t&rct=j&q=network%20resilience%20internet%20protocol&source=web&cd=2&ved=0CDIQFjAB&url=http%3A%2F%2Fwww.researchgate.net%2Fpublication%2F2372063_Fault_Tolerance_and_Resilience_Issues_in_IP-Based_Networks%2Ffile%2F5046351ac9da79a9ff.pdf&ei=kckPUuC0IueQ0QWZy4GwCQ&usg=AFQjCNFqF9-GoqXfLy7lhRDfW9eLzh0Kpg&bvm=bv.50768961,d.d2k

[65] ETSI EN 302 217-4-1 V1.4.1 (2009-09), “Fixed Radio Systems;
Characteristics and requirements for point-to-point equipment and antennas;
Part 4-1: System-dependent requirements for antennas”, page 19.
http://www.etsi.org/deliver/etsi_en/302200_302299/3022170401/01.04.01_40/en_3022170401v010401o.pdf

impacts to the sector include factors which do not cause a specific failure but will degrade the performance of an ICT system over time. These include risks to vehicle fleet performance and workforce performance, which will be discussed in section 4.3.

4.2.1 Extreme temperatures

As stated in section I, IPCC indicates that the average temperature of the earth's surface has risen by 0.74°C since the late 1800s, and is expected to increase by a further 1.8°C to 4°C by the year 2100 if no action is taken.

The failure rate of an electrical component increases exponentially with temperature[66]. Each component has an activation energy which is characteristic of its chemical composition. Failure will result when the temperature rises sufficiently to cause chemical or crystal lattice breakdown. Components are therefore highly underrated so that they operate in a statistically "safe" temperature range.

Semiconductor parts are most often specified for use in the "commercial" 0-70°C and, to a lesser extent, in the "industrial" –40 to +85°C operating temperature ranges. These ranges generally satisfy the demands of the computer, telecommunications and consumer electronic industries[67]. Some components such as processors are designed to run "hot": perhaps 50°C or more above ambient temperature. These require cooling systems to dissipate the heat and maintain a packaged device at a surface temperature of no more than 50°C. For a desktop personal computer, the cooling system may be no more than a heat-sink and fan blowing air at ambient temperature to avoid thermal breakdown. For mass deployments, such as in server farms, water cooling systems are used. Climate change may give rise to a higher ambient air temperature than was originally planned which in turn could necessitate an upgrade of the cooling system.

The usable life of an electronic device may be shortened by running it at an elevated temperature. Accelerated ageing tests are performed at elevated temperatures by component manufacturers to determine the reliability of components. For the user therefore, there is a benefit in terms of extended time to replacement if the device can be kept cool. For example, a laptop personal computer (PC) can be expected to have a longer life if dust is removed from the air filter before the cooling system fails. As a result of climate change, higher ambient temperatures will be reached and it is in just these conditions that a temperature stressed laptop PC may fail. Videos of how to clean many types of laptop air filters can be found via the Internet. A warning sign that this may be necessary is the noise produced when the fan is running continuously.

Liquid crystal displays (LCDs) are more sensitive to temperature than most other electronic components. An operating temperature range of –10°C to +60°C is typical[68]. They are used in TVs, personal computers, cell phones and vehicle instrument panels. Care must therefore be taken that they are not placed in situations where high temperatures are possible, for example, in direct sunlight near an unventilated window or a mobile device which is being overcharged and running "hot".

A somewhat worrisome aspect of Chapter 11 of the IPCC Fourth Assessment Report, "Regional Climate Projections"[50], is this statement on page 871 "Research on changes in extremes specific to Africa, in either models or observations, is limited". Whilst a rise in average temperatures could lead to accelerated ageing of ICT, a rise in *extreme* temperature could trigger a catastrophic failure. The situation is similar for Europe. However, South Asia has received more attention where future increases in extreme daily maximum and minimum temperatures throughout South Asia are expected due to the increase in greenhouse gas concentrations (Reference 52, p. 882). This projected increase is of the order of 2°C to 4°C in the mid-21st century in both minimum and maximum temperatures. Further research is needed to increase awareness of changes in extreme temperature for all regions. In the absence of more accurate projections of extreme temperature changes, an average for the location should be added to local (historic) observations of temperature extremes.

The ability of the ICT sector to adapt to such impacts may be taken into account in two ways:

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66 Semiconductor Device Reliability Failure Models, page 14. http://www.sematech.org/docubase/document/3955axfr.pdf

67 Rajeev Mishra, "The Temperature Ratings Of Electronic Parts" http://www.electronics-cooling.com/2004/02/the-temperature-ratings-of-electronic-parts/

68 Application Note example http://www.altadox.com/lcd/knowledge/lcd_temperature_ranges.htm

- Equipment exposed to increased temperature is likely to be replaced several times over the century and will evolve to cope with average temperatures increasing at a rate of, for example, 0.4°C per decade. Specifications typically state operating temperatures in the range –10 to 60°C and this can be raised as new data become available. There may be some devices which need special checks such as those containing LCDs.
- Buildings which contain ICT devices need to be adapted to cope with the additional temperature difference between the inside and outside.

One function of ICT buildings (such as data centres and central offices) is to maintain electronics at a safe operating temperature: for example, by making sure that there is sufficient circulation of air at ambient temperature, either through more efficient building design or using an air conditioning or water cooling system. These systems are normally referred to as heating, ventilation and air conditioning (HVAC). It is important that these systems are designed and maintained to keep the ICT equipment within the temperature and humidity limits specified by the manufacturers.

Extreme temperatures can give rise to conditions which prevent adequate cooling. This could happen with, for example, a decadal 0.4°C rise in temperature (as in the Africa example) and/or if the equipment room has had equipment added. Additional heat stress may also occur as a result of solar gain though windows. It is important that regular checks are made to ensure that the HVAC system is adequate to cope with the equipment heat load plus any solar gain or other heat sources introduced, e.g. human occupancy. See Annex 5 for an example checklist for buildings including other possible extreme climate impacts.

4.2.2 Extreme rainfall/floods

Telecommunications buildings and infrastructure can be at risk from extreme rainfall and flooding, depending on location. This risk may increase in frequency or severity as a result of climate change.

According to the IPCC Fourth Assessment Report,[20] "Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. The resulting increased flood risk poses challenges to society, physical infrastructure and water quality". A related paper states that "the shift in precipitation frequency distribution toward extremes results in large increases in very heavy precipitation events (> 50 mm day), so that for very heavy precipitation, the percentage increase in frequency is much larger than the increase in intensity (31.2% versus 2.4%)"[69]. Record breaking storms are already being recorded. The resulting flood stress causes outages to telecommunications services either directly or via failure of the electricity grid.

Whether or not driven by anthropological climate change, hurricanes give rise to extreme rainfall events and the ICT sector needs to take account of them (see example in Box 11).

[69] Ying Sun, *et al*. "How Often Will It Rain?", Journal of Climate, Vol. 20, 1 Oct 2007, p. 4801. http://journals.ametsoc.org/doi/pdf/10.1175/JCLI4263.1

Box 11: Impact of extreme events on the ICT sector

"The storm surge from Hurricane Sandy has resulted in flooding at several Verizon Central Offices in Lower Manhattan, Queens, and Long Island causing power failures and rendering back-up power systems at these sites inoperable. While these sites are currently on battery power, the inevitable loss of power requires that all equipment at these sites be powered down to prevent damage. Customers that are served by these central offices will experience a loss of all services including fibre (voice, internet and video), high speed Internet, and telephone services. Some customers may experience intermittent busy signals while attempting to dial 311 service for non-emergency calls. Verizon engineers continue to assess the damage at these locations and we will post updates as additional information is available".

Source: AT&T (2012).

The example in Box 11 illustrates the risk to telecommunications services from storm and flooding. The electricity grid failed, the backup generator was awash, and power was maintained by battery backup for a limited period and only for emergency services. The risk of this happening would have been taken into account in the design and build of the central office. The storm is claimed to have a 1 in 714 year probability of repeating[70]. However, the impact of climate change requires such statistics to be updated to show a higher probability of the event occurring, and today perhaps 1 in 25 years would be a safer estimate for planning purposes.

Possible remedial work to make central offices less vulnerable to flooding would be to raise equipment from the ground floor to higher floors. This has already happened in many instances when obsolete electromechanical switches were replaced by physically smaller digital switches, causing complete floors to be vacated.

A further step would be to check the location of the backup generator. In many examples, these are located outside the main building near ground level. Raising the generator should be considered to reduce risk of failure due to flooding.

A similar check may be made in the United States of America (USA).[71] It is left to the reader to check for a similar service in your locality.

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[70] Risks of Hurricane Sandy-like Surge Events Rising http://www.climatecentral.org/news/hurricane-sandy-unprecedented-in-historical-record-study-says-15505

[71] FEMA "How to Find Your Flood Map", https://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=firmHelp_1&title=How%20to%20Find%20Your%20Flood%20Map

Box 12: Example of flood risk checking

In the United Kingdom (UK) it is straightforward to check the risk of flooding online using the Environment Agency's website. Maps are available to search by postcode or town name. These show the risk as a colour code. Light blue indicates a risk of extreme flooding with a probability of once in 1000 years. If an ICT facility lies within a light blue area it may need remedial action.

Source: UK Environment Agency Flood Maps.

Fixed access and trunk networks are often buried alongside roads or railway lines. Whereas the trunk network is likely to be protected by alternative routing, the access network remains vulnerable to a single point of failure. Roadside cabinets are generally not sealed against water rising from below and contain manual flexibility points where open wires can come into contact with flood water. Flooding can lead to these becoming unserviceable until the flooding subsides[72].

The use of optical fibre in the access network will increase transmission speeds and reduce the risk of problems due to moisture and flooding. Possible remedial work could be to move street cabinets to a higher level if the risk of flooding is known to have increased due to climate change.

In their response to the survey (see Annex 9), Alcatel-Lucent noted the importance of grounding. If changes in climate and weather patterns occur, soil moisture content and resistivity will change as well. This can affect the safety of maintenance workers, the resilience of infrastructure to lightning and the performance of power supply systems and twisted pair networks.

Mobile network base stations are normally located at high points to provide optimum coverage and therefore the risk of flooding is minimal. Care needs to be taken when equipment is located on flood plains so that the base station equipment and generator are raised above ground level.

Mobile backhaul networks often use point-to-point microwave links between towers which are liable to outage during storms. Raindrops scatter the microwave signal and can cause loss of service. Sufficient system margin is applied so that the power is sufficient in all but the most severe conditions. An estimate of the margin needed to allow for rainfall has been published by ITU[73]. To this must be added the free space propagation loss and losses due to pointing variation with high winds. There is a need to know the maximum rainfall before the margin can be calculated, which will depend upon rainfall measurements in the locality[74]. As a result of climate change, more extreme rainfall can be expected and so the margin may need to be increased, which should be

72 For example, see news story at: http://recombu.com/digital/news/uk-floods-bt-700-new-engineers_M10673.html

73 ITU-R http://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.838-3-200503-I!!PDF-E.pdf

74 Harvey Lehpamer Transmission Systems Design Handbook for Wireless Networks, Artech House, 2002, p.229. http://books.google.co.uk/books?id=hZX37jfF21EC&pg=PA230&source=gbs_toc_r&cad=4#v=onepage&q&f=false

further studied. Fibre optical cables are now being laid between towers to replace microwave or copper in order to increase the capacity of the networks, and this will eliminate the risk of link loss due to rainfall.

Meanwhile, a method has been found to measure rainfall at 15-minute intervals over an entire country using existing microwave links in the cellular backhaul network. This could be of particular benefit for weather forecasting in developing countries where there are few ground based measurements or radar precipitation measurement systems[75].

4.2.3 Landslides

Telecommunications lines are frequently laid along roadsides which are vulnerable to landslides in some areas.

The risk of landslide and avalanche is increasing due to deforestation and climate change[76]. Facilities such as telecommunications cables located near risk areas are therefore becoming more vulnerable. Maps have been produced for most countries and regions which show the risk by colour code[77],[78]. "Landslides can be caused by over steepening or over loading of slopes, earthquakes, tsunamis, hurricanes, flooding, and other severe weather events; or by vegetation loss as a result of logging, development, or wildfires. Mitigation measures include planting ground cover (low growing plants) on slopes, or installing flexible pipe fittings to avoid gas or water leaks"[64].

In China, severe rainfall, 322 mm, led to a landslide which cut off road and telecommunication links and left the county with only one satellite phone to connect with the outside world[79].

Rainfall thresholds for the initiation of landslides have been studied. "Regional and local thresholds perform reasonably well in the area where they were developed, but cannot be easily exported to neighbouring areas. Global thresholds are relevant where local or regional thresholds are not available, but may result in (locally numerous) false positives, i.e. prediction of landslides that do not occur"[80].

4.2.4 Extreme winds

ICT facilities at risk of damage include buildings, overhead lines and antennas. Overhead lines using wooden poles are the cheapest method of providing fixed access but are vulnerable to the effects of wind through damage by falling trees and gradual wear out due metal fatigue. Antennas are at risk due to winds exceeding their design limit such as the ability to withstand 70 m/s (252 km/hr) wind speed. The IPCC Fourth Assessment Report says that "Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and heavier precipitation associated with ongoing increases of tropical sea-surface temperatures"[81]. The report states that there is low confidence in wind speed model trends other than for tropical cyclones. Overall, the changes do not appear to be very large so that adaptation measures may not be necessary in the ICT sector except where there is a risk of cyclone.

In some locations, such as the pacific island of Guam, the IPCC Special Report states that buildings are required to withstand peak gust wind speeds of 76 ms-1, expected every few decades (International Building Codes, 2003). This higher limit could be applied to ICT buildings and antennas in risk areas. The latest version of the

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75 Aart Overeema,Hidde Leijnseb, and Remko Uijlenhoeta, "Country-wide rainfall maps from cellular communication networks", Proc Nat Academy of Sciences USA (PNAS), Vol. 110, No. 8, pp. 2741-2745. http://www.pnas.org/content/110/8/2741

76 Farrokh Nadim, *et al.* "Global landslide and avalanche hotspots" http://link.springer.com/article/10.1007%2Fs10346-006-0036-1#page-1

77 USA Landslide Hazard Map http://nathazmap.com/hazards/landslide

78 JRC European Soil Portal. Soil data information systems. http://eusoils.jrc.ec.europa.eu/library/themes/landslides/

79 China Daily, "Rain triggers landslides, cuts telecom in Tibet" http://www.chinadaily.com.cn/china/2010-04/25/content_9772135.htm

80 Instituto di Ricerca per la Protezione Idrogeolocica "Rainfall Thresholds for Intitiations of Landslides" http://rainfallthresholds.irpi.cnr.it/extent_info.htm

81 IPCC "Climate Change 2007: Synthesis Report", page 46 http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

International Building Code is available online[82]. Chapter 16[12] of the IPCC Special Report includes maps of rainfall, seismic, snow and wind criteria across the USA. In general, coastal regions can be expected to have higher maximum wind speeds.

Wind load is proportional to the square of the wind speed. If the wind speed increases by 10% in your region as a result of climate change then the load acting on a structure will increase by 20%. It is therefore important to monitor the latest building regulations for your region and consider if the wind speeds and loads quoted are sufficient for the life of the building, which could be a century or more.

Whilst care must be taken when designing antennas to ensure safety to persons, pointing accuracy also must be considered. If the mast carries highly directional antennas such as microwave dishes, the structure must be able to maintain pointing accuracy. In some cases, a 0.1 degree displacement will be sufficient to cause loss of service[83]. In a storm both ends of the link are likely to be affected. System margin therefore needs to be added to allow for losses due to wind and pointing accuracy. Excess wind is normally allowed for in the antenna and mast design so that no permanent bending occurs in the structure. After the storm has past the signals should then return to normal level. In the context of adaptation to climate change, it would be wise to consider a 20% stiffening of the structure overcurrent building regulations to allow for the possible 10% increase in extreme wind over the coming decades.

4.2.5 Lightning

The risk of damage to equipment at telecommunication sites due to lightning can be assessed by risk analysis. ITU-T has published a Recommendation on this topic[84].

More research is needed to determine if the parameter (number of strikes per year), needs to be increased (or decreased) from those on keraunic (lightning strike) maps for the locality to take account of climate change.

4.2.6 Humidity

Humidity can affect the reliable operation of ICT systems. Effects such as corrosion under high humidity and damage due to static electricity under low humidity are well known. Most important is condensation which occurs when there is a change from a cold environment to a warm humid one such as the transport of a device from outdoors in winter to an indoor heated room.

More work is needed to determine the impact of humidity on the future climate. It is therefore too early to factor in general adaptation measures regarding humidity in the ICT sector. Even so local trends can be monitored and if necessary additional precautions can be taken if a dryer or wetter atmosphere is detected.

4.2.7 Ice storms and heavy snowfall

Ice storms and heavy snowfall can cause failure of electricity transmission lines, causing power outage of ICT services through lack of local supply. These weather events can also be responsible for damage to the

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82 International Building Code
http://archive.org/stream/gov.law.icc.ibc.2012/icc.ibc.2012#page/n411/mode/2up

83 What is the perfect VSAT antenna?
http://www.satprof.com/what-is-the-perfect-vsat-antenna/

84 "Risk assessment of damages to telecommunication sites due to lightning discharges", Recommendation ITU-T K.39, October 1996.
http://www.itu.int/rec/T-REC-K.39-199610-I

telecommunication lines, for example, when a branch breaks from a tree onto a telephone line. Radio systems are affected when antennas are covered in ice.

No information could be found on the change of risk of ice storms and heavy snowfall due to climate change. However, it seems likely that extreme events are increasing as a consequence of climate change. A recent example of the consequences of ice storm is noted in the New York area.

The ClimAID Report includes a chapter on Telecommunications[85]. “The December 2008 ice storm in New England and Central and Upstate New York formed late on December 11 and meteorologically dissipated by December 12. Its impact, however, lasted for more than a week in New York and in large portions of New England Telecommunications services were disrupted as a result of damaged lines, and electronic equipment in homes lost power. Cable-provided voice, video, and data services had problems at twice the normal levels during the week following the storm. Damage was primarily a result of fallen trees, utility wires, and poles, which were coated in a heavy layer of ice. The slow return of power in the aftermath of the storm resulted in a great deal of controversy about why the utilities could not restore services more expediently, if not avoid outages in the first place.”

4.3 *Chronic effects of climate change on the ICT sector*

The chronic effects of climate change may not give rise to an immediate catastrophic failure but have a more indirect impact that can degrade the performance of the service or system. The following are key areas where chronic climate change manifestations can have an impact, and therefore, where adaptive measures are also required:

4.3.1 Vehicles and climate change adaptation

The ICT sector uses vehicles to maintain supply, operation and disposal of devices and infrastructure. The vehicle fleet should therefore be included in climate change adaptation risk assessments as it is exposed to environmental vulnerabilities. However, it is not considered to be within scope of this report to cover the performance of the transport sector. ICT experts are not normally involved in maintaining the vehicle fleet but may be responsible for driving and personal safety. They should therefore be aware of weather conditions and be especially alert for extreme weather events and take note of local forecasts before making a journey.

4.3.2 Workforce and climate change adaptation

The ICT sector ultimately depends upon its workforce to maintain supply, operation and disposal. The workforce is also vulnerable to climate change events such as when making the journey to work. Occasionally, the transport systems fail due to extreme weather, for example, and it may not be possible to reach the workplace. Opportunities for remote working should therefore be explored. Ofcom[43] noted that remote working is becoming common practice as an alternative to travel to fixed offices.

4.3.3 Supply chain and climate change resilience

The supply chain provides new and replacement technology and maintenance services to the ICT sector. Normally suppliers are not in the critical path for day-to-day network operation but they are responsible for providing new equipment and ensuring maintenance of equipment in service.

Network devices may have an asset life of 2-13 years and ICT office devices 3-6 years from an accounting perspective (see example[86]). There is rapid turnover of equipment as new generations of equipment are introduced with increased capability due to advances made possible by Moore’s law[87]. The supply chain can therefore respond to the list of Adaptation Options listed above by introducing new features to enhance resilience and ensure a smooth adaptation to climate change.

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[85] Radley Horton, *et al*., Report 11-18 Response to Climate Change in New York State (ClimAID), Chapter 10 “Telecommunications”, http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/EMEP/climaid/11-18-response-to-climate-change-in-nys-chapter10.ashx

[86] BT Group plc Annual Report & Form 20-F 2013, page 111. http://www.btplc.com/Sharesandperformance/Annualreportandreview/pdf/2013_BT_Annual_Report.pdf

[87] “How Moore's Law Works” http://computer.howstuffworks.com/moores-law.htm

From the maintenance perspective, specialist technicians make regular inspections of HVAC systems. During an inspection, a check can be made on the ability of the equipment to cope with the thermal load as noted in section 4.2.1. This may increase beyond the design limit due to new equipment being added or if a change in extreme temperature is anticipated.

Suppliers may be vulnerable to extreme climate effects which could cause problems in the distribution of replacement or new equipment especially during times of disaster. Operators and suppliers therefore need to examine the handling of disaster recovery by taking account of possible scenarios and their associated response times with a focus on possible transport problems brought about by disasters related to climate change or other causes.

4.3.4 ICT end-user services and equipment

End-users normally have no expertise and control over their ICT devices and services, yet they are becoming increasingly dependent upon devices in order to carry out their daily lives. Smart phones (Internet connected) have recently overtaken feature (voice/text) phones in global sales[88]. This makes end users particularly vulnerable to the effects of failure due to climate change or other disasters.

It is therefore important that end-users understand the risks and mitigation options. Common failure modes include:

- Failure of the device (e.g. overheating/dropping/moisture ingress),
- Failure of the network (e.g. overload/accessibility),
- Loss of power (e.g. battery failure/grid supply failure).

Climate change can increase the vulnerability of user equipment but may not be a primary cause of failure.

Resilience can be increased by ensuring diversity is available. Examples include:

- Maintain access to two devices which can be connected to more than one different types of network (fixed/mobile/satellite and broadcast devices such as radio and TV receivers). Maintain connectivity to alternative access networks by taking advantage of communal or shared wireless local area network (LAN) services[89]. Maintain a source of off grid power (e.g. car battery with power derived from the cigarette lighter socket). For those without cars, a battery may be charged using a solar panel. These can be purchased for a number of applications including mobile phones and small device chargers and those for use in caravans or boats.
- Ensure TV and radio receiver antennas are able to operate under extreme weather conditions (wind, extreme rainfall and interference during ducting conditions). By using both terrestrial and satellite systems, continuity of the broadcast information services can be made resilient.

4.4 Identifying opportunities from climate change

It may seem perverse but, as discussed in section 3.2, not all impacts of climate change are negative. Economic benefits can be found as a result of climate change and adaptation strategies can encompass them. For example, the melting of the polar cap opens up opportunities for shorter shipping routes and drilling for oil. However, the ICT sector appears to lack economic benefits which are not driven by other climate change activity such as mitigation or remedial work specifically for adaptation. For example, the need to redesign ICT equipment and infrastructure to cope with the impact of climate change could provide an opportunity to develop and install more energy-efficient equipment and infrastructure and therefore reduce GHG emissions. This opportunity arises rarely once equipment is installed, and should be exploited.

Reference to Figure 8 also shows how one of the weakest links in the network, that to the end-user, can be plugged, at least for networks. Hurricane Sandy knocked out 25% of mobile phone masts across 10 states. Under

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88 Gartner confirms smartphones have overtaken feature phone sales http://www.t3.com/news/gartner-confirms-smartphones-have-overtaken-feature-phone-sales

89 BTfon "What is Fon?" https://www.btfon.com/

emergency situations, it could be required that mobile network operators pool their networks to allow home network roaming rather than tying users to a single network. This would make the network more resilient to individual base stations or link failures.

Extension of the coverage of telecommunications networks and devices to total populations is a major economic goal, especially in developing countries. For an example, Ghana, see Reference[90]. At this time, climate change adaptation may be taken account of at the outset. Apart from the economic advantage, populations can use the network for capacity building, and there may be a case for remote communities to receive a service via subsidy for this purpose.

Opportunities within the existing coverage areas include the upgrade of networks to have enhanced resilience. These are identified in section 4.1.1 on network resilience.

One example would be the addition of infrastructure to change from a "daisy chain", where each cellular base station is connected to the next in a linear fashion, but with no resilient pathway, to a folded ring topology with resilience via loop-back. This is illustrated in Figure 8 by imagining that link B had never been built. Base stations may have been laid out along a roadside using microwave links to form the primary connection. There may be insufficient radio range, or funding to complete the loop. However, the longer range of fibre optic technology may be used to upgrade the network.

Adaptation of communities to the effects of climate change is an opportunity for service providers. Networks may be used to provide warnings and other information related to climate change.

Business opportunities also lie in the cross-sectoral application of ICT. ICT is used to make efficiency improvements in all other sectors. Adaptation to climate change is especially important in the energy, water and food supply sectors. It is not within the brief of this report to examine details of cross-sectoral applications.

4.5 The adaptation process

An adaptation process is needed for the ICT sector to ensure that services are maintained as well as economically possible in the face of expected change risks.

The climate change adaptation process includes:[91]

- Assessment of the risk (see checklist example in Annex 5),
- Writing a climate change adaptation plan (see simplified example in Annex 1),
- Costing the work and time to payback,
- Gaining financial authorization,
- Carrying out remedial work,
- Checking that work meets the requirements.

Not all of these actions will be necessary. Some can be performed within normal maintenance procedures, such as clearing blocked drains, whereas others such as improved air conditioning could be carried out according to a longer-term investment plan.

To assist in this process, a series of checklist templates for different parts of a telecommunications network is proposed. An example of a "Climate adaptation risk assessment checklist for ICT buildings" is shown in Annex 5. Other categories of checklists could include infrastructure and accessibility, power supplies, ICT devices and systems, routing and end-end reliability, ICT services, workforce, vehicles, propagation (wireless and satellite), supply chain, ICT end-user services and equipment. These constitute areas for further study.

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90 ITU, "Information and communication technologies (ICTs) and climate change adaptation and mitigation: The case of Ghana", 2012, page 13, etc.
http://www.itu.int/dms_pub/itu-t/oth/4B/01/T4B010000020001PDFE.pdf

91 Climate adaptation: Risk, uncertainty and decision-making UKCIP Technical Report May 2003, page vii.
http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Risk.pdf

Before discussing the details of climate change adaptation, a special case should be mentioned. "Avoidance" may not be regarded as a strategy for dealing with adaptation to climate change but is mentioned here as a valid response[13].

4.5.1 Avoidance

Additional cost is incurred to assess (or reassess) the risk to ICT systems due to climate change and to carry out remedial actions, a cost which may not have been included in the original business case for the project. All business propositions carry an element of financial risk. It is normally up to the service provider to decide whether to let a project run to its conclusion under the original design specifications, or to take action and possibly reduce the profit margin. Climate change may be regarded as an additional threat to business operations, but it may be not a life-threatening risk as ICT devices have a short life of typically less than 13 years[83].

Under an "Avoidance Strategy" no remedial action is taken to counter possible climate change impacts. A business-as-usual approach is followed where it is assumed that climate variation occurs and is within normal operational bounds. Extreme weather patterns are assumed to be already accounted for in the specification for infrastructure and devices and in their operation over the life cycle. Additional checking of systems for performance under extreme weather conditions is not deemed necessary.

4.5.2 Assessment of the risk

This involves being aware of the performance of the infrastructure and devices under extreme weather conditions and making sure that regular checks are made to ensure that no degradations have occurred which would reduce the performance. For example, antenna towers will be checked for additional loading and corrosion; drains near car parks for maintenance staff will be checked for possible blockage.

4.5.3 Costing and financial authorization

The cost of the adaptation measure and time to payback are key factors in deciding which strategy to adopt for any particular example of a climate risk and adaptation plan. UNFCCC does not have any specific guidance for the ICT sector, but the steps outlined in Reference[92] and in Table 1 may assist in identifying practical steps that need to be taken.

In some cases, it will be noted that there is a deficiency but the equipment is due to be replaced and/or upgraded within a few years. The additional expense is of remedial work and is therefore avoided; wider tolerances to environmental conditions are included in the specification of the new infrastructure or devices.

4.5.4 Carrying out remedial work

Following a risk assessment of the infrastructure and devices, it is deemed necessary to carry out remedial work on legacy systems. A climate adaptation plan (see Annex 1 for a simplified example) shows how the deficiency can be remedied, funding is secured to carry out the work and the spending is authorized within the business. Remedial work could be burial of cables where there is a risk of extreme wind or re-routing cables near bridges where there is a risk of flood damage.

4.5.5 Checking that work meets the requirements

Normal business practice is to check that work has been completed successfully before final financial settlements are made. Once this check is completed to the satisfaction of the client, the network or facility affected can be reintroduced to periodic climate change risk assessment.

4.5.6 Holistic perspective on climate change adaptation

By standing back from the ICT sector and looking at several sectors together, adaptation plans can be made to serve populations more effectively. The UNFCCC website[93] suggests that adaptation activities cover a set of key components (i.e. observation, assessment, planning, implementation and monitoring). Although these steps are

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[92] Climate Change Adaptation Strategies for Local Impact
http://unfccc.int/resource/docs/2009/smsn/igo/054.pdf

[93] Elements of Adaptation
http://unfccc.int/adaptation/items/7006.php#Assessment

not sector-specific, they can provide insight into what could become a more robust and holistic response to climatic risks, and should therefore be useful in the design of the ICT sector's adaptation strategy.

Not all of these components can be carried out by ICT experts, but involve inter-sectoral collaboration and cross-fertilization of knowledge and expertise:

- *Observation* involves meteorologists who can sift through local observations and modulate these using climate projections to establish the environmental conditions for populations and sectoral activity (such as ICT).
- *Assessments* can fall within the scope of ICT experts (e.g. risk assessments) with vulnerabilities to extreme climate events being of particular importance in ensuring the smooth running of this sector (and possible impact on, or in, other sectors using ICT) during adverse conditions.
- *Planning* can involve single sector (e.g. ICT) responses as indicated below under Adaptation Options or cross-sectoral responses, for example, when new infrastructure is being planned.
- *Implementation* involves remedial action (as indicated below under adaptation options), new build, and disaster recovery.
- *Monitoring* refers to the periodic checking needed to ensure that infrastructure remains fit for purpose.

These different phases could help to improve the vigilance, remedial action and new design mentioned before.

V. List of suggested actions

From the discussion of climate risks to the ICT sector conducted up to this point, it is clear that there are adaptation options and opportunities that can help the telecommunications sector prepare and adapt smoothly to the impacts of climate change[78]. Key adaptation options and strategies are summarized below.

5.1 Adaptation options for the ICT sector

- Make the backbone network redundant for most if not all service areas, and resilient to all types of extreme weather events; provide reliable backup power with sufficient fuel supply for extended grid power outages.
- Decouple communication infrastructure from electric grid infrastructure to the extent possible, and make both more robust, resilient, and redundant.
- Minimize the effects of power outages on telecommunications services by providing backup power at cell towers, such as generators, solar-powered battery banks, and "cells on wheels" that can replace disabled towers. Extend the fuel storage capacity needed to run backup generators for longer times.
- Protect against outages by trimming trees near power and communication lines, maintaining backup supplies of poles and wires to be able to replace expediently those that are damaged, and having emergency restoration crews ready to be deployed ahead of the storm's arrival.
- Place telecommunication cables underground where technically and economically feasible, ensuring that they are appropriately protected against water ingress.
- Replace segments of the wired network most susceptible to weather (e.g., customer drop wires) with low-power wireless solutions.

- Relocate central offices that house telecommunication infrastructure, critical infrastructure in remote terminals, cell towers, etc., and power facilities out of future floodplains, including in coastal areas which are increasingly threatened by sea level rise combined with coastal storm surges.
- Further develop backup cell phone charging options at the customer's end, such as car chargers, and create a standardized charging interface that allows any phone to be recharged by any charger.
- Assess, develop, and expand alternative telecommunication technologies if they promise to increase redundancy and/or reliability, including free-space optics (which transmits data with light rather than physical connections), power line communications (which transmits data over electric power lines), satellite phones, and ham radio.
- Reassess industry performance standards combined with appropriate, more uniform regulation across all types of telecommunication services, and uniformly enforce regulations, including mandatory instead of partially voluntary outage reporting to the regulatory agencies.
- Develop high-speed broadband and wireless services in low-density rural areas to increase redundancy and diversity in vulnerable remote regions.
- Perform a comprehensive assessment of the entire telecommunications sector's current resiliency to existing climate perils, in all of their complexities. Extend this assessment to future climate projections and

likely technology advances in the telecommunications sector. This includes the assessment of codependency between the telecommunications and power sectors" relative vulnerabilities. Provide options and incentives to decouple one from the other while improving resiliency of each.

- Implement measures to improve public safety and continuity of communications services during extreme events.

5.2 Stakeholder reviews

Stakeholders include regulators, government departments, operators, suppliers and end-users. These may meet individually or collectively to assess the adaptation of the sector to climate change. Examples of publically available review reports include:

- UK Government[94]. This includes a risk assessment and national adaptation programme for all sectors. The Regulator, Ofcom[95], provided input to the National Adaptation Plan which includes fixed and mobile communications, interactive and broadcast. Impacts such as increased rainfall and ducting (in event of temperature inversion) on higher frequency propagation are noted. Remote working (as an alternative to travel to fixed offices) and cross-sector working are noted in the adaptation measures. Input on ICT was also provided by the Atomic Energy Agency (AEA) and ICT industry sector stakeholders, reporting to the Government Department for Environment Food and Rural Affairs (DEFRA)[96].
- New York State Authority: ClimAID[97]. This includes chapters on several sectors including Chapter 10 on telecommunications. The report draws upon extreme climate events elsewhere in the USA including Hurricane Katrina.

5.3 Adaptation schemes in practice

A survey was conducted among selected industry stakeholders involved in ICTs, climate change and the environment. The survey questions are shown in Annex 6.

Responses were received from Telefónica, Alcatel-Lucent and Mobinil. These are copied into this report as Annexes 7, 8 and 9, respectively. In addition, Alcatel-Lucent "road tested" the "Climate adaptation risk assessment checklist" on ICT buildings and HVAC. This is reproduced in Annex 10.

The survey showed that some companies are already taking measures to adapt to climate change. Their methodologies are currently part of the wider process of infrastructure build with measures against known risks. It may be too early to judge whether "climate change risk assessment" and "climate change adaptation plans" are needed as separate processes. However, the survey recommended that companies and organizations consider the need for a company-wide review of climate change impacts and the need to update business processes in the light of anticipated changes in climate. This report provides material to provide guidance on this.

5.4 Requirements for new standards

New standards in the area of ICT and adaptation to climate change would provide ICT organizations with a starting point for the identification of and reduction of the risks due to extreme weather events caused by climate change. International standards formed by consensus include contributions from many countries and organizations and so have global status and application. Some work items have been identified by ITU for contributions on adaptation to climate change, which include among others:

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94 UK Government policy on Adapting to climate change https://www.gov.uk/government/policies/adapting-to-climate-change

95 Ofcom, "Climate Change Adaptation Impact on our functions - A response to the Secretary of State's Direction of 31 March 2010" http://stakeholders.ofcom.org.uk/binaries/consultations/ofcomresponses/Climate-change-adaptation.pdf

96 AEA (2010), *Ibid.*

97 New York State, "Report 11-18 Response to Climate Change in New York State (ClimAID)", http://www.nyserda.ny.gov/climaid

- Recommendations to support adaptation to climate change and improve the resilience of the ICT infrastructure to the impacts of climate change.
- Practical examples and best practices of ICT standards to support adaptation to climate change for countries and ICT sector.

Text from this report may be used to contribute to the work of ITU-T Study Group 5.

It is suggested that the checklists be annexed or appended to a future standard that may be approved by the ITU. It could be used as a template for organizations to adapt and adopt within their own administration. Checklists could be included for ICT buildings (as shown in Annex 5), infrastructure and accessibility, power supplies, ICT devices and systems, routing and end-end reliability, IT services, workforce, vehicles, propagation (wireless and satellite), supply chain, ICT end-user services and equipment.

VI. Conclusions

Available evidence suggests that climate change will cause unavoidable impacts that will affect the ICT sector both directly and indirectly. Within this context, adaptive practices will increasingly become part of the "new normal" for business operations around the world, including those of the ICT sector.

ICT sector stakeholders face the challenge of building greater sensitivity to climate change impacts, especially in the context of increasing interconnectivity, globalized businesses and supply chains, and an enabling international policy domain (e.g. the NWP and its private sector initiative (PSI)). Positioning climate change in the sector's agenda requires an active role of senior managers and industry leaders in pushing the agenda forward, and ensuring that stakeholders at all levels are engaged in the implementation of adaptation measures.

Adaptive approaches involve a sector-wide assessment of the potential risks and vulnerabilities relating to climate impacts, including direct impacts (e.g. flood risks, storm exposure, etc.) and indirect ones (e.g. supply chain disruptions, etc.). It also involves mechanisms to tackle the business opportunities that may emerge with changing climatic conditions (including new standards, business and consumer demands), and to develop the skills and structures required to benefit from new economic possibilities.

As suggested by this report, the adoption of *resilient pathways* towards adaptation requires going beyond generic contingency and risk management measures. It entails the ICT sector to identify and implement specific actions to manage current threats, yet respond flexibly and adjust innovatively to future impacts.

Integrating the attributes of resilience can help strengthen the sector's approach to climate change adaptation by improving its ability to cope, adjust and potentially transform, and by enabling sector-wide strategies in the face of short-term shocks and long-term trends.

The adaptive practices identified in this report evidence the growing importance of adaptation in the agenda of ICT sector stakeholders. Emerging measures are contributing not only to reduce the sector's vulnerability to climate change impacts, but also to improve its preparedness and response capacity to future, and yet uncertain change.

The "ICT sector's adaptation framework: Resilient pathways" (Figure 5) suggests that the sector's approach to adaptation could be enhanced by adopting measures that strengthen a set of core resilience attributes, including the sector's robustness, self-organization, learning, redundancy, flexibility and diversity, rapidity and scale.

Based on a resilient perspective, the ICT sector adaptive actions could include:

- Improvements in service coverage in rural and vulnerable locations to climate change impacts, particularly in disaster-prone areas (e.g. remote locations that can become isolated during flood events) where interconnectivity is pivotal to ensure sectoral *robustness* and effective response.
- Development of new standards to strengthen the resilience of ICT infrastructure in the face of current and projected climatic threats, including measures to ensure sectoral *robustness* and *cross-scale* interactions (i.e. implications of the ICT sector's adaptation for other sectors/dependent systems).
- Design of sector-specific approaches to spatial planning and environmental design, improving the planning/construction of ICT infrastructure such as data centres, and mitigating long-term risk (i.e. *robustness*).
- Implementation of novel approaches to improve systems' diversity and interoperability, including virtualization, server networks and system's backup, in order to ensure sectoral *redundancy*, and thus the continuity of services and operations during climatic disturbances.
- Foster a new wave of R&D focused on "climate-resilient innovation", aimed at developing energy-efficient devices and components that are suitable to projected climatic conditions, and that support the adaptation of ICT users and sectors. This could motivate new *learning* processes within the sector, and contribute to its *flexibility* and *diversity* in the face of climate change.

- Improvement of the *cross-scale* collaboration between infrastructure and service providers, operators, and national and local authorities involved in climate change strategies, including more effective mechanisms for information and knowledge sharing, in order to ensure effective responses to extreme events and climatic disruptions.

The “resilient pathways” highlighted in this report constitute desirable routes of action amidst an increasingly interdependent and changing international environment. These pathways can allow the ICT sector to go beyond short-term coping and reactive measures, in order to improve its overall adaptability to future unforeseen effects, while approaching adaptation from a collaborative, multilevel perspective.

By proactively embracing resilient pathways, the ICT sector will be able to address the short-term priorities and long longer-term risks and opportunities posed by climate change, while ensuring that international, national, sectoral and local stakeholders join efforts towards the achievement of a better, more sustainable future.

Annex 1 Climate change adaptation plan: ICT sector

		A	B	C	D	E	F	G	H
	Climate Impact	**ICT buildings and HVAC**	**Infrastructure and Accessibility**	**Power Supplies**	**IT devices and Systems**	**Routing and End-End Reliability**	**IT Services**	**Work force**	**Vehicles**
1	**flood**	duplicate data centre.		Off grid supply planned				home working	
2	**drought**								
3	**extreme heat**						text alert service needed		
4	**extreme cold**								
6	**extreme wind**		Strengthen antenna mounts						
9	**extreme humidity**				check for condensation				
10	**biological risks**		Reduce foliage near overhead lines						

Source: Faulkner D. (2013).

Annex 2 UNFCCC: The international response to climate change

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change, to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable.

By 1995, countries realized that emission reductions provisions in the Convention were inadequate. They launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed countries to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. The second commitment period began on 1 January 2013 and will end in 2020.

There are now 195 Parties to the Convention and 192 Parties to the Kyoto Protocol. The UNFCCC secretariat supports all institutions involved in the international climate change negotiations, particularly the Conference of the Parties (COP), the Conference of the Parties serving as the meeting of the Parties (CMP), the subsidiary bodies (which advise the COP/CMP), and the COP/CMP Bureau (which deals mainly with procedural and organizational issues arising from the COP/CMP and also has technical functions).

Climate change is a complex problem, which, although environmental in nature, has consequences for all spheres of existence on our planet. It either impacts on - or is impacted by - global issues, including poverty, economic development, population growth, sustainable development and resource management. It is not surprising, then, that solutions come from all disciplines and fields of research and development.

At the very heart of the response to climate change, however, lies the need to reduce emissions. In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below 2 degrees Celsius.

This time line detailing the international response to climate change provides a contextual entry point to the Essential Background.

2013 - Key decisions adopted at COP19/CMP9 include decisions on further advancing the Durban Platform, the Green Climate Fund and Long-Term Finance, the Warsaw Framework for REDD Plus and the Warsaw International Mechanism for Loss and Damage. Release of the "Climate Change 2013: The Physical Science Basis", Working Group I Contribution to the Fifth Assessment Report of the IPCC.
2012 - The Doha Amendment to the Kyoto Protocol is adopted by the CMP at CMP8. In terms of adaptation, guidance is provided by COP to the Global Environment Facility to enable activities for the preparation of the NAP process by the LDC Parties.
2011 - The Durban Platform for Enhanced Action drafted and accepted by COP, at COP-17. Initial guidelines for the NAP process are also adopted.
2010 - Cancun Agreements drafted and largely accepted by COP, at COP-16.These included the Cancun Adaptation Framework.
2009 - Copenhagen Accord drafted at COP-15 in Copenhagen. This was taken note of by COP. Countries later submitted emissions reductions pledges or mitigation action pledges, all non-binding.
2007 - IPCC's Fourth Assessment Report released. Climate science entered into popular consciousness. At COP-13, Parties agreed on the Bali Road Map, which charted the way towards a post-2012 outcome in two work streams: the AWG-KP, and another under the Convention, known as the Ad-Hoc Working Group on Long-Term Cooperative Action Under the Convention.
2005 - Entry into force of the Kyoto Protocol. The first Meeting of the Parties to the Kyoto Protocol (MOP 1) takes place in Montreal. In accordance with Kyoto Protocol requirements, Parties launched negotiations on the next phase of the KP under the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP). What was to become the NWP (it would receive its name in 2006, one year later) is accepted and agreed on.

2001 - Release of IPCC's Third Assessment Report. Bonn Agreements adopted, based on the Buenos Aires Plan of Action of 1998. Marrakesh Accords adopted at COP-7, detailing rules for implementation of Kyoto Protocol, setting up new funding and planning instruments for adaptation, and establishing a technology transfer framework.
1997 - Kyoto Protocol formally adopted in December at COP-3.
1996 - The UNFCCC Secretariat is set up to support action under the Convention. More on the Secretariat.
1995 - The first Conference of the Parties (COP-1) takes place in Berlin.
1994 - UNFCCC enters into force.
1992 - The INC adopts the UNFCCC text. At the Earth Summit in Rio, UNFCCC is opened for signature along with its sister Rio Conventions, UNCBD and UNCCD.

Source: UNFCCC (2013).

*Further information on the UNFCCC Convention is available at:
http://unfccc.int/essential_background/items/6031.php

Annex 3 ITU events on ICTs, environment and climate change

	Event location/date	Further information
ITU Green Standards Week		
1	Rome, Italy 5-9 September 2011	http://www.itu.int/ITU-T/climatechange/gsw/201102/index.html
2	Paris, France 17-21 September 2012	http://www.itu.int/ITU-T/climatechange/gsw/201209/index.html
3	Madrid, Spain 16-20 September 2013	http://www.itu.int/en/ITU-T/Workshops-and-Seminars/gsw/201309/Pages/default.aspx
4	Beijing, China 22-26 September 2014	http://www.itu.int/en/ITU-T/Workshops-and-Seminars/gsw/201406/Pages/default.aspx
ITU Symposium on ICTs, the Environment and Climate Change		
1	Kyoto, Japan, 15-16 April 2008	http://www.itu.int/ITU-T/worksem/climatechange/2008/index.html
2	London, UK, 17-18 June 2008	http://www.itu.int/ITU-T/worksem/climatechange/2008/index.html
3	Quito, Ecuador, 8-10 July 2009	http://www.itu.int/ITU-T/worksem/climatechange/200907/
4	Seoul, Korea, 23 September 2009	http://www.itu.int/ITU-T/worksem/climatechange/200909/index.html
5	Cairo, Egypt, 2-3 November 2010	http://www.itu.int/ITU-T/worksem/climatechange/201011/
6	Accra, Ghana, 7-8 July 2011	http://www.itu.int/ITU-T/worksem/climatechange/201107/
7	Montreal, Canada, 29-31 May 2012	http://www.itu.int/ITU-T/worksem/climatechange/201205/
8	Turin, Italy, 6-7 May 2013	http://www.itu.int/en/ITU-T/climatechange/symposia/201305/Pages/default.aspx

Source: ITU (2013).

*Further information on past and forthcoming ITU events is available at:
http://www.itu.int/en/ITU-T/climatechange/Pages/events.aspx

Annex 4 ITU-T Study Group 5 (SG5)

ITU-T Study Group 5 is ITU's lead study group on environment and climate change.

Climate Questions (work areas) under study:

Q 13/5 – Environmental impact reduction including e-waste

Q 14/5 – Setting up a low cost sustainable telecommunication infrastructure for rural communications in developing countries

Q 15/5 – ICTs and adaptation to the effects of climate change

Q 16/5 – Leveraging and enhancing the ICT environmental sustainability

Q 17/5 – Energy efficiency for the ICT sector and harmonization of environmental standards

Q 18/5 – Methodologies for the assessment of environmental impact of ICT

Q 19/5 – Power feeding systems

Study items considered as part of Question 15/5 (Q15/5) " ICTs and adaptation to the effects of climate change" of ITU-T Study Group 5 "Environment and climate change" include, but are not limited to:

- How can ICT, including fibre submarine cable networks, be used more effectively to monitor the global environment/ecosystem and provide tsunami warnings? And what new standards and best practices are required? (e.g. supporting GDACS under the UN framework)?
- How is ICT used in gathering, processing and disseminating information about climate change?
- How can ICT be used to improve food and water security? What standards are needed in these areas? This cross-sectoral work should be in collaboration with other UN agencies and organizations as appropriate.
- How can ICT and standards be used and developed to be more effective in helping communities to adapt to climate change especially in developing countries and particularly in key sectors such as water management, etc.?
- What ICT and standards are used to disseminate information to enable farmers to better forecast crop yields and production?
- How can ICT be used to monitor deforestation and forest degradation and what standards are available or need development?
- How can ICT be used to reduce CO2e emissions by better waste management through a "cradle to cradle", i.e. "closed loop" approach whereby more efficient recycling means fewer raw materials need to be mined?
- What are the gaps in technologies and standards needed for ICT to be used to increase energy supply efficiency and maximize the use of renewable sources?
- How can ICTs be best used in education? How can they be used to raise awareness on climate change? What standards are required in this area?

Source: ITU (2013).

*Further information on the work of ITU-T Study Group 5 "Environment and Climate Change" is available at: http://www.itu.int/en/ITU-T/studygroups/2013-2016/05/Pages/default.aspx

Annex 5 Climate adaptation risk assessment checklist

ICT buildings and HVAC

As stated in section 4.2.1, an important function of ICT buildings (such as data centres and central offices) is to maintain electronics at a safe operating temperature. Heating, ventilation and air conditioning systems (HVAC) play a key role in that regard, and should be designed and maintained to keep the ICT equipment within the temperature and humidity limits specified by the manufacturers.

Example

Climate adaptation risk assessment: ICT buildings and HVAC

Scope: Exchanges, base stations for mobiles, data centres, repeater stations, transmitter stations.

Risk assessment to climate extremes:

A1. Flood

A1(i) Do you have a list of buildings which are vulnerable to floods and a Plan of Action in event of flooding?

A1(ii) Are any of your buildings near or on a slope which could subside?

A1(iii) Does your organization have measures in place to cope with extreme rainfall? (e.g. regularly inspect and clear drains)?

A2. Drought

A2(i) Do you have buildings which on land are liable to crack and become unsafe during an extended heat-wave? (e.g. brick buildings)?

A2(ii) Do you have sufficient off-mains water to cope with extended drought? (e.g. ponds for use by fire pumps)?

A3. Extreme heat

A3(i) Do you have ICT equipment operating in rooms with windows facing the sun?

A3(ii) Do you have blinds fitted in ICT equipment rooms with windows facing the sun?

A3(iii) Are your air conditioning units serviced regularly?

A3 (iv) Does the power load in the equipment room exceed the capacity of the air conditioning unit to remove the heat produced?

A4. Extreme cold

A4(i) Do your roofs have adequate strength to withstand 100 year snow accumulation predictions?

A4(ii) Do your roofs slope? If so do you have protection against ice and snow melt causing local avalanche risking injury to passers by?

A4(iii) Are the water supplies to your building adequately protected from freezing?

A4(iv) Are buildings able to maintain an adequate working temperature during periods of extreme cold? Are heating systems for employee areas checked annually?

A5. Extreme wind

A5(i) Are your building structures able to withstand increased wind loads?

A5(ii) Are components in the roof likely to detach during expected increases in maximum wind? Are roof panels and or/all tiles securely fastened?

A5(iii) Are any roof-mounted masts or solar panels able to withstand extreme winds?

A6. Humidity control

A6(i) Do your HVAC systems maintain humidity in the range of 20%-80% in computer or telecommunications rooms to minimize the risk of static discharge or dew point being reached?

A6(ii) Does the HVAC system enable 30% to 40% humidity in cold climates to maintain adequate comfort for employee areas?

A6(iii) Does the HVAC system enable 50% humidity to be maintained in cold climates to maintain adequate comfort for employee areas?

(In summer, indoor humidity levels should be kept below about 65% to minimize the potential for mould growth and below about 50% to minimize dust mites.)

A7. Biological risks (insect, rodent, foliage, disease) increase due to climate change

A7(i) Are there trees growing near the building which have roots which could undermine the structure?

Other checklists

Other categories of checklist could include infrastructure and accessibility, power supplies, ICT devices and systems, routing and end-end reliability, IT services, workforce, vehicles, propagation (wireless and satellite), supply chain, ICT end-user services and equipment.

Annex 6 Survey questions

As part of this report's activities, selected stakeholders of the ICT sector were invited to respond to the following questions:

(a) What are the priorities of your company with regard to climate change adaptation?

(b) Do you have examples of how these priorities are being implemented in practice?

(c) Does your organization have a "Risk assessment checklist concerning ICT and climate change adaptation" and/or a "Climate change adaptation plan"?

Annex 7 Telefónica survey responses

(a) What are the priorities of your company with regard to climate change adaptation?

We are aware of the fact that one of the greatest worldwide challenges is that of climate change. Neither the information and communication technology (ICT) sector nor Telefónica can be on the sidelines. We therefore have an organizational structure in place, which goes under the title of the Climate Change and Energy Efficiency Office. This Office, represented by corporate and business units, is responsible for managing, controlling and promoting all projects by Telefónica related to energy, climate change and green services. All with the same aim in mind: firstly, to reduce internal emissions through energy efficiency initiatives, and secondly to provide products and services that facilitate climate change mitigation and adaptation.

In this sense, Telefónica has two priorities regarding climate change adaptation. The first one related is to internal climate adaptation of our operations, and the second one focuses on the provision of green ICT services for climate change adaptation to our customers.

In this sense, Telefónica priorities are focused on:

1) Network risk management

Telefónica has operations worldwide in both the fixed and mobile networks and our networks and facilities are located in sites geographically dispersed all over the countries where we operate. A significant amount of these networks are ground based and located in coastal regions too. Climate change risks could affect fixed and mobile infrastructure as well as other facilities of Telefónica as extreme weather conditions (floods, soil desertification, high wind velocity, etc.) can generate damages or losses to the sites we operate.

Since 2007, Telefónica has established a global risk management model to asses, to mitigate and control global risks that could affect our business. Climate change risks are part of this global model and are embedded in the business risks category (possible losses in value or results deriving from strategic uncertainty, changes in the business scenario and the market/competition or changes in the legal framework) and in the operational risks category (possible losses in value or results deriving from events caused by shortfalls or failures generated by processes, human resources, physical equipment and systems or generated by external factors).

Change in precipitation patterns and extremes can cause floods, which can damage the facilities and infrastructure depending on the intensity of the disaster; this risk could affect especially Central and South America countries, due to the considerable frequency of these events in these zones. In addition, the increase of the mean temperature causes an increase of the operational cost of energy through cooling. Natural disasters such as earthquakes, hurricanes, high winds, tornados and fires eventually can cause disruption of the network on vulnerable sites. These risks can cause disruption of the supply chain if the event directly affects the supplier. They can also cause disruptions for the customers leading to contingency planning, complaints and financial losses due to the interruption of the network services. Moreover, recovery of the service is affected directly by the capital expenditure (CAPEX) for operations. Finally, but less likely, if the events occur with high intensity and/or frequency, they could provoke an increase of outsourcing, off-shoring, expansion of the business and acquisition of other branches.

In this sense, Telefónica assesses the risks – including climate change risks – based on a corporate model. For example, risk quantification for an operational failure in a network infrastructure includes an integrated accounting of non-sale traffic (based on number of customers, length of time of the incident, invoicing related to the services not provided); company churn rate of affected customers, and the replacement of damaged equipment.

2) Identification and development of green ICT services for climate change adaptation

Telefónica has a global strategy of green ICT services focused on the development of integrated solutions that could be used globally for developed and developing countries. Green ICT services must give answers for climate change mitigation and adaptation and should be clear examples of technology which can be applied worldwide.

In the Telefónica portfolio of green ICT services, services are included such as inmótica, telecommuting, M2M-based fleet management and virtual hosting. Moreover, Telefónica works to promote green ICT services for the electric vehicle and other smart services penetration as well as for smart cities. We will also reinforce the identification of products and services which monitor climate conditions on a global level, as well as provision of vegetation with regard to reforestation and deforestation. In addition, Telefónica is working to establish potential areas of work concerning the capability of submarine cables for ocean monitoring.

(b) Do you have examples of how these priorities are being implemented in practice? If you do, could you share them with us so that we can cite them in this report?

Related to the *Network risk management*, we provide two examples:

1) Flood risk – Perú experience

During the rainy season, some regions of Perú are under flooding risks and some Telefónica sites are exposed. In case of weather alert, the operations team of Telefónica Perú proposes some actions to prevent and avoid the damages to the facilities and infrastructure.

For this potential risk, Telefónica Perú has defined a specific fixed and mobile operator integrated procedure that defines the action plan for emergency cases. This document describes the plan of action for all operational areas that have responsibility for the operation and maintenance activities of the network infrastructure: switching, transmission, energy, broadband, data, mobile network, IP network services platforms for network management. The procedure also describes the methodology for communications and notifications to apply in case of emergency as well as the operational details for each step of an emergency plan.

Moreover, Telefónica Perú has taken preventive actions to protect the network sites. The solution consisted of locking the doors of network sites with sandbags on both sides of the door (inside and outside the room), as shown in the pictures below:

The total cost of this preventive action was extremely low in comparison to the potential damage of the equipment and network failure.

2) Sustainable site – Brazil experience

Brazil and specifically the coastal regions have elevated temperatures during summer; most sites require energy-consuming equipment. The solution proposed by Telefónica-Vivo (the mobile and fixed operator of Telefónica in Brazil) is the use of public lighting poles to meet the demand of base stations without introducing new elements to the infrastructure. Equipment is located in a box in the ground to avoid exposure to heat.

The solution shows an example of communications infrastructure adapted to the effects of climate change while reducing the visual impact of the antennas. In addition, the solution for urban areas uses existing lighting infrastructure and is a great alternative to building new sites in restricted areas, reducing the visual impact on the infrastructure and facilitating network deployment:

- Using public lighting infrastructure in standard public areas.
- Accommodation of equipment in the box underground.

The lamp-post used is manufactured by an approved supplier for Rio Light and requires a small adjustment in its interior to create ducts where the air circulates to cool the equipment inside the enclosure. Equipment is placed inside a box that is installed underground allowing the integrity of the equipment. The box is hermetically closed so it is resilient to flooding and high temperatures.

The project was developed by the team of Telefónica VIVO in partnership with a local company specializing in fiberglass technology and is appropriate to the climatic conditions of Brazil.

In relation to *Identification and development of green ICT services for climate change adaptation*, we provide the following example:

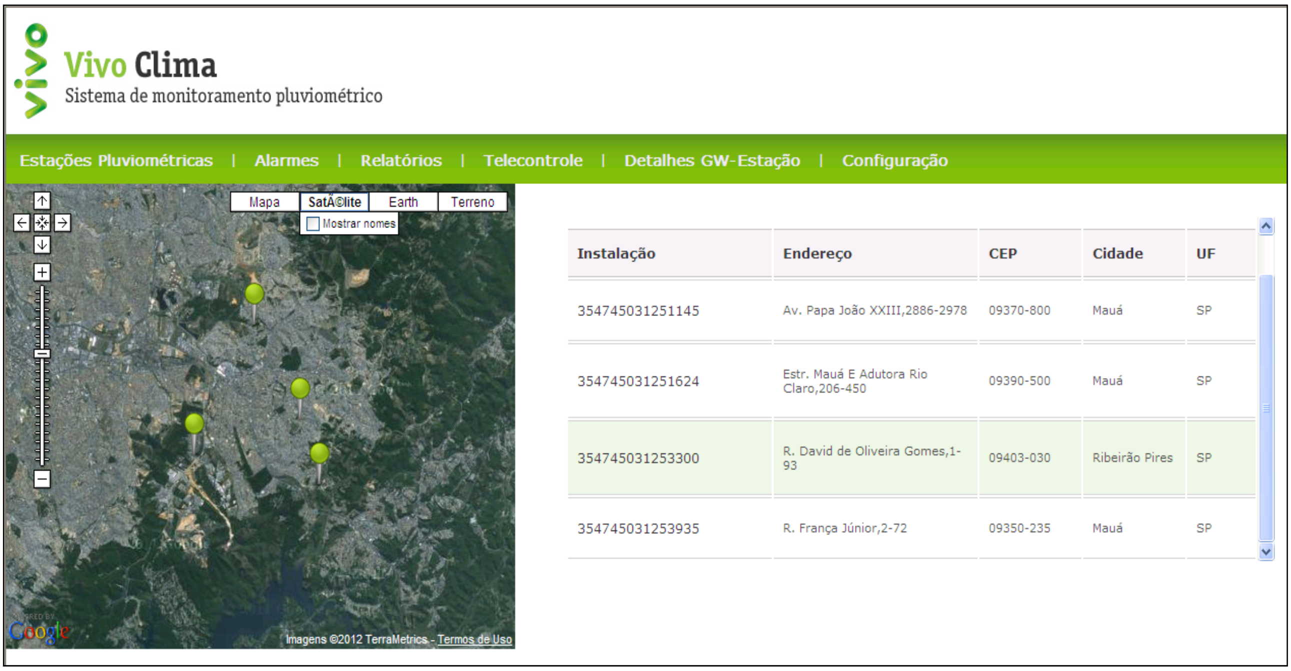
> *VIVO-Clima*: This solution consists of a service that provides real-time information on precipitation levels in different geographic areas. VIVO-Clima runs from the installation of rain gauges in the mobile phone sites of Telefónica Brazil, which sends information to the Company's using M2M management platform. The system focuses primarily on trying to prevent natural disasters such as floods, landslides and droughts in climate risk areas. This agreement makes the rainfall forecast system more effective, enabling better protection of people living in areas at risk.

The scope of this project covers the installation of 1500 rain gauges at federal government buildings and mobile phone masts located near risk areas. Telefónica has also been studying three complementary ways to expand Vivo Clima's service. The first way is by organizing the sales force to search for more possible new Vivo Clima's costumers, which is a way to increase the reach of the service internally and externally and push environmental results at the same time.

The second possibility is to expand the service via a partnership between Telefónica and the Ministry of Science, Technology and Innovation, whereby the government installs more pluviometers in Brazilian land and Telefónica provides the M2M connection. This will improve Brazilian disaster monitoring network as well as improving the effectiveness and the quickness of the responses.

The third way to improve the programme, in this case by extending it, is by bringing a new technology to capture more pluviometric (precipitation/rainfall) data to feed the platform. Telefónica is now studying a way of monitoring and analyzing the radio links" data between sites and recording how the radio links increase their power budget automatically when it is raining.

Through these measures, it is possible to obtain the real pluviometric data, to increase Vivo Clima's network and put this platform in a whole new level of recording meteorological data.



(c) Does your organization have a "Risk assessment checklist concerning ICT and climate change adaptation" and/or a "Climate change adaptation plan"? If you do, could you share them to be included as a reference as part of this report's annexes?

Until now, Telefónica does not have a "Risk assessment checklist concerning ICT and climate change adaptation" or a "Climate change adaptation plan". Physical climate change risks are part of the "Operational Risks" identified in the Risk Management model of Telefónica.

Even so, some actions have taken. Examples are:

1. Implementation of procedures to improve the design and planning of infrastructure (no costs);
2. Development and testing of continuity plans. Setting requirements of location and type of construction;
3. Design and creation of redundant systems and infrastructure;
4. Effective insurance acquisition (insurance for equipment damage and third party damages insurance). Costs depend on the countries.

Annex 8 Mobinil response to the buildings checklist

(a) What are the priorities of your company with regard to climate change adaptation?

Low priority. The impact of climate change was not really felt in our network and assets. We did not suffer from rising water sea levels for example, or experience unusual storms in the past 15 years. The only thing that we can attribute to climate change is longer, hotter and drier summers. Even then, the changes were still insignificant to impact our equipment or services.

Our more pressing priority is: reduce energy consumption and related costs. It is followed by reducing the company's carbon emissions and footprint. These two targets supersede "adapting to climate change".

We have two large projects addressing both priorities:

Reduce energy consumption by 25 GWh in 2015, that is 20% of the current consumption.

Register our first clean development mechanism (CDM) project aiming to capitalize on the reductions made and to support a business model on suitability of CO_2 reduction.

(b) Do you have examples of how these priorities are being implemented in practice? If you do, could you share them with us so that we can cite them in this report?

The only example that can be used as "adapting to climate change" is deployment of compact base station units which are more tolerant to heat and do not use air-conditioning, only simple ventilation. Either way, we do not mind sharing any of our energy-related practices and lessons learnt.

(c) Does your organization have a "Risk assessment checklist concerning ICT and climate change adaptation" and/or a "Climate change adaptation plan"?

No.

Annex 9 Alcatel-Lucent survey responses

(a) What are the priorities of your company with regard to climate change adaptation?

Compliance and increased operational expenses

- As regulatory environments respond to the consequences of climate change, companies are faced with increasing risks, e.g. taxes, insurance and other regulations.
- A natural catastrophe has the potential to affect our suppliers as well as our energy costs. (However, we have business continuity plans in place to take effect if and when a natural disaster occurs; please see our response to Annex 5: "Climate adaptation risk assessment checklist').

Environmentally conscious design

- **Resilience**

  Alcatel-Lucent recognizes the need to incorporate resilience into key ICT infrastructure so as to continue functioning in cases of extreme temperatures. For example, telecom cables, remote equipment huts and wireless base stations are designed and installed to the extent possible, with fire resistant materials and protective systems.

(b) Do you have examples of how these priorities are being implemented in practice?

- **Fuel/energy taxes and regulations** - In 2012, our Real Estate team implemented 23 projects globally to increase the energy efficiency of some of our major facilities. The projects included:
  - Installation of variable frequency drives (VFDs),
  - Time adjustments for use of lighting.

Tropical cyclones (hurricanes and typhoons) - In 2012, Alcatel-Lucent put in place 80 real estate business continuity plans (BCPs) to address environmental and other risks in terms of the potential loss of critical functions. The BCPs target locations with more than 500 employees (or with more than 200 employees in areas with elevated risks, such as proneness to earthquakes or political volatility). BCPs cover all critical real estate functions identified for a given location, allowing us to respond to diverse threats and systems that become material. Some plans − such as centrally managed plans within the corporate crisis management process and local emergency response plans − respond to particular hazards such as earthquakes and pandemics.

(c) Does your organization have a "Risk assessment checklist concerning ICT and climate change adaptation" and/or a "Climate change adaptation plan"?

Alcatel-Lucent has implemented a full enterprise risk management (ERM) process that comprises risk mapping (risk identification and evaluation) and risk mitigation. Our business continuity management (BCM) programme, an integrated part of ERM, is designed to enable Alcatel-Lucent to continue business-critical functions and meet customer expectations during significant business disruptions. Real estate business continuity plans (BCPs) address environmental risks not as a specific threat but rather as a risk response to loss of critical functions.

Additional issues

Telecom network equipment grounding

Grounding is critical for telecom equipment to work properly based on how electricity is distributed and power supply voltage/current levels are controlled and regulated. If changes in climate and weather patterns occur, soil moisture content and resistivity will change as well. This can bring about a change in the electrical grounding potential for all telecom equipment in the affected regions.

To prepare for this, equipment grounding systems will need to be tested and redesigned, if necessary, to meet proper standards and specifications. Continued monitoring may need to be done, so long as local soil resistivity changes continue to occur. Proper grounding will also impact telecom equipment's resiliency to lightning strikes and erratic voltage/current surges occurring over electricity grids.

Annex 10 Alcatel-Lucent response to the buildings checklist

A prototype climate change adaptation checklist for one element of a telecommunications network: "*buildings*" is given in Annex 5. The following example shows how this checklist can be used in practice.

ICT buildings and HVAC

As stated in section 4.2.1, an important function of ICT buildings (such as data centres and central offices) is to maintain electronics at a safe operating temperature. Heating, ventilation and air conditioning systems (HVAC) play a key role in that regard, and should be designed and maintained to keep the ICT equipment within the temperature and humidity limits specified by the manufacturers.

Example

Climate adaptation risk assessment: ICT buildings and HVAC

Scope: Exchanges, base stations for mobiles, data centres, repeater stations, transmitter stations.

Risk assessment to climate extremes:

A1. Flood

A1(i) Do you have a list of buildings which are vulnerable to floods and a Plan of Action in event of flooding? Every building has a disaster recovery plan. Each plan details which actions to take depending on the nature of the accident, e.g. fire, in a lab. Our priority is to determine how we can continue to conduct business in a secure fashion.

A1(ii) Are any of your buildings near or on a slope which could subside?

A1(iii) Does your organization have measures in place to cope with extreme rainfall? (e.g. regularly inspect and clear drains)?

A2. Drought

A2(i) Do you have buildings which on land are liable to crack and become unsafe during an extended heat-wave? (e.g. brick buildings)

A2(ii) Do you have sufficient off-mains water to cope with extended drought? (e.g. ponds for use by fire pumps)? Yes, for example in France, we have reserve rainwater that can be used in case of a fire.

A3. Extreme heat

A3(i) Do you have ICT equipment operating in rooms with windows facing the sun?

A3(ii) Do you have blinds fitted in ICT equipment rooms with windows facing the sun? Yes

A3(iii) Are your air conditioning units serviced regularly? Yes

A3 (iv) Does the power load in the equipment room exceed the capacity of the air conditioning unit to remove the heat produced? Temperatures are monitored regularly and once maximums are reached, air conditioning is adapted. Temperature is constantly monitored.

A4. Extreme cold

A4(i) Do your roofs have adequate strength to withstand 100 year snow accumulation predictions?

A4(ii) Do your roofs slope? If so do you have protection against ice and snow melt causing local avalanche risking injury to passers by? We abide by local regulations pertaining to this subject.

A4(iii) Are the water supplies to your building adequately protected from freezing? To date, we have not had a problem with this issue.

A4(iv) Are buildings able to maintain an adequate working temperature during periods of extreme cold? Are heating systems for employee areas checked annually? Yes

A5. Extreme wind

A5(i) Are your building structures able to withstand increased wind loads? Yes, for example our location in Murray Hill, NJ was able to withstand Hurricane Sandy in 2012.

A5(ii) Are components in the roof likely to detach during expected increases in maximum wind? Are roof panels and or/all tiles securely fastened? See above example, Murray Hill, NJ.

A5(iii) Are any roof-mounted masts or solar panels able to withstand extreme winds? See above example, Murray Hill, NJ.

A6. Humidity control

A6(i) Do your HVAC systems maintain humidity in the range of 20%-80% in computer or telecommunications rooms to minimize the risk of static discharge or dew point being reached? Yes

A6(ii) Does the HVAC system enable 30% to 40% humidity in cold climates to maintain adequate comfort for employee areas? Yes

A6(iii) Does the HVAC system enable 50% humidity to be maintained in cold climates to maintain adequate comfort for employee areas? Yes

(In summer, indoor humidity levels should be kept below about 65% to minimize the potential for mould growth and below about 50% to minimize dust mites.)

A7. Biological risks (insect, rodent, foliage, disease) increase due to climate change

A7(i) Are there trees growing near the building which have roots which could undermine the structure?

Glossary

2G	2nd Generation mobile networks (e.g. GSM)
3G	3rd Generation mobile networks providing data rates of at least 200 kbit/s
4G	4th Generation mobile networks that conform to the ITU IMT Advanced standards
AEA	Atomic Energy Agency (UK)
AR4	The IPCC Fourth Assessment Report
AWG-KP	Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol
BCM	Business Continuity Management
BCP	Business Continuity Plan
CAF	Cancun Adaptation Framework
CAPEX	Capital Expenditure
CBD	United Nations Convention on Biological Diversity
CD	Compact Disk
CDM	Clean Development Mechanism
CMP	Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol
CO2e	Equivalent carbon dioxide
COP	Conference of the Parties
DEFRA	Department for Environment Food and Rural Affairs (UK)
DJF	December January February
DVD	Digital Versatile Disk
EA	Environment Agency (UK)
EC	European Commission
ERM	Enterprise Risk Management
ETSI	European Telecommunications Standards Institute
EU	European Union
FIT	1 Failure in 10 billion (10^9) hours
GDACS	Global Disaster Alert and Coordination System
GDP	Gross Domestic Product
GeSI	Global e-Sustainability Initiative
GHG	GreenHouse Gas
GWh	Gigawatt hours
HVAC	Heating, ventilation, and air conditioning
ICT	Information and Communication Technology
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change (IPCC)
IPTV	Internet Protocol TeleVision

IT	Information Technology
ITU	International Telecommunication Union
JJA	June July August
JRC	Joint Research Centre
LAN	local Area Network
LDC	least Developed Country
LCD	Liquid Crystal Display
M2M	Machine-to-Machine
M&E	Monitoring and Evaluation
NAP	National Adaptation Plan
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NWP	The Nairobi Work Programme on impacts, vulnerability and adaptation to climate change
Ofcom	Office of Communications (United Kingdom) - Regulator for telecommunications, media and broadcasting
PC	Personal Computer
PREP	Partnership for Resilience and Environmental Preparedness
PSI	Private Sector Initiative
R&D	Research and Development
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDH	Synchronous Digital Hierarchy
SIDS	Small Island Developing State
SME	Small to Medium Enterprise
TV	Television
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VFD	Variable Frequency Drives

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the adaptation of the ICT sector to climate change

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