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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Overview on adaptation to climate change for information and communication technology networks

ITU-T L-series Recommendations – Supplement 49

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Supplement 49 to ITU-T L-series Recommendations

Overview on adaptation to climate change for information and communication technology networks

Summary

Supplement 49 to ITU-T L-series Recommendations provides an updated overview of existing Recommendations and Technical Standards on the topic of adaptation to climate change for ICT networks.

In this context, adaptation has to be understood to have a double meaning:

1) How ICT can help other areas (e.g., transport, buildings) to adapt to climate change challenges and effects;

2) How ICT networks themselves have to be designed and implemented in an ever more resilient way, in order to face climate change's effects (e.g., flooding, stronger winds).

This Supplement takes into account also the work already done on the topic of adaptation to climate change for ICT networks at other Workshops and in academia.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Climate change, climate change adaptation, global warming, greenhouse gas (GHG), green house gases, ICT network, information and communication technology (ICT), resilience.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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Introduction

Global emissions of greenhouse gases (GHG) are still on the rise and their concentration in the atmosphere will continue to increase over the coming decades, with average global temperatures climbing. As the climate heats up, it will bring with it all kinds of risks, with more frequent extreme weather events such as heatwaves, droughts and floods, coastal erosion from rising sea levels; the impacts will affect everyone.

Adapting to climate change is, therefore, necessary, with actions to prepare for and adjust to both the current effects of climate change and the predicted impacts in the future, in order to protect nature, people and livelihoods.

ITU, the UN specialized agency for ICTs, is contributing to addressing climate change by using digital technologies and is taking the necessary steps to deepen the global understanding on the relation between ICTs, digital technologies and climate change.

Several initiatives are ongoing, at a worldwide level, to face the challenges of climate change, which is now a global priority. The Intergovernmental Panel on Climate Change (IPCC) has issued, for example, its Sixth Assessment Report [b-IPCC-1]. The annual UN Climate Change Conference of the Parties (COP) was held at the end of 2021, to bring on coordination on climate change initiatives from different stakeholders [b-COP]. The International Telecommunication Union (ITU), World Meteorological Organization (WMO) and UN Environment Programme (UNEP) co-organized a third workshop to highlight uses of artificial intelligence (AI) for supporting the detection, forecasting, and communication of natural hazards and disasters [b-ITU-WMO-UNEP].

Supplement 49 to ITU-T L-series Recommendations

Overview on adaptation to climate change for information and communication technology networks

1 Scope

Climate change is creating a need to develop or update Recommendations on the adaptation of information and communication technology (ICT) networks to new environmental constraints, in order to realize more resilient networks able to provide service continuity under these new external conditions.

ICT and digital solutions can also help other networks (e.g., water, electricity, gas, transportation) and communities (e.g., buildings) to adapt to climate change effects.

This Supplement provides an updated overview of existing Recommendations and Technical Standards on the topic of adaptation to climate change for ICT networks.

2 References

None.

3 Definitions

The terms used in this Supplement are defined elsewhere in the referenced documents.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AI Artificial Intelligence

COP Conference of the Parties

GHG Greenhouse Gas

GIS Geographic Information Systems

ICT Information and Communication Technology

RS Remote Sensing

5 Conventions

None.

6 Overview on adaptation to climate change for ICT networks

The following clauses provide an overview of existing Recommendations and Technical Standards on the topic of adaptation to climate change for ICT networks. The work already done on this topic in other forums and workshops and in academia, is taken into account.

As a general example on this topic, in 2021 in the United States of America, climate change has led to 20 meteorological disasters, with more than USD 1 billion damages for each of them, for a total amount of USD 145 billion of total economic losses and 688 deaths [b-NOAA].

The following Figure 1 gives a graphical exemplification of this.

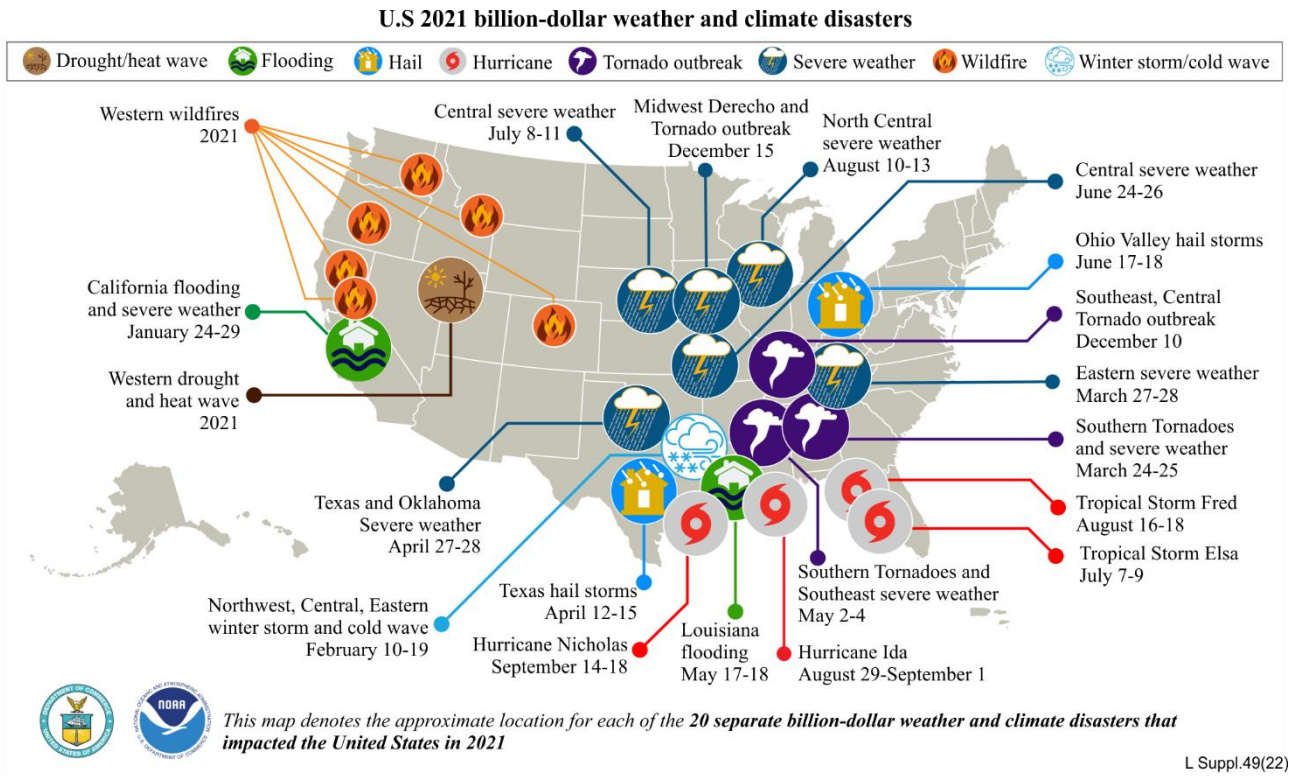

Figure 1 – Example of natural disasters in the USA in 2021

Power outages from severe weather have doubled over the past two decades across the USA, as a warming climate stirs more destructive storms that cripple broad segments of the nation's ageing electrical grid, according to an Associated Press analysis of government data [b-AP].

Forty states are experiencing lengthy outages – and the problem is most acute in regions seeing more extreme weather, US Department of Energy data show. The blackouts can be harmful and even deadly for the elderly, disabled and other vulnerable communities [b-AP].

6.1 Recommendations, Technical Standards and Technical Reports

The following references from standardization organizations are available on the topic of adaptation to climate change for ICT networks:

1) Recommendation ITU-T L.1500 (2014), *Framework for information and communication technologies and adaptation to the effects of climate change*.

2) Recommendation ITU-T L.1501 (2014), *Best practices on how countries can utilize ICTs to adapt to the effects of climate change*.

3) Recommendation ITU-T L.1502 (2015), *Adapting information and communication technology infrastructure to the effects of climate change*.

4) Recommendation ITU-T L.1503 (2016), *Use of information and communication technology for climate change adaptation in cities*.

5) Recommendation ITU-T L.1504 (2016), *ICT and adaptation of agriculture to the effects of climate change*.

6) Recommendation ITU-T L.1505 (2018), *Information and communication technology and adaptation of the fisheries sector to the effects of climate change*.

7) Recommendation ITU-T L.1506 (2018), *Framework of climate change risk assessment for telecommunication and electrical facilities*.

8) Recommendation ITU-T L.1507 (2019), *Use of ICT sites to support environmental sensing*.

9) ITU-T L.1500 Supplement 24 (2016), *Overview of climate change effects and possible impacts*.

10) ITU-T FG-DR&NRR – Focus Group on Disaster Relief Systems, Network Resilience and Recovery (2014), *Promising technologies and use cases – Part I, II and III*.

In the following clauses, the main outputs, conclusions and results from each of these references is highlighted.

6.1.1 Recommendation ITU-T L.1500, Framework for information and communication technologies and adaptation to the effects of climate change

This Recommendation describes a framework for using ICTs for adaptation to the effects of climate change. This Recommendation defines the scope of the subsequent three Recommendations (i.e., Recommendations ITU-T L.1501, L.1502, and L.1503) that have been published within this framework.

This Recommendation does not provide strategies or best practices for climate change adaptation as these are provided in the Recommendations developed within the framework.

The following Figure 2, taken from L.1500, shows a framework on ICT and climate change adaptation.

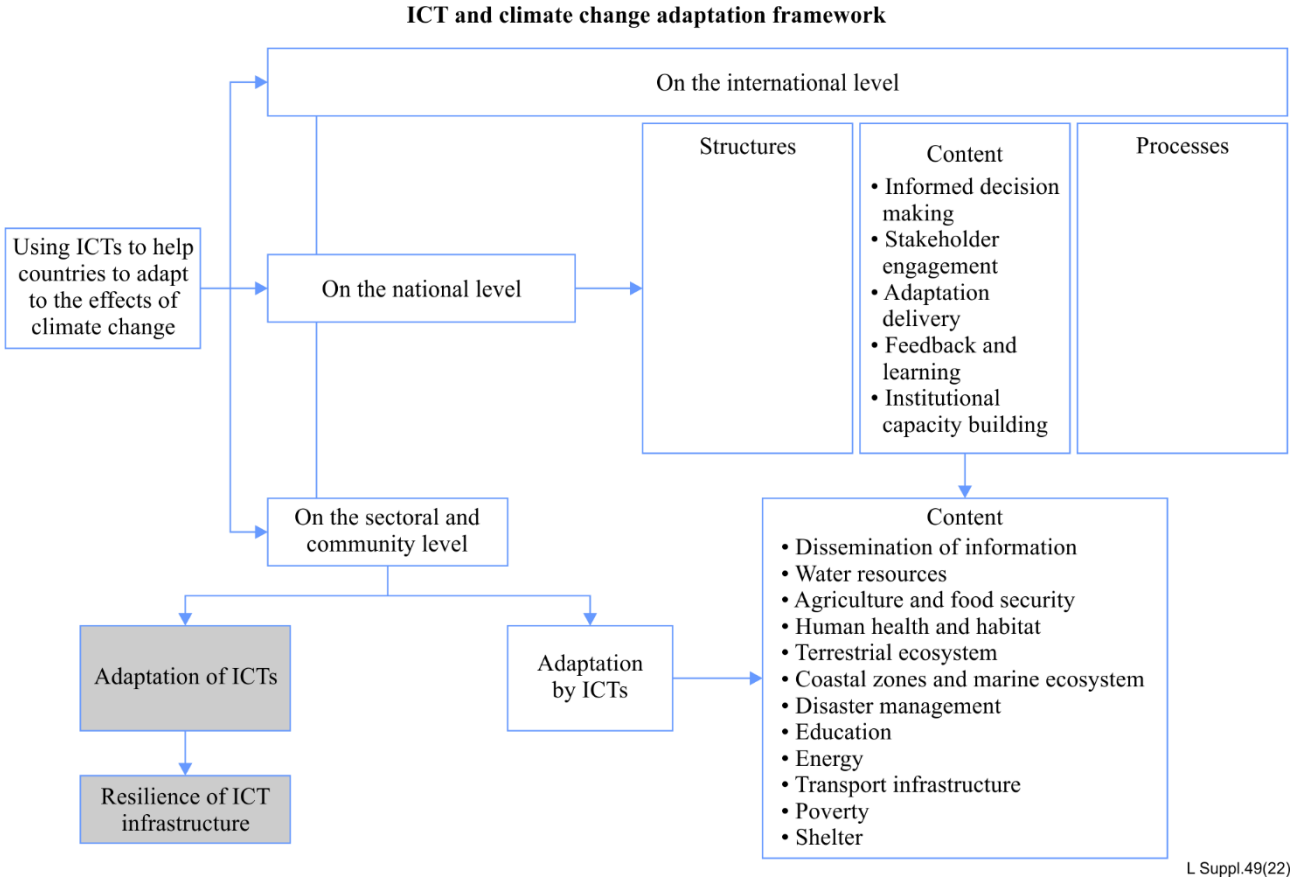

Figure 2 – ICTs and a framework for adaptation to climate change

6.1.2 Recommendation ITU-T L.1501, Best practices on how countries can utilize ICTs to adapt to the effects of climate change

This Recommendation considers how countries can utilize ICTs to adapt to the effects of climate change. It provides a framework for countries on how to integrate ICTs into their national strategies for adaptation to climate change. The Recommendation first provides an overview of climate change adaptation and adaptation actions in the country context. It then highlights the role of ICTs in climate

change. A checklist is provided as an instrument for policymakers to ensure that they have the necessary prerequisites to adapt the suggested framework in their national legislations and enabling them to assess the adoption and implementation of the framework.

Figure 3 gives an example of a multilevel framework for countries to integrate ICTs into their national climate change adaptation strategies.

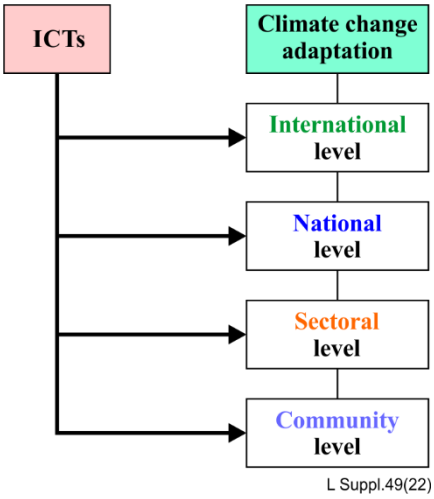

Figure 3 – Relation between ICTs and climate change adaptation

6.1.3 Recommendation ITU-T L.1502, Adapting information and communication technology infrastructure to the effects of climate change

This Recommendation describes how information and communication technology (ICT) can adapt to or may be adapted to cope with the effects of climate change. While it is clear that ICT can provide effective solutions for adaptation actions, ICT installation, equipment and infrastructure themselves are also vulnerable to climate change. Rising temperature, extreme rainfall, flooding, landslides, extreme winds, lightning, humidity and drought each have direct and indirect consequences on ICTs. Hence, there is an urgent need to upgrade ICT infrastructure to adapt to the effects of climate change.

The term "ICT infrastructure" includes the telecommunication network and its elements such as terrestrial cables, submarine cables, wireless antennas, satellite networks, towers, telecom offices, data centres and customer premises equipment.

Figure 4 shows a breakdown of the most destructive natural disasters based on a survey conducted among ITU membership [b-ITU-T L.390].

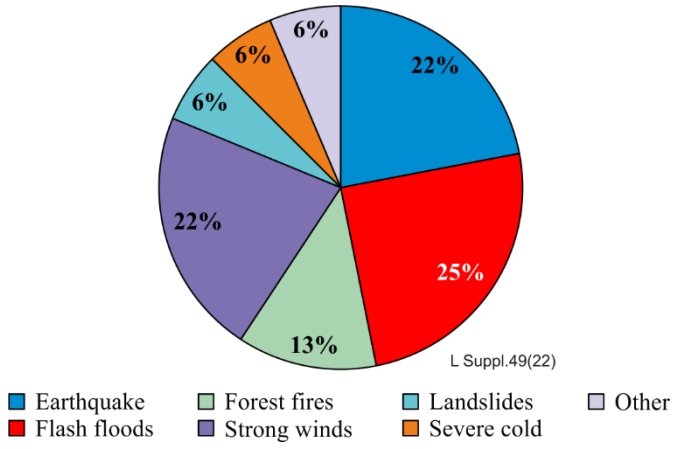

Figure 4 – Most destructive natural disasters

Recommendation ITU-T L.1502 also provides a checklist for identifying the effects of climate change on ICTs and classifying their severity (Figure 5). Network planners may use this as a guide to the identification and minimization of effects to ensure the survivability of the network under extreme weather conditions.

Effect / Infrastructure	Temperature rise	Humidity	Wind loading	Sea level rise	Rainfall	Floods	Land slides	Snow and ice fall	Lightning strikes	Species damage
Tower	L	L	H	M	L	H	M	L	H	L
Antenna	M	M	H	L	H	M	M	H	H	L
Electronics	H	H	L	L	M	L	L	L	H	L
Equipment room	M	M	L	H	H	H	L	L	H	L
Fibre optic	L	L	L	L	L*	L	H*	L	L	M
Twisted pair and coaxial cables	L	L	H	M**	M	H	H**	M	H	H
Grid supply	L***	L	L	M	M	H	M	M	H	M
Standby generators	L	L	L	M**	M	H	H**	H	M	L
Satellite earth stations	L	L	H	M	H/M	M	M	H	H	L
HVAC	H	M	L	L	L	L**	L	L	L	L

L: Low; M: Moderate; H: High

* The fibre optic installation should take note of the risk of landslides and heavy rainfall; their respective installation should avoid areas with a high risk of landslides.

** Location dependent.

*** Demands on grid supply may increase beyond its capacity when temperatures rise due to increased requirements for cooling.

Figure 5 – Checklist of climate change effects and their impact on ICT infrastructure components

6.1.4 Recommendation ITU-T L.1503, Use of information and communication technology for climate change adaptation in cities

This Recommendation identifies the impacts of climate change in cities and highlights how cities can utilize ICTs to accelerate their adaptation actions, including how to adapt ICT infrastructure to the effect of climate change in cities, the role of ICT in enhancing disaster risk management, city resilience and adaptive capacity, and informing decision making. An ICT-based framework for climate change adaptation is included to assist policy makers in developing effective adaptation strategies and building resilient cities. A framework for engaging key stakeholders involved in urban climate change adaptation strategies is also provided. A checklist is included to assess the integration of ICTs into an urban climate change adaptation plan, and to identify aspects that could be strengthened in local adaptation planning and response. In addition, a series of best practices are presented in the standard to promote solutions that are proven to be useful and successful and facilitate global learning on this important topic.

6.1.5 Recommendation ITU-T L.1504, ICT and adaptation of agriculture to the effects of climate change

Recommendation ITU-T L.1504 provides a description of how the use of information and communication technology (ICT) can help sustain the agricultural sector in the event of poor yields or disasters triggered by climate change. The possible impacts of climate change on agriculture and farming communities are described. This is followed by an outline of what measures are needed to adapt the sector and how ICT can play a role in this. The Appendices share some examples of best practices in different countries with details of specific ICT implementations. Examples are given from different countries of best practices on the use of ICT systems and tools to adapt the agricultural sector.

6.1.6 Recommendation ITU-T L.1505, Information and communication technology and adaptation of the fisheries sector to the effects of climate change

Climate change will affect both fish stocks and their habitats. Rising or falling temperatures will influence the abundance, migratory patterns and mortality rates of wild fish stocks and determine what species can be farmed in specific regions. Climate change can lead to changes in the volume of water in rivers and lakes. The composition of water bodies can affect the species and quantities of fish stocks. These climatic effects on fish stocks will have social and economic consequences for people dependent on fisheries and aquaculture ranging from fisheries workers to coastal communities as well as to the consumers of fish.

Recommendation ITU-T L.1505 includes a review of the effects of climate change on fisheries and fishing communities. It recognizes the need for adaptation and for the use and dissemination of relevant innovative techniques. It explores adaptation plans and the potential role of information and communication technologies (ICTs) in supporting the adaptation of the fisheries sector to cope with the effects of climate change. Examples of best practices from different countries on the use of ICT systems and tools to adapt the fisheries sector are also provided in this Recommendation.

6.1.7 Recommendation ITU-T L.1506, Framework of climate change risk assessment for telecommunication and electrical facilities

Recommendation ITU-T L.1506 describes the framework for assessing climate change risk to telecommunication and electrical facilities. The framework consists of a risk assessment methodology and considerations for applying the defined methodology. The methodology specified in this Recommendation provides a climate change risk assessment that integrates multiple climate change risk factors into a single metric and shows the assessment result from an overall perspective.

It should be noted that the methodology defined in this Recommendation is not intended for comparison between different organizations but is mainly targeted at use for self-assessment purposes.

6.1.8 Recommendation ITU-T L.1507, Use of ICT sites to support environmental sensing

Mitigating and adapting to climate change are global issues and developing solutions to enable effective adaptation and early warning becomes important. One of the key aspects for developing the innovative solutions is the availability of highly stable environmental monitoring data. The meteorological organizations work on realizing the stable and fine grained collection of global environmental conditions. To achieve this goal, it is necessary to deploy a large number of environmental sensing stations, which requires a considerable amount of effort. Information and communication technology (ICT) sites are good candidates to resolve such issues due to their global distribution, reliable power, network communications and maintenance as well as the availability of poles and towers to host various environmental sensors.

Recommendation ITU-T L.1507 presents a set of rules for installing the environmental sensing system on ICT sites to utilize them as environmental sensing stations, focusing on collecting environmental data utilizing ICT sites and infrastructure. This Recommendation presents a set of rules

for installing the environmental sensing system on ICT sites in order to utilize the ICT sites as environmental sensing stations. This Recommendation covers the following:

– General architecture of an environmental sensing system;

– Requirements for installing environmental sensing system on ICT sites;

– Deployment use cases.

The architecture of an environmental sensing system for ICT sites is shown in Figure 6.

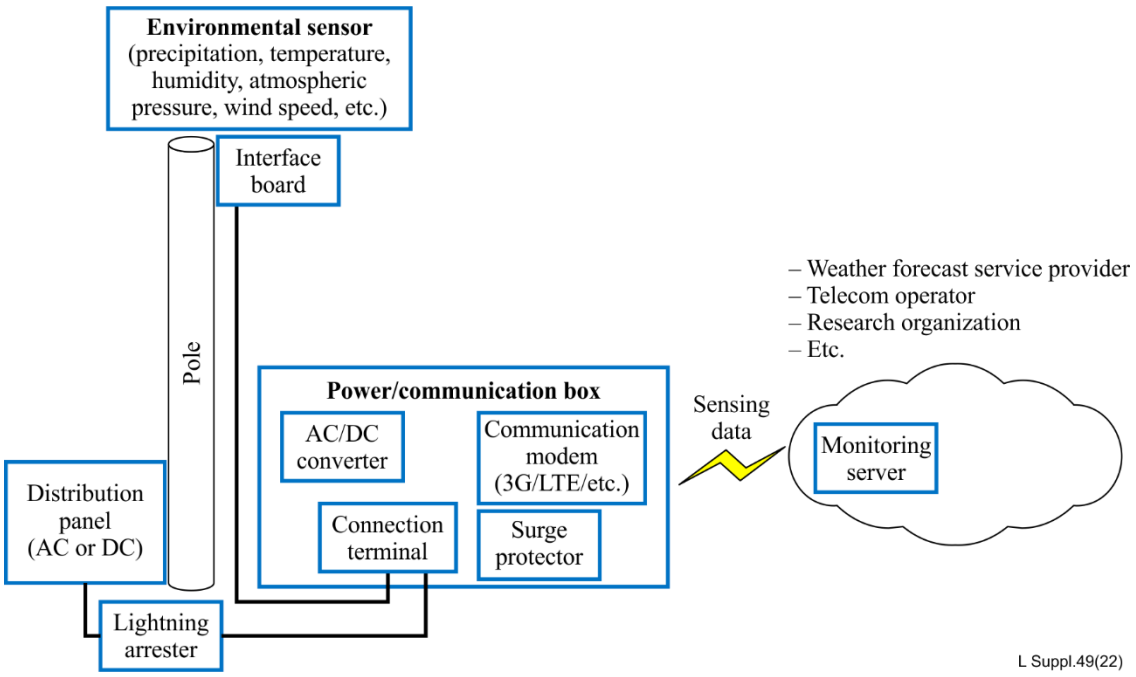

Figure 6 – Architecture of environmental sensing system for ICT sites

6.1.9 ITU-T L.1500 Supplement 24, Overview of climate change effects and possible impact

A historic treaty to combat climate change and unleash actions and investment towards a low carbon, resilient and sustainable future was agreed by 195 nations in Paris on 12 December 2015. The Paris Agreement for the first time brings all nations into a common cause based on their historic, current and future responsibilities. The universal agreement's main aim is to keep the global temperature rise this century well below 2 degrees Celsius and to drive efforts to limit the temperature increase even further to 1.5 degrees Celsius above pre-industrial levels. Additionally, the agreement aims to strengthen the ability to deal with the impacts of climate change. The Paris Agreement and the outcomes of the UN climate conference (COP21) at which it was signed cover all the crucial areas identified as essential for a landmark conclusion:

– Mitigation – reducing emissions fast enough to achieve the temperature goal;

– A transparency system and global stock-take – accounting for climate action;

– Adaptation – strengthening the ability of countries to deal with climate impacts;

– Loss and damage – strengthening the ability to recover from climate impacts;

– Support – including finance, for nations to build clean, resilient futures.

Countries will submit updated climate plans – called nationally determined contributions (NDCs) – every five years, thereby steadily increasing their ambition in the long term. Climate action was taken forward in the period before 2020. Countries will continue to engage in a process on mitigation opportunities and will place added focus on adaptation opportunities.

In view of such important international developments, Supplement 24 acquires a special relevance, as it aims at offering a better understanding of climate change effects that could assist in the

development of national reports and Recommendations related to adaptation, as well as being used as a reference to relevant decision makers and for other Recommendations.

Supplement 24 identifies and describes climate change effects on the ICT sector and other sectors. It also provides a general introduction to identified climate change effects and describes the possible impacts of climate change effects on the ICT sector, human behaviours, human health and the energy sector.

Supplement 24 provides an overview on the effects of climate change and climate adaptation and describes a broad range of climate change effects and their impacts, including climate change effects related to wind, rain, air temperature, sea temperature, thunder, snow, ocean acidification and drought. It also provides an overview of the possible impacts of climate change on several key sectors, including the ICT sector, the health sector, human behaviour and the energy sector. In addition, it serves as a reference to other relevant Recommendations.

As an example of Supplement 24's content, Figure 7 shows sea level changes observed by NASA.

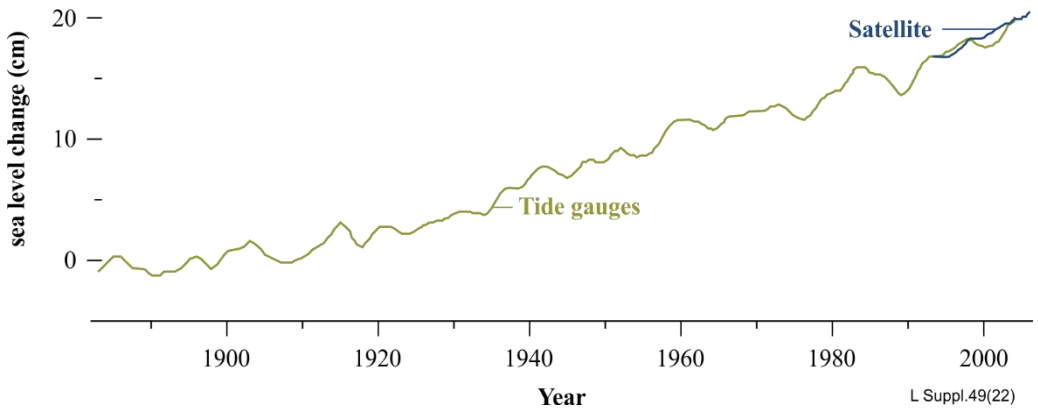

Figure 7 – Sea level change with recent satellite observations by NASA

6.1.10 FG-DR&NRR – Focus Group on Disaster Relief Systems, Network Resilience and Recovery

The ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR) was established in January 2012, as a Japanese government initiative, to study international standardization related to disaster response by utilizing information and communication technology (ICT). By May 2014, the FG-DR&NRR had held a total of 11 meetings (including two virtual conferences) and developed eight deliverables. Detailed information about this Focus Group and related technical reports are available [ITU-FG-DR&NRR].

A report of the results of the final FG-DR&NRR meeting is also available [b-Araki].

An integrated view of networks supporting disaster relief services is shown in Figure 8.

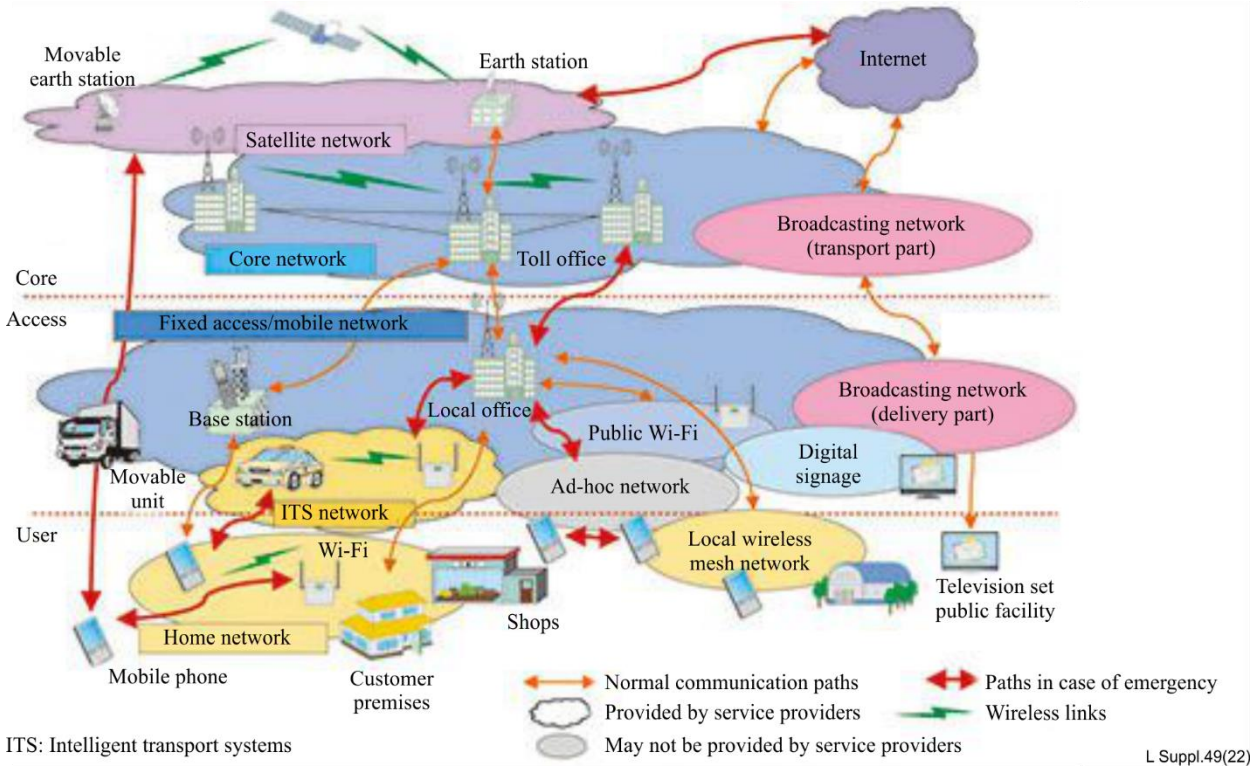

Figure 8 – Integrated view of networks supporting disaster relief services

6.2 Workshops and academia

The references available in this clause originate from the work of workshops and academia and gives further information on the topic of adaptation to climate change for ICT networks. These references are, obviously, a subset of the ones available at worldwide level and are given as examples that can be further expanded in the future. Currently, the following refences are pointed out:

1) ITU Workshop on Using Information and Communication Technologies (ICTs) for Climate Change Adaptation (Naples, Italy, 21 October 2013) [b-ITU-1].

2) ITU-T publication "Resilient pathways: the adaptation of the ICT sector to climate change" (2014) [b-ITU-2].

3) University of Genova (Italy), working on engineering for natural risk management, with a campus located in Savona (Italy) focusing on remote sensing and electromagnetic techniques for risk monitoring [b-Genova].

In clauses 6.2.1–3. the main outputs, conclusions and results from each of these references will be highlighted.

6.2.1 ITU Workshop on Using Information and Communication Technologies (ICTs) for Climate Change Adaptation

ITU organized a Workshop on Using ICTs for Climate Change Adaptation on 21 October 2013 in Naples, Italy. Experts from ITU-T, Telefónica and KPN gathered to discuss how the integration of ICTs and ICT standards in national adaptation policies can help countries to develop long term, creative and effective adaptive strategies, providing support for information gathering, decision making, implementation and evaluation processes.

The workshop highlighted the ITU standards supporting the use of ICTs for climate adaptation as well as ITU publications on climate adaptation. It also highlighted how the ICT sector is supporting adaptation for climate change, including the introduction of relevant programmes and applications.

Climate change is a complex and dynamic challenge. In order to reduce the impacts of climate change and increase resilience to future threats, developing countries must implement innovative strategies to adapt to changing climatic conditions.

By providing useful tools to monitor, record and analyse information about the changing climate and environment, ICTs can help countries in strengthening adaptive capacity and building resilience.

This workshop pointed out also the importance of integration of ICTs and ICT standards in national adaptation policies, in order to help countries to develop long term, creative and effective adaptive strategies, providing support to information-gathering, decision-making, implementation and evaluation processes.

IPCC definition of climate change adaptation was provided, as follows: "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" [b-IPCC-2].

According to UNFCCC (United Nations Framework Convention on Climate Change), ICT tools "can be critical in predicting, identifying and measuring the extent of climate change; as well as in the development of effective response strategies to adapt to negative effects of climate change in sectors such as agriculture, employment, technology transfer and energy, among others".

The workshop pointed out also that:

- There is not a single ICT solution, but flexible, combined approaches that prioritize the most appropriate technologies for the local context;
- The key ICT functions are observation, analysis, planning, implementation and management, capacity building and networking;
- The need for design and implementation of long-term strategies that integrate issues of ICT and climate change content, structures and process;
- The need to continue to raise awareness on ICTs' adaptation and mitigation potential.

In Figure 9, taken from this workshop, an example is given of how ICT services can help in the fields of climate change and energy efficiency, to promote products and services with the potential and capacity to lead customers to be more efficient.

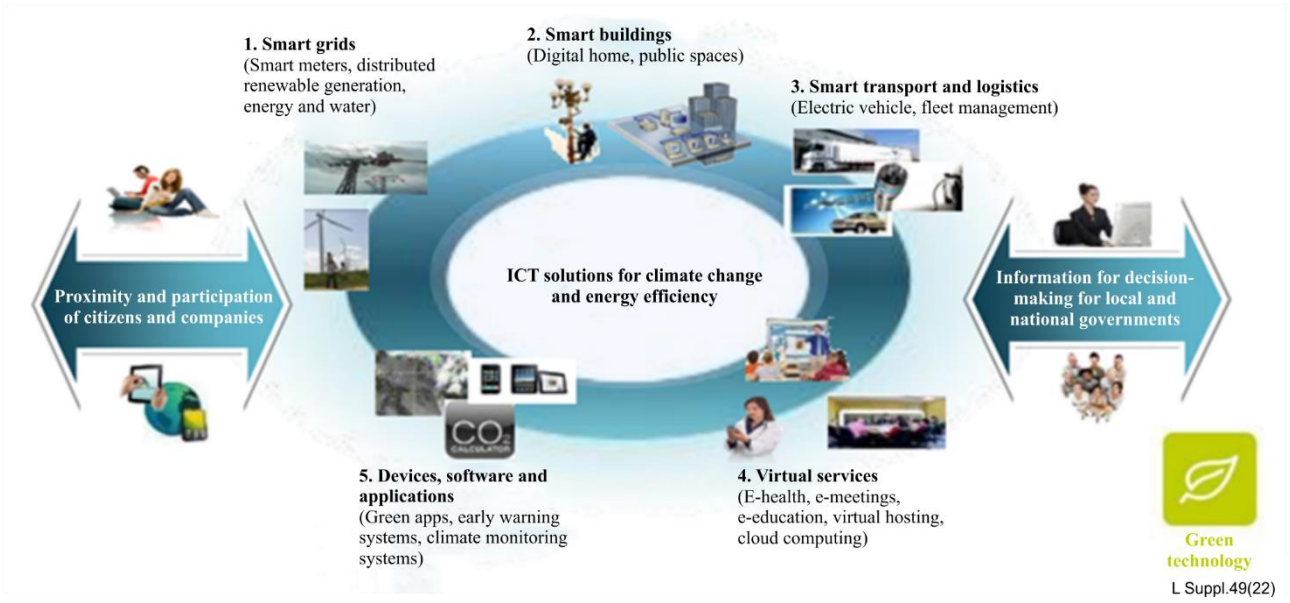

Figure 9 – Example of green ICT services for climate change and energy efficiency

More information on the workshop can be found online [b-ITU-1].

6.2.2 ITU-T publication – Resilient pathways: the adaptation of the ICT sector to climate change

The ITU report on resilient pathways suggests that their adoption for climate change adaptation requires going beyond generic contingency and risk management measures. It entails the ICT sector identifying and implementing specific actions to manage current threats yet responding flexibly and adjusting 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 reducing the sector's vulnerability to climate change impacts, but also to improving its preparedness and response capacity to future, as yet uncertain change.

Figure 10 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.

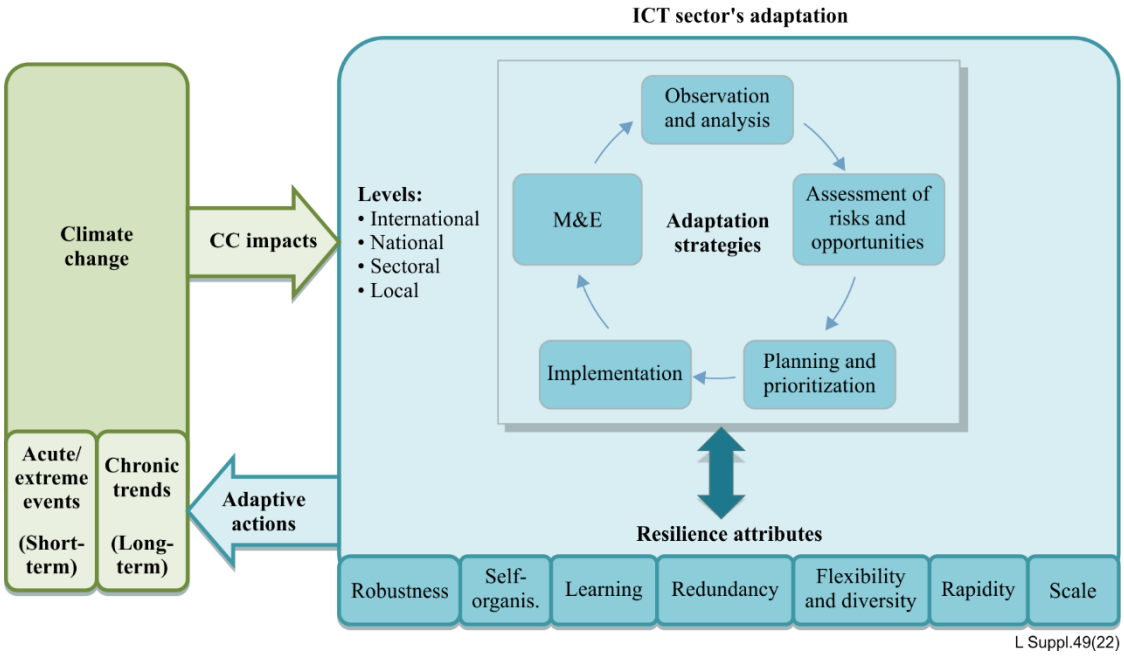

Figure 10 – ICT sector's adaptation framework: resilient pathways

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

- Improvements in service coverage in locations that are rural and that are vulnerable 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 and 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 system diversity and interoperability, including virtualization, server networks and system 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 the Resilient Pathways 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 longer-term risks and opportunities presented by climate change, while ensuring that international, national, sectoral and local stakeholders join efforts towards the achievement of a better, more sustainable future.

More information on the workshop can be found online [b-ITU-2].

6.2.3 University of Genova (Italy)

The University of Genova (Italy) is working, like many other research institutions around the world, on engineering for natural risk management (specific course details available [b-Genova]), with a campus located in Savona (Italy) focusing on remote sensing and electromagnetic techniques for risk monitoring.

Specifically, the research fields under study and development are:

- electromagnetic techniques for monitoring structures and protecting systems;
- remote sensing of natural disasters;
- analysis of remotely observed images.

7 Resilient digital technologies and practical solutions emerging from the above references

The following digital technologies and practical solutions have been identified and are seen as potential resilient applications for the ICT sector and its role in supporting other sectors to adapt to the effects of climate change.

1) The cover Recommendation series L.1500 is hereby provided for technologies on adaptation to climate change. This is the basis for other outputs referred to in this Supplement.
2) Recommendation ITU-T L.1501 identifies a framework for ICTs and climate change adaptation, including content, structure, and process, and a checklist of indicators for climate change adaptation. It is recommended to use this Recommendation at the country level and across all relevant sectors.

3) Recommendation ITU-T L.1502 identifies a checklist for climate change effects and their impact on ICT infrastructure components. It is recommended to use this Recommendation at the country level and in the ICT sector.

4) Recommendation ITU-T L.1503 identifies a framework for the integration of ICTs into urban climate change adaptation plans. The resilient technologies discussed include satellite-based technology and disaster early warning networks. It is recommended to use this Recommendation at the city level.

5) Recommendation ITU-T L.1504 identifies geographic information systems (GIS), remote sensing (RS), mobile, computing modelling, early warning systems, sensing networks and information processing systems as resilient digital technologies. It is recommended to use this Recommendation in the agricultural sector.

6) Recommendation ITU-T L.1505 identifies ICT systems, network, forecasting and early warning systems, and wireless sensor network as the key resilient technologies. It is recommended to use this Recommendation in the fisheries sector.

7) Recommendation ITU-T L.1506 identifies a framework for self-assessing climate change risk to telecommunication and electrical facilities. It is recommended to use this Recommendation for this kind of assessment.

8) Recommendation ITU-T L.1507 provides a set of rules for installing an environmental sensing system on ICT sites to utilize them as environmental sensing stations, focusing on collecting environmental data utilizing ICT sites and infrastructure. It is recommended to use this Recommendation in the deployment of environmental sensing stations.

9) The ITU-T publication "Resilient pathways: the adaptation of the ICT sector to climate change" describes ICT sector adaptive actions and technologies that can be adopted for ICTs for mitigating the negative effects of climate change and being more resilient.

8 Use of this Supplement

Countries are encouraged to make use of this Supplement in identifying and applying resilient sustainable digital technologies for adaptation to climate change. This will help in avoiding duplication and repeating research on already established technologies.

9 Need to update and improve existing Recommendations

Following changes in technology, it is recommended that the referenced ITU publications on adaptation to climate change, such as those indicated in clause 6, be updated wherever and whenever necessary.

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