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Use of information and communication technology for climate change adaptation in cities

Recommendation ITU-T L.1503

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ITU-T L-SERIES RECOMMENDATIONS

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For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.1503

Use of information and communication technology for climate change adaptation in cities

Summary

This Recommendation is aimed at a broad audience of stakeholders interested in information and communication technologies (ICTs), climate change adaptation, and smart sustainable cities (SSCs), including city decision-makers and planners. Urban stakeholders, including mayors and city planners, are invited to consider novel approaches to sustainability by integrating the use of ICTs in their climate change adaptation strategies and policies. The following are the key steps:

- assess climate change risks and vulnerabilities:
- develop an action plan;
- identify the role of ICTs and infrastructure in the adaptation plan;
- implement adaptation actions;
- monitor and evaluate adaptation actions using ICT.

Climate change may negatively impact urban ICT infrastructure and the provision of key public services (e.g., health, water supply and sanitation, energy provision, waste management, mobility, urban planning and food security), which are all crucial dimensions for sustainable development and are becoming heavily dependent on ICTs for their operation.

The main areas where ICTs can support urban adaptation policies are:

- the development of effective climate-related disaster risk management (DRM) programmes in cities;
- the early stage of urbanization planning, by providing high quality data and information to help city planners to cope with climate change and build resilient cities;
- facilitation of communication and exchange of information between the relevant stakeholders involved in climate change adaptation for informed decision-making.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Adaptation, cities, climate change, ICT, information and communication technology, infrastructure, telecommunications.

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FOREWORD

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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.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

Climate change is a serious challenge for cities around the world. [b-IPCC, 2014] indicates 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."

Although rapid urban growth is often seen as contributing to climate change and environmental degradation, cities forming the epicentre of urban growth can also be highly vulnerable to the effects of climate change. Climate change threatens to increase vulnerability, undermine economic gains, hinder social and economic development, and worsen access to basic services and the quality of life of citizens. Therefore, it is imperative for cities to adapt to climate change.

Information and communication technologies (ICTs) have the potential to play a leading role in climate change adaptation. They can help to enhance and improve climate change adaptation strategies in cities.

This Recommendation responds to the need to explore how ICTs can support urban adaptation to climate change and for the integration of ICTs in climate change adaptation programmes in cities.

Climate change adaptation strategies could receive a fundamental boost if national, regional and local governments choose to harness and utilize the transformational potential of ICTs.

This Recommendation recognizes that the impacts of climate change in cities could be significant. This is because cities contribute significantly to the gross domestic product (GDP), since economic activities are centred in and around them for every nation. Climate change could disrupt economic activities and services, damaging important sectors and services, including water supply and sanitation, agriculture, urban planning, mobility, building infrastructure, energy, health, waste management and food security.

This Recommendation identifies three enabling roles of ICTs for climate adaptation in cities. Using ICTs can: first, enhance disaster risk management (DRM); second, improve city resilience and adaptive capacity; and third, inform adaptation decision-making. For these three roles, this Recommendation provides detailed examples, drawing from a wide and prolific range of country and city experience.

In order to guide countries in their overall adaptation planning and implementation, a national adaptation plan (NAP) process has been put in place under the United Nations Framework Convention on Climate Change (UNFCCC). The NAP process allows countries to develop their adaptation activities in a coherent and strategic manner. Based on the NAP process, countries can reduce their vulnerability to the impacts of, and build adaptive capacity and resilience to, climate change. This process also helps to facilitate the integration of climate change adaptation into the already existing development planning processes within all the sectors in a city.

This Recommendation gives a general overview of the enabling role of ICTs in climate change adaptation plans and policies. It suggests a guiding framework to support cities in the challenging process of adapting to climate change.

This Recommendation also provides several case studies from developed and developing countries that could encourage other countries to develop climate change adaptation plans along similar lines.

Recommendation ITU-T L.1503

Use of information and communication technology for climate change adaptation in cities

1 Scope

This Recommendation identifies the impacts of climate change in cities and explains why cities need to adapt to its harmful effects. The roles ICTs can play in helping cities to adapt to climate change are presented. An ICT-based framework for climate change adaptation is included to assist policy makers in developing effective adaptation strategies and building resilient cities. Key stakeholders involved in urban climate change adaptation strategies are identified. 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.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

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

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 adaptive capacity [Glossary A–D of b-IPCC, 2007]: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

3.1.2 climate change [b-ITU-T L.1500]: 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 forces, 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 Recommendation, either definition may be suitable depending on the context of analysis.

3.1.3 climate change adaptation [b-ITU-T L.1500]: 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.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 smart sustainable city: An innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.

3.2.2 snowpack: A mass of lying snow that is compressed and hardened by its own weight. Snowpack forms from layers of snow that accumulate in geographic regions and high altitudes where the climate includes cold weather for extended periods during the year.

3.2.3 vulnerability to climate change: Vulnerability to climate change is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change. Vulnerability can be described using the following components: exposure, sensitivity and adaptive capacity.

NOTE – Definition based on 19.1.2.1 of [b-IPCC, 2007].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CB	Cell Broadcast
DRM	Disaster Risk Management
EWS	Early Warning System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GOS	Global Observing System
GPS	Global Positioning System
ICT	Information and Communication Technology
m2m	machine-to-machine
NAP	National Adaptation Plan
NGO	Non-Governmental Organization
SMS	Short Message Service
USN	Ubiquitous Sensor Network

5 Conventions

None.

6 Adaptation of ICT infrastructure

6.1 Climate change adaptation in cities

Cities have started to address climate change by making efforts to reduce their emissions, putting in place several mitigation actions, such as sustainable transport strategies, waste management systems, establishing building codes or by promoting enhanced use of renewable energy. However, greenhouse gas (GHG) emissions continue to rise and cities are starting to feel the effects of climate change, evidencing the need for them to adapt to both current and future manifestations [b-UN-Habitat, 2012].

Clause 6.2 explores the main climate change risks, vulnerabilities and impacts that cities are facing, and will likely face in the foreseeable future. The analysis also addresses, in general terms, how cities are adapting to these risks and vulnerabilities, to provide a basis for an understanding of how cities can apply ICTs to better adapt to climate change.

6.2 Climate change risks, vulnerabilities and impacts in cities

There is an increasing recognition of the potential impacts of climate change in cities. Cities contribute to a large portion of a country's gross domestic product (GDP), therefore they are the dominant hubs of economic activities for every nation [b-Hallegate, 2011]. Climate change may affect urban economic activities and services, thereby damaging important sectors and services, including water supply and sanitation, agriculture, urban planning, mobility, building infrastructure, energy, health, waste management and food security.

Urban sectors are interconnected, and therefore, a failure in one sector (e.g., in the case of extreme weather events) could have a domino effect on other urban sectors and lead to an overall economic loss for a country or region [b-GTZ, 2009]. Studies suggest that windstorms and floods that took place in Asia between 1996 and 2005 caused over 70 000 deaths, with an estimated economic loss of around USD 190 billion. A large part of this loss is due to the lack of resilient and adequate infrastructure, including ICT infrastructure.

Similarly, rapid urbanization and population growth can worsen the impacts of climate change in cities. The United Nations Department of Economic and Social Affairs (UNDESA), has estimated that by 2050, about 70% of the world's population is expected to live in urban areas and over 60% of the land projected to become urban by 2030 is yet to be built. This high concentration of population and economic activity makes cities particularly vulnerable to climate change [b-UNDESA, 2014].

The effects of climate change will be felt by cities with varying degrees of intensity. Evidence from the field indicates that climatic changes, such as variation in rainfall or temperature patterns and sea level rise, are having an impact on development dimensions like agricultural production, food supply, water supply, health and disease proliferation in cities. Cities in both developed and developing countries are vulnerable to the effects of climate change. Cities located in developing countries are particularly susceptible due to their limited resources and capacity to adapt and recover from climatic extreme events.

Climate change impacts in cities also depend on their geographical location. For instance, low elevation coastal zones will face the combined threats of sea level rise and storm surges, while cities in hot climates may be affected by longer and more severe heat waves. Ultimately, cities located in port or coastal lines and inland cities are and will be affected by climate change.

Cities are the main engine for growth and development. They drive all national economies and generate substantial wealth. Any abrupt disruption that can occur has the potential to negatively affect urban productivity with impacts on public services and wealth. For example, if European economic hubs such as London, Paris or Rotterdam experience climate related problems, Europe's economy and quality of life can be affected [b-EEA, 2012]. Moreover, climate change impacts could also hamper the ability of developing nations in achieving the Millennium Development Goals [b-UN, 2016a] or working towards the Post 2015 Development Agenda [b-UN, 2016b]. The impacts of climate change may also raise barriers to overcoming poverty and marginalization in urban areas [b-ITU, 2012a]. As such, it is essential that cities take the required action to strengthen their infrastructure and adapt to new climatic conditions.

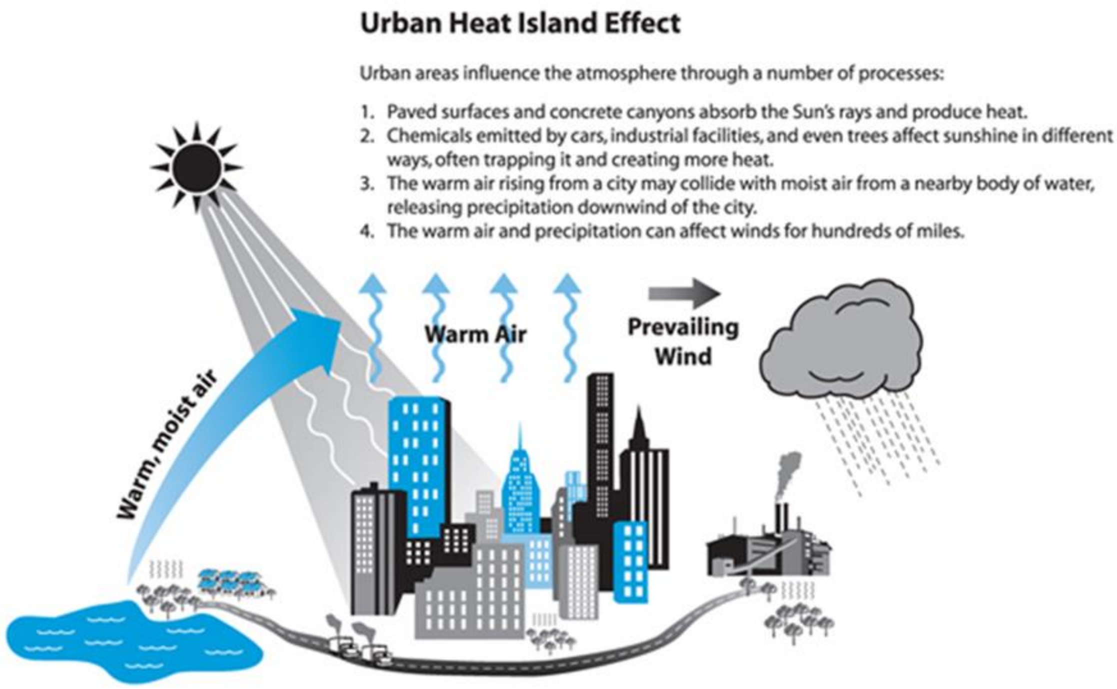
Many cities already are undertaking various measures to adapt to the climate change risks and vulnerabilities as reflected in the following examples:

- **Coastal cities**: These cities tend to be more concentrated in low coastal zones and are exposed to extreme coastal water level events. 65% of cities in the world with population greater than 5 million located are in these areas; on which some of them are already below normal high-tide levels and prone to flooding and storm surges. The most threatened coastal urban environments include deltas, low-lying coastal plains, islands and barrier islands, beaches and estuaries [b-Hunt, 2011]. Cities facing these challenges are located across the globe, in both developed and developing countries. Some examples of cities facing these challenges include New Orleans, New York, Los Angeles, Tokyo, Amsterdam, Mumbai, Shanghai, Singapore, Jakarta and Dhaka [b-OECD, 2007].
- **Inland cities**: They are found in the interior part of the mainland. These cities, like their coastal counterparts, are also at risk. Settlements located along rivers are specifically considered high-risk locations. Inland cities will also face an increase in flooding potential due to more sizeable rainfall events. Equally, changes in climate that reduce precipitation and impair underground water will have impact on water resource availability especially in semi-arid and arid areas in both developed and developing cities [b-UN-Habitat, 2009].

Climate change has a range of short- and long-term consequences on cities. It will have both direct and indirect impacts on human health, physical assets, economic activities, and social systems, depending on how well prepared a city is and how it responds [b-World Bank, 2011]. The direct impacts of climate change in cities depend mainly on exposure to heat or cold waves, as well as to extreme weather events that can translate into storms, floods, and droughts, related landslides and wildfires. Indirect impacts are a consequence of the aforementioned events, e.g., food or water-related infections, diseases, people displacement, adverse psychological effects and other stresses [b-IPCC, 1997].

Examples of the impacts of climate change on ICT infrastructure are described in [ITU-T L.1502]. Examples of direct and indirect impacts of climate change that are particularly relevant to cities include:

- **Increased temperature**: Heat stress represents a serious public health concern especially in summer. Urban residents are particularly at risk of heat stress given that higher temperatures occur in urban regions more than in rural areas due to the urban heat island effect (see Figure 2-1). Illustrating these impacts, the 2003 summer heat wave in Western Europe has been linked to 35,000 deaths [b-UN-Habitat, 2009]. Indirect impacts include the overstress of energy transmission and distribution, due to the increased incidence or duration of summer heat waves, in conjunction with high energy demand for cooling [b-IEA, 2013].



Source: [b-UCAR, 2009]

Figure 2-1 – The urban heat island effect

- **Heat waves**: These events could reduce the ability to work and result in lower productivity, thereby shortening or delaying the delivery of products and services to clients within the city and elsewhere. They can reduce the use of public spaces and thus constrain social life. High temperatures can put infrastructure at risk, including ICT, as fluctuating heat levels can cause continuous thermal expansion and contraction of roads and railroad tracks, physically weakening the construction infrastructure, and in the process hamper the supply of goods and movement of commuters. This also adds to maintenance costs (in terms of labour as well as finances) of these structures. [b-EEA, 2012].
- **Sea level rise**: Rise in sea level is one of the most well-known effects of climate change, which has proved detrimental to human life and property. One common cause of sea level rise is accelerated glacial melting as a result of increased temperatures due to global warming. Such rises in sea level are unpredictable, and can cause coastal flooding that may lead to loss of life and property [b-UNFCCC, 2012]. Other direct effects of sea level rise include inundation and displacement, coastal erosion and land loss, increased storm flooding and damage, increased salinity in estuaries and coastal aquifers, rising coastal water tables and impeded drainage. Indirect impacts have been linked to changes in the distribution of sediments, changes in the functioning of coastal ecosystems, and impacts on recreational or tourism activities [b-Hunt, 2011].
- **Snowstorms**: The prime feature of lake effect snow storms is a dramatic crippling event out of season, with unprecedented cold air and wet snow. The associated uplift and dynamic cooling is so strong that it overcomes the boundary layer warming of the lake. These storms can be associated with severe cold spells with persistent weather patterns at mid-latitudes and are considered to be a direct consequence of warming due to climate change [b-NWS, 2006].
- **Droughts**: Climate change is also known to cause alterations in the global water cycle. Fluctuations in temperature caused by climate change can lead to significant alterations in precipitation patterns, e.g., areas that were previously receiving adequate rainfall may face drought, while other regions experience flooding. Cities are likely to face water stress, which will have a direct impact on energy supply sourced from hydropower. Furthermore, areas

affected by drought are likely to face land degradation with low agricultural yield and increased risk of food shortage. Indirect impacts can include reduced water quality and availability due to an increase in drought occurrence, especially from sources (e.g., snowpack) outside of city borders. This can threaten drinking water supply and reduce agricultural production, affecting food security in cities [b-World Bank, 2011]. Other indirect impacts include greater migration into cities by rural inhabitants pressured by drought or other climate extremes.

- **Floods**: These events can destroy homes, business sites and infrastructure, as well as contribute indirectly to the loss of employment and other income sources. People and businesses could have limited access to vital services, such as energy, transport and clean water, with consequent impacts on health [b-EEA, 2012]. Floods also have an indirect effect on the health infrastructure and other lifeline systems in terms of reduced access to energy, transport, food and sanitation services [b-EEA, 2012].
- **Human health**: Climate change is likely to affect human health in cities, either directly or indirectly. Impacts can range from physiological effects of heat and cold, or indirectly, through the transmission of vector-borne pathogens or effects on personal well-being from flooding episodes [b-Hunt, 2011]. Impacts of climate change may also facilitate the transmission of vector-borne (e.g., malaria, dengue and dengue haemorrhagic fever, yellow fever, and West Nile fever) and water-borne diseases (e.g., typhoid fever, cholera, leptospirosis and hepatitis A). According to the World Health Organization (WHO) "between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress" [b-WHO, 2014].
- **Global security**: Climate change is seen as a threat to the well-being, safety and survival of people around the world, although more evidence is needed to understand the nature of this relationship [b-World Bank, 2011]. Increasing water stress due to climate change can lead to mass migration to urban areas. This increase in urban population may cause conflict for scarce natural resources, leading to security concerns in affected regions. In [b-UN, 2011], the Security Council declares that the adverse effects of climate change would trigger or aggravate international and national peace and security issues.

Table 6-1 provides a comprehensive list of examples of climate change effects in cities as a guide to understand the link between direct and indirect impacts. The specific impacts on each city will depend on the actual changes experienced and on their geographical location, among other factors. Figure 6-1 is a risk heat map for climate change.

Table 6-1 – Examples of direct and indirect impacts of climate change in cities

Projected climate change impacts	Likelihood	Direct impacts	Indirect impacts	Geographical location affected
(1) Warmer with fewer cold days and nights, more hot days and nights	Virtually certain	Exacerbation of urban heat island effect increases risk of related mortality	Declining air quality	Inland cities and cities reliant on snowpack for water supply
(2) Hot spells or heat waves: increased frequency	Very likely	Increased demand for cooling, and reduced energy demand for heating. Greater stress on water resources including those that rely on snowmelt from increased water demand and declining water quality	Energy transmission and distribution maybe overstressed Wider geographical incidence of vector-borne diseases (e.g., malaria) Less disruption to transport from snow and ice	Inland cities and cities reliant on snowpack for water supply
(3) Heavy precipitation events: increased frequency	Very likely	Flooding, strong winds and landslides Disruption of public water supply	Withdrawal of risk coverage in vulnerable areas by private insurers	Coastal and port cities, those on riverbanks or land marginal to flood plains, mountainous regions
(4) Intensity of tropical cyclone activity increases	Likely	Damage and losses of physical assets and infrastructure Increased risk of death , injuries and illnesses Disruption of transport, commerce and economic activities	Impacts on tourism and local livelihoods, psychological impacts on or stress in vulnerable populations	Coastal and port cities.
(5) Areas affected by drought increase	Likely	Stress on water resources Reduced energy supply from hydropower Land degradation with lower agricultural yields, increased risk of food shortage and dust storms	Water quantity and quality for consumption and food production Population migration	Cities unused to arid conditions
(6) Rising sea level	Virtually certain	Permanent erosion and submersion of land Cost of coastal protection or coast of relocation Decreased ground water availability Increase salinity in estuaries and coastal aquifers Effects of tropical cyclones and storm surges, particularly coastal flooding	Recreational activities are affected	Coastal cities
Sources: Compiled from [b-World Bank, 2011] and [b-Hunt, 2011]				

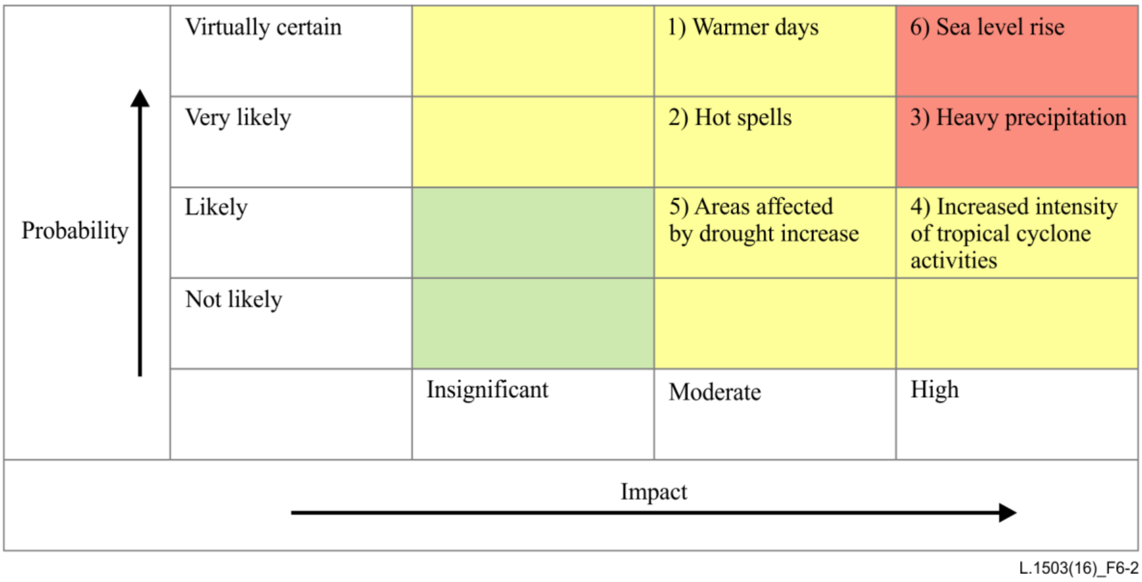


Figure 6-1 – Risk heat map of the potential climate change impacts

6.3 Approaches to climate change adaptation in cities

A number of cities have developed adaptation strategies, frameworks or plans using different approaches. These range from sector plans, strategic plans focusing on specific themes or risks, to broader holistic plans that integrate the various approaches or different aspects in a city. Selected examples are listed below:

- The New York City adaptation approach followed a multistep process that included identification of climate hazards and impacts, developing and evaluating adaptation strategies, implementing actions, and monitoring results. The work was led by the New York City Climate Change Adaptation Task Force, with the assistance of the New York City Panel on Climate Change [b-Rosenzweig, 2010].
- In developing its climate change strategy, the Durban Municipality identified a set of 10 interrelated climate change response themes: water, sea level rise, biodiversity, food security, health, energy, waste and pollution, transport, economic development, and knowledge generation and understanding. The approach included the development of a separate implementation framework, and a monitoring and evaluation system [b-DCCS, 2014];
- The Hoi An climate change vulnerability assessment approach involved a 10 step process following UN-Habitat's Cities and Climate Change Initiative:
  - establishing contact with the city government, gaining participation at city level and forming an assessment team;
  - identifying key issues through disaster profile and climate change scenarios for 2020, 2050 and 2100; developing the city profile;
  - mapping and mobilizing key stakeholders; consulting with local communities, government and private sector;
  - identifying the main climate hazards for Hoi An;
  - analysing sensitivity of the city infrastructure and physical systems;
  - developing an adaptive capacity analysis based on evaluation of technology, human and financial resources, policy and mechanism, and coordination and implementation capacity;

– identifying hotspot areas based on disaster profile, modelling, stakeholder interviews and community mapping; and conducting city feedback and evaluation meeting; and

– identifying priority actions and planning for implementation [b-UN-Habitat, 2014].

• London's climate change adaptation strategy contains seven tasks to be undertaken in order to manage risks and increase resilience. These are: (i) analysing how London is vulnerable to weather-related risks today (establishing a baseline to assess how these risks change); (ii) using projections from climate models to identify how climate change may accentuate existing risks and create new risks or opportunities in the future; (iii) prioritizing the key climate risks and opportunities for London; (iv) providing a framework; (v) establishing a strategic process by which London can put in place the measures necessary to adapt to future climate change; (vi) recommending how London should capitalize on the opportunities presented by climate change; and demonstrating how London can become an international referent on adaptation [b-GLA, 2011].

In order to guide countries in their overall adaptation planning and implementation, a national adaptation plan (NAP) process has been put in place under the United Nations Framework Convention on Climate Change [b-UNFCCC, 2014]. The NAP process provides an opportunity for countries to consolidate overall adaptation activities, and embark on a coherent and strategic adaptation approach. It is designed to assist countries to reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience, and to facilitate the integration of climate change adaptation into development planning processes and strategies within all relevant sectors and at different levels.

The process is framed along four elements: laying the groundwork and addressing gaps; preparatory elements; implementation strategies; and reporting, monitoring and review. Table 6-2 provides an overview of the steps involved in the adaptation cycle along those four elements.

Table 6-2 – Steps under each of the elements of the formulation of national adaptation plans that may be undertaken as appropriate

Element A – Lay the groundwork and address gaps
1. Initiating and launching of the NAP process 2. Stocktaking: identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process 3. Addressing capacity gaps and weaknesses in undertaking the NAP process 4. Comprehensively and iteratively assessing development needs and climate vulnerabilities
Element B – Preparatory elements
1. Analysing current climate and future climate change scenarios 2. Assessing climate vulnerabilities and identifying adaptation options at the sector, subnational, national and other appropriate levels 3. Reviewing and appraising adaptation options 4. Compiling and communicating NAPs 5. Integrating climate change adaptation into national and subnational development and sectorial planning
Element C – Implementation strategies
1. Prioritizing climate change adaptation in national planning 2. Developing a (long-term) national adaptation implementation strategy 3. Enhancing capacity for planning and implementation of adaptation 4. Promoting coordination and synergy at the regional level and with other multilateral environmental agreements
Element D – Reporting, monitoring and review
1. Monitoring the NAP process 2. Reviewing the NAP process to assess progress, effectiveness and gaps 3. Iteratively updating the NAPs 4. Outreach on the NAP process and reporting on progress and effectiveness.
Source: [b-LDC Expert Grp, 2012]

The framework in Table 6-2 can be applied at national and subnational levels. Best practices in climate change adaptation in various cities and countries are provided in Appendix I. The general considerations on adaptation planning adopted by many cities around the world, in both developed and developing countries, are in line with the elements under the NAP process, as per the general framework described in Table 6-2.

It is important to acknowledge that adaptation efforts rely on different types of technologies, as cities are dynamic and growing every day. While many cities have shown considerable advances in the design and implementation of adaptation plans, ICTs remain, for the most part, absent from those strategies. As stated previously, this Recommendation focuses on the role of ICTs in urban adaptation initiatives, particularly as part of smart sustainable city (SSC) strategies. These issues will be explored in clauses 7-9.

7 The role of ICTs in climate change adaptation in cities

The complexity of urban contexts poses new challenges to the process of developing and implementing climate change adaptation strategies. However, it also offers new opportunities for the ICT sector to contribute to climate change adaptation in cities. Cities that are in the process of becoming smart and sustainable, have an enormous opportunity to include ICT infrastructure and ICT solutions as part of their climate change adaptation strategies to respond more effectively to both current and future climate change challenges. Most of the urban infrastructure that will exist in 40 to 50 years has not yet been built [b-ITU, 2012a]. The ICT sector can be an enabler of climate change adaptation in cities, but the sector itself has to adapt to climate change in order to guarantee the continuity of essential ICT-related services provision.

The relationship between ICTs and climate change adaptation is described in [ITU-T L.1501]. There have also been a number of reports published on this subject, especially by the ITU and UNFCCC, including [b-ITU, 2014] and [b-ITU, 2012a]. These have identified the opportunities and potential of the ICT sector to support climate change adaptation on a global and country level, including the adaptation of the sector itself to climate change impacts. This report focuses on ICTs for climate change adaptation in cities.

There is a growing number of experiences of ICT use to support countries to better adapt to climate change. Examples include remote sensing for monitoring of natural disasters, such as floods and tidal waves, improved communications to help deal with natural disasters more effectively or satellite and surface-based remote sensors for environmental observation. Other examples related to the use of ICT tools for climate monitoring and to provide data for climate change prediction on a local basis, among others. The role of ICTs in support of climate change adaptation requires further analysis.

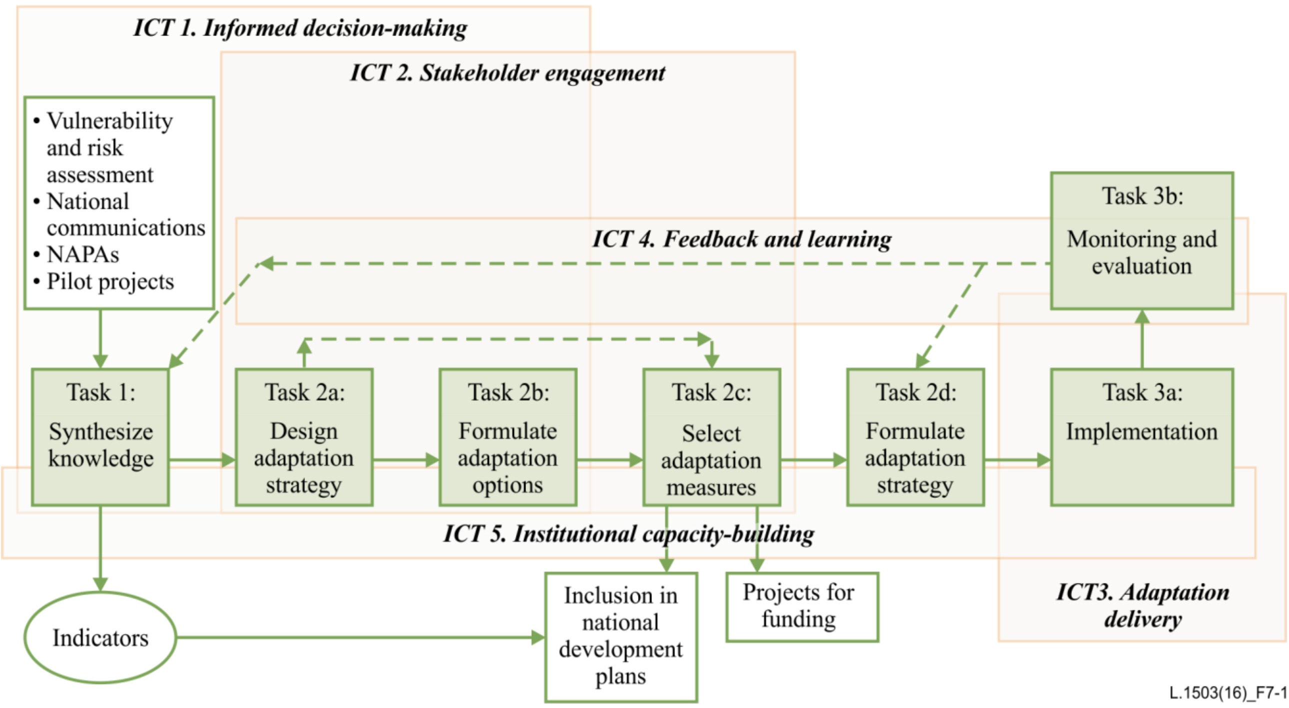
This clause is intended to highlight the role of ICTs in urban climate adaptation based on three approaches. The first is based on the understanding of the needs of climate change adaptation policies and initiatives in cities. The second is based on the experience and research carried out by ITU, ITU-T SG5 and Q15 towards the development of standards for ICTs and climate change adaptation and the use of ICTs for disaster risk management (DRM). Finally, the role of ICTs can be described based on different examples of cities that have implemented ICT-based programmes to advance their climate change adaptation plans.

According to the World Bank Cities and climate change leadership initiative, over-arching adaptation policies must include an integrated approach on strategies for DRM, poverty reduction and city resilience. ICT tools can deliver clear solutions for DRM processes and also across planning activities for resilience. Within this framework and with the support of ICTs, climate adaptation strategies in cities can be improved and new long-term pro-active solutions can be carried out for DRM and city resilience initiatives.

These adaptation strategies require robust ICT infrastructure and also specific standards to enhance its use. Different types of disasters and adaptation challenges may require different ICT solutions. Along with communication technologies and infrastructure, the development of ICT standards is also required for effective inclusion of ICTs in city adaptation programmes; and helping to strengthen the response of cities to climate change adaptation worldwide. Standards can facilitate massive rollout of technologies and procedures across cities. For instance, the ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery [b-ITU, 2012b] was tasked, until it ceased operations in 2014, to study the development of appropriate standards.

Finally, it is important to highlight the potential role that ICTs have to promote informed decision-making in adaptation processes. According to research on the role of ICTs in the formulation of climate change adaptation strategy at the national level [b-Ospina, 2011], ICTs can support adaptation strategies within the three broad categories: a) generating information and knowledge; b) capturing and storing information and knowledge; and c) processing and disseminating information and knowledge among an increasingly interconnected society.

The process for developing a climate change adaptation strategy is addressed in [ITU-T L.1501]. Figure 7-1 illustrates the process at national level which can also be applied to cities.



Source: [b-Ospina, 2011]

Figure 7-1 – ICTs and the formulation process of climate change adaptation strategies at a national level

Considering the national formulation process, the uses of ICTs for climate change adaptation can be grouped into three strategic categories: (1) for enhanced DRM; (2) to improve city resilience and adaptive capacity; and (3) for informed adaptation decision-making. Clause 7.1 provides an overview of these categories, including selected examples of the urban application of ICTs to address these challenges.

7.1 ICTs for enhanced disaster risk management

Climate change action plans in cities include adaptation strategies based on DRM programmes. These provide a well-proven framework and tool-set for cities to address natural disasters, and help cities explore strategies *before* disasters occur, as well as *during* and *after* disasters have taken place. ICTs facilitate communication and exchange of information between local governments, communities and all relevant stakeholders involved in DRM processes. ICTs are very important for disaster prevention and amelioration, for emergency preparedness and response, and finally, for recovery. Communications are vital to prevent damage; to enable and coordinate timely emergency relief responses to protect the population, and to contain damages and losses in urban infrastructures. In this sense, it is very important to understand the role of ICTs during all stages of DRM programmes. Table 7-1 describes some examples of ICT-based services to support DRM processes in cities.

Table 7-1 – Examples of ICT use for disaster risk management in cities

Disaster phase	ICT services involved	Major tasks
DISASTER PREVENTION: ***Prediction and detection***	• Meteorological services (meteorological aids and meteorological-satellite service) • Earth exploration-satellite service • Geographic information systems (GISs) • Blogging, web 2.0 and social networking	• Weather and climate prediction • Detection and tracking of hurricanes, typhoons, forest fires, among others • Providing warning information
EMERGENCY PREPARDNESS & RESPONSE: ***Alerting***	• Amateur services • Broadcasting services terrestrial and satellite (radio, television, etc.) • Fixed services terrestrial and satellite • Mobile services (land, satellite, maritime services, etc.) • Blogging, web 2.0 and social networking	• Receiving and distributing alert messages • Disseminating alert messages and advice to large sections of the public • Delivering alert messages and instructions to telecommunication centres for further dissemination to the public • Distributing alert messages and advice to individuals
RECOVERY: ***Relief***	• Amateur services • Broadcasting services terrestrial and satellite (radio, television, etc.) • Earth exploration-satellite services • Fixed services terrestrial and satellite • Mobile services (land, satellite, maritime services, etc.) • Blogging, web 2.0 and social networking	• Assisting in organizing relief operations in areas (especially when other services are still not operational) • Coordination of relief activities by disseminating information from relief planning teams to population • Assessment of damage and providing information for planning relief activities • Exchange of information between different teams or groups for planning and coordination of relief activities • Exchange of information between individuals or groups of people involved in relief activities
Sources: Adapted from [b-ITU-R, 2016] and [b-LIRNEasia, 2008].		

ICT tools enable information dissemination and analysis. They help to manage, analyse and disseminate geographic information that can be used for contingency planning, disaster assessment and post-disaster response. Best practices in disaster early warning networks in various cities and countries are provided in Appendix II. ICTs also support climate modelling research, and provide new opportunities for policy makers and urban planners to understand cities and to project future scenarios.

During the disaster prevention phase, the use of ICTs such as geographic information systems (GISs) in local hazard mapping and analysis can help to identify and illustrate evacuation routes as well as to locate housing, business and structures that are at risk of threats including rises in water levels [b-NICCD, 2011].

When a disaster occurs or an emergency situation takes place, technical standards facilitate the use of public telecommunication services and systems for communications during emergency and disaster relief operations. This capability, referred to as the "emergency telecommunication service", enables authorized users to organize and coordinate disaster relief operations as well as have preferential treatment for their communications via public telecommunication networks. This preferential treatment is essential as public telecommunication networks often sustain infrastructure damage that, coupled with high traffic demands, tends to result in severe congestion or overload to the system. In such circumstances, technical features need to be in place to ensure that users who must communicate during emergencies have the communication channels that they need, along with appropriate security and the best possible quality of service.

To ensure reliable universal access to communication in extreme weather events, the common alerting protocol (CAP) [b-ITU-T X.1303] provides a general format for exchanging all-hazard emergency alerts and public warnings over a range of networks. CAP allows a consistent warning message to be disseminated simultaneously over many different warning systems, thus increasing the warning's effectiveness and simplifying the warning task.

[b-ITU-T E.164] assigns the country code 888 to the UN Office for the Coordination of Humanitarian Affairs (OCHA). This number is used by terminals involved in disaster relief activities in areas that have been cut off or disconnected from the national telecommunications system.

Best practices in ICT tools to help in managing, analysing and disseminating geographic information that can be used for contingency planning, disaster assessment and post-disaster response in various cities and countries are provided in Appendix III. Climate modelling research supported by ICT tools allows the different levels of vulnerability in cities to be mapped. This provides a new opportunity for policy makers and urban planners to better understand cities and to project future scenarios.

In summary, ICTs are effective tools for hazard mapping and environmental monitoring in cities. ICTs can aggregate, create, and integrate information, delivering a comprehensive set of data appropriate for each end user. Real-time information on the changing climate can support risk assessments, strengthen early warning systems (EWSs) and enhance disaster preparedness.

7.2 ICTs for city resilience and adaptive capacity

City resilience can be achieved in two ways: (i) by making urban ICT systems more robust and by (ii) increasing the city's adaptive capacity. A robust system is designed with safety margins that allow residents to survive sudden change and to quickly bounce back. It is important to mention that the social, economic and physical elements of a city; including ICTs, can become more robust.

Adaptive capacity refers to the ability to respond to change and surprise, to quickly learn and easily adapt to new conditions without any major costs or permanent loss in function. ICT tools capture, transmit and disseminate data on climate and weather conditions, providing useful information on the environment for policy makers for the elaboration of adaptive responses. ICTs can provide information dissemination and opportunities for urban planners to assess risks and work with future scenarios, thus contributing to the city's adaptive capacity, including its ability to design and implement both preventive and reactive measures. Best practices are provided in Appendix IV.

These preventive measures also apply to the ICT sector itself, as disasters can also affect existent ICT infrastructure, including SSC structures such as smart buildings, smart grids or smart transport systems. It is critical to ensure that any form and means of communication (e.g., broadcasting radio receivers, Internet, mobile phones) and network infrastructure are not compromised by a disaster. Recovery and resilience of the telecommunication network infrastructure are also important factors in ensuring efficient adaptive responses. Best practices in telecommunications network risk management in various cities and countries are provided in Appendix V. During the rehabilitation of affected infrastructure after an event, it is recommended that the opportunity be taken to include adaptation measures in the renovated ICT infrastructure. This could lead to cost reduction and to the earlier implementation of adaptive measures in order to be prepared for future events.

The need to improving the resilience of telecommunication infrastructure in cities when a disaster occurs has been stressed in [b-ITU, 2014]. This study responds to the need to explore further the effects of climate change on the ICT sector, and aims to raise awareness of the need to design and implement strategies for the ICT sector to better cope with a disaster in the urban context. Additional examples of initiatives to increase the resilience of the telecommunications sector at the city level are also provided in Appendix V.

Observing and understanding atmospheric processes and impacts in cities is essential to preparing a sustainable response, and to build urban resilience to climate change. ICT tools and services are a key resource in facilitating environmental data collection and analysis that can be used by city planners to improve urban preparedness to natural hazards and changing climatic conditions. Thus, ICTs (including radio, satellites, radar, earth observation systems) are valuable tools for environmental and climate change monitoring systems that can save thousands of lives.

Remote monitoring and data collection using ICT-equipped sensors (telemetry) is essential for climate change-related research. ICTs have also proved invaluable to conduct climate modelling experiments. The development of aerial photography, satellite imagery, grid technology and, in particular, the use of the global positioning system (GPS) by satellite for tracking slow and long-term movement, represent significant results of the use of ICTs that can support the development of climate change adaptation projects at the city level. Best practices in real-time monitoring to respond to saline intrusion into various cities and countries are provided in Appendix VI.

Ubiquitous sensor network (USN) technology is also proving useful in the field of environmental monitoring. USNs combine a network of sensors with computer processing power for data collection and analysis. All these systems form the Global Observing System (GOS). GOS is the primary source of technical information on the world's atmosphere, and is a composite system of complex methods, techniques and facilities for measuring meteorological and environmental parameters. WMO and ITU, together with other UN agencies, administrations and organizations, are contributing to further develop such systems. An additional example of the use of ICTs in the field of environmental monitoring is also included in Appendix VI.

Strategic sectors for the urban economy can also be impacted by climate change, including the agricultural sector. Heat waves, droughts, or flooding associated with rising sea levels can lead to increased losses in land, agriculture and infrastructure, if unaddressed. ICTs can support city adaptation planning processes in order to strengthen agricultural practices. Best practices in the use of ICTs for climate change adaptation in the agricultural sector in various cities and countries are provided in Appendix VII.

7.3 ICTs for informed adaptation decision-making

According to the UNFCCC, effective engagement of stakeholders and management of knowledge for adaptation is vital in supporting all adaptation activities. Under the Cancun Adaptation Framework [b-UNFCCC, 2010], relevant multilateral, international, regional and national organizations, the public and private sectors, civil society and other relevant stakeholders are invited to undertake and support enhanced action on adaptation at all levels.

In addition to monitoring the environment and the changing climate, ICTs have a role to play in urban climate change adaptation decision-making by facilitating information dissemination. ICTs facilitate the inclusion of multiple voices in the design and implementation of adaptation strategies. ICT tools should be used to identify climate change-related needs and priorities at the city level, and support the identification of resources and capacities available to respond to climatic opportunities and threats. The availability of information provided through hazard mapping and monitoring, as well as urban risk reduction in a format that is easily understood by all levels of stakeholders, could motivate all urban dwellers to engage in joint climate change responses. Best practices in the use of ICTs for informed adaptation decision-making are provided in Appendix VIII.

ICTs can also help raise public awareness on health-related problems that are intensified by climate change manifestations (e.g., malaria), supporting EWSs to disseminate information in order to prevent or control the spread of disease. Similarly, they can support public awareness and education campaigns on safe-housing construction, water storage and robust drainage systems, empowering the community to mitigate the impacts of climatic occurrences.

New and traditional ICTs (e.g., mobile phones, community radios) can also be used as effective information and EWSs among populations settled in dangerous terrains. Policy and research networks can be supported by social media tools to discuss and give visibility to climate-related agendas that respond to the needs and priorities of low-income urban populations.

ICTs used in support of social networking can also improve the capacity of low-income urban communities to respond effectively in climate-induced emergencies, as well as to access information about markets, employment opportunities and livelihood alternatives. Tools such as online training, blogging or web 2.0 tools; can contribute to the dissemination of knowledge and the strengthening of the capacity of experts involved in the process of resilience building and DRM programmes. As suggested by [b-NICCD, 2011], social media tools can also support public awareness and education campaigns, as well as foster participative processes.

> "ICT applications such as participatory videos, photo-diaries or the use of mobile phones for collective mapping/monitoring exercises, could be used to foster greater involvement of low-income urban dwellers in climate change and risk-reduction initiatives, involving them in decisions such as the best location for drinking water supplies in case of sudden salinization, or failures in drainage systems due to floods."

ICTs can also be applied to facilitate communication and exchange between local governments, communities, grass-roots organizations and researchers working in urban development programmes, strengthening transparency, accountability and public support. Best practices in the use of social media for this are provided in Appendix IX.

ICTs can help strengthen the capacity of institutions involved in processes of climate change adaptation, improving the availability of resources and skills needed for effective adaptation. For example, online training programmes and access to broader networks of practitioners and experts to share lessons and resources could help to strengthen the institutional capacity of those involved in urban planning and design processes.

It is important to acknowledge that, through their role in the three categories mentioned above (i.e., enhanced DRM, city resilience and adaptive capacity, and informed decision-making), ICTs also facilitate the integration of climate change adaptation into broader national development planning processes, which constitutes a key goal of adaptation strategies. The examples included in Table 7-3 reflect the potential role of ICTs towards this end.

Table 7-3 – ICT contributions to the integration of adaptation into development strategies

ICT category	Integration of adaptation into development strategies
(a) ICTs for enhanced disaster risk management	ICTs can help to strengthen vulnerability and risk assessments in susceptible locations in the city (e.g., through the use of GIS and modelling techniques), as well as to improve indicators and data collection.
(b) ICTs to improve city resilience and adaptive capacity	ICTs can help to gather city-specific evidence on adaptation practices (e.g., using satellite and mobile-based applications) and to highlight their impact on vulnerability reduction.
(c) ICT-based adaptation informed decision-making	ICTs can help to strengthen institutional and capacity development (e.g., through online training, improved knowledge access) to inform the implementation of sectoral and local programmes.

8 Framework for integration of ICTs into urban climate change adaptation plans

After the identification of the role that ICTs can play in the development of urban adaptation initiatives, it is important to provide a framework to foster the inclusion of ICTs into cities climate change adaptation policies and plans.

As mentioned in clause 6.3, according to the UNFCCC, the key elements for an urban adaptation process are: 1) laying the groundwork and addressing gaps; 2) preparatory elements; 3) implementation strategies; and 4) reporting, monitoring and review. Within this framework, the first step to integrating ICTs into urban adaptation processes entails merging the specific ICTs roles identified in clause 7 during the conceptualization of climate change adaptation plans. This framework should be built upon several components, which may include: a trans-sectoral vision of urban adaptation planning, an assessment of climate change risks and vulnerabilities in cities, pointing out the key role of ICT and a cross-sectoral adaptation policy process. Recognizing the benefits of ICTs for climate change adaptation in cities will facilitate the integration of ICT tools and services in supporting their policies.

The framework for the integration of ICTs into urban adaptation planning should follow "the one step at the time approach". The steps are based on the policy cycle suggested in [b-UNFCCC, 2014]. In this sense, the proposed framework for integrating ICTs into cities can have the following steps.

1) **Laying the basis: Observation and understanding**: City planners should consider the role of ICTs in climate change adaptation as a new alternative in their local adaptation plans. They should take stock of existing measures, opportunities and challenges on the integration of ICTs into climate change adaptation.

2) **Assessing climate change risks and vulnerabilities**: This should involve an assessment of how ICTs can support cities during this step to identify adaptation options, as well as to carry out an assessment of the specific risks and vulnerabilities of ICT infrastructure.

3) **Planning of adaptation options**: During this step it is important to define the role of ICTs in identifying adaptation options for cities, as well as those options that would require ICT adaptation due to the impacts of climate change. Once the potential adaptation options are identified, an assessment should be carried out to determine which of them suit the specific urban context. The approach consists of prioritizing those ICTs that would best support adaptation options in a given city context, including the evaluation of social, environmental and economic variables. This step also involves the prioritization of adaptation options for the ICT infrastructure.

4) **Implementation of adaptation actions**: This step relates to the development of an implementation plan to convert adaptation options into actions. It involves the integration of ICTs into the design of implementation strategies for identified or prioritized adaptation options, together with the implementation of specific adaptation options for the ICT infrastructure.

5) **Monitoring and evaluating adaptation actions**: This step consists of a monitoring system and evaluation of the role of ICTs in climate change adaptation, in order to ensure the focus and effectiveness of adaptive actions. ICTs can support this process, e.g., through software tools to enable modelling, monitoring and analysis of climate change impact in cities.

This Recommendation strongly encourages the collaboration of all stakeholders involved in the implementation of adaptation strategies at city level. Collaboration among cities can also contribute to the creation of platforms to share good practices and lessons learned. This requires the participation of all stakeholders and the active involvement of civil society. This wide set of stakeholders is explored in further detail in clause 8.1.

8.1 Engaging stakeholders for the integration of ICTs into urban climate change adaptation plans

Cities in their journey to become smart and sustainable could be the first responders to the effects of climate change and the use of ICTs to improve their climate change adaptation policies and strategies. Cities are complex systems in which a variety of stakeholders coexist. Key stakeholders range from local government to civil society and business, international organizations, the ICT industry, non-governmental organizations (NGOs) and citizens, among others. They span multiple disciplines and areas of expertise.

In such complex systems, collaboration between stakeholders is needed to develop urban resilience strategies, including ICTs. It is hence crucial to identify the players relevant to issues of climate change adaptation in cities in order to strengthen coherent adaptive response capability.

The Technical Report [b-ITU-T FG-SSC, 2015] suggests that cities in the process of becoming smart and sustainable must identify all stakeholders that can contribute to achieve cities goals. This proposal includes three stages. First, the identification of all stakeholders involved; second, the categorization of the listed stakeholders; and third, the development of a detailed analysis of selected stakeholders. This view could also be applicable in the process of introducing ICTs into climate adaptation plans.

Urban actors that are particularly vulnerable to the potential impacts of climate change can be identified as key stakeholders [b-CSIRO, 2009]. Their vulnerability can be measured by taking into account the following parameters: exposure, sensitivity, potential impact and adaptive capacity to climate change. Their engagement in urban climate change adaptation strategies will ultimately depend on their level of vulnerability. Their role in urban climate change adaptation will vary based on the nature of each player's business, and on the city's specific needs [b-ALU, 2012].

According to these considerations, a non-exhaustive list of potentially relevant stakeholders can be identified as follows [b-CSIRO, 2009]:

- **Citizens or specific communities** are located in areas that are vulnerable on the basis of their location.
- **National and regional governments** are in charge of climate change adaptation policies for their respective areas.
- **Infrastructure management agencies and utility providers** are responsible for the deployment of infrastructure and services that could be affected by climate change.
- **Associations and non-governmental organizations** are involved in all initiatives that can influence society and facilitate the use and introduction of ICTs in urban adaptation policies.

- **ICT companies** (telecommunications operators, start-ups, software companies) are providers of the global and integrated solutions for ICT services, including solutions for climate change adaptation in cities. In addition, they are responsible for the ICT infrastructure in the cities.
- **International, regional and multilateral organizations**, including UN agencies and multilateral organizations, may assert their authority as promoters of initiatives towards ICTs and climate change adaptation in cities.
- **Urban planners** provide expertise that is important to better understand how to include ICTs in medium- and long term city planning, as well as to consider urban complexities including present and future climate impacts and vulnerabilities in the city.
- **Academia, research organizations and specialized bodies** can contribute to the process of including ICTs in adaptation policies, as they are familiar with innovative projects and environmental trends in cities.

These stakeholders will have a role to play in one or more of the following areas, according to their expertise and experience:

- urban planning: to identify the areas of a city which are most likely to be affected by the effects of climate change;
- mobility: to monitor the status of the urban transportation infrastructures and issue early alerts;
- infrastructure and construction (including ICT infrastructure): to promote safe building practices in areas of high risks, to monitor the status of infrastructures and buildings and issue early alerts;
- energy: to ensure continuing energy supply in emergency situations;
- water supply and sanitation: to manage water resources and prevent scarcity of clean water;
- health: to monitor diseases and issue early warning alerts;
- waste management: to manage municipal waste and e-waste;
- food security: to ensure food supply under climate stress;
- disaster management: to provide prediction and detection, alerting and relief, and make recovery and resilience of city infrastructure, including telecommunication networks infrastructure;
- environmental management: to ensure that environmental problems, such as the degradation of ecosystem services, are addressed.

Within this stakeholder system, international organizations such as the UN agencies offer platforms and activities to enable countries to collaborate in order to find solutions to combat climate change. Governments lead the policy formulation process; they review, approve and harmonize climate change adaptation strategies. Business offers its services and technical expertise. NGOs and civil society are involved in advocacy and raising awareness, sharing experiences and best practices in climate change adaptation. Academia provides the knowledge and expertise to advise policy makers.

9 Smart sustainable city adaptation checklist

A checklist of the impact of climate change on ICT infrastructure is provided in [ITU-T L.1502]. Network planners may use this as a guide to the identification and minimization of effects to ensure survivability of the network under extreme weather conditions. In order to understand how ICTs can support climate change adaptation in SSCs, it is important to understand that cities face challenges to implement climate change adaptation policies as they are dynamic and complex interconnected systems. Adaptation to climate change requires collaboration across all urban sectors and will require investments and technology. This process involves both challenges and opportunities, as cities provide the optimal scenario to lead in the use of ICTs for climate change adaptation, due to their concentration of population and connectivity.

Within this context and the definition of SSCs provided in this Recommendation, it is important to understand that city policies and activities towards climate change adaptation should actively integrate the use of ICTs as a key component in their process towards becoming SSCs.

As mentioned before and illustrated through a number of examples, ICTs have a significant role to play in reinforcing disaster prevention and in coordinating the information flow between multiple public agencies, businesses and civil society, among other key functions. On the one hand, ICT infrastructure and solutions embedded in cities can help move "practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change" (2.1 of [b-OECD/IEA, 2006]) and boost resilience.

Having suggested a framework for city mayors to integrate ICTs into their climate change adaptation plans and help to build resilience of their cities, this clause provides a checklist that can support the assessment of their ICT-enabled adaptation plans. This checklist can help mayors and municipal authorities to evaluate whether climate change adaptation actions were successful and if ICTs met their role of enablers in the process.

The proposed SSC adaptation checklist (Table 9-1) aims to provide practical guidance to city planners for assessing the integration of ICTs into their adaptation strategies. It can help city planners to evaluate the degree of inclusion of ICT tools and services in the strategic adaptive response, and assist them in improving adaptation strategies.

Table 9-1 – Smart sustainable city climate change adaptation checklist

Key area for the integration of ICTs into adaptation plans	Description
(a) Climate change adaptation planning	Integration of ICTs in urban climate change adaptation planning based on benchmarking studies or concrete examples already implemented in the city (e.g., number of concrete examples of ICT applications or related services used for observation and understanding, climate risk and vulnerability assessment, planning of adaptation options, implementation of adaptation options, monitoring and evaluation of adaptation options)
(b) Institutional coordination	Participation of multiple actors that understand the enabling effect of ICTs in climate adaptation policies. Use of ICTs in the coordination of climate risk management among relevant institutions and SSC stakeholders (e.g., concrete examples of ICT usage to enable communication between key players involved in practical adaptation)
(c) Institutional knowledge and capacity	Use of ICTs to enhance the level of knowledge and training of key personnel in climate change issues and mainstreaming processes (e.g., number of ICTs used to facilitate access to climate change information by city planners and experts; number of online training courses or resources used for institutional capacity building on climate change adaptation)
(d) Informed decision-making	Use of ICTs to inform institutional decision-making and to reduce climatic uncertainty (e.g., examples of ICT applications used to strengthen decision-making processes and to improve climate change forecasts)
(e) Stakeholder participation	Use of ICTs to foster participatory processes and improve stakeholder engagement in climate change adaptation decision-making (e.g., social networking tools used to broaden stakeholder participation in adaptation processes, number of ICT applications used to increase transparency and share citizen's voices as part of adaptation processes)

Table 9-1 – Smart sustainable city climate change adaptation checklist

Key area for the integration of ICTs into adaptation plans	Description
(f) Stakeholder awareness	Use of ICT tools to raise stakeholders' awareness about climate change issues, risks and responses options in the city (e.g., number of ICT applications used as part of public awareness or education campaigns on climate change issues)
(g) Vulnerability/resilience	Use of ICTs to strengthen the coping capacity of the city in face of climate change impacts, including increased resilience of livelihoods, more robust public utilities infrastructures (e.g., number of cases in which ICTs are used to improve the ability of different city sectors and services (e.g., transport, water, energy, health) to withstand and recover from climate-related disasters).
Source: adapted from [b-IIED, 2011].	

Appendix I

Best practices in climate change adaptation

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in climate change adaptation in various countries.

Climate change adaptation in Quito, Ecuador
Quito's Climate Change Strategy (QCCS) includes a range of innovative programmes that combine risk reduction with institutional capacity building and enhanced citizen participation. Within an urban context characterized by intense seismic activity and a landscape of steep slopes, ravines and gorges, recurrent floods, earthquakes and landslides cause extensive damage, particularly in informal settlements located on steep hillsides or in the urban periphery. Since 2009, the QCCS has been an official municipal environmental policy. It is organized under four strategic areas: (1) access to adequate information to promote adaptation and reduce vulnerabilities; (2) use of good environmental practices for adaptation; (3) focus on communication, education, and citizen participation; and (4) strengthening institutional capacities for climate change adaptation. Source: [b-Quito, 2013].

Climate change adaptation in the city of Melbourne
The City of Melbourne is expected to be significantly affected by warmer temperatures and heat waves, reduced rainfall and drought, bushfire, intense rainfall and windstorm, and sea level rise. In order to address these challenges, the city has embarked on a citywide adaptation plan that builds on an urban system assessment (covering the current state and potential climate change impacts on water, transport and mobility, building and property, social, health and community, businesses and industry, energy and telecommunications, and emergency systems. It recognizes the following key principles (among others): (1) Delivering on a leadership approach to climate adaptation requires engagement with key stakeholders to ensure climate change risks are incorporated into decision-making. (2) Ensuring that all adaptation efforts underway are consolidated under a framework of reducing climate risks, collaboratively, to deliver the greatest benefits at the least cost. (3) Adaptation to climate change cannot ignore the subtleties of the everyday changes, such as overall higher temperatures and reduced rainfall. Such impact over time must be considered, particularly in the design and maintenance of infrastructure, parks and gardens. Source: [b-Melbourne, 2008]

Appendix II

Best practices in disaster early warning networks

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in disaster early warning networks in various countries.

Disaster Early Warning Network (DEWN)

The Disaster Early Warning Network (DEWN) was launched in Sri Lanka on 30th January 2009. It aims to provide timely, reliable and cost-effective mass-scale disaster early warnings. DEWN represents a multipartite effort and a case of public–private partnerships in delivering ICT-based early warnings. DEWN's alerts are multi-modal; it makes use of multiple technologies to disseminate information to all interested stakeholders. The end devices are normal cellular phones and alarm devices which have been specially developed for this initiative. DEWN can generate mass, personnel-directed or location-based alerts to the end devices using the two commonly available mobile communication technologies: cell broadcast (CB) and short message service (SMS).

The DEWN server is located in Sri Lanka's Disaster Management Centre (DMC), the responsible agency on the island for all disaster management issues. The DMC receives early warning information from recognized technical agencies. Accordingly, information regarding floods, landslides, earthquakes and tsunamis is provided by the Irrigation Department, National Building Research Organization, Geological Survey and Mines Bureau, and Meteorological Department, respectively. The DMC holds the responsibility for verifying the emergency situation and then issuing alerts. Emergency personnel are alerted first in the case of a potential disaster and public alerts are issued after the threat is further verified (DMC 2009).

Source: [b-DEWN, 2011].

Appendix III

Best practices in virtual centres on climate change

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices to help manage, analyse and disseminate geographic information that can be used for contingency planning, disaster assessment and post-disaster response in various cities and countries.

Virtual centre on climate change

The Mexico City Government has identified a number of strategic adaptive actions that need to be taken to react to climate change. Short-term, extreme event-related actions include: implementation of a metropolitan hydro-meteorological monitoring and forecasting system; micro-basin management of urban ravines; assistance to people who are identified as specifically vulnerable to extreme climate events; epidemiological monitoring; protection and recovery of native crops; and remote detection and monitoring of forest fires during the dry season. Actions for a medium- term response – which also encompass actions on mitigation of emissions – include: growth and improvement of public transportation and the transformation of vehicle technology; the efficient use of energy in buildings, industrial facilities, public lighting systems, water pumping systems and homes; the exploitation of renewable energy sources; the rational use of water, as well as the reduction of waste generation and the promotion of an effective waste management system. However, such strategic actions require a sound evidence base and also the opportunities for discussion among relevant stakeholders. In order to support this, in 2008, a Virtual Centre on Climate Change was created (Centro Virtual de Cambio Climático de la Ciudad de México – CVCCCM). The rationale for the Centre was that it would provide not just evidence and advice to policy-makers, but also help inform broader society – always enabled by ICT-based networks and other digital tools.

Source: [b-CVCCCM,]2011].

Appendix IV

Best practices in use of satellite-based technology

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in use of satellite-based technology in various cities and countries.

ClimSAT

In 2008 a partnership between the regional government of Brittany and UNDP, established a climate science and technology hub in Brest, France: ClimSAT. It was initiated with the primary aim of improving access to information on the impacts of climate change for some of the most vulnerable areas in the developing world.

Satellite-based technology was used to enable governments and communities to monitor and model the effects of climate change, and to base climate change and development strategies on accurate, location-specific information. ClimSAT in its original form ceased operation in mid-2011 but was integrated into a wider UNEP programme, the Territorial Approach to Global Change, Scientific Services and Knowledge (TASK).

Source: [b-ClimSAT,. 2011].

Appendix V

Best practices to improve resilience in telecommunications networks

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in telecommunication network risks management in various cities and countries.

Telecommunication network risks management

During the rainy season in Lima, Perú, some mobile sites from the telecommunications operator, Telefónica, are exposed to flooding risks. In case of weather alerts, the operations team of the company implements actions to prevent and avoid the damages to the facilities and infrastructure. For this potential risk, they have defined a specific fixed and mobile operator integrated procedure that defines the action plan to emergency cases. This document describes the action plan for all operational areas that have responsibility for the operation and maintenance activities of the network infrastructure. The procedure also describes the methodology for communications and notifications to apply in case of emergency, and the operational details for each step of an emergency plan. Telefónica Perú has also taken preventive steps to protect the network sites. The total cost of these preventive actions was extremely low in comparison to the potential damage to the equipment and network failure. The solution consisted of locking the doors of network sites with sandbags located on both sides of the door (inside and outside the room), as shown in Figure V.1.

Figure V.1

Source: Annex 7 b) 1) of [b-ITU, 2014].

Initiatives for increasing resiliency in the telecommunications system in New York City, USA

New York City developed a comprehensive plan entitled *A stronger, more resilient New York* [b-New York, 2013], containing recommendations for both rebuilding the communities impacted by Sandy and increasing the resilience of infrastructure and buildings citywide. The plan contains the following initiatives designed to mitigate the impact of climate change on New York's telecommunications system:

- establishing an office within The New York City Department of Information Technology and Telecommunications (DoITT) to focus on telecommunications regulation and resiliency planning;
- establishing new resiliency requirements for providers using scheduled renewals of the City's franchise agreements;
- requesting business continuity plans from current city franchisees as permitted under existing franchise agreements;
- developing flood protection standards for placement of telecommunications equipment in buildings;
- using the DoITT franchise agreements to ensure hardening of all critical facilities;
- studying options to increase conduit infrastructure redundancy and resiliency;
- continuing the implementation of Connect NYC Fiber Access to create broadband redundancy;
- adding telecommunications provider quality and resiliency to the WiredNYC and NYC Broadband map ratings.

A progress report of the implementation of the plan [b-New York, 2014] emphasizes that a robust telecommunications network is the backbone to New York City, supporting every aspect of work and life. That communication is especially critical during disasters or citywide catastrophes, during which the city is most vulnerable. The report indicates achievements under the telecommunications system, including a process for establishing the Telecommunications Planning and Resiliency Office (TPRO) to address telecommunication policy and enforcement issues in the event of future storms and disruptions like Sandy, a review of all of the city's existing franchise agreements and procurement contracts to identify opportunities for enhancing telecommunications resiliency.

Appendix VI

Best practices in ICTs for environmental monitoring

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in ICTs in the field of environmental monitoring in various cities and countries.

Real-time monitoring for responding to saline intrusion in Can Tho, Vietnam

Can Tho is the fourth largest city in Vietnam in the Mekong Delta, crossed by canals and waterways that are the primary source of water in the city. The municipal water supply is drawn from this surface water to meet the different demands of the city: domestic uses by the city dwellers, irrigation and other uses by farmers. Historically unaffected due to its distance from the sea, saline intrusion has begun to influence river water in Can Tho in recent years, due to multiple climate change-related factors include sea level rise, increased droughts and increasing temperatures. Recent detection of inland salinity suggests that the city's surface water system is threatened by saline water intrusion as a result of sea level rise and changing Mekong river flow. This affects the livelihoods and health of the city's population, in particular the vulnerable poor.

To address this challenge, the Institute for Social and Environmental Transition Vietnam, the Center for Natural Resources and Environment Monitoring (CENRM) of Can Tho City, and the Can Tho Climate Change Coordination Office, among other institutions, have partnered in developing a project to enhance Can Tho's resilience to the salinization of surface water resource. The project, includes real-time network of salinity monitoring stations linked to public warning systems via salinity maps published on public website, SMS alert system, and news on local media. The salinity monitoring system has an automatic system to record and publish real-time salinity data in the Mekong delta. The information is accessible to a wide group of stakeholders so that people's health and livelihoods, especially those of the poor and vulnerable, are less affected. In addition, the project includes development of an alert with radio, television, and text message systems. The project is anticipated to directly benefit 300,000 to 400,000 people currently without information on salinity and the poor who are most vulnerable when water salinity levels rise.

Source: [b-ACCCRN, undated]

Sustainable urban development planner for climate change adaptation: The case of Wuppertal, Germany

Sustainable Urban Development Planner for Climate Change Adaptation is a European Union project that was implemented from 2010 to 2012 to assist cities in developing a web-based planning, prediction and training tool to support decisions in long-term urban planning. Wuppertal was selected as one of the pilot cities.

Wuppertal is located in the steep, narrow, long valley of the Wupper River. The main concern regarding climate change impacts is uncontrollable, extremely localized run-off from increased heavy, short rainfall events. The city copes with run-off from 350 km of creeks (over 800 creek sections) and 650 km of a drainage channel system.

By expanding the possibilities for risk assessment, using among others a 3D topography model, a scenario management system SUDPLAN was applied to decision-making on building measures. The models used in the pilot city of Wuppertal simulate surface drainage during a heavy rain event, allowing the influence of climate change on the frequency and intensity of future rainfall to be studied. This created a basis for the approval process with affected decision-makers and for advising affected individuals. It is a case study that illuminates integration of climate change in an actual, long-term urban planning process that also enhances public awareness for future risks.

Sources: [b-Wuppertal, 2012], [b-German Fed Env, 2009], [b-Michel, 2012].

Appendix VII

Best practices in ICTs for climate change adaptation in the agricultural sector

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in how ICTs can support city adaptation planning processes in order to strengthen agricultural practices in various cities and countries.

ICTs for climate change adaptation in the agricultural sector, Japan

ICT can provide support in making informed decisions as well as production management for farmers by using a sensing network, cameras and cloud-monitoring service. Such technology can measure, accumulate and analyse environmental information like temperature, humidity, quality of soil, solar insolation and amount of rainfall in the field. ICTs can also enable automatic optimization of environmental conditions in a greenhouse or inform the decisions of farmers for best timing of harvesting and epidemic prevention in the field.

Figure VII.1 – Examples of functions in a greenhouse controlled by ICT and related climate events

Miyagi Prefecture, Japan, installed a system that is capable of finely controlling greenhouse temperatures, humidity, sunlight and other growing conditions by measuring and accumulating such data in a cloud to improve production stability and efficiency (See Figure VII.2). This system employs the ubiquitous environment control system (UECS) information standard for plant cultivation. UECS enables the use of a smartphone and other devices to remotely manipulate devices and equipment for controlling temperature, levels of sunlight and other environmental conditions. This system is chosen because of its low implementation cost, ease of installation and low maintenance requirements.

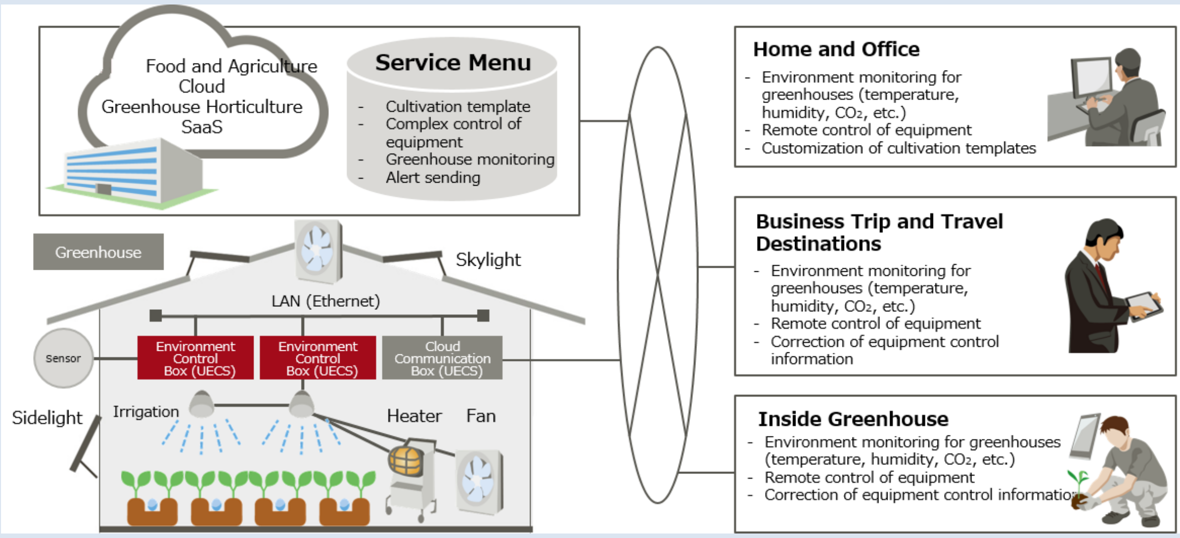


Figure VII.2 – Schematic diagram of greenhouse environment control by sensors and the cloud

Source: [b-UECS, 2016].

Appendix VIII

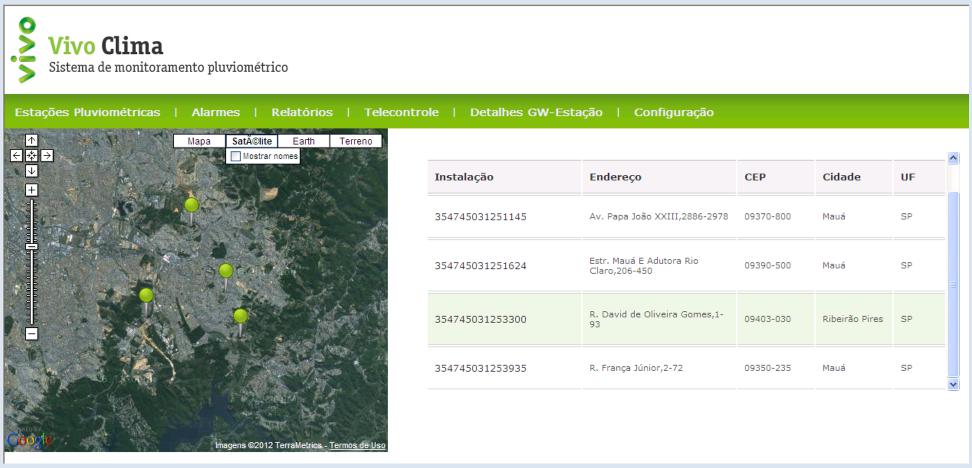
Best practices in use of ICTs for informed adaptation decision-making

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in the use of ICTs for informed adaptation decision-making in various cities and countries.

Maua municipality, city of São Paulo, VIVO-Clima precipitation public information

This service provides real-time information on precipitation levels in different geographic areas in the Maua municipality of the city of São Paulo. VIVO-Clima operates using rain gauges installed in the mobile phone masts of Telefónica Brazil, which send information to the company machine-to-machine (m2m) management platform. The system focuses primarily on trying to predict natural disasters such as floods, landslides and droughts in climate risk areas. This initiative gathers information in real time and provides more effective rainfall forecasts, enabling better protection of people living in areas at risk. The information gathered is displayed on a web-based platform that can be accessed via Internet by the public and the government.



Source: Annex 7 b) 2) of [b-ITU, 2014].

Appendix IX

Best practices in use of social media in climate change adaptation

(This appendix does not form an integral part of this Recommendation.)

The appendix identifies best practices in the use of ICTs to facilitate communication and exchange between local governments, communities, grass-roots organizations and researchers working in urban development programmes, strengthening transparency, accountability and public support.

Social media for rising temperature adaptation in Eldoret, Kenya
The local community of the Rift Valley in the Kenyan city of Eldoret have been working to raise public awareness about climate change and how to adapt to rising temperatures in the region. They educated themselves by attending workshops and conferences organized by environmental organizations. The group has more than 900 followers on Facebook, who access the information shared on the site and have online discussions about farming. Use of social media networks among young Kenyans is growing rapidly. Most use them for socializing; however, Young Volunteers for the Environment (YVE) views them as a means to reach young farmers. Recent changes in weather patterns have affected cereal farmers in parts of the Rift Valley. Planting maize every year is an increasing challenge because of irregular rainfall, as well as outbreaks of pest-borne diseases, such as maize lethal necrosis. Farmers need good information about changing weather patterns and ICT tools: Facebook and mobile SMS have been very useful for them.
Source: [b-Kemboi, 2013].

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