International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.1502

(11/2015)

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

Adapting information and communication technology infrastructure to the effects of climate change

Recommendation ITU-T L.1502

ITU-T

International
Telecommunication
Union

Recommendation ITU-T L.1502

Adapting information and communication technology infrastructure to the effects of climate change

Summary

Information and communication technologies (ICTs) can be part of the solution to climate change by, for example, helping countries adapt to the effects of climate change. At the same time, ICT equipment and infrastructure are themselves exposed to the effects of climate change and therefore need to be both robust and resilient.

Recommendation ITU-T L.1502 identifies direct and indirect threats of climate change on ICT services and provides options for adaptation and mitigation. These threats include extreme rainfall, flooding, landslides, extreme wind, lightning, extreme humidity, drought, ice storms and heavy snowfall.

This Recommendation was developed within the framework of Recommendation ITU-T L.1500. It focuses on telecommunication networks and infrastructure.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1502	2015-11-29	5	11.1002/1000/12629

Keywords

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

* 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

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

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/.

Table of Contents

Recommendation ITU-T L.1502

Adapting information and communication technology infrastructure to the effects of climate change

1 Scope

This Recommendation describes how information and communication technology (ICT) can adapt to or may be adapted to cope with the effects of climate change. It provides a set of requirements and it is to be referred to when planning or upgrading 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.

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.3] Recommendation ITU-T L.3 (1988), *Armouring of cables.*

[ITU-T L.26] Recommendation ITU-T L.26 (2015), *Optical fibre cables for aerial application.*

[ITU-T L.46] Recommendation ITU-T L.46 (2000), *Protection of telecommunication cables and plant from biological attack.*

[ITU-T L.67] Recommendation ITU-T L.67 (2006), *Small count optical fibre cables for indoor applications.*

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 climate change [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. [b-IPPC SPM]

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

3.1.2 climate change adaptation [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

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

HVAC Heating, Ventilation and Air Conditioning

ICT Information and Communication Technology

IPCC Inter governmental Panel on Climate Change

LAN Local Area Network

TSP Telecommunications Service Provider

5 Conventions

None.

6 Adaptation of ICT infrastructure

6.1 Impact of climate change on ICT infrastructure

More intense and frequent climatic extremes are expected as a result of climate change. These extremes pose a threat to industries, like the ICT industry that relies on physical infrastructures. There is an increased risk of service disruption to a range of essential services which now depend on ICT.

[b-IPPC 2012] quotes: "Major settlements are dependent on lengthy infrastructure networks for water, power, telecommunications, transport, and trade, which are exposed to a wide range of extreme events (e.g., heavy precipitation and snow, gale winds). Modern logistics systems are intended to minimize slack and redundancies and as a result are particularly vulnerable to disruption by extreme events".

Telecommunication networks and related ICTs must therefore be able to cope with extreme weather events. A more robust and resilient infrastructure may be required in the future than the infrastructure that is in operation today. Costs can be greatly reduced by considering the requirements at the initial design stage rather than by retrospective upgrade. The need for the ICT infrastructure to cope with extremes of climate or adapt to its effects can be considered from two complementary perspectives – the direct and the indirect perspectives.

[b-ITU-T L.92] deals with disaster management for outside plant facilities. It gives an overview of the technical considerations for protecting outside plant facilities from natural disasters. Disaster management for outside plant facilities such as cables, poles and manholes are introduced, and countermeasures for natural disasters such as earthquakes, strong winds and floods are described.

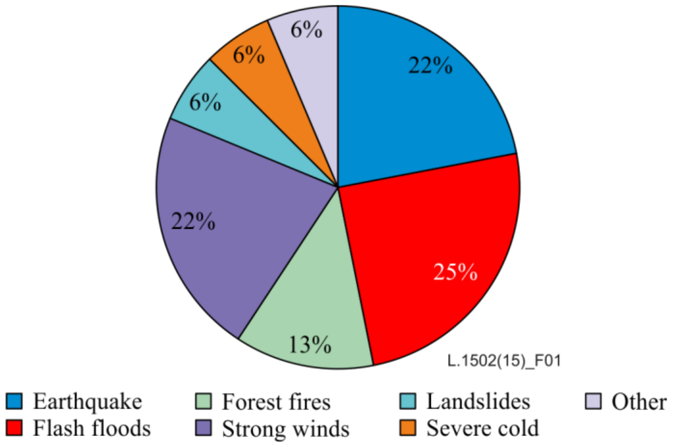

Figure 1 – Most destructive natural disasters

As described in [b-ITU-T L.92], sixteen countries responded to a questionnaire on the protection of outside plant facilities from natural disasters. One of the results of the questionnaire is shown in Figure 1, which ranks natural disasters according to their destructiveness. Most of these natural disasters can be expected to become more frequent as a result of climate change. Note however that the relationship between climate change and earthquakes is being considered, but has yet to be acknowledged by the IPCC [b-IPPC Quake].

In addition to these effects, this Recommendation also considers the risks to ICT infrastructure posed by more extreme changes in temperature, humidity, drought, ice storms and heavy snowfall, and considers ways to make the infrastructure more robust so as to reduce the impact of natural disasters.

6.2 Direct consequences of climate change for ICTs

Direct effects of climate change on ICTs include the vulnerability of ICT equipment to extreme weather events such as increased flooding, wind speed, precipitation, humidity, temperature, snow and ice fall and lightning strikes.

The ICT infrastructure includes telecommunication centres, outside plants, data centres, base stations and user terminals, including handsets. The ICT devices making up this infrastructure are designed to operate within specified ranges of temperature and humidity, and need protection against dust and/or water ingress. When ICT devices operate outside their specified environmental conditions, they are at risk of malfunction, failure and/or damage.

Most ICT services depend upon an end-to-end connection to be maintained for their operation. Telecommunication service providers (TSPs) and other network-based industries are applying techniques such as redundancy (of equipment and of path) to avoid single points of failure which could disrupt service. Such redundancy is usually applied to trunk routes where many users share a common path. This does not totally remove the risk of failure and many parts of the network remain unprotected and are thus vulnerable to climate change-related weather events.

TSPs are significantly exposed to physical risks since extreme weather conditions could result in network damage, restoration costs, loss of revenue and rising insurance costs. Network-based service providers may have to consider protecting or relocating elements of their network that could become exposed to damage from severe weather conditions. This is particularly true in the case of remote sites, especially in developing countries, where road access to the sites is needed for access and maintenance and often for providing energy supplies.

Operators have already begun taking into consideration climate change when planning the location of new central nodes for next generation networks.

Wireless technologies may be seen as more resilient, and could fare better than fixed networks when climate-related events strike, although their backhaul is becoming increasingly dependent on the higher capacity of fixed network technology such as optical fibre. As ITU has noted, "In many cases, when disaster strikes the "wired" telecommunication infrastructure is significantly or completely destroyed and only radio communication services can be employed for disaster relief operation (especially amateur radios and satellite systems) [b-ITU Climate]."

6.2.1 Temperature

The failure rate of an electrical component increases exponentially with temperature. Each component has an activation energy that is characteristic of its chemical composition. Failure will result when the temperature rises sufficiently to cause breakdown in the chemical or crystal lattice. Components are therefore highly underrated so that they operate in a statistically "safe" temperature range [b-ITU Adapt]. Since ICT equipment and facilities usually require proper cooling for their performance management, longer and more intense heat waves, high temperature atmosphere and long tropical nights increase the risk of performance degradation and even device failure.

Semiconductor parts are most often specified for use in the "commercial" 0-70°C and, to a lesser extent, in the "industrial" –40 to +85°C operating temperature ranges. These ranges generally satisfy the demands of the computer, telecommunication and consumer electronic industries. Some components such as processors are designed to run "hot": perhaps 50°C or more above ambient temperature. For a desktop personal computer, the cooling system may be no more than a heat-sink and fan blowing air at ambient temperature to avoid thermal breakdown. For mass deployments, such as in telecommunications buildings and data centres, liquid cooling systems may be used. However, many are or will be using ambient air cooling. Climate change may give rise to a higher ambient air temperature than was originally planned which in turn could necessitate an upgrade of the cooling system. Equipment stored outdoors (e.g., cabinets and shelters) are more subjected to the external temperature changes compared to indoor equipment. Such equipment could experience up to 65 degrees Celsius inlet temperature [b-temp].

6.2.2 Extreme rainfall/flooding

Telecommunications buildings and infrastructure can be at risk from extreme rainfall and flooding, depending on their location. This risk may increase in frequency or severity as a result of climate change. If the electricity grid fails, the backup power systems may also become awash, and power can then only be maintained by other backups such as batteries, if available, for a limited period, and only for emergency services. The risk of this happening would have been taken into account in the design and build of the central office, but the impact of climate change requires the statistics to be updated to show a higher probability of the event occurring, and today perhaps 1 in 100 years would be a better estimate for planning purposes. It should be noted that severe climate events, are now happening much more frequently than in the past.

Possible remedial work to make central offices less vulnerable to flooding would be to raise equipment from the ground floor to higher floors. This has already happened in many instances when obsolete electromechanical switches were replaced by physically smaller digital switches, causing complete floors to be vacated. Problems remain as, typically, the ingress of electrical energy is located at ground (or even underground) level. Large telecommunication sites (typically in cities) have large batteries that could be as much as 10,000Ah @48V. Due to their weight, to cope with the building's structural stability needs, such batteries are typically installed at ground/underground level which may be subject to flooding.

An evolutionary step, which eliminates the need for central offices, is the location of ultra-broadband equipment in roadside cabinets or a shelter that, for economical reasons, are typically installed outdoors at ground level. This step leads to issues regarding water ingress to these cabinets or shelters which may or may not, be protected against flooding. Possible remedial work could be to move street cabinets to a higher level or the use of waterproof solutions if the risk of flooding is known to have increased due to climate change.

A further step would be to check the location of the backup generator and heat exchangers for air-conditioning units. For practical and operational reasons, these are often located outside the main building near ground level. Raising their level or applying techniques resilient to floods should be considered, with due consideration to other factors such as weight, loading and vibration.

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

New technologies with gigabit transmission along twisted pairs such as fibre to pedestal or distribution point (i.e., at a location closer to customer premises), are being introduced into telecommunication networks [b-ITU-T G.9701]. The use of optical fibre in the access network and shorter twisted pair lines will increase transmission speeds and reduce the risk of problems due to moisture and flooding, provided that the electronic components are protected from environmental damage, by for example, water ingress. Fibre to the premises is an option which further reduces the risk of damage due to flooding or from extreme rainfall.

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

When mobile backhaul networks use point-to-point microwave links between towers, these are liable to outage during storms. Raindrops scatter the microwave signal and can cause a loss of service. A system margin is applied so that the power is sufficient in all but the most severe conditions. An estimate of the margin needed to allow for rainfall can be found in [b-ITU-R P.530-9]. To this must be added the free space propagation loss and losses due to pointing variation with high winds. There is a need to know the maximum rainfall and wind speed before the margin can be calculated, which will depend upon rainfall measurements in the locality. As a result of climate change, more extreme rainfall can be expected and so the margin may need to be increased. This is a topic for further study. However, fibre optical cables are now being laid between towers to replace microwave or copper in order to increase the capacity of the networks, and this will eliminate the risk of link loss due to rainfall.

6.2.3 Landslides

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

The risk of landslides and avalanches is increasing due to deforestation and climate change. Facilities such as telecommunication cables located near risk areas are therefore becoming more vulnerable. Maps have been produced for most countries and regions which show the risk by colour code. Landslides can be caused by the over steepening or overloading of slopes, earthquakes, tsunamis, hurricanes, flooding, erosion and other severe weather events, or by vegetation loss as a result of logging, development or wildfires. Landslides can be caused also by various erosions such as rain splash erosion, lateral erosion in river sides and coastal erosion by the sea level rise. Base stations may be destroyed by such erosion cases. Mitigation measures include planting ground cover (low growing plants) on slopes.

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

Landslides could cause telecommunication poles to fall, bringing down aerial cables. Soil erosion is a problem in some areas particularly when reclaimed land is at or below sea level.

6.2.4 Extreme winds

ICT facilities at risk of damage include buildings, overhead lines and antennae. Overhead lines provide fixed access connectivity at lower cost than underground ones, but the cables are vulnerable to the effects of wind through damage by falling trees and gradual wear out due to metal fatigue and vibration [ITU-T L.26]. In areas more prone to falling trees, the route of new overhead lines should be kept at reasonable distance from trees. When this is not possible (existing overhead lines or forest crossing), trees close to the line should be cut to form a safety zone, same as what is today done for the electricity overhead lines.

Antennae are at risk due to winds exceeding their design limit such as the ability to withstand 70 m/s (252 km/h) wind speed. The IPCC Fourth Assessment Report [b-IPCC 4th AR] says that "Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and heavier precipitation associated with ongoing increases of tropical sea-surface temperatures". The report states that there is low confidence in wind speed model trends other than for tropical cyclones. Overall, the changes do not appear to be very large so that adaptation measures may not be necessary in the ICT sector except where there is a risk of cyclone.

In some locations, such as the pacific island of Guam, the IPCC Special Report [b-IPCC SR] states that buildings are required to withstand peak gust wind speeds of 76 m/s, expected every few decades (International Building Codes, 2003). This higher limit could be applied to ICT buildings and antennae in risk areas. The latest version of the International Building Code is available online. Chapter 1612 of the [b-IPCC SR] includes maps of rainfall, seismic, snow and wind criteria across the USA. In general, coastal regions can be expected to have higher maximum wind speeds.

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

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

6.2.5 Lightning

The risk of damage to equipment at telecommunication sites due to lightning can be assessed by risk analysis. ITU-T has published ten K-series Recommendations on this topic (see the bibliography).

More research is needed to determine if, in order to take climate change into account, the values of the parameter 'number of strikes per year' need to be increased (or decreased) with respect to the values on keraunic (lightning strike) maps for the locality.

Adequate grounding is necessary. If changes in climate and weather patterns occur, soil moisture content and resistivity will change as well, and prolonged drought could cause significant increase in grounding resistance, even beyond safety limits. This can affect the safety of maintenance workers, the resilience of infrastructure to lightning, and the performance of power supply systems and telecommunication networks. It may therefore be necessary to install additional protection in some locations.

In mains-powered cabinets and remote base stations, an increase in the grounding resistance or an increase in the frequency and strength of lightning could cause an increase in the residual current circuit breaker trips. This could cause prolonged service disruption as a truck roll is normally required to reset the circuit breaker. To increase resilience against these unwanted power breaks, it is advisable to install either high-noise-immunity differential switches (reinforced immunity) or self-restoring breakers. Self-restoring breakers typically include a control system that verifies the integrity of the system and prevent reactivation if a permanent fault is detected, such as a ground fault caused by a breakdown of the insulation.

6.2.6 Humidity

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

More work is needed to determine the direct impact of extreme humidity on ICT infrastructure. However, there may be an indirect impact on the workforce required to install and maintain networks. "The combination of high temperature and humidity in some areas for parts of the year is expected to compromise common human activities, including growing food and working outdoors (high confidence)." [b-IPCC 2014].

6.2.7 Drought

Drought is illustrated by dry, cracked earth; low reservoir levels; barren fields. There are different types of drought though, each of which is measured differently. The meteorological drought is reflected by levels of precipitation, assessment of the degree of dryness (in comparison to a local or regional average) and the duration of the dry period. There is also hydrological drought, or how decreased precipitation affects stream-flow, soil moisture, reservoir and lake levels, and groundwater recharge. Agricultural drought occurs when water supplies are not able to meet crop water demands.

The changes in precipitation regimes can lead to long periods of drought, increasing the risk of subsidence, hence affecting the stability of foundations and tower structures. Corrosion rates can result from this phenomenon and require different equipment maintenance schemes for ICTs. This could lead to the degradation of ICT infrastructure, business cost and safety risks to personnel.

Some telecommunication installations have a pond nearby to provide water to extinguish fires. The level of this pond must be maintained to cope with extreme drought conditions.

Among the cooling technologies used in ICT plants there are some that need large amounts of water in the refrigeration cycle. For large sites water is used in the heat exchangers, while in other sites evaporative cooling is increasingly used. In case of drought, this raises the problem of possible diversion of water from the needs of the population. Lack of water would be critical to such cooling systems as lack of water would stop their functioning, with the consequent increase of temperature to the ICT equipment. This could cause malfunction of the ICT service and even failure.

6.2.8 Ice storms and heavy snowfall

Ice storms and heavy snowfall can cause failure of electricity transmission lines, causing power outage of ICT services through a lack of local supply. These weather events can also be responsible for damage to the telecommunication lines, for example, when a branch breaks from a tree onto a telephone line and when ice forms around the aerial cable, increasing its weight and its surface exposed to wind (more stress). Radio systems are affected when antennae are covered in ice.

The IPCC [b-IPPC 2014] have reported that "There is very high confidence that the extent of Northern Hemisphere snow cover has decreased since the mid-20th century by 1.6 [0.8 to 2.4]% per decade for March and April, and 11.7% per decade for June, over the 1967 to 2012 period."

However, it seems likely that extreme events are increasing as a consequence of climate change. A recent example of the consequences of ice storms is noted in the New York area. The ClimAID Report includes a chapter on Telecommunications [b-ClimAid]. It says: "The December 2008 ice storm in New England and Central and Upstate New York formed late on December 11 and dissipated meteorologically by December 12. Its impact, however, lasted for more than a week in New York and in large portions of New England Telecommunications services were disrupted as a result of damaged lines, and electronic equipment in homes lost power. Cable-provided voice, video, and data services had problems at twice the normal levels during the week following the storm. Damage was primarily a result of fallen trees, utility wires, and poles, which were coated in a heavy layer of ice. The slow return of power in the aftermath of the storm resulted in a great deal of controversy about why the utilities could not restore services more expediently, if not avoid outages in the first place."

6.2.9 Species damage

It is known that damage to telecommunication infrastructure such as cables, either buried or laid on the ground, may be caused by:

– mammals, squirrels, mice, rats, moles, gophers and other rodents
– birds like woodpeckers and cockatoos
– insects such as termites, ants, beetles, wasps and caterpillars
– micro-organisms like bacteria, fungus and/or moulds.

In areas where these species are normally active, their effects are known and measures can be taken to counter their effects. However, climate change is causing animal and plant species to migrate, usually northwards in the Northern hemisphere and southwards in the Southern hemisphere, and sometimes to increase their overall range. Therefore, they may become active in areas where they have not previously been present, and measures may need to be taken to counter their impact in new areas.

Measures that can be taken to protect fibre optic cables against damage include polyamide protection and helically applied steel tape armour [ITU-T L.3], [ITU-T L.26], [ITU-T L.46] and [ITU-T L.67].

6.3 Indirect consequences of climate change for ICTs

Indirect effects of climate change on ICTs and the additional consequences of climate change impacts include increases in operators' energy demands, as higher temperatures will, under the current increasing temperatures, require more air conditioning in the exchanges. Network damage will require trucks to be used for repairs, with implications for fuel use. Operators are also likely to have to run more back-up generators in areas experiencing extreme weather conditions.

Where sea levels are expected to rise materially, and rivers to flood due to severe rainfalls, network operators would likely be required to move or to replace a significant amount of network equipment. For example, equipment positioned in sites at risk of flooding would need repositioning, and displaced populations would likely require new networks to be built. In countries like Bangladesh, more than a fifth of the territory could be under water with a one-metre rise in sea levels, highlighting the risk to telecommunication companies in such regions. In other words, it is likely that the consequences of climate change will be very different for TSPs in different regions, and that the requirements for adaptation will, as a consequence, also be different.

The data centres, server farms and hosting environments that have become an essential part of the ICT ecosystem have very demanding requirements for electricity and air conditioning. Such facilities have become essential for the delivery of many telecommunication-based services and applications. Thus, adaptive and remedial actions related to the energy-efficient supply of data centres need to be considered [b-ITU-T L.1300].

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

6.3.1 Vehicles and climate change adaptation

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

6.3.2 Workforce and climate change adaptation

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

6.3.3 Supply chain and climate change resilience

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

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

From the maintenance perspective, specialist technicians make regular inspections of HVAC systems. During an inspection, a check can be made on the ability of the equipment to cope with the thermal load as noted in clause 6.2.1. This may increase beyond the design limit due to new equipment being added or if a change in extreme temperature is anticipated.

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

6.3.4 ICT end-user services and equipment

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

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

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

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

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

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

6.4 Checklist

Table A.1 is a matrix of climate change effects and their impact on ICT infrastructure components. Risks have been classified according to their severity: low, medium and high.

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.

Annex A

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

(This annex forms an integral part of this Recommendation.)

Table A.1 is a matrix of climate change effects and their impact on ICT infrastructure components. Risks have been classified according to their severity: low, medium and high. 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.

Table A.1 - Matrix of climate change effect and their impact on ICT infrastructure components

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 more requirements for cooling.

Bibliography

[b-ITU-T G.9701] Recommendation ITU-T G.9701 (2014), *Fast access to subscriber terminals (FAST) – Physical layer specification*.

[b-ITU-T L.92] Recommendation ITU-T l.92 (2012), *Disaster management for outside plant facilities.*

[b-ITU-T L.1300] Recommendation ITU-T L.1300 (2014), *Best practices for green data centres*.

[b-ITU-R P.530-9] Recommendation ITU-R P.530-9 (2001), *Propagation data and prediction methods required for the design of terrestrial line-of-sight systems*.

[b-ITU Adapt] International Telecommunication Union ITU-T (2014), *Resilient pathways: the adaptation of the ICT sector to climate change.*
http://www.itu.int/en/ITU-T/climatechange/Documents/Publications/Resilient_Pathways-E.PDF

[b-ClimAID] ClimAID 2011, *Responding to Climate Change in New York State*, Chapter 10 Telecommunications (2011),
http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Telecommunications.pdf

[b-ITU climate] International Telecommunication Union, 2008, *ITU and Climate Change*.
http://www.itu.int/pub/S-GEN-CLIM-2008-11/en

[b-IPPC Quake] *IPCC Studies Link Between Warming and Earthquake Activity Climatequake: Will global warming rock the planet?*
http://www.heatisonline.org/contentserver/objecthandlers/index.cfm?ID=8094&Method=Full

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

[b-IPCC 4th AR] IPCC 4th Assessment Report *Climate Change 2007: Synthesis Report* page 33,
http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[b-IPPC 2012] IPCC Special Report (2012), *Managing the risks of extreme events and disasters to advance climate change adaptation*
http://ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf

[b-IPPC 2014] IPCC (2014), *Climate Change 2014 – Synthesis Report, page 15*
https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf

[b-Ofcom] Ofcom, UK *The availability of communications services in the UK,*
http://stakeholders.ofcom.org.uk/binaries/research/markets-infrastructure/economic-geography.pdf

[b-ITU-T K-ser] ITU-T Recommendations in the K-series (39, 46, 47, 56, 67, 85, 89, 92, 101 and 105)
https://www.itu.int/rec/T-REC-K/en (entries for each recommendation)

[b-temp] News clip (1 June 2015)
http://english.alarabiya.net/en/variety/2015/06/01/Saudi-Arabia-may-face-65-C-temperatures-during-Ramadan.html

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2016