Final Report

ITU-D
Study Group 2

Question 6/2

ICT and climate change

6th Study Period
2014-2017

CONTACT US

Website:	www.itu.int/ITU-D/study-groups
ITU Electronic Bookshop:	www.itu.int/pub/D-STG/
e-mail:	devsg@itu.int
Telephone:	+41 22 730 5999

Question 6/2: ICT and climate change

Final Report

Preface

ITU Telecommunication Development Sector (ITU-D) study groups provide a neutral contribution-driven platform where experts from governments, industry and academia gather to produce practical tools, useful guidelines and resources to address development issues. Through the work of the ITU-D study groups, ITU-D members study and analyse specific task-oriented telecommunication/ICT questions with an aim to accelerate progress on national development priorities.

Study groups provide an opportunity for all ITU-D members to share experiences, present ideas, exchange views and achieve consensus on appropriate strategies to address telecommunication/ICT priorities. ITU-D study groups are responsible for developing reports, guidelines and recommendations based on inputs or contributions received from the membership. Information, which is gathered through surveys, contributions and case studies, is made available for easy access by the membership using content-management and web-publication tools. Their work is linked to the various ITU-D programmes and initiatives to create synergies that benefit the membership in terms of resources and expertise. Collaboration with other groups and organizations conducting work on related topics is essential.

The topics for study by the ITU-D study groups are decided every four years at the World Telecommunication Development Conferences (WTDCs), which establish work programmes and guidelines for defining telecommunication/ICT development questions and priorities for the next four years.

The scope of work for **ITU-D Study Group 1** is to study "**Enabling environment for the development of telecommunications/ICTs**", and of **ITU-D Study Group 2** to study **"ICT applications, cybersecurity, emergency telecommunications and climate-change adaptation"**.

During the 2014-2017 study period **ITU-D Study Group 2** was led by the Chairman, Ahmad Reza Sharafat (Islamic Republic of Iran), and Vice-Chairmen representing the six regions: Aminata Kaba-Camara (Republic of Guinea), Christopher Kemei (Republic of Kenya), Celina Delgado (Nicaragua), Nasser Al Marzouqi (United Arab Emirates), Nadir Ahmed Gaylani (Republic of the Sudan), Ke Wang (People's Republic of China), Ananda Raj Khanal (Republic of Nepal), Evgeny Bondarenko (Russian Federation), Henadz Asipovich (Republic of Belarus), and Petko Kantchev (Republic of Bulgaria).

Final report

This final report in response to **Question 6/2: "ICT and climate change"** has been developed under the leadership of its Rapporteur: Philip Kelley (Alcatel-Lucent International, France); and three appointed Vice-Rapporteurs: Nasser Al Marzouqi (United Arab Emirates), Naoki Fuke (KDDI Corporation, Japan) and Joseph Bruno Yuma Utchudi (D.R. of the Congo). They have also been assisted by ITU-D focal points and the ITU-D Study Groups Secretariat.

ISBN

978-92-61-23111-8 (Paper version)

978-92-61-23121-7 (Electronic version)

978-92-61-23131-6 (EPUB version)

978-92-61-23141-5 (Mobi version)

This report has been prepared by many experts from different administrations and companies. The mention of specific companies or products does not imply any endorsement or recommendation by ITU.

Please consider the environment before printing this report.

Table of Contents

List of Tables, Figures and Boxes

Tables

Figures

Executive Summary

This report provides a summary of numerous on-going activities in ITU and elsewhere, including information on country experiences, for participating developing countries as well as those who did not participate in the meetings of ITU-D Study Group 2 Question 6 on “ICT and climate change”. Information contained in this Report includes information directly from the two other sectors of the ITU, and in particular ITU-T Study Group 5 on “Environment, climate change and circular economy”.

As a background to this report it is noted that the rise in the world temperature since 1870 is an established fact that is now recognized by numerous Member States taking part in the United Nations Convention for Climate Change (UNFCC). There is a rising consensus that greenhouse gases (GHG) emitted by human activity substantially contribute to this undeniable warning, and the latest Conferences of the Parties (COP) to the UNFCC set the objective of limiting long-term global warming to at most 2°C by comparison to the pre-industrial era.

In **Chapter 1** and **Chapter 2**, this report provides developing countries with a synthesis summarizing the recent climate change observations, the different methods for monitoring climate change, and the state-of-the-art ICT technologies in use for such studies. Monitoring by means of terrestrial, satellite, maritime and airborne meteorological systems are briefly described. International initiatives on climate change from United Nations agencies and other institutions are recalled, and references are provided to their Recommendations and Reports related to ways and means in which ICTs are used to monitor climate change and reduce overall GHG emissions.

Chapter 3 of this report on “Climate change mitigation” addresses the policies and technological efforts from ICT organizations that contribute by reducing their own GHG emissions. The Report then recalls an estimation of the potential GHG reduction that can result from enabling the following economic sectors with ICT: mobility and logistics, manufacturing, food, buildings, energy, work and business, health and learning. In this respect, particular attention is paid to urban areas where a growing proportion of the world population lives, and the benefits of innovative ICTs applied to “smart cities” are summarized and illustrated with references to some best practices.

Chapter 4 on “Climate change adaptation” provides a summary of the main climate change impacts on the ICT sector and the recommended adaptation measures, illustrated by a couple of country experiences. The report then reviews adaptation to climate change in other industrial and agricultural sectors. It associates a variety of indicators of climate change and their corresponding causes and impacts, with the contribution to adaptation provided by ICTs.

In **Annex 1** of this report, country experiences on monitoring/mitigating climate change are provided, based upon the results of a survey completed in 2016. **Annex 2** shares a list of the contributions received for Question 6/2 during study period.

1 CHAPTER 1 – Climate change

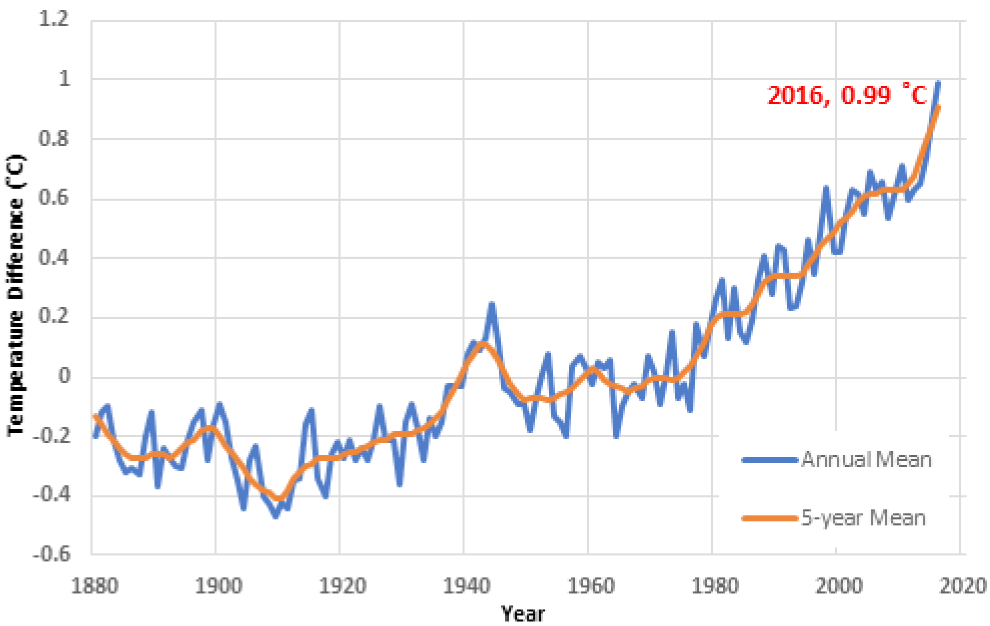
1.1 Background

1.1.1 Increase of temperature

The global temperature is the first indicator of global warming. The temperature increase on the Earth's surface has been 0.8 ± 0.2°C since 1870. It differs markedly between the two hemispheres, being more accentuated in the North and in the higher latitudes. Variability among continents is also observed. There has been a constant upward trend since 1870.

Figure 1 shows that the global mean temperature has been steadily rising since 1880, reaching record levels in the first decade of the current century. According to NASA's Goddard Institute for Space Studies (GISS),[1] the globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.99 °C from 1880 to 2016.

Figure 1: Global temperature difference since 1880



According to the World Meteorological Organization (WMO),[2] the year 2015 made history, with shattered temperature records, intense heatwaves, exceptional rainfall, devastating drought and unusual tropical cyclone activity. That record-breaking trend has continued in 2016. The global average surface temperature in 2015 broke all previous records by a strikingly wide margin, at 0.76±0.1° Celsius above the 1961-1990 average. For the first time on record, temperatures in 2015 were about 1°C above the pre-industrial era, according to a consolidated analysis from WMO. It is worth noting that 2014 previously broke a temperature record, and it took place in the absence of a genuine El Niño event. This phenomenon, which warms the climate, occurs when higher than normal sea surface temperatures in the east of the tropical Pacific interact with atmospheric pressure systems. The year 1998 – the hottest before the twentieth century – was marked by high temperatures coinciding with a high-intensity El Niño episode.

[1] NASA/GISS, Global Climate Change – Vital signs of the planet; http://climate.nasa.gov/vital-signs/global-temperature/.

[2] WMO Press Release, *World Meteorological Day: Hotter, Drier, Wetter. Face the Future*, 21 March 2016; http://public.wmo.int/en/media/press-release/state-of-climate-record-heat-and-weather-extremes.

Under such conditions, WMO recommends that it is more necessary than ever to have reliable meteorological and climatological services in order to strengthen the resilience of populations and help countries and communities to adapt to a rapidly evolving climate which, in many regions, is becoming less hospitable.

1.1.2 Extreme events

The fifth report of the Intergovernmental Panel on Climate Change (IPCC) warns against a worsening of climate extremes, stating that the risks associated with climate change, in the form of extreme events such as heat waves, extreme rainfall and coastal area flooding, are already materializing to a moderate extent, and will do so to a high extent with additional warming of 1°C. It is therefore not the frequency but the intensity of cyclones that is worsening, with two combined phenomena: warming of the oceans – which creates more water vapour and therefore energizes cyclones as they form above the sea – and rising sea levels, which IPCC experts put at between 26 and 82 cm by the year 2100. The climate change now occurring is taking us towards ever more intense meteorological events.

On balance, the most powerful hurricanes, cyclones and storms have grown in number. This was also the conclusion of two studies published in 2005, the first in Nature[3], which showed that the total energy dissipated by hurricanes in the northern Atlantic and western Pacific had increased by 70 per cent over 30 years; and the second, in Science,[4] which confirmed that the number of category four or five hurricanes increased by 57 per cent between 1970 and 2004.

Extreme heat events are becoming increasingly frequent, as is explained in in several publications, for example in the April 2011 edition of *Science.*[5] The WMO Statement on the Status of the Climate in 2015[6] gave details of several extremes events recorded worldwide. In addition, the American Meteorological Society published a report entitled, "Explaining Extreme Events of 2014 from a Climate Perspective",[7] that shows that human-caused climate change has influenced the frequency or intensity of events in a substantial manner.

1.1.3 Increase of sea level

For a better understanding of climate change, one has to look closely at ocean dynamics. The oceans store large amounts of heat, which they redistribute around the planet: sea water is heated by the sun in the tropics and then transferred by currents to temperate coasts, where it cools down as it transfers its heat to the atmosphere. Colder and denser, it sinks to a great depth where it moves back towards the equatorial regions, and so on, in a circuit lasting over a thousand years.

The mean level of the oceans is an indicator which includes the effects of several components of the climate system (ocean, continental ice and continental waters). Up until 1992, the sea level was measured by means of sea-level gauges positioned along continental and a number of island coasts. The level of the oceans, as a worldwide global average, rose at the rate of 0.7 mm/year between 1870 and 1930, and by some 1.7 mm/year as from 1930. Since 1992, measurements have been taken from satellites, and have shown the mean annual sea-level rise to have been in the order of 3.4 mm/year. Superimposed on this average rise are multi-year oscillations associated with the natural variability

---

[3] Emanuel, Kerry, Increasing destructiveness of tropical cyclones over the past 30years, *Nature* 436, 686-688 (4 August 2005); http://www.nature.com/nature/journal/v436/n7051/full/nature03906.html.

[4] Webster, P. J., et al., Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment, *Science Translational Medicine* 309 (5742), 1844-1846 (15 September 2005); http://science.sciencemag.org/content/sci/309/5742/1844.full.pdf.

[5] David Barriopedro, Erich M. Fischer, Jürg Luterbacher, Ricardo M. Trigo, Ricardo García-Herrera, The Hot Summer of 2010: Redrawing the Temperature Record Map of Europe, Science, 220-224 (08 Apr 2011).

[6] http://library.wmo.int/pmb_ged/wmo_1167_en.pdf.

[7] Herring, S. C., M. P. Hoerling, J. P. Kossin, T. C. Peterson, and P. A. Stott, Eds., Explaining Extreme Events of 2014 from a Climate Perspective, *Special Supplement to the Bulletin of the American Meteorological Society*, Vol. 96, No. 12, December 2015; https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/.

of the climate system. Since the early 1990s, the climate contributions to this rise are approximately one-third attributable to ocean expansion due to warming, and two-thirds attributable to continental ice melt, shared almost equally between the polar ice caps of Greenland and the Antarctic on the one hand, and continental glaciers on the other.

As already mentioned, the satellite data have been available only since 1993. This date corresponds to the first satellite data obtained from the Topex satellites, which were subsequently replaced by Jason 1, 2 and 3. The data gathered by these satellites are extremely reliable and accurate.

Figure 2 shows a mean sea level rise of 3.35 mm/year.

Figure 2: Mean sea level from 1993 through 2015[8]

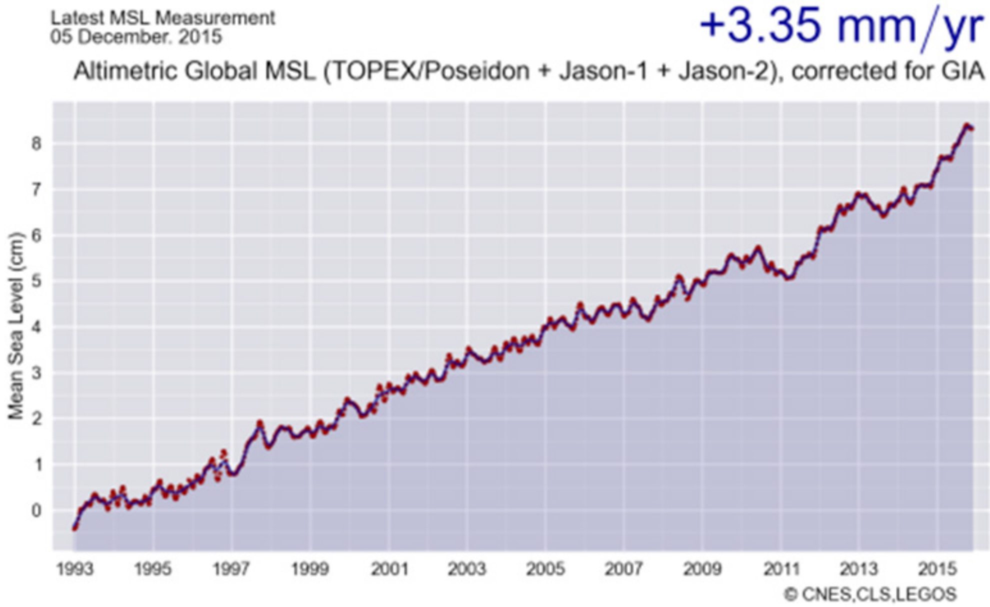
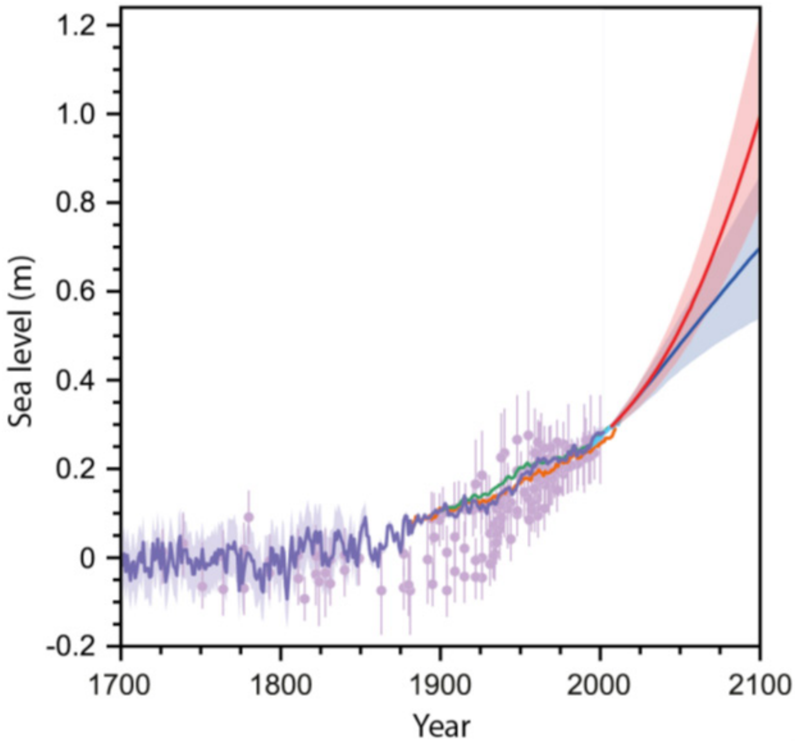


Figure 3 places the mean sea-level rise phenomenon since 1700 within a global context. In the latest IPCC report (Fifth Assessment Report (AR5)), an assessment of the likely range of sea level rise for the 21st century is indicated. Figure 13.27 of chapter 13 of that report[9] is repeated in **Figure 3**). This figure is a compilation of paleo sea level data (purple), tide gauge data (blue, red and green), altimeter data (light blue), and central estimates and likely ranges for projections of global-mean sea level rise from the combination of models for Representative Concentration Pathways for a scenario that corresponds to above 700 ppm CO_2-eq but below 1500 ppm) (blue) and a worst case scenario (red), all relative to pre-industrial values. These data confirm that the rate of rise has increased from low rates of change (on the order of tenths of mm/yr) to rates of almost 2 mm/yr averaged over the 20th century, with a likely continuing acceleration during the 20th century.

[8] CNES, CTOH and OMP, Évolution du niveau moyen des mers vu par les altimètres, *Satellite Altimetry Data*; http://www.aviso.altimetry.fr/fr/donnees/produits/produits-indicateurs-oceaniques/niveau-moyen-des-mers.html.

[9] Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S., Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter13_FINAL.pdf.

Figure 3: Global mean sea-level evolution from the 18th to the 21st centuries[10]



The rising sea level is a direct consequence of climate change, and the oceans have warmed over the past few decades. Today, 80 per cent of the heat accumulated over 50 years in the climate system owing to anthropogenic greenhouse-gas emissions is stored in the oceans.[11]

1.1.4 Increase of CO_2

The CO_2 (carbon dioxide) that is present in the atmosphere in gaseous form is responsible for a greenhouse effect that produces a rise in temperature.

Since the beginning of the industrial era in the late eighteenth century, the CO_2 content of the atmosphere has risen sharply, exceeding the 0.03 per cent mark and now reaching as high as 0.04 per cent.

This increase is due to human activities such as deforestation, which limits the effects of photosynthesis and hence the "recycling" of CO_2 into O_2 (dioxygen), or the burning of fossil fuels, which releases into the atmosphere, in the form of CO_2, the carbon that was "stored" in the lithosphere. Plant photosynthesis is unable to compensate for such a huge CO_2 overload, resulting in a considerable increase in CO_2 levels in the atmosphere and a heightened greenhouse effect.

To what extent is the human being responsible for this undeniable warming? The US Space Agency (NASA) confirms that the rise in temperatures is largely underpinned by the increase in greenhouse-gas – particularly carbon dioxide – concentrations in the atmosphere, produced by human activities (power generation, transportation, industry, etc.). Thus, observes NASA, whereas the concentration of CO_2 was 285 parts per million (ppm) in 1880, by 1960 it had risen to 315 ppm. Today it has passed the symbolic mark of 400 ppm mark and is continuing to rise by some 2 ppm each year and its current value end of 2015 was 402 ppm. Many scientists are in agreement that 350 ppm is the maximum acceptable limit for atmospheric CO_2.

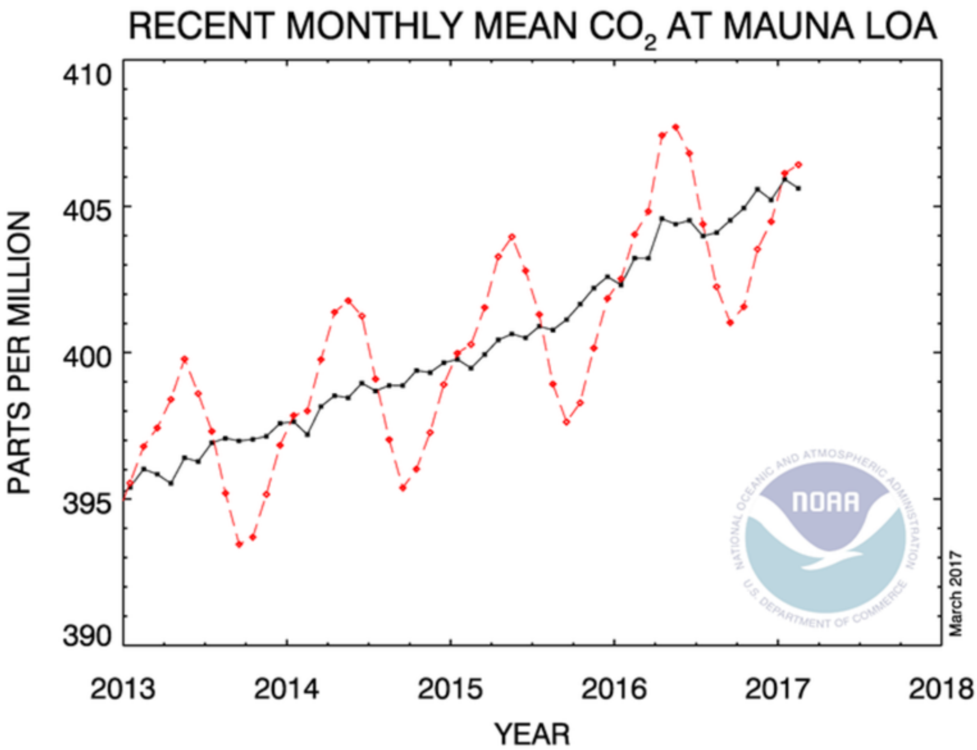
10 *ibid*, Figure 13.27.
11 Ocean and climate scientific notes, http://www.ocean-climate.org.

In 2013, the atmospheric concentration of CO_2 was 142 per cent higher than in pre-industrial times (1750), while the equivalent figures for methane and nitrous oxide were 253 and 121 per cent, respectively. The difference in CO_2 concentration between pre-industrial times and the present day is 120 ppm.

The difference in CO_2 concentration between pre-industrial times and the present day is 120 ppm. Thus, the most pessimistic scenario from the latest IPCC report is for a CO_2 concentration in the order of 900 ppm by 2100. According to climate experts, this would result in a surface temperature increase of 4.8°C over the period 2081-2100 as against the average for 1986-2005, a rise in sea levels of almost one metre, the proliferation of extreme climate events (such as droughts, torrential rainfall and stronger hurricanes), together with worsening food insecurity.

In addition, BBC has reported[12] that scientists say that in 2015 carbon dioxide levels in the atmosphere grew more than at any time in the past 56 years. Measurements at the Mauna Loa Observatory in Hawaii went up by more than three parts per million (ppm) in 2015. The spike is due to a combination of human activities and the El Niño weather pattern. The following figure shows the evolution of CO_2. In February 2017, a value of 406.42 ppm for the concentration of CO_2 was measured at Mauna Loa in Hawaii.

Figure 4: Recent monthly mean CO_2 at Mauna Loa



In **Figure 4**,[13] the dashed **red line** with diamond symbols represents the monthly mean values, centred on the middle of each month. The **black line** with the square symbols represents the same, after correction for the average seasonal cycle. The latter is determined as a moving average of seven adjacent seasonal cycles centred on the month to be corrected, except for the first and last three

12 McGrath, Matt, CO_2 data is 'wake-up call' for Paris climate deal, *Science & Environment webpage (10 March 2016);* http://www.bbc.com/news/science-environment-35778464.

13 National Oceanic and Atmospheric Administration, U.S. Department of Commerce; http://www.esrl.noaa.gov/gmd/ccgg/trends/.

and one-half years of the record, where the seasonal cycle has been averaged over the first and last seven years, respectively.

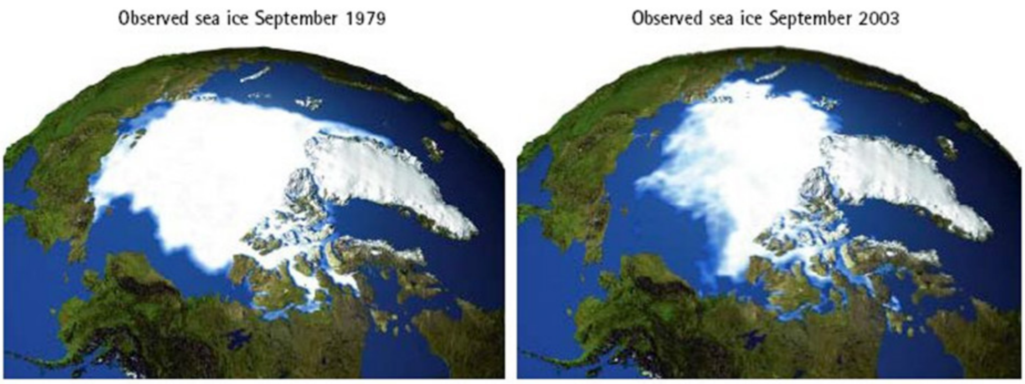
1.1.5 Melting ice

Sea ice, which is frozen sea water, floats on the sea. In line with the Archimedes' principle, this ice displaces a volume of sea water whose weight is the same as its own. Were it to melt, the water thus produced would constitute exactly the same volume of sea water as the volume previously occupied by the ice, without any consequent change in sea level. The melting of sea ice in and of itself does not play any part, therefore, in rising sea levels.

By contrast, however, the melting of fresh-water ice, i.e. the ice caps and glaciers, does contribute to rising sea levels. Antarctica contains 30 million km^3 of ice, which represents 2 per cent of the world's water, but 75 per cent of fresh water and 90 per cent of ice. If all of Antarctica's ice were to melt, this would result in a sea-level rise of some 60 m, to which the melting of Greenland's ice would add a further rise in the order of 7 m, give or take an uncertainty of a few metres.

According to a recent Arctic Climate Impact Assessment, the extent the ice shrinkage of the arctic sea ice is shown in **Figure 5** between September 1979 and September 2003.[14]

Figure 5: Arctic sea ice concentrations in September 1979 and 2003



These two images, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

According to IPCC, the sea ice has a climatic influence, mainly on account of its high albedo, which is the percentage of received light it reflects, compared to that of a thin layer of ice and that of an ice-free ocean. While thick ice with a snow covering has an albedo of 90 per cent, that of a thin layer of ice is 50 per cent, and that of an ice-free ocean is in the order of 6 per cent. With its much higher albedo, the sea ice reflects the light and hence limits the warming effect. By forming a "protective" layer, it also limits heat exchanges between the atmosphere and ocean. When it melts, however, those exchanges increase and the surface albedo diminishes, resulting in a local temperature increase. Sea-ice shrinkage has a positive retroaction on global warming, meaning that it amplifies it.

It is to a great extent for this simple reason that temperatures are rising 2.5 times more rapidly in the Arctic than elsewhere in the world. By 2100, IPCC, on the basis of a very specific scenario, foresees global warming of 2.8°C, but of 7°C in the Arctic. According to the model used, the summertime arctic sea ice could disappear altogether sometime between 2040 and 2060.

[14] ACIA 2004, Impacts of a Warming Arctic: Arctic Climate Impact Assessment, *ACIA Overview report*, Cambridge University Press, page 25.

1.2 International initiatives on climate change

1.2.1 United Nations conferences on climate change

1.2.1.1 The Conference of the Parties

The Conference of the Parties (COP) each year brings together those countries that are Parties to the United Nations Framework Convention on Climate Change. The twenty-first such meeting (known as COP21) took place in Paris in December 2015, the two last most emblematic COPs having been those held in Kyoto in 1997, and in Copenhagen in 2009. The COP21 event set the objective of limiting long-term global warming to 2°C by comparison with the pre-industrial era, this having represented a decisive milestone.

COP21[15] agreed to keep global temperatures "well below" 2.0°C above pre-industrial times and "endeavour to limit" them even more, to 1.5°C. COP21 committed to limit the amount of greenhouse gases emitted by human activity to the same levels that trees, soil and oceans can absorb naturally, beginning at some point between 2050 and 2100.

The agreement includes the review of each country's contribution to cut emissions every five years so they scale up to the challenge.

The measures include to peak greenhouse gas emissions as soon as possible in order to achieve a balance between sources and sinks of greenhouse gases in the second half of this century.

$100 billion a year in climate finance are dedicated for developing countries by 2020, with a commitment to further finance in the future, through 2025, with a new, higher goal to be set for the period after 2025.

COP21 reaffirmed the binding obligations of developed countries under the United Nations Framework Convention on Climate Change (UNFCCC) to support the efforts of developing countries, while for the first time encouraging voluntary contributions by developing countries too. Governments agreed to strengthen societies' ability to deal with the impacts of climate change, and to provide continued and enhanced international support for adaptation to developing countries.

1.2.1.2 United Nations Framework Convention for Climate Change – Supplementary Fund

The United Nations Convention for Climate Change (UNFCCC) – Supplementary Fund provides developing countries with technical activities that help them implement their goals and commitments under UNFCCC, such as having high-quality national inventories, deploying clean technology or developing national adaptation strategies.

1.2.2 ITU and climate change

1.2.2.1 ITU-R

The use of Earth observation satellites provides systematic and homogeneous measurements in support of the scientific analysis. ITU-R is responsible for identifying the necessary radio-frequency spectrum for climate monitoring, disaster prediction and detection and relief operations, including through the establishment of cooperative arrangements with the World Meteorological Organization (WMO) in the field of remote-sensing applications.

[15] United Nations Framework Convention on Climate Change, draft of 12 December 2015; https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

ITU-R plays an important role in climate change monitoring through Resolutions 646 (Rev. WRC-15) and 647 (Rev. WRC-15) on use of radiocommunications for environmental monitoring, public protection and disaster relief. The Radiocommunication Sector manages the detailed coordination and recording procedures for space systems and earth stations, which are used for climate data collection and environmental monitoring.

ITU-R Study Group 7 (SG 7), in particular Working Party 7C (WP 7C), deals with radio-based devices called sensors (passive or active), which are the main tools for global monitoring of the geophysical parameters of the Earth and its atmosphere.

Resolution 673 (Rev. WRC-12), on the importance of Earth observation radiocommunication applications, called for ITU-R studies on possible means to improve the recognition of the essential role and global importance of Earth observation radiocommunication applications and the knowledge and understanding of administrations regarding the utilization and benefits of these applications. These studies resulted in Report ITU-R RS.2178: *The essential role and global importance of radio spectrum use for Earth observations and for related applications*. It is stressed that information about climate, climate change, weather, precipitation, pollution or disasters is a critically important everyday issue for the global community. Earth-observation activities provide such information, which is required for daily weather forecasting, climate change studies, environmental protection, economic development (transportation, energy, agriculture, and construction) and for safety of life and property.

Most of the data for the WMO Global Observing System (GOS) and Global Climate Observing System (GCOS) are provided by radiocommunication systems and radio-based applications operating in the Earth exploration satellite, meteorological-aids and meteorological satellite services. These systems are described in a number of ITU-R Recommendations. In particular, WP 7C has developed Recommendation ITU-R RS.1883[16] on the use of remote sensing in the study of climate change and its effects. ITU-R Study Group 7 (Science services), in cooperation with the World Meteorological Organization, produced in 2002 a WMO and ITU Handbook on Use of Radio spectrum for meteorology: weather, water and climate monitoring and prediction providing information on the development and proper use of radiocommunication systems and radio-based technologies for environmental observation, climate control, weather forecasting and natural and man-made disaster prediction, detection and mitigation. ITU-R Study Group 7 and WMO are currently preparing a revision to this Handbook, which is planned for completion in 2017.

The ITU Radiocommunication Bureau published in 2012 a report entitled *Radio-based technologies in support of understanding, assessing and mitigating the effects of climate change*. This report lays particular emphasis on the crucial importance of satellite observations, which are an indispensable means of understanding climate evolution thanks to the repetitiveness and homogeneity of their measurements.

In addition, the Radiocommunication Assembly 2015 adopted Resolution ITU-R 60: Reduction of energy consumption for environmental protection and mitigating climate change by use of ICT/radiocommunication technologies and systems. The aim of this ITU-R Resolution is to strengthen collaboration among ITU-R, ISO, IEC and other bodies as appropriate, with a view to cooperating in identifying and fostering implementation of all appropriate measures to reduce power consumption in radiocommunication devices and to utilize radiocommunications/ICTs in monitoring and mitigation of the effects of climate change, in order to contribute to a global reduction of energy consumption. Member States, Sector Members and Associates are invited to contribute actively to ITU-R's work in the field of radiocommunications and climate change, taking due account of relevant ITU initiatives, and to continue to support ITU-R's work in the field of remote sensing (active and passive) for monitoring of the environment.

[16] Recommendation ITU-R RS.1883, *Use of remote sensing systems in the study of climate change and the effects thereof*, February 2011; https://www.itu.int/rec/R-REC-RS.1883/.

1.2.2.2 ITU-T

ITU-T Study Group 5 has developed several Recommendations, including:

– ITU-T L.1300 (06/2014), *Best practices for green data centres*.[17]

– ITU-T L.1301 (05/2015), *Minimum data set and communication interface requirements for data centre energy management*.[18]

– ITU-T L.1302 (11/2015), *Assessment of energy efficiency on infrastructure in data centre and telecom centre*.[19]

– ITU-T L.1310 (08/2014), *Energy efficiency metrics and measurement methods for telecommunication equipment.*[20]

– ITU-T L.1320 (03/2014), *Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres*.[21]

– ITU-T L.1330 (03/2015), *Energy efficiency measurement and metrics for telecommunication networks*.[22]

As of 2016, ITU-T Study Group 5 is developing several best practices and energy efficiency measurement methodologies covering topics such as "Energy efficiency metrics of mobile station cell site and best practice for energy saving". It is also currently in process of developing a Supplement to Recommendation ITU-T L.1500 (06/2014), *Framework for information and communication technologies and adaptation to the effects of climate change*, discussing climate change effects and possible impacts. ITU-T Study Group 5 is also currently developing a new specific recommendation addressing the use of ICT for the adaptation of agriculture.

1.2.3 WMO and climate change

1.2.3.1 Global Framework for Climate Services

The need to provide decision-makers and other users with scientific data and information to help them confront the risks associated with climate and climate change and take fully informed decisions was stressed by numerous participants in the third World Climate Conference (Geneva, 2009), who recommended the establishment of a Global Framework for Climate Services (GFCS), following which the High Level Task Force responsible for implementing GFCS prepared a report containing a series of recommendations in this field. The Sixteenth World Meteorological Congress (Geneva, May-June 2011) approved, in the form of a set of decisions and resolutions, the initiation of the process to establish the Global Framework.

The Global Framework for Climate Services is an international initiative directed by the World Meteorological Organization (WMO) intended to coordinate efforts made at global level to ensure the provision of climate services focused on the needs of users and thus make best possible use of knowledge on climate.

[17] Recommendation ITU-T L.1300 (06/2014), *Best practices for green data centres*; https://www.itu.int/rec/T-REC-L.1300.

[18] Recommendation ITU-T L.1301 (05/2015), *Minimum data set and communication interface requirements for data centre energy management*; https://www.itu.int/rec/T-REC-L.1301.

[19] Recommendation ITU-T L.1302 (11/2015), *Assessment of energy efficiency on infrastructure in data centre and telecom centre*; https://www.itu.int/rec/T-REC-L.1302.

[20] Recommendation ITU-T L.1310 (08/2014), *Energy efficiency metrics and measurement methods for telecommunication equipment*; https://www.itu.int/rec/T-REC-L.1310.

[21] Recommendation ITU-T L.1320 (03/2014), *Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres*; https://www.itu.int/rec/T-REC-L.1320.

[22] Recommendation ITU-T L.1330 (03/2015), *Energy efficiency measurement and metrics for telecommunication networks*; https://www.itu.int/rec/T-REC-L.1330.

In brief, farmers, livestock breeders, dam operators, lowland dwellers, etc., will dispose of information (months and even years in advance) allowing them to prepare for and anticipate climate-related risks, taking advantage of the possibilities offered in four priority areas (agriculture, water, health and disaster prevention).

– Around seventy countries currently not in a position to develop and provide real climate services – in particular least developed countries, small-island developing States, land-locked developing countries and other vulnerable countries – will see their resources strengthened in this area.

– All countries and all their inhabitants are liable to benefit from establishment of the Global Framework, which will result in the provision of climate services adapted to the requirements of all.

1.2.3.2 GFCS within the context of adaptation to climate change

Establishment of the Global Framework for Climate Services will bring numerous benefits at the economic, social and environmental levels, as the provision of targeted climate services will make it possible to better manage the risks of climate-related disasters. For example, agrometeorological forecasts, epidemiological predictions and early warnings for floods or droughts will come in support of adaptation measures at community level. The GFCS will allow the United Nations system to better help Members States to fulfil their commitments regarding the Millennium Development Goals, the Sustainable Development Goals, and meet the new challenges they face.

1.2.4 Other initiatives

1.2.4.1 Collaborative Adaptation Research Initiative in Africa and Asia

Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) supports high-calibre research and policy engagement in Africa and Asia by targeting three climate-change hot spots: semi-arid regions, deltas and glacier- and snow-fed basins. Each hot spot is home to large numbers of poor people whose livelihoods depend on climate sensitive sectors.

Using the hot spots as a lens for research on common challenges across different contexts, new opportunities and insights can emerge. Each of the consortia that CARIAA supports brings together up to five institutions with a range of regional, scientific and socio-economic development expertise to explore the physical, social, economic and political dimensions of vulnerability and adaptation options. The consortia also tackle climate change over different timeframes and across different scales – from impacts on households and villages up to regional and global policies.

CARIAA is implemented jointly by IDRC and the United Kingdom Department for International Development, and is in force from 2012 to 2019.

1.2.4.2 International Research Initiative on Adaptation to Climate Change

International Research Initiative on Adaptation to Climate Change (IRIACC) is a five-year (2011-2016) research programme designed to help vulnerable populations and sectors adapt to climate change.

IRIACC makes it possible to enhance knowledge on climate change and related stress factors, and to develop tools, technologies and harmonized approaches regarding adaptation. The programme aims to shape policies by exchanging the results of research between the different competent authorities in order to guide the planning of adaptation.

1.2.4.3 Climate and Clean Air Coalition

The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) is a voluntary international framework for concrete and substantial action to accelerate efforts to reduce Short-Lived

Climate Pollutants (SLCPs), with an initial focus on methane, black carbon, and many hydrofluorocarbons (HFCs), in ways that protect the environment and public health, promote food and energy security, and address near-term climate change.

1.2.4.4 The Major Economies Forum on Energy and Climate

The Major Economies Forum on Energy and Climate (MEF) is an initiative launched in March 2009 to bring together the world's 17 largest emitters to advance key issues under consideration in international climate change negotiations.

The Major Economies Forum also provides an important venue for broader international collaboration on the development, demonstration and deployment of transformational clean energy technologies.

1.2.4.5 Global Methane Initiative

GMI is a voluntary initiative that serves as an international framework to promote cost-effective methane recovery and use as a clean energy source.

Launched in 2004, GMI is the only international effort to specifically target the abatement, recovery and use of methane by focusing on the five main methane emission sources: agriculture, coal mines, municipal solid waste, oil and gas systems, and wastewater. The Initiative works in concert with other international agreements, including the United Nations' Framework Convention on Climate Change, to reduce GHG emissions. Unlike other GHGs, methane is the primary component of natural gas and can be converted to usable energy. The reduction of methane therefore serves as a cost-effective method to reduce GHGs and increase energy security, enhance economic growth, improve air quality and improve worker safety.

GMI is an international public-private initiative that advances cost effective, near-term methane abatement and recovery and use of methane as a clean energy source in five sectors: agriculture, coal mines, municipal solid waste, oil and gas systems, and wastewater. The projects reduce GHG emissions in the near term and provide a number of important environmental and economic co-benefits such as:

- Stimulating local economic growth;
- Creating new sources of affordable alternative energy;
- Improving local air and water quality, with associated public health benefits;
- Increasing industrial worker safety.

The Initiative aims to reduce informational, institutional and other market barriers to project development through the development of tools and resources, training and capacity building, technology demonstrations and direct project support.

Special emphasis is given to bringing together all of the actors necessary for project development, including governments, financial institutions, project developers, technology providers and others.

1.2.4.6 International Fund for Agricultural Development

The main objective of the International Fund for Agricultural Development (IFAD) is to help poor rural smallholder farming communities withstand the effects of climate change and weather-related disasters. The programme achieves this objective by supporting the creation and sharing of knowledge, approaches and practices related to climate change adaptation. The Canadian International Development Agency's support expects to help farmers reduce their crop yield losses, gain increased access to water supplies, use water resources more efficiently, and build individual and community level capacity to adapt to climate change.

1.2.4.7 Forest Carbon Partnership Facility – Readiness Fund

The Readiness Fund of the Forest Carbon Partnership Facility (FCPF) is a World Bank-managed global partnership that assists developing countries in their efforts to reduce greenhouse gas emissions from deforestation and forest degradation. It also promotes forest conservation, sustainable management of forests and the enhancement of forest carbon stocks (amount of carbon stored in forest ecosystems) in developing countries in tropical and subtropical regions.

1.2.4.8 Climate Risks Early Warning Systems

Strengthening early warning systems is at the heart of resilience in the face of climatic risks. As a concrete response to a strong demand, notably from the least developed countries and small-island developing states, for a prioritisation of adaptations in climate action, France has launched an initiative, Climate Risks Early Warning Systems (CREWS), which has become an integral part of the agenda for action following COP21. This initiative has seen international support growing in the months since COP21.

CREWS had its first steering committee meeting in Geneva on 12 September 2016. At this meeting, France was designated as its President for a one year term. The governance and structure of CREWS was also approved, relying upon the trust fund of the World Bank and a "light" secretariat within the World Meteorological Organization (WMO). Currently, partner organizations include the United Nations Office for Disaster Risk Reduction, WMO and the Global Facility for Disaster Reduction and Recovery within the World Bank. The initial plan of investments for CREWS during the period 2016-2020 has been approved. Six priority projects have been identified, with a global amount provisionally allocated of 16.46 million USD: Burkina Faso, Mali, Niger, the Democratic Republic of Congo, Papua New Guinea and the Pacific Region (Fiji, Kiribati, Papua New Guinea, Tuvalu, Vanuatu, the Solomon Islands, and the Marshall Islands).

The CREWS fiduciary fund has a capitalization objective of 100 million USD by 2020. The first financial decisions per country were taken in the second steering committee meeting, which will take place on the margins of COP22. US$12 million funding was secured for Burkina Faso, the Democratic Republic of the Congo and Small Island Developing States (SIDS) in the Pacific.

2 CHAPTER 2 – Climate change monitoring

2.1 Terrestrial systems

Over the past several decades, scientific organizations established networks of weather-observing stations around the world. These stations also provide data for climate monitoring. Many stations have compiled continuous weather records over many decades, but other stations only operated for few years before stopping. Data usually consist of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals and may include additional hydrological or meteorological data such as evaporation or soil temperatures.

Typical weather stations have the following instruments:

– Thermometer for measuring air and sea surface temperature;

– Barometer for measuring atmospheric pressure;

– Hygrometer for measuring humidity;

– Anemometer for measuring wind speed;

– Pyranometer for measuring solar radiation;

– Rain gauge for measuring liquid precipitation over a set period of time.

In addition, at some airports, additional instruments may be employed as shown in **Figure 6**, including:

– Present Weather/Precipitation Identification Sensor for identifying falling precipitation;

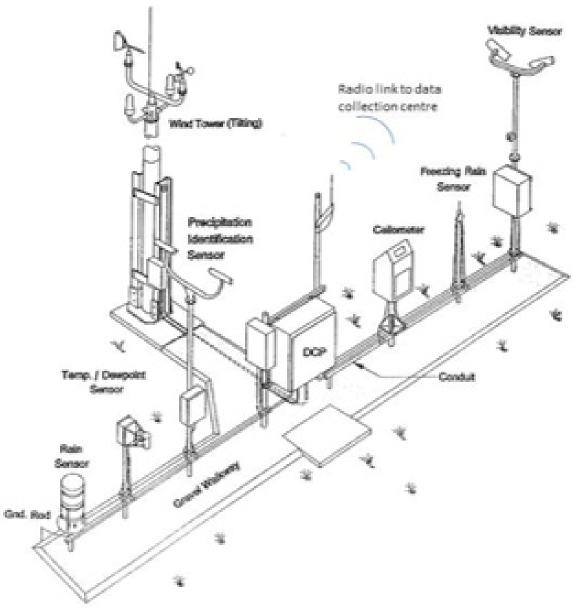
– Disdrometer for measuring drop size distribution;

– Transmissometer for measuring visibility;

– Ceilometer for measuring cloud ceiling.

More sophisticated stations may also measure the ultraviolet index, leaf wetness, soil moisture, soil temperature, water temperature in ponds, lakes, creeks, or rivers, and occasionally other data.

Figure 6: Automated Surface Observing System



The Global Climate Observation System (GCOS) is a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. The GCOS addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, terrestrial hydrologic, and cryospheric components. The GCOS is sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization, the United Nations Environment Programme, and the International Council for Science.

The siting of an observation station is a very difficult matter and much research remains to be done in this area. The general principle is that a station should provide measurements that are, and remain, representative of the surrounding area, the size of which depends on the meteorological application. Some observation stations have to operate unattended for long periods at sites with difficult access. Construction costs can be high and extra costs can be necessary for servicing. They may have to operate from highly unreliable power supplies or from sites at which no permanent power supply is available. The availability of telecommunication facilities should be considered. Security measures (against lightning, flooding, theft, vandalism, and so forth) are to be taken into account and the stations must, of course, be able to withstand severe meteorological conditions. The cost of providing systems capable of operating under all foreseen circumstances at an automatic station is prohibitive; it is essential that, before specifying or designing an observation station, a thorough understanding of the working environment anticipated for the observation station be obtained. At an early stage of planning, there should be a detailed analysis of the relative importance of the meteorological and technical requirements so that sites can be chosen and approved as suitable before significant installation investment is made.

As an observation station is based on the application of technology, a comprehensive review of existing training programmes and of the skills of the necessary technical staff is obviously required. Any new training programme should be organized according to a plan that is geared to meeting user needs. It should especially cover the maintenance and calibration outlined by the WMO and should be adapted to the system. Requesting existing personnel to take on new functions, even if they have many years of experience with conventional stations, is not always possible and it may create serious problems if they have no basic knowledge of electrical sensors, digital and microprocessor techniques or computers. It could be necessary to recruit new personnel who have such knowledge. Personnel competent in the different areas covered by observation stations should be present well before the installation of a network of observation stations.

It is essential that equipment manufacturers for observation stations provide very comprehensive operational and technical documentation, together with operational and technical training courses. Generally, two sets of documentation are required from the manufacturer: user manuals for operational training and use of the system, and technical manuals with more complex documentation describing in great technical detail the operating characteristics of the system, down to the subunit and even the electronic component level and including maintenance and repair instructions. These manuals can be considered as the basic documentation for training programmes offered by the manufacturer and should be such that they can serve as references after the manufacturer's specialists are no longer available for assistance. For some countries, it may be advisable to organize common training courses at a training centre that serves neighbouring countries. Such a training centre would work best if it is associated with a designated instrument centre and if the countries served have agreed on the use of similar standardized equipment.

2.2 Satellite systems

Report ITU-R RS.2178[23] provides an extensive overview of different radiocommunication applications employed for Earth observation, space research and radio astronomy and describes their societal weight and economic benefits for the global community and, especially, their importance for climate change monitoring and climate change prediction, and for early warning, monitoring and mitigation of man-made and natural disasters.

Spacecraft in the Earth Exploration Satellite Service (EESS) routinely provide worldwide coverage with the same, or functionally identical, instruments. Thus, they provide datasets that are truly consistent over the entire globe. Frequently such datasets overlap in time and allow the construction of contiguous datasets spanning decades. While such datasets do not span centuries or millennia, they nonetheless provide crucial data to those who are studying climate change.

Satellites are the best means of providing a snapshot of the present state of our planet from a single, unified perspective. No single instrument spacecraft can provide a complete picture; however, the current fleet of spacecraft, operating in concert and sharing their data, arguably give the best assessment of global conditions. The data serve two purposes:

– To provide reliable and consistent (same sensors) data for use in the construction of climate models;

– To provide a reference for the measurement and monitoring of climate changes and their impact on the planet.

Climate science has advanced spectacularly through satellite observations. The radiometer flown on Explorer 7 from 1959 to 1961 made possible the direct measurement of the energy entering and leaving Earth. This mission and follow-on missions enabled scientists to measure Earth's energy balance with much greater confidence compared to earlier indirect estimates and resulted in improved climate models. As radiometers improved, these measurements achieved the precision, spatial resolution, and global coverage necessary to observe directly the perturbations in Earth's global energy budget associated with short-term events such as major volcanic eruptions or the El Niño-Southern Oscillation (ENSO). These radiometers directly measure the equator-to-pole heat transport by the climate system, the greenhouse effect of atmosphere trace gases, and the effect of clouds on the energy budget of Earth. These observations have advanced our understanding of the climate system and improved climate models. Coordinated use of the international fleet of available satellites sharing their data enables a better assessment of the global situation. The continuity of space-based sensors through time allows for the construction of datasets with seamless coverage of several decades.

Of the 50 key variables that enable us to determine how the climate is evolving, 26 are observable only from space. Satellite data represent a veritable revolution in our understanding of the climate system, the most striking example of this being in relation to sea levels. Satellites also enable us, moreover, to obtain a very high level of accuracy in regard to regional characteristics and differences.

According to DocSciences,[24] "a non-exhaustive list of the geophysical variables that can be observed from space includes: solar irradiance (total and spectral), the Earth radiation budget (incoming solar flux, outgoing infrared flux, cloud cover), temperature of the atmosphere, water vapour, ozone, carbon dioxide levels, methane levels, vegetation and forest cover, snow cover, extent of sea ice, extent of continental ice, sea-surface temperature, colour of the ocean (associated with the concentrations of phytoplankton), sea-level variations, etc.".

---

[23] Report ITU-R RS.2178, *The essential role and global importance of radio spectrum use for Earth observations and for related applications*, October 2010; http://www.itu.int/pub/R-REP-RS.2178-2010.

[24] DocSciences, Space Series Number 1, *Une nuée de variables climatiques*, p.13, Centre régional de documentation pédagogique de l'académie de Versailles, June 2007; http://www.reseau-canope.fr/docsciences/Observer-le-climat.html?artpage=2-3.

Satellites engaged in atmospheric research (e.g., AURA) and supporting operational meteorology (e.g., the European MetOp series and the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites) provide daily three-dimensional worldwide profiles of atmospheric temperature and humidity as well as data regarding minor atmospheric constituents, such as ozone. While these data are fed into weather forecasting models, they also serve to define the current state of the atmosphere and to provide a short-term test of climate models.

Other terrestrial features are monitored by spacecraft that are not engaged by atmosphere-related endeavours. For example, one can note:

– The Earth's surface has been monitored continuously for decades by the Landsat series (since 1973) and the SPOT series (since 1986);
– Sea ice concentrations have been monitored continuously since 1978 by Numbus-7 and then by the DMSP series;
– Sea surface winds have been monitored intermittently since 1996 by ADEOS-1 and-2, QUIKSCAT, and lately by the RapidSCAT instrument on the ISS;
– Sea surface heights and temperatures have been monitored continuously since 1992 by TOPEX/Poseidon and the Jason series; and
– Soil moisture and ocean salinity have been monitored since 2009 by the SMOS, Aquarius, and SMAP satellites.

Other spacecraft and techniques, such as Synthetic Aperture Radar (SAR) and passive microwave observations, are adding to our capabilities for describing our planet, particularly in observing the Polar Regions where winter darkness precludes taking optical images, and in observing where persistent cloud cover obscures the surface (e.g. the Amazon, central Africa, and island nations).

Recommendation ITU-R RS.1883[25] describes the applications of satellite-borne remote sensors to the study of climate change.

2.3 Marine systems

The ocean, which covers 71 percent of the Earth's surface, exerts profound influence on the Earth's climate system by moderating and modulating climate variability and altering the rate of long-term climate change. The ocean's enormous heat capacity and volume provide the potential to store 1,000 times more heat than the atmosphere. The ocean also serves as a large reservoir for carbon dioxide, currently storing 50 times more carbon than the atmosphere.[26] Eighty-five per cent of the rain and snow that water the Earth comes directly from the ocean; conversely prolonged drought is influenced by global patterns of ocean temperatures. Coupled ocean-atmosphere interactions, such as the El Niño-Southern Oscillation (ENSO), influence weather and storm patterns around the globe. Sea level rise and coastal inundation are among the most significant impacts of climate change, and abrupt climate change may occur as a consequence of altered ocean circulation.

Due to high thermal inertia, the "memory" of the ocean is a hundred years or more for certain weather and climate-relevant phenomena, whereas the memory of the global atmosphere is about a week or less. Consequently, the forecast of weather conditions beyond a week or two requires ocean information, and, particularly under storm conditions, even short-term weather forecasts are improved by including ocean-atmosphere interaction. The longer the time-scale, the more important the ocean becomes. Predictions of climate conditions in the seasons and decades ahead, therefore, depend critically on ocean data.

[25] Recommendation ITU-R RS.1883, *Use of remote sensing systems in the study of climate change and the effects thereof, February 2011*; http://www.itu.int/rec/R-REC-RS.1883/.

[26] Christopher L. Sabine and Richard A. Feely**,** The oceanic sink for carbon dioxide, U.S. National Oceanic and Atmospheric Administration (NOAA); http://www.pmel.noaa.gov/pubs/outstand/sabi2854/sabi2854.shtml.

A key feature of the ocean is its constant motion, which redistributes heat and the freshwater the ocean receives from precipitation, snow and ice-melt. The ocean and atmosphere influence global climate in different but complementary ways as they exchange heat and freshwater. For example, evaporation, which adds water vapor that is less dense than air to the atmosphere, induces upward mixing and subsequent release of energy into the upper atmosphere with widespread influence on weather and climate; conversely, precipitation, which adds freshwater to the ocean, makes its surface layer less salty and less dense, reducing downward mixing in the ocean. Cooling the lower atmosphere makes the air more stable, reducing upward mixing, whereas cooling the upper ocean makes surface water denser, increasing downward mixing. Because the relative influences of such phenomena vary regionally, it is important to observe the ocean in many locations. In the tropics, warming of the ocean surface associated with El Niño increases evaporation and convection, altering distant rainfall patterns; in high latitude regions, atmosphere-induced ocean cooling is a major contributor to global phenomena such as the meridional overturning circulation.

It has been a challenge to observe the whole ocean, globally and throughout its depth on the appropriate time scales. The traditional approach of using observations from ships is expensive and inherently limited in spatial and temporal scope.[27] Moored and autonomous drifting buoys have revolutionized the observing system capabilities and made a global system possible. Space-based active sensor observations of sea level through altimetry and surface wind stress through radar scatterometry; along with other passive sensing of ocean colour and sea surface temperature through infrared and microwave techniques have been established but are largely confined to surface variables, so that in-situ observations are an essential complement.

Global ocean temperature data below the surface are primarily measured using moorings and drifters. Moorings are good for measuring time series through the depths of the water column and one particular longitudinal/latitudinal location. Most temperature data of the deeper ocean are measured from free-floating ocean device called "drifters". There are over 3000 drifters in the ocean today.[28] Ocean drifters are usually placed at a particular place in the ocean and then descend to a predefined depth where they record a time series of water temperature while moving with the currents at that depth. One disadvantage of drifters is that most shut off their sensors between 5m deep and the surface to avoid fouling.

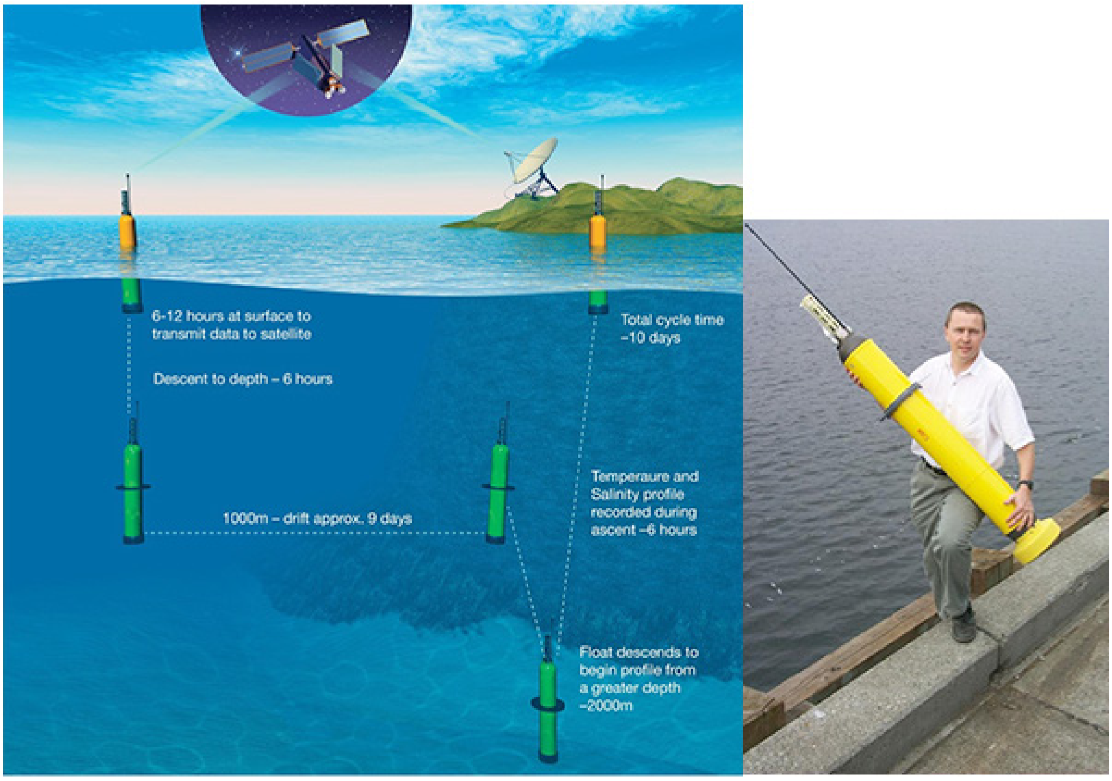
High-Frequency (HF) surface wave oceanographic radars are used to accurately measure currents and waves (sea state) in coastal waters. The measurements provide many societal benefits that include aiding in developing a better understanding of issues like coastal pollution, fisheries management, search and rescue, beach erosion, maritime navigation, sediment transport and tsunami detection. They also support meteorological operations through the collection of sea state and dominant ocean wave data and provide maritime domain awareness by allowing for the long-range sensing of surface vessels to improve the safety and security of shipping and ports, ensure safe maritime travel and improve the response time of maritime search and rescue operations.

The Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), combining the expertise and technological capabilities of World Meteorological Organization (WMO) and UNESCO's Intergovernmental Oceanographic Commission (IOC), provides a mechanism for international coordination of oceanographic and marine meteorological observing, data management and services. The JCOMM combines the expertise, technologies and Capacity Development capabilities of the meteorological and oceanographic communities. JCOMM has managed the Argo programme of international, collaborative ocean observation. Each Argo float is an autonomous, free-floating ocean device that

27 Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden and P. Zhai, 2007: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, US; http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter3-supp-material.pdf.

28 Jet Propulsion Laboratory/NASA, Sea Surface Temperature, https://podaac.jpl.nasa.gov/SeaSurfaceTemperature.

Figure 7: Operation of Argo floats



collects vertically-resolved data, including temperature, to a depth of 2 kilometres, surfacing every 10 days to transmit data. The Argo floats operate for over four years without servicing (shown in **Figure 7**).

If a particular area or line of interest is to be measured underwater, autonomous gliders and/or forward propelled vehicles may be used. These vehicles carry temperature-recording devices along with depth and salinity sensors, clocks and GPS. These vehicles enable scientists to select specific routes over which measurements are obtained.

Seasonal climate predictions require information below the surface for many tens of metres depth. For decadal climate prediction, information from the full depth of the ocean may be needed. The use of submarine cables presents a new opportunity for climate scientists.

The ITU, IOC and WMO established a Joint Task Force (JTF) in late 2012, tasked with developing a strategy and roadmap that could lead to enabling the availability of submarine repeaters equipped with scientific sensors for ocean and climate monitoring and disaster risk reduction (tsunamis). It will also analyze the potential renovation and relocation of retired out-of-service cables in this realm. Several publications have been produced by the JTF that provide more detailed information on the technical and legal challenges, as well as the societal opportunities:

- The scientific and societal case for the integration of environmental sensors into new submarine telecommunication cables: http://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-ICT-2014-03-PDF-E.pdf.
- Using submarine cables for climate monitoring and disaster warning: Strategy and roadmap: http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000150001PDFE.pdf.
- Using submarine cables for climate monitoring and disaster warning: Opportunities and legal challenges: http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000160001PDFE.pdf.
- Using submarine cables for climate monitoring and disaster warning: Engineering feasibility study: http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000170001PDFE.pdf.

2.4 Airborne meteorological systems

Around the world meteorological weather balloons are launched twice daily, and continuously transmit weather telemetry to a ground station using something called a radiosonde. Since 1957 all stations have made their soundings at the same times, 00.00 and 12.00 UTC, although many stations outside North America and Europe have reduced soundings to one per day because of budgetary constraints. Countries launching operational radiosondes are members of the World Meteorological Organization's World Weather Watch program; as such, they freely share their sounding data with each other.

There are two primary purposes of upper-air soundings: to analyse and describe current weather patterns, and to provide input for short and medium-range computer-based weather forecast models. Other uses of radiosonde data include climate studies, air pollution investigations, aviation operations, and defence applications. They also provide "ground truth" for satellite data.

The radiosonde is an electronics unit that comprises three major sections: a suite of sophisticated meteorological sensors; signal-processing electronics; and a radio transmitter to relay the measurements back to a receiver at the radiosonde launch station. The meteorological measurements are made at intervals that vary from 1 to 6 seconds, depending on the type and manufacturer of the radiosonde.[29]. The meteorological community has been assigned two radio frequency bands for use in transmitting meteorological data: 400-406 MHz and 1 675-1 700 MHz. Recommendation ITU-R RS.1165[30] specifies the characteristics and performance criteria of the meteorological aids service in these bands.

A dropsonde is a special radiosonde that is launched from research aircraft and measures winds, pressure, temperature, and humidity while descending on a parachute. A rocketsonde is similar to a dropsonde, except that a rocket is used to carry the sonde to the desired deployment altitude where the sonde is ejected and floats to Earth on a small parachute. Rocketsondes reach an altitude ranging from 20 to 110 km. Rockets provide excellent vehicles for probing this "middle atmosphere" that lies between the upper limit of most aircraft and radiosondes and the levels of most low-orbiting satellites. This is the region where the maximum stratospheric ozone concentration is found.[31]

Modern radiosondes measure or calculate the following variables:

- Altitude;
- Pressure;
- Temperature;
- Relative humidity;
- Wind (both wind speed and wind direction);
- Cosmic ray readings at high altitude;
- Geographical position (Latitude/Longitude).

[29] Dabberdt, W. F. et al., *Radiosondes*, Encyclopedia of Atmospheric Sciences, 2nd Edition, Academic Press, 4 November 2014.

[30] Recommendation ITU-R RS.1165-2006, *Technical characteristics and performance criteria for systems in the meteorological aids service in the 403 MHz and 1 680 MHz bands*, March 2006; http://www.itu.int/rec/R-REC-RS.1165/.

[31] Daniel, R.R., Concepts in Space Science, University Press, May 1, 2002.

3 CHAPTER 3 – Climate change mitigation

3.1 Positive and negative impact of ICT

The 2014 edition of the ITU-D Report on ICT and Climate Change[32] included the following results from the SMARTer2020 report from the Global e-Sustainability Initiative (GeSi) establishing that carbon emissions of ICT can be largely offset by the savings resulting from the use of ICT in other industrial sectors:

"Knowing that the ICT sector would have spent in 2011 a volume of 0.91 billion tons of carbon dioxide and that these costs are expected to reach 1.27 billion in 2020 tons of CO2, ICT would be able to generate equivalent reductions to 7 times their own carbon footprint (manufacturing, IT infrastructure and usage)."

Meanwhile, new results from GeSi have been published in the SMARTer2030 (2015) report,[33] showing that ICT has the potential to enable a 20 per cent reduction of global CO_2 emissions by 2030, thus holding emissions at 2015 levels, and demonstrating that ICT could decouple effectively economic growth from emissions growth.

3.2 Green ICT

3.2.1 The global ICT footprint

The SMARTer2020 report forecast of a 2020 global ICT footprint of 1.27Gt, representing 2.3 per cent of global emissions, was revised to further decrease, with ICT's own footprint expected to reach 1.25Gt in 2030, or 1.97 per cent of global emissions. This improvement in the global ICT footprint results from growing awareness and engagement from ICT organizations, investments to reduce emissions from ICT companies and improvements in the efficiency of devices. Section 3.2.2 provides example of Key Performance Indicators (KPIs) from engaged ICT organizations. **Section 3.2.3** presents research showing how such improvement can be achieved.

3.2.2 KPIs for ICT organizations

ICT organizations now issue yearly sustainability reports, where they set environmental performance goals for their operations in the form of KPIs, and assess achievement of these goals from one year to the next. A typical example of such environment performance assessment is provided in **Table 1.**[34]

For a manufacturer, the opportunity to make the biggest difference is not in its own operations, but in the network elements it provides to its customers. Coming from the same source as above, **Table 2**[35] illustrates typical progress in network elements sustainability.

3.2.3 Reducing ICT energy consumption

Internet data traffic is increasing exponentially owing, on the one hand, to the increasingly widespread use of smartphones and tablets and, on the other hand, to the ever-growing number of applications available on terminals that are becoming more and more diverse and mobile. Report ITU-R M.2370[36]

---

[32] ITU-D Final Report – ITU-D Question 24/2, ICT and Climate Change, 01/2014: https://www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG02.24-2014-PDF-E.pdf.

[33] GeSI.org, *GeSI Smarter 2030 Report*, 2015, Chapter 2.2 Environment – Decreasing emissions and resource consumption whilst allowing for growth; http://smarter2030.gesi.org/downloads/Chapter_Environment.pdf.

[34] People & Planet Report 2015, Nokia: http://company.nokia.com/sites/default/files/download/nokia_people_and_planet_report_2015.pdf.

[35] Ibid.

[36] Report ITU-R M.2370, *IMT traffic estimates for the years 2020 to 2030*, Figure 12.

Table 1: Example of manufacturer tracking environmental performance in its operations

Target for 2015	Progress in 2015	Status
We aim to reduce electricity consumption at our factories by 2% per unit produced, compared to 2014.	Our overall electricity consumption at our factories decreased but we failed to reach the reduction target per unit produced.	Not achieved ☹
We aim to continue reducing the total greenhouse gas emissions from our facilities (Scope 1 and 2) compared to 2014.	Our greenhouse gas emissions from offices and factories declined by approximately 12%, including our renewable electricity purchases. *	Achieved ☺
We aim to maintain the share of renewable electricity at around 50% globally, depending on its availability in countries where we operate.	The share of the electricity coming from certified renewable sources increased to 51%.	Achieved ☺
We aim to further develop our low-emission fleet and maintain related emissions below the market average.	We encouraged our employees to select cars that consume less CO_2 per km than the market average and we installed charging stations for electric cars in some of our biggest offices. We started tracking the fuel consumption and emissions of our global services fleet in order to improve transparency and enable us to develop company car policies globally. Our global services fleet generated 1,200 metric tons of CO_2 emissions.	On track ☺
We aim to reduce the amount of waste generated across our operations and increase recycling by improving facilities for collection and sorting, and encouraging employees to recycle more.	We generated 31% less waste than in 2014, but we weren't as efficient in waste utilization as in 2014. Our waste utilization fell from 95% to 92%.	Partly achieved 😐
We aim to reduce the amount of water used in our operations.	We used 28% less water than in 2014.	Achieved ☺

* As per Greenhouse Gas Protocol: Market-based Scope 1 and 2 from facilities

Table 2: Example of manufacturer tracking how it helps operators deal with the growth in mobile data traffic in a sustainable way

Target for 2015	Progress in 2015	Status
We aim to improve the energy efficiency of our products in each main release by 15%.	We launched a new product offering, the Zero CO_2 emission base station site, which includes more than 20 products and services for our Single RAN Advanced portfolio. The offering enables a reduction in base station site energy consumption of up to 70%.	On track, partially exceeded ☺
We aim to work with our customers to help them reduce the energy consumption of their telecommunications networks through our innovative product solutions.	We had over 50 cases which helped our customers reduce their networks' energy use and emissions. On average, the radio networks we modernized during 2015 consume now 45% less energy. In a pre-launch trial on a live network, iSON Manager Energy Efficiency module helped reduce the LTE radio network energy consumption by 40%.	On track ☺
We aim to implement a methodology to measure product energy efficiency, following the European Telecommunications Standards Institute's standard.	Our base station products are now tested according to ETSI's power consumption test standard. We also tested around 95% of the products that are no longer under active development but which are still used by our customers.	Exceeded and completed ☺

indicates, based upon data from Nokia, that by 2017 the volume of mobile traffic will be 85 times greater than in 2010. Furthermore, the number of Web users is expected to rise from 2.3 billion in 2010 to 3.6 billion in 2017, when it is also anticipated that the global telecommunication network will handle more than 5 000 billion gigabytes. The widespread use of cloud services and applications (e.g., storage and remote software services) will generate a considerable increase in Internet data traffic. All of these factors entail more resources both for networks (access, core, transport) and for data centres. Players in the ICT sphere must bring the Internet's power consumption under control in the coming years if they are to remain economically and environmentally sustainable.

The Revue de l'Electricité et de l'Electronique[37] discusses two recent avenues of research showing that telecommunication networks can be sustainable despite the massive increase in traffic and applications foreseen over the coming years if the right strategies for the evolution of network architecture and components are applied.

The first avenue involves a knowledge-sharing application, called G.W.A.T.T (Global What-if Analyzer of neTwork energy consumpTion), that is available through the Internet (www.gwatt.net). Developed by Bell labs, this interactive tool provides an end-to-end macroscopic view and a simple means of determining the current power consumption of a telecommunication network and its evolution over the coming years, as well as the positive (or negative) impacts of architecture and technology choices. Bell Labs is continuing to develop this tool by incorporating the latest traffic evolution forecast data and newly available technologies. It therefore constitutes an evaluation tool for quantifying the gain to be derived from any new innovation and measuring it against a benchmark.

The second avenue of research is the "GreenTouch" consortium, established in 2010, which, at the end of its mandate on 18 June 2015, presented results showing that network energy efficiency could potentially be improved by a factor of one thousand by 2020. The studies, brought together in an article[38] entitled "Green Meter", demonstrate the feasibility, through combinations of new technologies, network architectures and new components, algorithms and protocols, of achieving a considerable reduction in the power consumption of fixed access, mobile access and core networks against a 2010 benchmark. More specifically, the research concludes that the following results could be achieved with a theoretical network ignoring practical implementation constraints:

– Enhancement of mobile radio access network efficiency by a factor of 10 000;
– Enhancement of optical fixed access efficiency by a factor of 254;
– Enhancement of core network efficiency by a factor of 316.

It should be noted that the above figures also take into account the "business as usual" improvement in the efficiency of network technologies (measured in Joules expended per transmitted bit) resulting, in particular, from Moore's Law. Of course, these improvements in energy efficiency do not imply a proportional reduction in the power consumption of existing telecommunication services. In order to determine this consumption, account must also be taken of traffic growth, network dimensioning, actual network load and investment in new technologies.

These results demonstrate that it is possible not only to manage sustainably the very significant growth in ICT usage in the years to come, but also to ensure that the energy footprint of tomorrow's networks is no bigger than today's through judicious investment in R&D and network deployment. This makes ICT one of the rare domains in which very strong growth in activity can take place without increasing its own ecological footprint, while at the same time making a major contribution to

37 Richard, Philippe, *Comprendre les défis énergétiques des technologies de l'information et de la communication*, La Revue de l'Electricité et de l'Electronique, N°4, 2015.

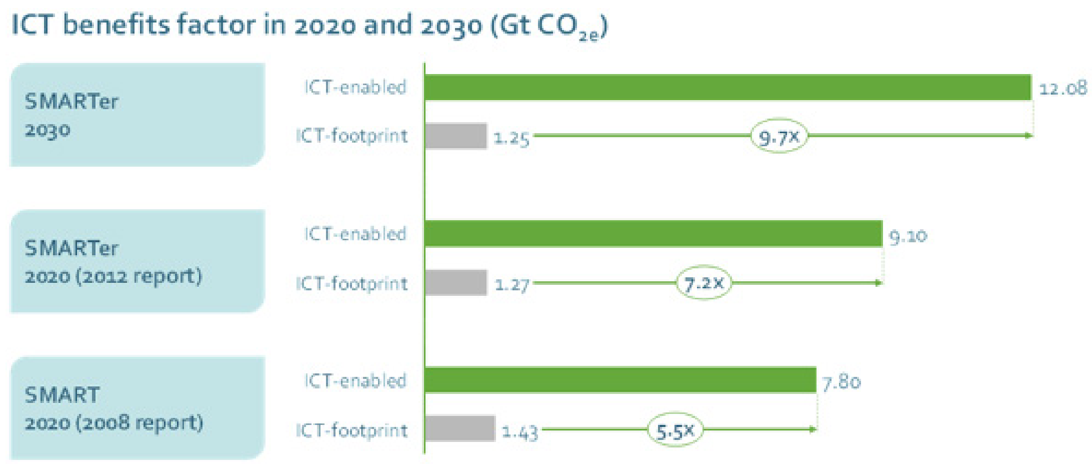
38 GreenTouch, "GreenMeter White Paper", 2015. https://s3-us-west-2.amazonaws.com/belllabs-microsite-greentouch/uploads/documents/White%20Paper%20on%20Green%20Meter%20Final%20Results%20August%202015%20Revision%20-%20vFINAL.pdf.

reducing that of other industries.[39] In all of this, the G.W.A.T.T. software provides rapid evaluation of the relevance of proposed solutions.

3.3 ICT for reducing GHG emissions

Figure 8, taken from the SMARTer2030 report, summarizes the estimation of overall benefits of enabling economic sectors with ICT, as they evolved from the first SMART2020 report published in 2008, to the latest SMARTer2030 report.

Figure 8: Evolution of estimate of ICT benefits for economic sectors

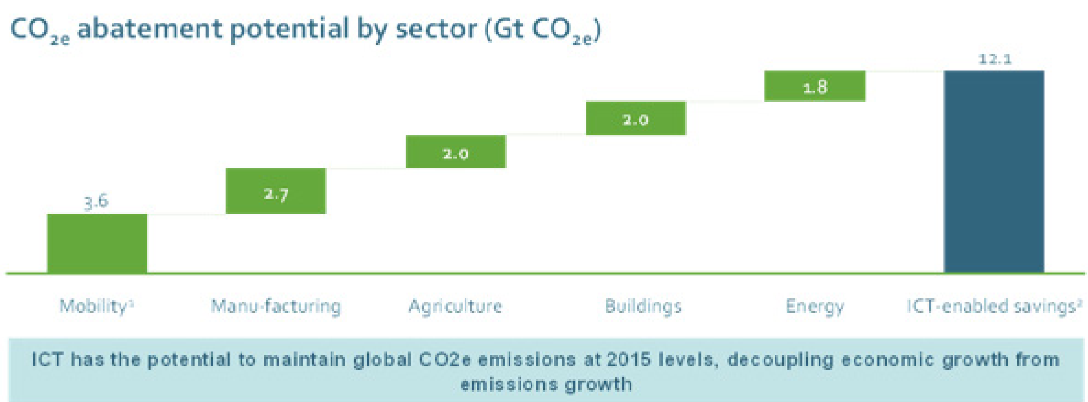


Source: WRI, IPCC, GeSI,SMARTer2020, Accenture analysis & CO_2 models.

3.3.1 Concerned industrial sectors

The global reduction of 12Gt CO_{2e} by 2030 is the contribution to the mitigation of global emissions by eight economic sectors: mobility & logistics, manufacturing, food, buildings, energy, work & business, health and learning. **Figure 9**, also taken from the SMARTer2030 report, shows the potential reduction per sector.

Figure 9: Potential reduction by economic sector



[1] Smart mobility solutions consider improved driving efficiency but also the reduced need to travel from various sectors, including health, learning, commerce, etc.

[39] http://www.GeSI.org, *GeSI Smarter 2030 Report*, 2015; http://smarter2030.gesi.org/downloads/Full_report.pdf.

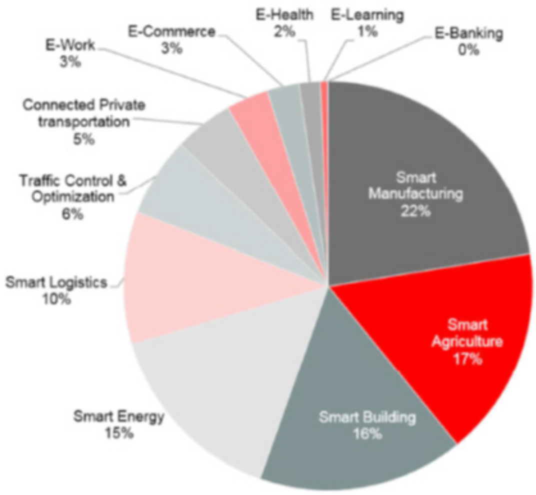
[2] 12 Gt CO_{2e} reduction in 2030 enabled by ICT include 2 Gt CO_{2e} abatement from integration of renewable energy production into the grid. In its business as usual emissions forecast for 2030, the Intergovernmental Panel on Climate Change (IPCC) already considers the CO_{2e} abatement potential from renewable energy. Therefore, the additional ICT-enabled CO_{2e} reduction against the IPCC emissions forecast for 2030 is 10 Gt CO_{2e}.

Source: WRI, IPCC, World Bank, GeSI, Accenture analysis & CO_2 models.

3.3.2 ICT applications for improving sustainability

The global reduction of 12Gt CO_{2e} by 2030 foreseen in the SMARTer2030 report results from an analysis of the impact of ICT enablement across twelve ICT use cases. **Figure 10** shows the potential for each of these twelve use cases.

Figure 10: Twelve use cases of ICT



Source: WRI, IPCC, GeSI, SMARTer2020, Accenture analysis & CO_2 models.

3.3.3 The case of smart cities

It is now clearly established that the Earth is experiencing climatic disturbances caused in part by human activity. That activity includes industry, housing and ways of life that involve high energy consumption, generate greenhouse gas emissions and waste natural resources. It is also noted that a growing proportion of the world's population lives, or will live, in urban areas. This means that cities must tackle environmental and organizational challenges, as well as societal ones. The development of ICTs in areas including sensors and other connected objects, networks, storage and processing of data collected in every greater volumes, as well as the spread of powerful mobile terminals, give a glimpse of an urban model in which all infrastructure, persons and, by extension, all everyday objects, will be connected and capable of generating and processing feedback data.

In this context of the (hyper)-connected city, it is possible to envisage innovative digital services based on the five technological pillars, which are collection, transmission, processing, securing and exploitation of the generated data. Such services will enable the optimisation of the functioning of a city and its infrastructures (telecommunications, transport and mobility, water, waste disposal, energy, and so on). This may mean dynamic regulation of resources. Smart electricity networks ("smart grids") are intended to maintain a balance between different sources of energy production, centralized or local, and electricity consumers. This evolution of the electricity grid makes it possible to integrate renewable energy sources, thanks in particular to better demand management during peak hours. ICTs also help to make dwellings less energy-hungry (using home automation, sensors, and so on), and empower consumers by giving them access to tools for monitoring their own consumption and their own production, which they may choose to redistribute. Other examples of such optimization can be cited in the field of water management and waste recycling. Whether in the form of individual meters for analysing consumption of water, gas or electricity, or sensors that provide feedback on leaks, quality or flow rates, the purpose of such systems is to conserve a resource, monitor quality and ensure the user's wellbeing. Similarly, volumetric sensors fitted in sorted waste containers are already enabling some cities to anticipate fill rates and thus optimize waste collection (frequency, number and size of trucks, and so on).

This technology-centred approach to the city must not make us lose sight of the fact that one of the aims of this development is to place the citizen at the centre of concerns, not just as a passive spectator of urban policy adopted at a high level but as an actor for change. The opportunities offered by ICTs associated with volunteering policies already allow citizens to participate actively in this collaborative (or collective) intelligence via participative platforms on the Internet or through mobile applications (participative production or "crowdsourcing"). Innovation in policies is also possible. Some cities, such as Paris and Grenoble, have earmarked an investment budget for projects that have been proposed and approved by citizens themselves. In the first round, more than 5 000 project proposals have been put forward by Parisians for a total of 75 million euros, or 5 per cent of the city's investment budget. It is interesting to note that quality of life and security within a pleasant environment top the list of citizens' concerns.

The public aspires to a better quality of urban life. This encompasses a multitude of dimensions including factors such as stress, various negative aspects of urban life, both tangible (road traffic, congestion of public transport, noise pollution and air quality) or intangible (exposure to electromagnetic radiation), better access to services (administration, transport), a more natural environment and urban conditions conducive to well-being, security of property and persons, and so on.

Such hyper-connectivity of machines and citizens and the geographic concentration of technical services mean that vast quantities of data, geo-referenced or otherwise, time-sensitive or not, from public sources (communities and authorities), private sources (companies or citizens), or just "free" ("open data"), have to be stored, classified, processed, made secure, used, and traced. The data management plan for all these data (infrastructure and processes) is crucial to ensuring the optimal use that results in effective decision-making and greater benefits. Every city is unique, with its own history and goals for well-being. This is the key point where we can benefit from the contribution of digital technology, without changing the city's character.

For digital businesses, new opportunities are emerging to design solutions that will multiply the capacity of radiocommunication networks by a factor of 100 or even 1 000, to connect tens of billions of objects while reducing electricity consumption tenfold. With ever-increasing demand for spectrum resources to meet the growing demand for high-speed mobile communications, innovative spectrum management will be crucial to ensuring optimal use of different networks for different communication requirements. See the final report of [the Resolution 9 studies of Spectrum Management].

Communication protocols should focus on solutions aiming to strike a compromise between radiated power of equipment, power consumed, spectrum consumption and, for certain countries, levels of exposure to electromagnetic radiation. For example, the European Lexnet research project (http://lexnet-project.eu/) sought engineering solutions that could achieve optimal growth in network capacity through the addition of small cells while reducing emission levels and average exposure of individuals to electromagnetic radiation.

Together with designing a connected city, collaboration (among elected leaders, technical specialists and citizens) in designing a sustainable city is the second key challenge if we are to succeed in transforming a city into one that is "smart". By way of example, VIVAPOLIS is a French governmental initiative involving industries that are very active in efforts to construct sustainable cities. As a result, two innovative initiatives have been implemented recently. Hundreds of French companies have been brought together into two groups to work on two projects for the development of cities presenting different characteristics and constraints. The first was Astana, a new city that has to cope with the extreme variations of a continental climate. The second city studied was Santiago in Chile, which faces serious problems of mobility and pollution. This highly innovative communal initiative has resulted in the creation of two 3D sustainable city simulators. For example, one project[40] has objectified policy visions with a hundred or so indicators divided up into 11 key categories for the sustainable city. On the basis of an analysis of the city's situation and in collaboration with all the city's services and elected officials, two urban projects have been put forward, simulating the positive impact of 200 technical solutions on the city's functioning.

ITU-T Study Group 20, created in 2015, is working to address the standardization requirements of Internet of Things (IoT) technologies, with an initial focus on IoT applications in smart cities and communities.

[40] See http://www.siradel.com/fr/santiago-des3ado-siradel-et-ses-partenaires-presentent-le-simulateur-de-ville-durable.

4 CHAPTER 4 – Climate change adaptation

4.1 Adaptation of ICT equipment

Information in this paragraph is taken from the 2014 ITU report on "Resilient pathways: the adaptation of the ICT sector to climate change".[41] This report identified the main climate change impact on the ICT sector, and proposed the following adaptation measures:

– Make the backbone network redundant for most if not all service areas, and resilient to all types of extreme weather events; provide reliable backup power with sufficient fuel supply for extended grid power outages;

– Decouple communication infrastructure from electric grid infrastructure to the extent possible, and make both more robust, resilient, and redundant;

– Minimize the effects of power outages on telecommunications services by providing backup power at cell towers, such as generators, solar-powered battery banks, and "cells on wheels" that can replace disabled towers. Extend the fuel storage capacity needed to run backup generators for longer times;

– Protect against outages by trimming trees near power and communication lines, maintaining backup supplies of poles and wires to be able to replace expediently those that are damaged, and having emergency restoration crews ready to be deployed ahead of the storm's arrival;

– Place telecommunication cables underground where technically and economically feasible, ensuring that they are appropriately protected against water ingress;

– Replace segments of the wired network most susceptible to weather (e.g., customer drop wires) with low-power wireless solutions;

– Relocate central offices that house telecommunication infrastructure, critical infrastructure in remote terminals, cell towers, etc., and power facilities out of future floodplains, including in coastal areas which are increasingly threatened by sea level rise combined with coastal storm surges;

– Further develop backup cell phone charging options at the customer's end, such as car chargers, and create a standardized charging interface that allows any phone to be recharged by any charger;

– Assess, develop, and expand alternative telecommunication technologies if they promise to increase redundancy and/or reliability, including free-space optics (which transmits data with light rather than physical connections), power line communications (which transmits data over electric power lines), satellite phones, and ham radio;

– Reassess industry performance standards combined with appropriate, more uniform regulation across all types of telecommunication services, and uniformly enforce regulations, including mandatory instead of partially voluntary outage reporting to the regulatory agencies;

– Develop high-speed broadband and wireless services in low-density rural areas to increase redundancy and diversity in vulnerable remote regions;

– Perform a comprehensive assessment of the entire telecommunications sector's current resiliency to existing climate perils, in all of their complexities. Extend this assessment to future climate projections and likely technology advances in the telecommunications sector. This includes the assessment of co-dependency between the telecommunications and power sectors relative vulnerabilities. Provide options and incentives to decouple one from the other while improving resiliency of each;

41 http://www.itu.int/en/ITU-T/climatechange/Documents/Publications/Resilient_Pathways-E.PDF.

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

More detailed information is also available in Recommendation ITU-T L.1502 (11/2015), *Adapting information and communication technology infrastructure to the effects of climate change*.[42]

The following clauses report experiences in climate change adaption in Japan and Africa.

4.1.1 KDDI experience in Japan

More efforts should be provided to reduce electric power consumption by systems and facilities used for the provision of telecommunications services and to cut carbon dioxide emissions as a general telecommunications carrier. Mobile base stations ("base stations") account for approximately 60 per cent of all of KDDI's electric power consumption, and reducing power consumption in base stations is a key issue in cutting power use. KDDI has worked to reduce power consumption through various measures such as downsizing base stations and introducing cooler-free base station equipment. New base stations with patented technology have been installed to achieve next-generation power saving. The new base stations are expected to achieve power savings and carbon dioxide reductions of 20 to 30 per cent compared to the same base stations without the new technology.

Also important is disaster preparedness. As a result of the Great East Japan Earthquake in 2011, the communication infrastructure including mobile base stations (up to 14 000 base stations) was severely damaged in the coastal region and the communication capability was almost completely lost for a few weeks during the initial stage. Additionally, significant loss of service was caused by power outages including the batteries. This new technology is also expected to keep mobile stations operating for longer time.

4.1.1.1 Electric power control technology

The new electric power control technology achieves the maximum efficiency by controlling three sources of power to base stations: (1) power generated from solar panels, (2) power from batteries that are charged from commercial power at night, and (3) power from commercial sources. In good weather, solar panels provide sufficient power to the wireless equipment and any excess power is stored in the batteries. After the sun sets, the base station equipment is powered by the batteries, and the batteries are also charged from commercial power late at night when the electric bill is reduced.

A key feature of this new technology is that power from the solar panels is supplied to a DC power unit connected between the rectifier, batteries, and the base station equipment. The Direct Current (DC) generated by solar panels is generally converted to Alternating Current (AC) before being supplied to household appliances, lighting equipment, and so on. Although a lot of ICT equipment directly operate on direct current, the direct current is originally converted from the commercial alternating current internally at the equipment. In using solar power, the current is converted twice, i.e. from the DC to the AC and then back to the DC, resulting in substantial power losses. The new control technology directly links DC components to the DC source to reduce conversion losses, leading to efficient use of the green power generated by solar panels. The power generation by solar panels is also expected to increase in the future. With the new system, excess power from solar panels can be charged in batteries without flowing into the network.

[42] Recommendation ITU-T L.1502 (11/2015), *Adapting information and communication technology infrastructure to the effects of climate change*; https://www.itu.int/rec/T-REC-L.1502.

4.1.1.2 Operating principle

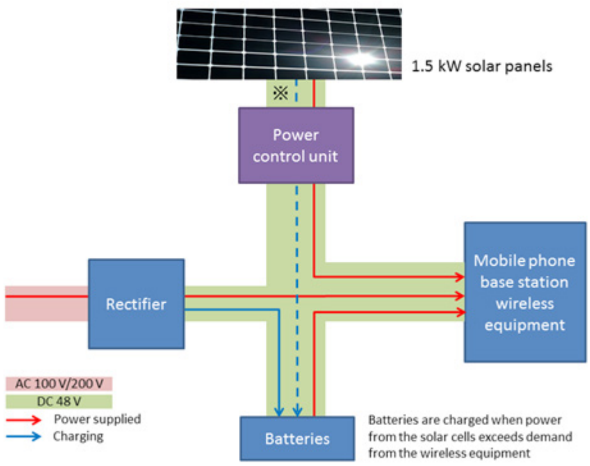
To achieve the power control, solar panels, a power control unit and an output voltage control unit with a rectifier are added to a conventional base station as shown in **Figure 11**. The equipment can be installed in operating base stations.

Some power companies provide a discount price plan during off-peak times, in which the same amount of power can be used at a lower price. Also during off-peak times, the activity ratio of hydroelectric power is higher than other times, contributing lower emissions of carbon dioxide (a greenhouse gas).

In natural disasters, power outages can occur. To keep base stations operating during such events, conventional base stations are equipped with rechargeable lead batteries (secondary batteries) as a backup. With the new power control technology, batteries are charged late at night from commercial power, and excess power generated by the solar panels is also used for the base station equipment. To accommodate this usage pattern, batteries have to be equipped with high-performance charge/discharge characteristics. The use of smaller and lighter lithium-ion batteries is being explored.

The following is an explanation of the operating principles of the output voltage control function. When voltage at the rectifier is reduced, the relative voltage of the batteries increases, which triggers the supply of energy from the batteries to the wireless equipment and decreases the use of energy from the commercial power supply. When the solar power increases, the output voltage of the power control unit increases to a level higher than the battery voltage, and increases the percentage of energy supplied by the solar panels to the wireless equipment. As the batteries discharge, the voltage declines and the power from the solar panels also charges the batteries. On the other hand, as the power from the solar panels decreases, the percentage of the power supplied by the batteries increases. As the battery voltage continues to decline, the supply of the commercial power increases. Generally, solar panels generate a lot of power during daytime in good weather conditions, and solar panels in the Kanto area of Japan generate power at their rated capacity for an average of three hours per day. Thus, 1.5 kWh solar batteries can be expected to generate 4.5 kWh of energy each day.

Figure 11: Configuration Diagram



4.1.1.3 Conclusion

To assess the availability and scalability of the technology, the new power control equipment was installed in commercial base stations and field trials, commencing in December 2009. The trials were conducted at 10 locations nationwide to determine optimal solar panel installation methods and power supply configurations, taking into consideration environmental conditions such as geography and climate.

It is vital for mobile operators to provide communication services as long as possible even in emergency situations. KDDI has installed extra batteries to keep the service functioning for at least 24 hours in such cases, and also installed the new power control equipment at more than 100 base stations, which contributes to high service availability and the greening of ICT.

4.1.2 Orange experience in Africa

At global level, consumption of information and communication technologies (ICTs) represents around 2-3 per cent of total energy consumption. This might be a small percentage of global energy, but reduction of ICT consumption provides essential leverage given the need for it to counterbalance the growth across all segments (terminals, networks, datacentres) generated by:

– The increasing number of connected entities (both private and business, public bodies, associations) and connected things;

– The increased use of connections, increasingly continuous connection times, digital conversion of services and applications in vertical sectors;

– Increased geographical coverage and rates.

By way of example, the case of Orange SA sheds interesting light on a possible strategy, initiated in 2006, for powering mobile network radio stations with solar energy. In some of the countries concerned – Senegal, Côte d'Ivoire, Mali, Niger, Madagascar, Guinea, Cameroon, to name only few – the solar energy approach is particularly suited in terms of significantly reducing fossil fuel consumption (diesel generators) and making up for the lack or very poor quality of electric grid networks in rural or desert areas.[43]

The consumption of fossil fuels (oil-based) has not been fully eliminated. Indeed, the powering of mobile radio base stations with solar energy, using batteries at night or in bad weather (low UV index), can also be hybridized using diesel to provide some of the power. The significant energy-saving involves eliminating air-conditioning, leading in turn to elimination of the inverters used to produce the alternating current required for the cooling compressor motors. This simplification, and the resulting switch to direct current, results in much lower energy consumption, making pure solar, or hybrid, power very cost-effective and reliable solutions.

At the end of 2015, 2 600 solar-powered stations in the mobile radio network were deployed and are operational: they provide solar power to radio relays in rural or desert areas.[44] These stations produce 18GWh of renewable energy per year. Each of these stations makes it possible to save 1 300 litres of fuel per year, and in addition to powering the radio station they produce 25 per cent surplus power that can be used, for example, to make up for the lack of electricity networks in the vicinity of each station. This surplus is used, for example, to power schools or health centres serving the surrounding villages. This surplus energy is used in a multitude of ways.

The stations closely follow advances in standardization. Indeed, Orange is very much involved in the work of ITU-T Study Group 5, which develops standards in collaboration with EE ETSI, making it possible to massively and safely deploy renewable energies while reducing energy consumption and simplifying matters by using direct current and eliminating alternating current.

Deployment of solar-powered stations is being pursued at a sustained pace by Orange subsidiaries. These solutions, devised within the context of the developing countries, could be studied and adapted for other environments where power supply is a critical factor.

---

[43] D. Marquet, M. Aubrée, S. L. Masson, A. Ringnet, P. Mesguich and M. Kirtz, "The first thousand optimized solar BTS stations of Orange group", 2011 IEEE 33rd International Telecommunications Energy Conference (INTELEC), Amsterdam, 2011, pp. 1-9: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6099814&isnumber=6099710.

[44] ibid.

The photograph in **Figure 12** shows one of the sites with a mobile radio network solarstation as an illustration.

Figure 12: Solar station at a mobile network site in Senegal

4.2 Adaptation in the industrial sector

The effects of climate change vary across industries. Differences in geography, exposure and vulnerability yield different adaptation strategies.

The following table is taken from Recommendation ITU-T L.1501 (12/2014), *Best practices on how countries can utilize ICTs to adapt to the effects of climate change*.[45] It provides a checklist of indicators of climate change and associated impact, with examples of ICT implementation in adaptation to climate change.

4.3 Adaptation in the agricultural sector

Ensuring food security and providing the world's population with nutritious food constitute one of the most urgent challenges faced today. Given that the global population is forecast to exceed 9 billion by 2040 and that the effects of climate change are already being felt in all areas of food security, the viability and productivity of food systems must be enhanced.

In order to underscore the need for agriculture to appear on the agenda of the international programme to combat climate change, a number of alliances and initiatives have been created at international level aimed at fostering the implementation of measures to mitigate and adapt to the effects of climate change and encourage research and the development of policies to respond to the various challenges. Those alliances and initiatives include: Global Alliance for Climate-Smart Agriculture, Solutions from the Land, Global Research Alliance on Agricultural Greenhouse Gases, and Initiative 20x20.

Of these projects, it is particularly worth noting the Global Alliance for Climate-Smart Agriculture (GACSA), a voluntary coalition managed by farmers that brings together multiple players, supporting action and the integration of climate-smart approaches in food and agriculture systems.

[45] Recommendation ITU-T L.1501 (12/2014), *Best practices on how countries can utilize ICTs to adapt to the effects of climate change*; https://www.itu.int/rec/T-REC-L.1501.

Table 3: Some indicators of climate change and ICT implementation in adaptation to climate change

Indicator (trends) of climate change	Causes of the observed trends	Changes in ecosystems	Impact on agriculture	Impact on economic systems	Impact on public health	ICT use (some examples include)
Changes in surface temperature (global warming)	Deforestation, industrialization, increased fossil fuel use leading to enhanced greenhouse effect.	Changes in: species distribution, vegetation cover, increased glacial melting, changes in weather patterns, affecting biogeochemical cycles, forest fires, encroachment of invasive species.	Droughts, decrease in yield in warmer environments (endangering food security), increased vulnerability to weeds and pests, increased expenditure on irrigation.	More investment of energy for cooling facilities, increased demand for water supplies, migration to wetlands from arid regions.	Changes in disease vectors (possible epidemics caused by strains of viruses or bacteria which thrive in warmer temperatures, heat strokes, starvation due to reduced agricultural yield.	Recording surface temperature changes to maintain records and as well as predict possible disaster events using global observation system (GOS) which include weather satellites, earth observation satellites; improved communication with farmers using radio and mobile networks; geographic information system (GIS) for monitoring deforestation; mobile health management systems.
Sea level rise	Rise in temperature (as a result of global warming).	Coastal flooding, floods, shoreline erosion, wetland flooding, saltwater intrusion into groundwater resources, displacement of marine ecosystems, risk of coastal land submergence.	Affected in case of proximity to coastal areas.	Increased monetary investment to prevent damage to coastal areas and flood proofing as well as ecosystem reconstruction in post flood situations.	Affects communities living near coastal areas, Risk of floods, damage of coastal property, increased risk of drowning.	Monitoring and recording sea level rise (to keep a record of any anomalies) using satellite altimetry thereby helping predicting disasters to avoid loss of life and property.

Table 3: Some indicators of climate change and ICT implementation in adaptation to climate change (continued)

Indicator (trends) of climate change	Causes of the observed trends	Changes in ecosystems	Impact on agriculture	Impact on economic systems	Impact on public health	ICT use (some examples include)
Changes in precipitation	Changes in the water cycle (as a result of sudden temperature changes in the atmosphere).	Increased precipitation may cause run-off, landslides, Soil erosion, changes in vegetation cover, habitat destruction, Decrease in precipitation causes droughts, increased risk of forest fire, Changes in water table.	Increase in precipitation may increase yields but there may also be a risk of flooding leading to destruction of crops before harvest, Decrease in precipitation causes drought leading to reduced yields.	Reduced water availability and over-reliance on ground water supplies in case of decrease in precipitation, Investment required in case of flooding.	Risks to water borne diseases, stagnant water sources act as breeding grounds for disease parasites, loss of life in heavy rainfall situations.	Measure and maintain records (GOS, global telecommunication system) of seasonal as well as monthly rainfall/snow/hail; GIS for flood risk management; promoting awareness among farmers through radio and mobile systems; use of GIS and Global Positioning System (GPS) to identify new freshwater sources.
Dune movement/ migration	Drought, rising temperatures, erosion, deforestation.	Erosion, changes in habitat structure, loss of soil nutrients.	Affects desert agricultural systems.	Desert agricultural systems require irrigation systems hence loss soil will require most investment for desert irrigation systems, problems linked to travelling and transport.	Sandstorms exacerbating asthma and other respiratory disorders.	Monitoring and predicting dune movement using satellite imagery, GPS.
Glacial melting	Rise in temperature of the Earth's surface (global warming).	Flooding, loss of glacial mass, erosion leading to loss of soil nutrients.	Run-off from crops lands, soil degradation, decreased in yield.	Monetary investment required for habitat reconstruction in post flood areas.	Communities affected by floods, lack of freshwater supplies.	Satellite systems (GIS, GPS) record glacial movement and mass of glaciers lost to help predict floods and run-offs; smart

Table 3: Some indicators of climate change and ICT implementation in adaptation to climate change (continued)

Indicator (trends) of climate change	Causes of the observed trends	Changes in ecosystems	Impact on agriculture	Impact on economic systems	Impact on public health	ICT use (some examples include)
Eutrophication levels	Deforestation leads soil to be exposed to erosion agents which results in run-offs of soil and into nearby water bodies inducing excessive algal growth.	Algal bloom, death of aquatic species increase in biochemical oxygen demand (BOD).	Loss of soil cover and nutrients, reduced crop yield, lack of clean water for irrigation.	Reduced maximum sustainable yield (MSY).	Reduced food supply from aquatic sources, contaminated aquatic food supplies.	Track and record polluted water sources, measure and maintain records of the levels of toxicity, promoting awareness among fishermen.
Forest fires	Rise in temperature of the Earth's surface.	Habitat destruction, risk of species extinction, reduced vegetation cover, particulate emissions.	Affects nearby agricultural areas.	Increased investment for habitat re-construction.	Asthma, bronchitis and other respiratory disorders caused by particulate or smoke emission.	Record and maintain satellite imagery (GIS, GPS), emergency communication using mobile communication.
Water pollution	Dumping of industrial and sewage waste into water bodies without the required level of treatment.	Death of aquatic species, increase in biological/ BOD.	Soil pollution, crop destruction, reduced yield.	Investment required for treatment of water from contaminated sources.	Water borne diseases, biomagnification, bioaccumulation.	Monitoring of industrial activities, smart metering, regular testing of water samples, adequate information through ICT given to communities living around contaminated water bodies.
Soil Erosion	Deforestation.	Loss of soil cover, reduced availability of nutrients, loss of plant cover.	Reduced yield, loss of precious soil cover.	Investment for landscaping schemes.	Respiratory disorders.	GIS, GPS system to monitor and record soil movement.

Table 3: Some indicators of climate change and ICT implementation in adaptation to climate change (continued)

Indicator (trends) of climate change	Causes of the observed trends	Changes in ecosystems	Impact on agriculture	Impact on economic systems	Impact on public health	ICT use (some examples include)
Air Pollution	Industrialization, landfills site emissions, incineration of waste, burning of fossil fuels.	Global warming, changes in weather patterns, smog, acid rain, soil pollution.	Reduced yield due to changes in weather patterns and rainfall, soil acidification.	Reconstruction of acid rain affected areas and urban constructions, smog disturbs traffic and transport.	Respiratory disorders, nervous system damage, cancer, skin irritation, headaches.	GIS to map pollution caused by transportation, spatial analysis techniques.

The initiative was launched on 23 September 2014 at the United Nations Climate Summit. The World Farmers' Organisation already supports the GACSA initiative, and considers it to be a pillar of its climate-change policy. As of August 2016, GACSA had some 144 members.

Several organizations have recommended that sustainable agriculture be interpreted on the international level as being synonymous with agro-ecology.

Unfortunately, agro-ecology today includes principles that reject the use of soil additives in farming activities along with general farming operating methods. This makes participation in initiatives like GACSA important, in order to ensure that the regime put in place by the United Nations foresees decision-making corresponding to modern farming methods.

Table 3 in **Section 4.2** provides associations between the impacts of climate change on agriculture and examples of ICT implementation in adaptation to these impacts.

Abbreviations and acronyms

Various abbreviations and acronyms are used through the document, they are provided here.

Abbreviation/acronym	Description
AC	Alternating Current
ADEOS	ADvanced Earth Observing Satellite, also known as 'Midori' in Japan
AURA	A multi-national NASA scientific research satellite studying the Earth's ozone layer, air quality and climate. The name "Aura" comes from the Latin word for air.
BBC	British Broadcasting Corporation
BoD	Biochemical Oxygen Demand
CARIAA	Collaborative Adaptation Research Initiative in Africa and Asia
CCAC	Climate and Clean Air Coalition
CIMGC	Interministerial Commission on Global Climate Change (Comissão Interministerial de Mudança Global do Clima) (Federative Republic of Brazil)
CO2	Carbon dioxide
COP	(United Nations) Conference of the Parties (on climate change)
CREWS	Climate Risks Early Warning Systems
DBS	Direct Broadcast Satellite
DC	Direct Current
DMSP	Defense Meteorological Satellite Program
EAS	Emergency Alert System
EE ETSI	European Telecommunications Standards Institute Technical Committee on Environmental Engineering
EESS	Earth Exploration Satellite Service
ENSO	El Niño-Southern Oscillation
FCPF	Forest Carbon Partnership Facility
FEMA	Federal Emergency Management Agency
GACSA	Global Alliance for Climate-Smart Agriculture
GCOS	Global Climate Observing System
GeSi	Global e-Sustainability Initiative
GFCS	Global Framework for Climate Services
GHG	Greenhouse gas(es)

Abbreviation/acronym	Description
GIS	Geographic Information System
GISS	(NASA's) Goddard Institute for Space Studies
GMI	Global Methane Initiative
GOS	Global Observation System
GPS	Global Positioning System
GWATT	Global What-if Analyzer of neTwork energy consumpTion
HF	High-Frequency
HFC	Hydrofluorocarbons
ICT	Information and Communication Technologies
IDRC	International Development Research Centre (Canada)
IEC	International Electrotechnical Commission
IFAD	International Fund for Agricultural Development
INTELEC	International Telecommunications Energy Conference
IOC	Intergovernmental Oceanographic Commission
IoT	Internet of Things
IPAWS	Integrated Public Alert and Warning System
IPCC	Intergovernmental Panel on Climate Change
IRIACC	International Research Initiative on Adaptation to Climate Change
ISO	International Organization for Standardization
ISS	International Space Station
IT	Information Technology
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardization Sector
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JTF	Joint Task Force
KPI	Key Performance Indicator
MCIT	Ministry of Communications and Information Technology (Arab Republic of Egypt)
MEF	Major Economies Forum (on Energy and Climate)

Abbreviation/acronym	Description
MetOp	(EUMETSAT's) Meteorological Operational satellite Programme
MHz	Megahertz
MSIP	Ministry of Science, ICT and Future Planning (Republic of Korea)
MSY	Maximum Sustainable Yield
NASA	National Aeronautic and Space Administration (United States of America)
NOAA	National Oceanographic and Atmospheric Administration (United States of America)
NTC	National Telecommunications Corporation (Republic of the Sudan)
QUIKSCAT	(NASA's) Quick SCATterometer (satellite)
PUC	Public Utilities Commission (Belize)
R&D	Research and Development
RapidSCAT	(NASA's) Rapid SCATterometer (on the ISS)
SAR	Synthetic Aperture Radar
SDARS	Satellite Digital Audio Radio Service
SLCP	Short-Lived Climate Pollutants
SMAP	(NASA's) Soil Moisture Active Passive (satellite)
SMOS	(ESA's) Soil Moisture and Ocean Salinity (satellite)
SPOT	(European) Satellite Pour l'Observation de la Terre
TOPEX/Poseidon	NASA's and CNES's TOPographic Expedition (to measure ocean surface topography)
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
UTC	Coordinated Universal Time
UV	UltraViolet
VIVAPOLIS	French governmental initiative involving industries that are very active in efforts to construct sustainable cities
WEA	Wireless Emergency Alerts
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
WRI	World Resources Institute

Annexes

Annex 1: Country experiences on monitoring/mitigating climate change

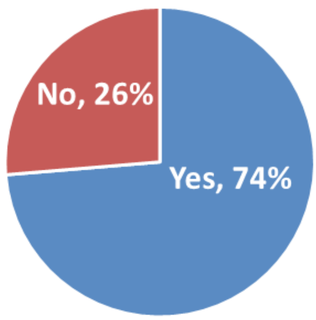
A1.1 Background of the 2016 survey

Out of the 193 Member States of ITU, a total of 19 completed questionnaires were returned, covering 18 countries of the 6 regions. This was lower than the 69 answers received in the survey of 2011.

Survey responses were received from: Armenia, Belize, Bolivia, Brazil, Chile, Cameroon, Colombia, Dem. Rep. of the Congo, Egypt, Israel, Kazakhstan, Mali, Republic of Korea, State of Palestine, Sudan, Uruguay, United States of America, ATDI (France) and GSMA (United Kingdom).

A1.2 Preliminary findings and comparison with the 2011 survey

Q1 Does your government (or company) have any policy regarding climate change?



In 2016, about the same number of answers than in 2011 (74% vs 70%) stated that they have a policy on climate change. There seem to be little progress in the awareness of the topic. These policies have been detailed as follows:

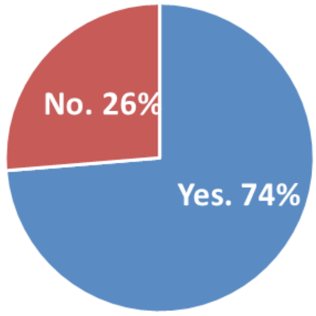
Country	Entity
State of Israel	*ATDI (France)* Recycling of non-used ICT
State of Israel	*Ministry of Environmental Protection* Israel has a policy regarding mitigation of greenhouse gas emissions: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Israel/1/Israel%20INDC.pdf. This does not specifically address ICT issues. However, technological measures which might involve ICT will be part of these efforts – for example management of smart electricity grids and smart metering, promotion of renewable energy and its integration into the electricity grid, energy efficiency measures in buildings and industry (ESCO), water system management, monitoring of climate change trends and implications.

Country	Entity
Arab Republic of Egypt	*Ministry of Communications and Information Technology (MCIT)* – Link ICT, climate, environment, and energy policies across governments. – Develop the appropriate legislations and regulations that support the achievement of sustainable management of e-Waste. – Adopt and promote of life-cycle perspectives that promote environmentally efficient R&D, design, production, use, and disposal of ICTs. – Support for research and innovation in green technologies and services. – Develop skills and capacities in the area of "green ICT". – Increase public awareness of the role of ICTs in improving environmental performance. – Encourage best practices to maximize diffusion of ICTs and "smart" ICT-enabled applications – Promote of green ICT concepts, with governments leading by example. – Consider environmental criteria in public procurement. – Measure environmental impacts of ICT and the usage of ICT in other sectors. – Set up of policy targets, monitoring compliance, and improving accountability.
Republic of the Sudan	*National Telecommunications Corporation (NTC)* – Ratification of conventions and the outputs of international meetings. – Reducing gas emissions using environmentally-friendly energy in ICT systems, equipment and devices.
Republic of Korea	*Ministry of Science, ICT and Future Planning (MSIP)* Technological innovation and Industrialization Plan for Climate Change (on March 2015, Steering Committee of National Science & Technology Council).
Republic of Mali	*Autorité Malienne de Régulation des Télécommunications/TIC* *Unofficial translation:* It consists in putting information on the web sites of climate change and environment of Mali, to animate radio and television broadcasts etc.
Democratic Republic of the Congo	*Autorité de Régulation de la Poste et des Télécommunications* *Unofficial translation:* Our climate change policy has not integrated the ICT aspect yet. However, it is planned to integrate it.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* The Government through the Ministry of the Environment, Nature Conservation and Sustainable Development does not have a clearly defined policy on the use of ICTs to combat climate change in short term. However, it is defined by a series of international commitments, namely the use of technology transfer to pursue the coherence of sectoral policies and the intensification of its efforts over the past several years Implementation of an observation, information management and alert system on climate risks in Cameroon, and through initiatives such as the increasing the use of ICTs in the fight against climate catastrophes: floods, earthquakes, droughts, thunderstorms, dry mist, rising sea levels.
Republic of Armenia	*Ministry of Transport and Communication* The Climate Change information and developments in the country are accessible through the special portal of the Climate Change Information Center: http://www.nature-ic.am. The GHG inventory of Armenia is developed using the IPCC software and is accessible from above mentioned web-site and from http://www.unfccc.int. The energy using appliances labelling policy is considered as important market tool in the Energy saving and renewable energy policy of the country.

Country	Entity
Republic of Kazakhstan	*Communication, Informatization and Information Committee* Yes. Climate change issues are included in the Strategic Plan of Kazakhstan's Ministry of Energy for 2014-2018 (ensuring Kazakhstan's transition to low-carbon development and a "green economy"). Important steps are being taken to develop renewable energy sources. In 2013, the Law regarding amendments and additions to certain legislative enactments of the Republic of Kazakhstan regarding support for the use of renewable energy sources. This has involved development of a number of legal texts. By 2020 the total volume of emissions in the electrical energy sector should not exceed that of 2012. Use of ICTs is planned in connection with maintaining a register of enterprises according to greenhouse gas emissions and a register of enterprises for participation in carbon trading.
State of Palestine	*Ministry of Telecommunications & Information Technology* A national climate change strategy and plan exists, covering 12 fundamental sectors; among these is the infrastructure sector, under which telecommunications and information technology is included.
Belize	*Public Utilities Commission (PUC)* To "support the people of the Caribbean as they address the impact of climate variability and change on all aspects of economic development through the provision of timely forecasts and analyses of potentially hazardous impacts of both natural and man-induced climatic changes on the environment, and the development of special programmes which create opportunities for sustainable development."
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* The National Policy on Climate Change (NPCC) formalizes the voluntary commitment of Brazil to the United Nations Framework Convention on Climate Change to reduce greenhouse gas emissions between 36.1 % and 38.9 % of projected emissions 2020. it was instituted in 2009 by Law No. 12.187, seeking to ensure that economic and social development contribute to the global climate system protection. In Brazil it was created the Interministerial Commission on Global Climate Change (CIMGC), which is the Designated National Authority for approving projects under the Clean Development Mechanism of the Kyoto Protocol.

Q2 Does your government (or company) have current actions in terms of adaptation to climate change?

Note: Adaptation involves taking action to cope with the effects of climate change at the local or country level. ICTs can greatly support this action. Examples include remote sensing to gather climate data, dissemination of information such as sea-level forecasts, and impact minimization measures such as building on higher ground with respect to the sea level. ICT infrastructure is already used to warn of natural disasters such as earthquakes and tidal waves. Additional or new ICT infrastructure and services may be needed to help deal with problems such as water and food shortage, etc., arising from extreme climate conditions.

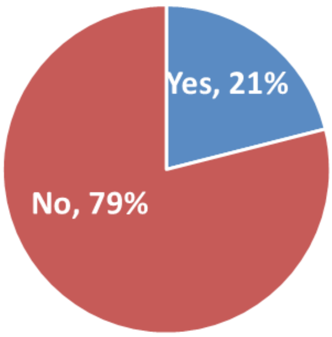


There were slightly fewer answers than in 2011 stating that they have adaptation policies (74% vs 80%).

It was then asked "If no, do you intend to propose adaptation measures to climate change in the future?" 71% of the answers indicated intention to propose adaptation measures.

Q3 Have you estimated the global ICT footprint in your country, in terms of greenhouse gas (GHG) emissions?

Note: The ICT industry has for a long time been focused on delivering productivity enhancements in and through its products and solutions. Energy efficiency has only recently become a critical issue: in some countries, energy consumption of ICT is now more than 13 per cent. It is estimated that the ICT industry accounts for approximately 2.5 per cent of global CO_2 emissions.



There were fewer answers than in 2011 (21% vs 30%) indicating that they had estimated global ICT footprint in their countries.

If yes, it was asked "what measures are you taking to reduce your GHG ICT footprint?" The following answers were provided:

Country	Entity
State of Israel	*ATDI (France)* Also more efficient transformers.
United Kingdom of Great Britain and Northern Ireland	*GSM Association, International* NIL
State of Israel	*Ministry of Environmental Protection* Partially – An estimate from 2011 states that more efficient stand-by modes could reduce emissions by 0.186 MtCO2eq in the domestic sector and 0.14 MtCO2eq in the governmental sector.
Republic of the Sudan	*National Telecommunications Corporation (NTC)* – Use of bioenergy and alternative energy; – Participation in infrastructure and reducing quantity of energy used; – Establishing shared data centres using cloud computing.
Republic of Kazakhstan	*Communication, Informatization and Information Committee* No. The ICT footprint in Kazakhstan needs to be estimated in the form of greenhouse gas emissions and the telecommunication companies contributing to that footprint must be identified.

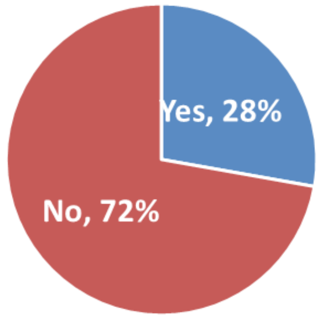
Country	Entity
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* According to Decree No. 7.390 / 2010, which regulates the National Policy on Climate Change (NPCC), the baseline greenhouse gas emissions for 2020 was estimated at 3,236 Gt CO2 – eq. Therefore, the corresponding absolute reduction was made between 1 168 Gt CO2 – eq and 1,259 Gt CO2 – eq, 36.1 % and 38.9 % reduction, respectively. To assist in achieving the reduction targets, the law also stipulates the development of sectoral mitigation and adaptation plans at the local, regional and national levels.

If no, it was asked "what are your plans for the future?" The following answers were provided:

Country	Entity
Chile	*SERMECOOP* *Unofficial translation:* Establish a policy with clearly defined regulations in this regard for 2016.
United Kingdom of Great Britain and Northern Ireland	*GSM Association, International* NIL
Eastern Republic of Uruguay	*Universidad de Montevideo* *Unofficial translation:* The government has indicated that the issue of measuring the carbon footprint will be studied. In our university, one objective that we consider is the possibility for the measurement of the carbon footprint in both undergraduate and postgraduate projects.
Arab Republic of Egypt	*Ministry of Communications and Information Technology (MCIT)* Develop ICT carbon footprint.
Republic of Korea	*Ministry of Science, ICT and Future Planning (MSIP)* Assess the achievements on GHG emission reduction using technological innovation by each sector.
Democratic Republic of the Congo	*Autorité de Régulation de la Poste et des Télécommunication* *Unofficial translation:* Our project is to equip us with the tools to assess the global carbon footprint.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* – Conduct a study to assess the overall carbon footprint of ICTs (in terms of greenhouse gas emissions) in Cameroon and mainly in large cities; – Consider raising awareness of the carbon footprint of ICT in Cameroon; – Drafting a national strategy / plan to reduce GHG emissions from ICTs in Cameroon; – Strengthening human capacity building and technology transfer for GHG assessment and reduction through ICTs.
Republic of Colombia	*Ministerio de Tecnologías de la Información y las Comunicaciones* *Unofficial translation:* Carry out a quantification of the greenhouse gas emissions by using ICTs in Colombia. This is expected to be done jointly by the Ministry of Information Technology and Telecommunications MINTIC and the Ministry of Environment and Sustainable Development (Deputy Management of Climate Change).

Country	Entity
State of Palestine	Ministry of Telecommunications & Information Technology Determination of emissions of greenhouse gases to be expanded to include other sectors. Note that we have made a general estimate of greenhouse gas emissions in the energy sector, which includes the energy consumed by the ICT sector.
Plurinational State of Bolivia	Ministerio de Obras Públicas, Servicios y Vivienda Viceministerio de Telecomunicaciones *Unofficial translation:* Conduct a study of greenhouse gas emissions from the telecommunications sector.
Federative Republic of Brazil	*Agência Nacional de Telecomunicações - ANATEL* N/A

Q4 Are you aware of "green" ICT initiative which would provide better design and energy consumption?



There were many fewer answers than in 2011 (28% vs 63%) indicating awareness of "green" ICT initiative.

In case these ICT initiatives are regional initiatives, the following details and the level of implementation of these initiatives in the countries were provided:

Country	Entity
Chile	*SERMECOOP* *Unofficial translation:* Initiatives at the level of the organization, taking into account the corporate and national strategic guidelines.
Eastern Republic of Uruguay	*Universidad de Montevideo* *Unofficial translation:* In our country there is not a joint effort, there are only a few initiatives aligned with green ICTs.
State of Israel	*Ministry of Environmental Protection* According to a Government Resolution, the Governmental Procurement Administration incorporates energy efficiency criteria (Energy Star label) in all its ICT tenders. These tenders are used also by local authorities and other public organizations

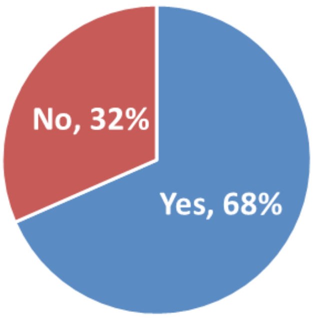
Country	Entity
Federative Republic of Brazil	*Agência Nacional de Telecomunicações - ANATEL* This is not a Regional Initiative for the Americas. Although this, according to the Interministerial Commission on Global Climate Change Activity Report 2013-2014 (CIMGC) on December 31, 2014 Brazil had a total of 416 project activities approved by CIMGC, with 333 already registered the Executive Board of the Clean Development Mechanism, equivalent amount to 4.4% of the global total, ranking 3rd in the world ranking in number of registered project activities. Geographically, the projects are distributed heterogeneously the national territory, which has five official regions of Brazil. It is noted clearly that the distribution of activities reflects characteristics physical and socioeconomic regions. The Southeast Region has 139 projects, with a predominance of Biogas activities (32) Landfill gas (31), Hydro (26) and Energy Biomass (25). Furthermore, the region has all the designs Substitution Fossil Fuel (9), of Use and Heat Recovery (4) Substitution for SF6 (1) and Solar Energy (1), and 80% of N2O destruction projects (4). The South region has 83 projects, with a predominance of Hidroeletrecidade (34), followed by activities Biogas (17), Wind Power Plants (11) and Energy Biomass (10). The Northeast It reached the record of 59 projects with a total area of wind farms (43) followed by Landfill Gas Project (7) and Biogas (3). The region The Midwest, with 63 projects presented predominance of Biogas projects (29) and Hydro (28). Finally, the North region of Brazil, with only 17 Clean Development Mechanism projects that took advantage of its water resources to record nine Hydroelectric projects.

In case these ICT initiatives are regional initiatives, the following details and the level of implementation of these initiatives in the countries were provided:

Country	Entity
Eastern Republic of Uruguay	*Universidad de Montevideo* Unofficial translation: It is not at any status.
Arab Republic of Egypt	*Ministry of Communications and Information Technology (MCIT)* Sustainable development goals.
Republic of the Sudan	*National Telecommunications Corporation (NTC)* Yes, they are global initiatives, the outputs of which are adopted by the Sudan for gradual implementation; currently at the stage of planning, standardization and determining methods of implementation.

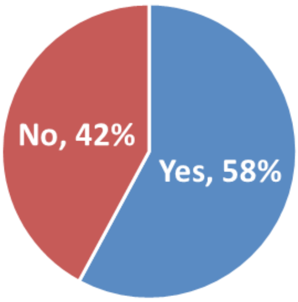
Country	Entity
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* Registered Brazilian projects are distributed in 15 types, which can be grouped into eight sectoral scopes. Among the types of Clean Development Mechanism projects developed in Brazil are Hydroelectric projects, Wind, Biogas, Landfill Gas, Biomass Energy, Replacement Fossil Fuel, Methane Avoided, Oxide Decomposition Nitrous (N2O), of Use and Heat Recovery, Reforestation and Afforestation of Other Renewable Energy (Solar Photovoltaic) of Energy efficiency, Sulfur hexafluoride Replacement (SF6), Reduction and Replacement perfluorocarbons (PFCs) and replacement of fossil origin CO_2 Industrial Use or Mineral CO_2 by renewable sources. The breakdown of the number of Brazilian projects of Clean Development Mechanism registered annually until December 2014, is as follows: hydroelectric projects, including micro plants (CGHs), small plants (SHP) and large plants (HPPs), representing 27.0% of total Brazilian projects. In addition, following the biogas use projects, accounting for 19.2%, the wind farm projects, representing 16.2%, landfill gas projects, representing 15% projects using biomass energy, representing 12.3%, the fossil fuel replacement projects, representing 2.4% and methane avoidance projects, representing 2.4%. Such projects together represent 94.9% of the total portfolio in Brazil.

Q5 Do you have severe weather conditions in your rural/remote regions?



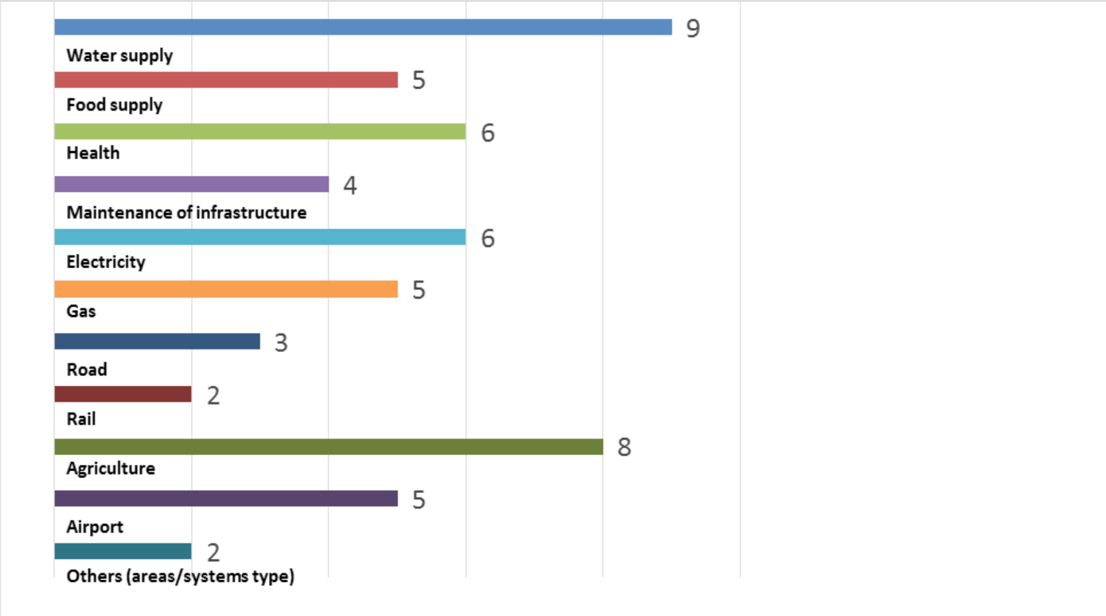
The question had not been asked in a comparable manner in 2011. 68% of the 2016 answers indicated having severe weather conditions in their rural/remote regions.

Q6 Is your administration using any Systems and Applications of ICT to adapt to climate change?



There were about the same number of answers than in 2011 (58% vs 60%) stating that administration is using any Systems and Applications of ICT to adapt to climate change.

It was then asked to specify in which area and the type of system and application used. The answers are reported in the following **figure**:



Q7 What ICT services would enable communities to better adapt to climate change? (One example could be automated text messages to communities about water shortage and emergency water supply, etc.)

The following answers were provided:

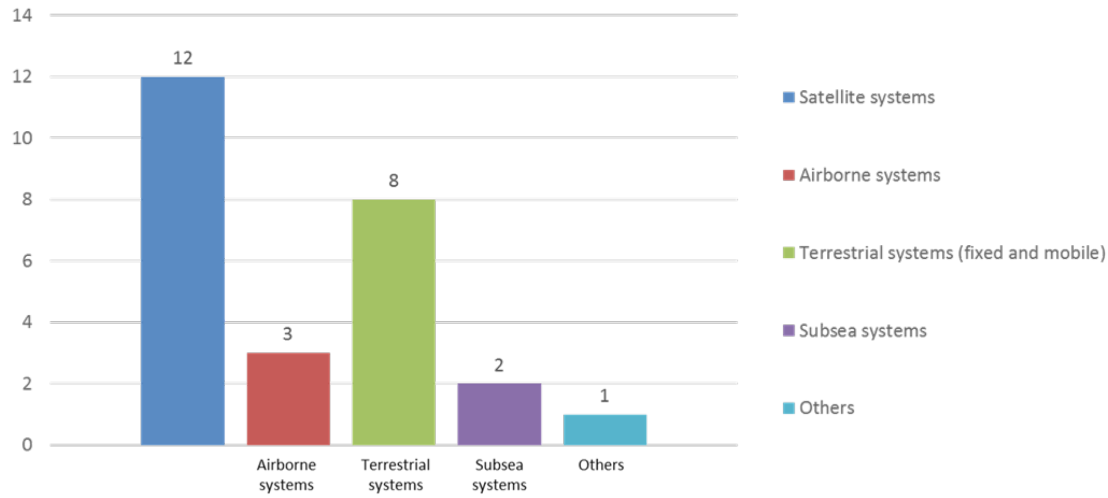
Country	Entity
Republic of the Sudan	*National Telecommunications Corporation (NTC)* Mobile telephone services. Various means of communication.
Republic of Korea	*Ministry of Science, ICT and Future Planning (MSIP)* SMS services to communities when issuing a fine dust warning.
Republic of Mali	*Autorité Malienne de Régulation des Télécommunications/TIC* *Unofficial translation:* Sending automated text messages, websites, radio and TV news, climate change websites.
Democratic Republic of the Congo	*Autorité de Régulation de la Poste et des Télécommunications* *Unofficial translation:* SMS, social networks, call center.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* SMS, telephone, television, radio, fax, réseaux sociaux.
Belize	*Public Utilities Commission (PUC)* Natural disaster warnings and updates.
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* Due to the use of the Internet and social networks to increase the populations of urban and rural areas , we suggest the adoption of communications mechanisms associated with the Internet, such as social and Apps communication networks (like WhatsApp) and others.
Plurinational State of Bolivia	*Ministerio de Obras Públicas, Servicios Y Vivienda Viceministerio de Telecomunicaciones* *Unofficial translation:* Voice and data telecommunication services.

Country	Entity
Republic of Armenia	*Ministry of Transport and Communication* The SMS information on extreme weather and road conditions is already applied in Armenia. The water shortage information also can be important for advance actions on proper management of available resources. Kazakhstan Communication, Informatization and Information Committee (Kazakhstan) Sending out alerts on such threats via mobile phones.
State of Palestine	*Ministry of Telecommunications & Information Technology* SMS, text messaging, social media sites, websites of relevant enterprises, TV and radio broadcasts.
Arab Republic of Egypt	*Ministry of Communications and Information Technology (MCIT)* In 1987 expert system technology was identified as an appropriate technology to speed up agricultural desert development in Egypt. The Central Laboratory for Agricultural Expert Systems (CLAES) has been established for agriculture management. It is domain independent and can be used with any commodity. CALES consists of three separate modules: an executive, a scheduler, and an expert system shell. In 1991, serious efforts have been started in Egypt to develop crop management expert systems for different crops. A prototype for an expert system for cucumber seedlings productions has been developed. This prototype has six functions: seeds cultivation, media preparation, control environmental growth factors, diagnosis, treatment, and protection.
State of Israel	*ATDI (France)* Sensors to indicate water wastes and remote readings of water meters
Chile	*SERMECOOP* *Unofficial translation:* Intensive use of sending messages and testimonies in social networks (Facebook, Twitter, Youtube, etc.). Develop a game or competition on social networks (with access from mobile devices), and compete by using several notifications of actions to mitigate climate change.
United Kingdom of Great Britain and Northern Ireland	*GSM Association (International)* See our Mobile for Development activities: http://www.gsma.com/mobilefordevelopment/.
Eastern Republic of Uruguay	*Universidad de Montevideo* *Unofficial translation:* SMS, data collection systems for sensors, big data management and emergency communications of preference.

Country	Entity
Republic of Colombia	*Ministerio de Tecnologías de la Información y las Comunicaciones* *Unofficial translation:* – Improve hardware and software as well as interoperability between national and sectoral information systems that allow the automatic transmission of data (hydrometeorological, energy consumption, sectoral statistics, watershed status, etc.) that allow the country to have efficient and useful systems for decision-making in order to face of climate change. – Improvement of the data transmission technologies of hydrometeorological and oceanographic stations. – Generate technological and human capacity for the management of geographic data that allow to improve the quality of the analysis on vulnerability, risk and adaptation. – Generate early warning systems for agriculture, energy sector, etc. – Develop Apps and information tools to present the information to the public more efficiently. – Policies (and materialization) of open data that allow the government to better access geographical information, satellite images, remote sensors, etc. in order to improve the level of knowledge of vulnerability in the territory. – Technological strengthening of the entities generating information and the Environmental Information System at national level, as well as local entities that must use the information to influence the generation of local policies, development strategies, project. – Social ownership of knowledge on adaptation to climate change. – Improve diffusion through different audiovisual media, radio, massive networks. – Improve knowledge of the regions to design more appropriate strategies. – Access to cartography generated by different actors (i.e. mapatons).

Q8 What specific technologies or standards for ICT equipment are used by your administration to gather data to monitor climate change? Please select those that are applicable:

Answers are illustrated in the following figure, where it appears that Satellite systems are the most used (52% of the answers), followed by terrestrial systems (26%).



Q9 What technologies and/or standards could enhance the gathering of data/information about climate change for your administration?

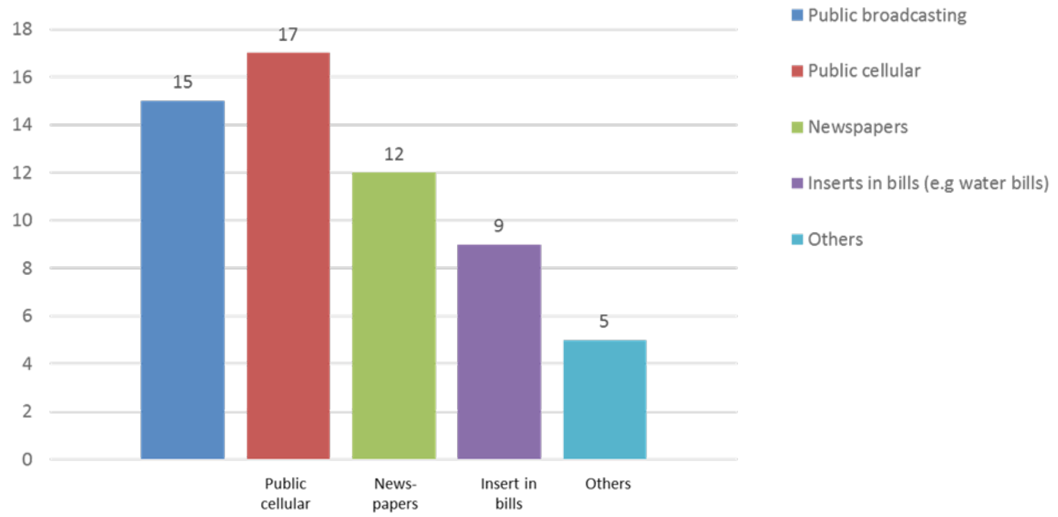
The following answers were provided:

Country	Entity
State of Israel	*ATDI France* Israel enforces sharing of cellular sites by different operators
Chile	*SERMECOOP* Unofficial translation: A formal policy, which defines the role, the responsibility, the attributions and resources. So far these are the actions taken at an informal level.
Republic of the Sudan	*National Telecommunications Corporation (NTC)* Communications technology and information technology
Republic of Korea	*Ministry of Science, ICT and Future Planning (MSIP)* Developing a Geostationary Satellite (GSS) for climate and environmental predictions
Republic of Mali	Stations, des Observatoires etc.
Democratic Republic of the Congo	Systèmes à satellite.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* Satellite systems; Earth systems (fixed and mobile) and submarine system.

Country	Entity
Republic of Colombia	*Ministerio de Tecnologías de la Información y las Comunicaciones* *Unofficial translation:* – Greater access to satellite information; – Remote sensors; – Open data in all national and local entities; – Geographic information systems (capacity, management, use of open data); – Information systems (hardware and software) that allow the use of geographic and alphanumeric data efficiently and safely; – Interoperability of existing systems and subsystems; – Accessible modelling tools and training for their management; – Improvement of hydrometeorological and oceanographic stations in data transmission; – Technological capacity of national and local entities in data management.
Republic of Armenia	*Ministry of Transport and Communication* Expansion of the network automated hydrometriological observation stations, improved of the affordable systems for the assessment of the snow cover in mountainous areas for prediction of water resources and flood alarming. The water level measurement in reservoirs in real time for better planning.
State of Palestine	*Ministry of Telecommunications & Information Technology* Advanced weather monitoring network; Time series of high-precision remote sensing satellite images.
Belize	High altitude platforms.
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* Terrestrial radio systems (private networks), terrestrial cellular systems and satellite broadcasting.

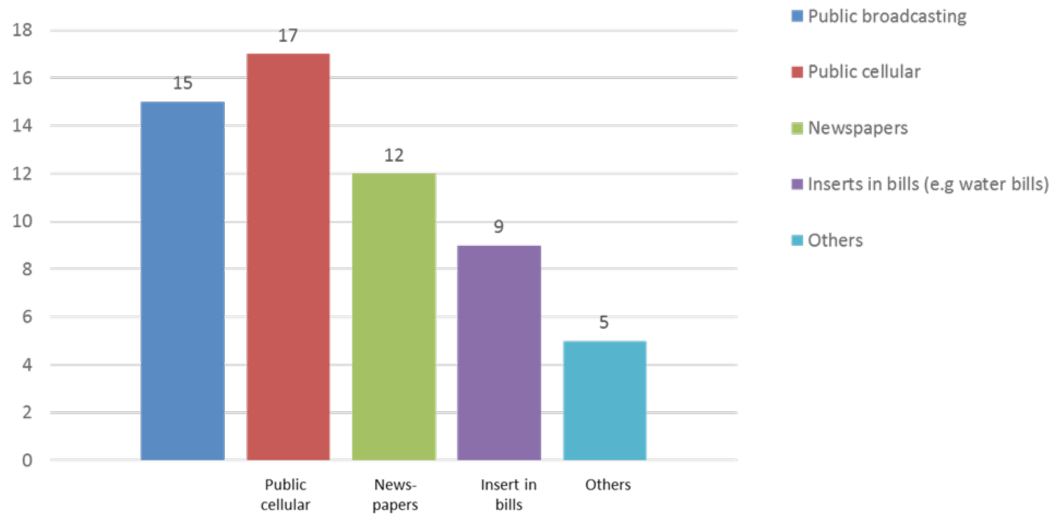
Q10 What information communication technologies and standards are used by your administration to disseminate information about climate change to those who need it (e.g. in broadcast, Satellite systems)?

Answers are illustrated in the following figure. Terrestrial systems still represent about 70% of the answers regarding technologies and standards used by administrations to disseminate information about climate change.



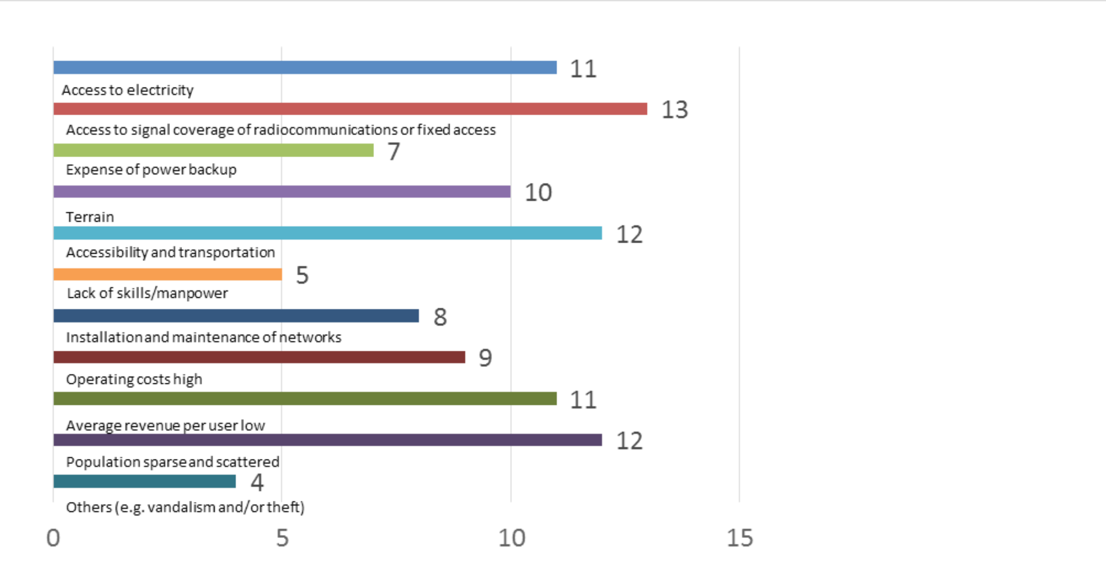
Q11 What technologies and/or standards could enhance the dissemination of information about climate change to those who need it?

Answers are illustrated in the following figure. Public cellular was the most often quoted (30%), followed by Public broadcasting and Newspaper.



Q12 Access to information is important for communities needing to adapt to climate change. What are the challenges to deploying Telecommunication infrastructure in rural/remote areas in your region? Please indicate those that affect you most from the following examples:

As shown in the following **figure**, there were many challenges to deploying Telecommunication infrastructure in rural/remote areas, almost all equally important. These challenges included Average revenue per user, Access to electricity, Accessibility and transportation, Access to signal coverage of radiocommunications or fixed access, Population scarce or scattered.



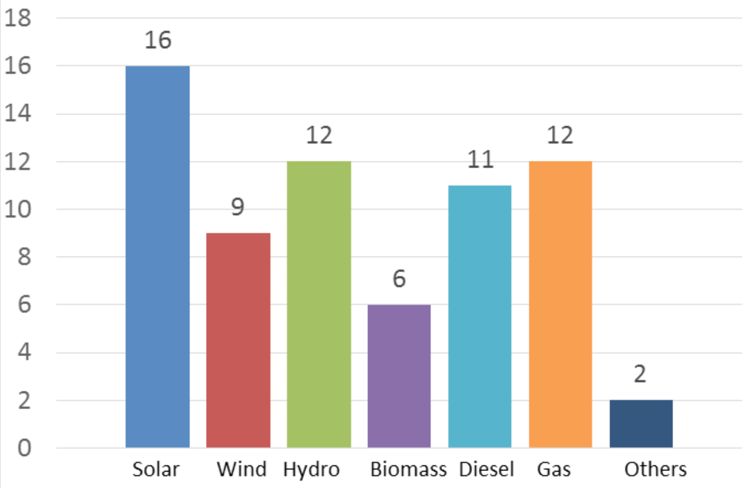
Further information was provided as follows:

Country	Entity
Chile	*SERMECOOP* *Unofficial translation:* Not having the necessary electrical energy, the culture of the population.
United Kingdom of Great Britain and Northern Ireland	*GSM Association, International* See our Mobile for Development activities: http://www.gsma.com/mobilefordevelopment/.
Sudan	*National Telecommunications Corporation (NTC)* The US economic boycott on systems, equipment, devices and spare parts.
Democratic Republic of the Congo	*Autorité de Régulation de la Poste et des Télécommunications du Congo (A.R.P.T.C.)* *Unofficial translation:* Lack of road infrastructure to access rural and remote areas and insufficient deployment and/or lack of electricity distribution network
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* The main obstacles found are: – Access to electricity: it is not only that the network is not extended but also the power cuts are frequent. – Access to radio signal or fixed access: rugged terrain. – Accessibility and transport: low density of the transport network. – Natural hazards: high frequency of natural disasters due to climate events.

Country	Entity
Republic of Armenia	*Ministry of Transport and Communication* Because of the factors/challenges mentioned above, possible investments by private operators in telecommunication projects in rural/remote areas are less cost-effective and require longer payback periods than similar investments in urban areas
State of Palestine	*Ministry of Telecommunications & Information Technology* Other challenges include the presence of military occupation, resulting in lack of control over territory and of full control over crossing points and imports
Plurinational State of Bolivia	*Ministerio de Obras Públicas, Servicios y Vivienda Viceministerio de Telecomunicaciones* *Unofficial translation:* Municipal authorization for the installation of towers, supports of antennas and telecommunications networks. Installation of telecommunication infra-structures in national protected areas. Opposition of some people in urban areas.
Brazil	*Agência Nacional de Telecomunicações – ANATEL* Brazil is a country with vast territory, where geographical, economic, social and environ-mental conditions are very different. Overcome the differences and difficulties of this reality, especially those related to access to information for people in remote areas, it is a major challenge for the national strategy related to climate change.

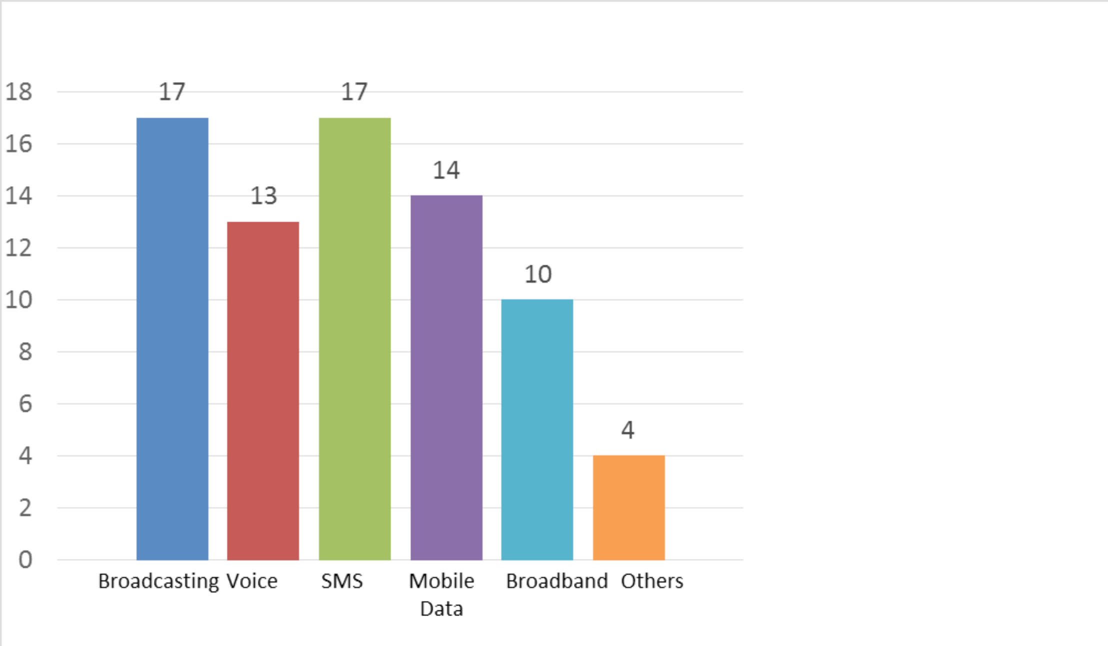
Q13 What primary and backup energy sources are available in your rural/remote areas?

As evidenced in the following figure, solar was the most often quoted (24%), followed by Hydro and Gas (18%). Diesel was 16% of the quotes.



Q14 What types of broadcasting/telecom/mobile systems are needed to allow enhanced access to information concerning climate change or extreme weather events in rural/remote regions?

SMS and Broadcasting were the most often quoted (23%), followed by mobile data and voice



Further information was provided as follows:

Country	Entity
Chile	*SERMECOOP* *Unofficial translation:* electric energy.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* Fax.
Republic of Colombia	*Ministerio de Tecnologías de la Información y las Comunicaciones* *Unofficial translation:* Television.

Country	Entity
United States of America	*U.S. Department of State, Bureau of Economic, and Business Affairs Communication and Information Policy, Multilateral Affairs* Some examples of systems in the United States for extreme weather events or other emergency alerts: Emergency Alert System (EAS): The Emergency Alert System (EAS) is a national public warning system that requires broadcasters, cable television systems, wireless cable systems, Satellite Digital Audio Radio Service (SDARS) providers, and Direct Broadcast Satellite (DBS) providers to provide the communications capability to the President to address the American public during a national emergency. Additionally, EAS equipment can directly monitor the National Weather Service for local weather and other emergency alerts, which local broadcast stations, cable systems, and other EAS participants can then rebroadcast, providing an almost immediate relay of local emergency messages to the public. Wireless Emergency Alerts (WEA): WEA is a public safety system that allows customers who own certain wireless phones and other enabled mobile devices to receive geographically-targeted, text-like messages alerting them of imminent threats to safety in their area. The technology ensures that emergency alerts will not get stuck in highly congested areas, which can happen with standard mobile voice and texting services. Wireless companies volunteer to participate in WEA. WEA enables government officials to target emergency alerts to specific geographic areas through cell towers that broadcast the emergency alerts for reception by WEA-enabled mobile devices. The alerts from authenticated public safety officials are sent through the Federal Emergency Management Agency's (FEMA's) Integrated Public Alert and Warning System (IPAWS) to participating wireless carriers, which then push the alerts from cell towers to mobile devices in the affected area. The alerts appear like text messages on mobile devices. Both EAS and WEA are part of FEMA's IPAWS, which is a modernization and integration of the nation's alert and warning infrastructure. IPAWS provides public safety officials with an effective way to alert and warn the public about serious emergencies using the EAS, WEA and other public alerting systems from a single interface.

Q15 What are the educational means in rural/remote regions to train individuals for the use of ICTs for adaptation to climate change?

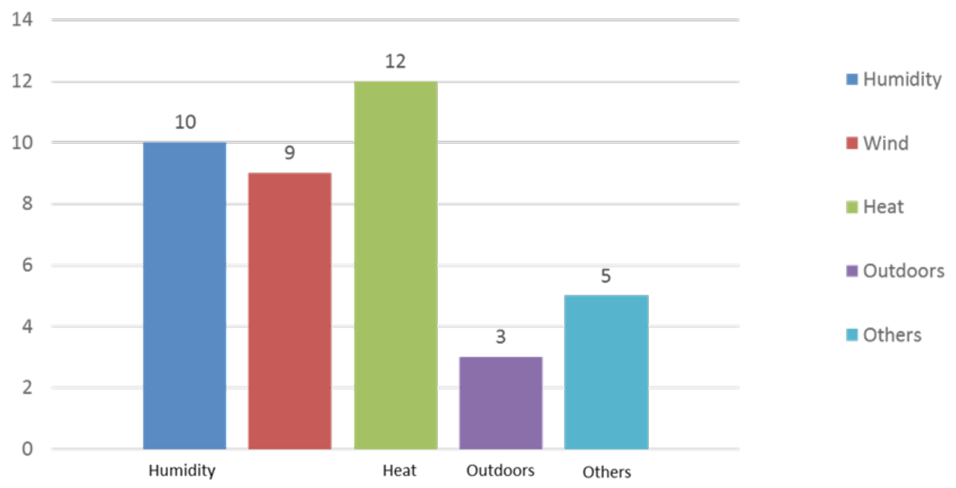
The following answers were received:

Country	Entity
Chile	*SERMECOOP* *Unofficial translation:* There are several possibilities, but a good motivation is required, based on the advantages and/or benefits for them to adapt themselves to those effects. Given the culture of these areas it is not useful to talk about benefits for the country and/or the world.
United Kingdom of Great Britain and Northern Ireland	*GSM Association (International)* See our Mobile for Development activities: http://www.gsma.com/mobilefordevelopment/.
Republic of Uruguay	*Universidad de Montevideo* *Unofficial translation:* Rare or none.

Country	Entity
Republic of the Sudan	*National Telecommunications Corporation (NTC)* – Universal access services. – Awareness-raising and educational campaigns.
Republic of Korea	*Ministry of Science, ICT and Future Planning (MSIP)* Providing necessary facilities.
Republic of Mali	*Autorité Malienne de Régulation des Télécommunications/TIC e (Mali)* *Unofficial translation:* Existence of strategy documents, existence of technical services of the State, NGOs etc.
Democratic Republic of the Congo	*Autorité de Régulation de la Poste et des Télécommunications (Dem. Rep. of the Congo)* Unofficial translation: – Installation of telecenters for the community; – Churches; – Schools.
Republic of Cameroon	*Ministère des Postes et des Télécommunications* *Unofficial translation:* seminars; broadcasts/community radio and television; awareness campaigns; associations and religious networks; written materials (leaflets, posters, banners, technical sheets…).
Republic of Colombia	*Ministerio de Tecnologías de la Información y las Comunicaciones* *Unofficial translation:* There are good possibilities to the extent that strategies are designed taking into account the local needs and conditions of vulnerability and having a component of social ownership. In Colombia, we have worked on some pilot projects of this type from which important lessons have been learned. In addition, it would be necessary to ensure the coverage of data networks in such remote areas and the capacity of national and local institutions to generate the necessary data in a sustainable manner over time.
Republic of Armenia	*Ministry of Transport and Communication* E-Learning tools, booklets, leaflets, etc.
State of Palestine	*Ministry of Telecommunications & Information Technology* Educational and training workshops; Instructional materials (leaflets, compact discs).
Plurinational State of Bolivia	*Ministerio de Obras Públicas, Servicios y Vivienda Viceministerio de Telecomunicaciones* *Unofficial translation*: The training should be carried out by the Plurinational Authority of Mother Earth [Autoridad Plurinacional de la Madre Tierra] under the Ministry of Environment and Water as the head of sector on the issue of climate change.
Federative Republic of Brazil	*Agência Nacional de Telecomunicações – ANATEL* As already mentioned, Brazil is a country with vast territory, where geographical, economic, social and environmental conditions are very different. In rural / remote areas, educational facilities are also very different, but we believe that the recent spread of modern media (such as Internet, mobile and social networks) is presented as a viable option to be used as appropriate educational means.

Q16 Some systems are specifically developed for developing countries; most of them have some features that are not essential enough to justify their cost and/or lack the required specification to meet the existing conditions in developing countries. What are the conditions requiring specific features that are essential in rural/remote regions in your country?

Heat was the most often quoted condition (31%), followed by Humidity (25%) and Wind (23%).



Annex 2: List of contributions received for Question 6/2 during study period 2014-2017

The contributions received for consideration by Question 6/2 are listed below.

Question 6/2 contributions for Rapporteur Group and Study Group meetings

Web	Received	Source	Title
2/466 +Ann.1	2017-03-23	Argentine Republic	Pursuing UN Sustainable Development Goals through IoT for irrigation systems
2/443	2017-01-19	Rapporteur for Question 6/2	Report of the Rapporteur Group meeting on Question 6/2, Geneva, 19 January 2017
2/418 [OR]	2017-02-17	Rapporteur for Question 6/2	Final Report for Question 6/2
RGQ/237 + Ann.1	2016-12-22	Rapporteur for Question 6/2	Proposed Annex 1 to Question 6/2 final report
RGQ/232	2016-12-08	BDT Focal Point for Question 6/2	ITU-D activities on ICTs and climate change
RGQ/223	2016-11-29	Rapporteur for Question 6/2	Proposed text for clause 2.3 on submarine systems for climate change monitoring
RGQ/222	2016-11-29	Rapporteur for Question 6/2	Proposed text for clause 2.1 on terrestrial systems for climate change monitoring
RGQ/214 **[OR]**	2016-11-25	Rapporteur for Question 6/2	Draft Final Report for Question 6/2
2/372	2016-09-13	Telecommunication Development Bureau	Overview of input received through the ITU-D Study Group 2 consolidated survey for Questions 6/2, 7/2 and 8/2
2/363	2016-09-13	France	Proposed revision of report on question 6/2 on ICT and climate change
2/356	2016-09-07	Qualcomm, Inc.	India- Stove Trace Case Study
2/336	2016-08-09	The ITU Association of Japan	Proposal for recycling method of lead acid battery
2/331 (Rev.1)	2016-08-12	Alcatel-Lucent France, Nokia Siemens Networks GmbH & Co. KG	Revised outline of output report for Question 6/2 - Section 4
2/327	2016-08-12	BDT Focal Point for Question 6/2	ITU-D activities on the ICTs and Climate Change
2/324	2016-08-11	Nokia Siemens Networks GmbH & Co. KG,Alcatel-Lucent France	Revised outline of output report for Question 6/2

Web	Received	Source	Title
2/275	2016-06-29	Orange (France)	Utilisation de l'énergie solaire pour les réseaux mobiles des pays en développement
2/267 **[OR]**	2016-04-27	Rapporteur for Question 6/2	Draft Question 6/2 report following the 25 April 2016 Q6/2 meeting
2/262	2016-04-25	Rapporteur for Question 6/2	Report of the Rapporteur Group Meeting on Question 6/2, Geneva, 25 April 2016
RGQ/167	2016-04-26	Rapporteur for Question 6/2	Working document: draft Question 6/2 report following the 25 April 2016 Q6/2 meeting
RGQ/165 +Ann.1	2016-04-25	France	COP21- Résultats et prochaines étapes
RGQ/160	2016-04-08	France	Proposal for the Question 6/2 output report
RGQ/154	2016-04-05	United States of America	Proposed revision of clause 1 of the Q6/2 report
RGQ/153	2016-04-05	United States of America	Proposed editorial revision of clause 2.2 of the Q6/2
RGQ/152	2016-04-05	United States of America	Proposed text for clause 2.4 of the Q6/2 report
RGQ/151	2016-04-05	BDT Focal Point for Question 6/2	ITU-D activities on the ICTs and Climate Change
RGQ/134	2016-03-30	Orange	Utilisation de l'énergie solaire pour les réseaux des pays en développement
RGQ/109	2016-03-02	France	Réduire la consommation énergétique des TIC
2/248	2015-09-14	Rapporteur for Question 6/2	Outline of output report for Question 6/2
2/226	2015-08-19	Democratic Republic of the Congo	Initiatives internationales sur les changements climatiques
2/195	2015-07-26	United States of America	Proposed initial text for clause 2.2 of the Q6/2 report
2/194	2015-07-26	United States of America	Comments on the draft outline of the Q6/2 report
2/168	2015-07-22	BDT Focal Point for Question 6/2	ITU-D activities on the ICTs and Climate Change
2/162	2015-07-21	France	Eléments scientifiques sur le changement climatique
2/161	2015-07-21	France	The connected and sustainable city
2/152	2015-07-06	Rapporteur for Question 6/2	Draft Questionnaire on ICT and Climate Change
2/151	2015-07-06	Rapporteur for Question 6/2	Draft table of contents for Question 6/2: ICT and climate change

Web	Received	Source	Title
2/138	2015-05-08	Rapporteur for Question 6/2	Report of the Rapporteur Group Meeting on Question 6/2, Geneva, 28 April 2015
RGQ/68	2015-04-14	KDDI Corporation	Mobile base stations with tribrid electric control technology
RGQ/53 Rev.1	2015-03-21	France	Éléments scientifiques sur le changement climatique
RGQ/49	2015-03-12	BDT Focal Point for Question 6/2	ITU-D activities on ICTs and climate change? Trends in telecommunication reform 2010 Chapter on climate change
RGQ/39	2015-03-11	BDT Focal Point for Question 6/2	ITU-D activities on the ICTs and climate change
RGQ/10	2014-12-15	Rapporteur for Question 6/2	Draft work plan for Question 6/2
2/89	2014-09-09	General Secretariat	WSIS Stocktaking: Success stories
2/87	2014-09-08	General Secretariat	Report on WSIS Stocktaking 2014
2/85	2014-09-08	Alcatel-Lucent France	Proposal for initial work plan for Question 6/2
2/47	2014-08-14	BDT Focal Point for Question 6/2	Work of ITU in the area of ICTs and Climate Change
2/33	2014-08-04	Telecommunication Standardization Bureau	Executive summary of the Working Party 3 of ITU-T Study Group 5 meeting (Geneva, 19-23 May 2014)
2/32	2014-08-04	Telecommunication Standardization Bureau	Executive summary of the ITU-T Study Group 5 meeting (Lima, 2-13 December 2013)
2/31	2014-08-04	Telecommunication Standardization Bureau	ITU-T activities on ICTs, the environment and climate change

Liaison Statements

Web	Received	Source	Title
1/272	2016-05-18	ITU-T Study Group 5	Liaison statement from ITU-T Study Group 5 to ITU-D Study 1 and 2 on updates on ITU-T SG 5 activities relevant to ITU-D study groups
1/268	2016-04-11	ITU-R Working Party 7C	Liaison Statement from ITU-R Working Party 7C to ITU-D SG2 on Response on ICT and climate change
RGQ/87	2015-11-24	ITU-T Study Group 5	Liaison Statement from ITU-T SG5 to ITU-D SG2 on ITU-D SG2 Q6/2 work for the 2014-2017 study period

Web	Received	Source	Title
RGQ/33	2015-03-03	ITU-T Study Group 5	Liaison Statement from ITU-T Study Group 5 to ITU-D Study Group 2 on the Executive Summary of the ITU-T Study Group 5 Meeting
RGQ/21	2015-02-09	ITU-T Study Group 5	Liaison Statement from ITU-T Study Group 5 to ITU-D Study Group 2 Question 6/2 on Inviting ITU-D Study Group 2 Question 6 to provide information to Question 15/5 "ICTs and adaptation to the effects of climate change" with respect to work item: Recommendation ITU-T L.1500 Supplement on Adaptation

International Telecommunication Union (ITU)
Telecommunication Development Bureau (BDT)
Office of the Director
Place des Nations
CH-1211 Geneva 20 – Switzerland
Email: bdtdirector@itu.int
Tel.: +41 22 730 5035/5435
Fax: +41 22 730 5484

Deputy to the Director and Chief, Administration and Operations Coordination Department (DDR)
Email: bdtdeputydir@itu.int
Tel.: +41 22 730 5784
Fax: +41 22 730 5484

Infrastructure Enabling Environment and e-Applications Department (IEE)
Email: bdtiee@itu.int
Tel.: +41 22 730 5421
Fax: +41 22 730 5484

Innovation and Partnership Department (IP)
Email: bdtip@itu.int
Tel.: +41 22 730 5900
Fax: +41 22 730 5484

Projects and Knowledge Management Department (PKM)
Email: bdtpkm@itu.int
Tel.: +41 22 730 5447
Fax: +41 22 730 5484

Africa

Ethiopia
International Telecommunication Union (ITU)
Regional Office
P.O. Box 60 005
Gambia Rd., Leghar ETC Building
3rd floor
Addis Ababa – Ethiopia
Email: ituaddis@itu.int
Tel.: +251 11 551 4977
Tel.: +251 11 551 4855
Tel.: +251 11 551 8328
Fax: +251 11 551 7299

Cameroon
Union internationale des télécommunications (UIT)
Bureau de zone
Immeuble CAMPOST, 3e étage
Boulevard du 20 mai
Boîte postale 11017
Yaoundé – Cameroun
Email: itu-yaounde@itu.int
Tel.: + 237 22 22 9292
Tel.: + 237 22 22 9291
Fax: + 237 22 22 9297

Senegal
Union internationale des télécommunications (UIT)
Bureau de zone
8, Route du Méridien
Immeuble Rokhaya
B.P. 29471 Dakar-Yoff
Dakar – Sénégal
Email: itu-dakar@itu.int
Tel.: +221 33 859 7010
Tel.: +221 33 859 7021
Fax: +221 33 868 6386

Zimbabwe
International Telecommunication Union (ITU)
Area Office
TelOne Centre for Learning
Corner Samora Machel and Hampton Road
P.O. Box BE 792 Belvedere
Harare – Zimbabwe
Email: itu-harare@itu.int
Tel.: +263 4 77 5939
Tel.: +263 4 77 5941
Fax: +263 4 77 1257

Americas

Brazil
União Internacional de Telecomunicações (UIT)
Regional Office
SAUS Quadra 06, Bloco "E"
10º andar, Ala Sul
Ed. Luis Eduardo Magalhães (Anatel)
70070-940 Brasilia, DF – Brazil
Email: itubrasilia@itu.int
Tel.: +55 61 2312 2730-1
Tel.: +55 61 2312 2733-5
Fax: +55 61 2312 2738

Barbados
International Telecommunication Union (ITU)
Area Office
United Nations House
Marine Gardens
Hastings, Christ Church
P.O. Box 1047
Bridgetown – Barbados
Email: itubridgetown@itu.int
Tel.: +1 246 431 0343/4
Fax: +1 246 437 7403

Chile
Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Merced 753, Piso 4
Casilla 50484, Plaza de Armas
Santiago de Chile – Chile
Email: itusantiago@itu.int
Tel.: +56 2 632 6134/6147
Fax: +56 2 632 6154

Honduras
Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Colonia Palmira, Avenida Brasil
Ed. COMTELCA/UIT, 4.º piso
P.O. Box 976
Tegucigalpa – Honduras
Email: itutegucigalpa@itu.int
Tel.: +504 22 201 074
Fax: +504 22 201 075

Arab States

Egypt
International Telecommunication Union (ITU)
Regional Office
Smart Village, Building B 147, 3rd floor
Km 28 Cairo – Alexandria Desert Road
Giza Governorate
Cairo – Egypt
Email: itu-ro-arabstates@itu.int
Tel.: +202 3537 1777
Fax: +202 3537 1888

Asia and the Pacific

Thailand
International Telecommunication Union (ITU)
Regional Office
Thailand Post Training Center, 5th floor,
111 Chaengwattana Road, Laksi
Bangkok 10210 – Thailand

Mailing address
P.O. Box 178, Laksi Post Office
Laksi, Bangkok 10210 – Thailand
Email: itubangkok@itu.int
Tel.: +66 2 575 0055
Fax: +66 2 575 3507

Indonesia
International Telecommunication Union (ITU)
Area Office
Sapta Pesona Building, 13th floor
JI. Merdan Merdeka Barat No. 17
Jakarta 10110 – Indonesia

Mailing address:
c/o UNDP – P.O. Box 2338
Jakarta 10110 – Indonesia
Email: itujakarta@itu.int
Tel.: +62 21 381 3572
Tel.: +62 21 380 2322/2324
Fax: +62 21 389 05521

CIS countries

Russian Federation
International Telecommunication Union (ITU)
Area Office
4, Building 1
Sergiy Radonezhsky Str.
Moscow 105120
Russian Federation

Mailing address:
P.O. Box 47 – Moscow 105120
Russian Federation
Email: itumoskow@itu.int
Tel.: +7 495 926 6070
Fax: +7 495 926 6073

Europe

Switzerland
International Telecommunication Union (ITU)
Telecommunication Development Bureau (BDT)
Area Office
Place des Nations
CH-1211 Geneva 20 – Switzerland
Switzerland
Email: eurregion@itu.int
Tel.: +41 22 730 6065

International Telecommunication Union
Telecommunication Development Bureau
Place des Nations
CH-1211 Geneva 20
Switzerland
www.itu.int

ISBN 978-92-61-23121-7

Printed in Switzerland
Geneva, 2017

07/2017