ICTs and Climate Change

ITU-T Technology Watch Briefing Report No. 3 (November 2007)

In October 2007, the Nobel Peace Prize was awarded jointly to former US vice-president Al Gore and to the UN Intergovernmental Panel on Climate Change (IPCC) with a citation "*for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change*".

ITU Technology Watch Briefing Reports are intended to evaluate the potential of emerging technologies, in a manner that is accessible to non-experts, with a view to:

- Identifying candidate technologies for standardization work within ITU.
- Assessing their implications for ITU Membership, especially developing countries.

Previous reports in the series include:

#1 Intelligent Transport System and CALM

#2 Telepresence: high-performance video-conferencing

See: http://www.itu.int/ITU-T/techwatch/index.phtml

The award recognizes that climate change represents a threat to mankind on a similar plane to violent conflict and war, and indeed can lead to a breakdown of peace because of the increased competition for the earth's resources. Information and Communication Technologies (ICTs) are undoubtedly part of the cause of global warming as witnessed, for instance, by the millions of computer screens that are left switched on overnight in offices around the world. But ICTs can also be part of a solution. This Technology Watch briefing report looks at the potential role that ICTs play at different stages of the process, from contributing to global warming (section 1), to monitoring it (2), to mitigating its impact on the most vulnerable parts of the globe (3), to developing long-term solutions, both directly in the ICT sector and in other sectors like energy, transport, buildings etc (4). The final sections look at what ITU-T is already doing in this field (5) and strategic options (6).

1. Climate change and the impact of ICTs

There are a number of different causes of climate change, many of which are naturally generated (e.g., variations in solar radiation, volcanic activity etc). However, it is man-made climate change that is of major concern because it appears to be leading to a progressive and accelerating warming of the planet, as a result of the release of greenhouse gases (GHG), primarily carbon-based emissions. As shown in Figure 1, taken from the work of the IPCC, global greenhouse gas emissions have risen by 70 per cent since 1970[1]. As a consequence, global average temperatures have risen by around half a degree centigrade (from 14° to 14.5°C) since 1950, and there has been a rise in sea level of around 10 cm and a reduction of Northern hemisphere snow cover of around 2 million km^2 over the same period (see Figure 2)[2]. Since measurements began, eleven of the warmest annual average temperatures recorded have been in the last twelve years.[3]

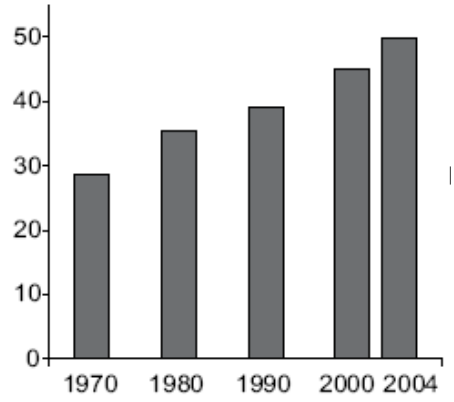

Figure 1: Total Greenhouse Gases (in Gigatonnes of Carbon Dioxide equivalents – $GtCO_2$-eq)
Source: IPCC (WG 3 contribution to 4th assessment report)

The primary sources of GHG are energy production and consumption, transport, buildings, land-use change, waste management etc. Other industries, including the ICT Sector, generate around 4 per cent of total GHG, but this would be much higher—around 14 per cent—if indirect energy use were included. The ICT Sector itself contributes around 2.5 per cent of GHG[4], which is much smaller than its share of global Gross Domestic Product (GDP). Indeed, because the main output of the ICT Sector is information rather than physical goods ("bits", not "atoms") it can be seen as part of the solution rather than problem. Nevertheless, ICTs are far from innocent in the matter of climate change:

- The major contribution of ICTs to climate change comes from the proliferation of user devices, all of which need power and radiate heat. For instance, in the decade between 1996 and 2006, the number of mobile phones rose from 145 million to 2.7 billion. Over the same period, estimated Internet users grew

from 50 million to 1.1 billion. In 1996, virtually all residential Internet users were using dial-up whereas by 2006 a majority had always-on broadband connections, further increasing power use.

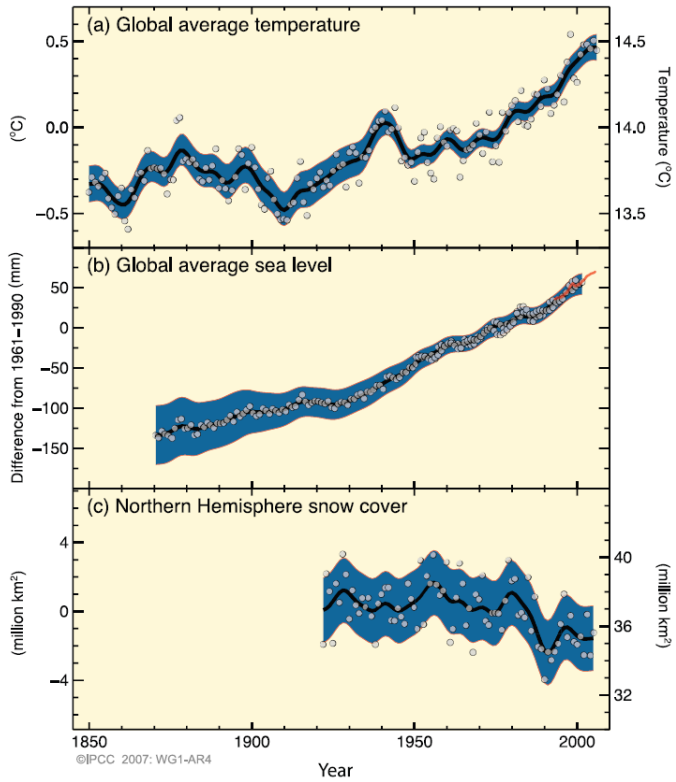

Figure 2: Long-term changes related to the climate
Source: IPCC, WG1 contribution to 4th assessment report.

- In addition to the proliferation of users, each individual user may now own many more devices. For instance, in the field of consumer electronics, whereas twenty years ago a single television might have provided entertainment for a household, now a typical family in a developed country might own multiple television sets, as well as a digital cinema, video-recorder, a DVD player, a hard-drive recorder, one or more set-top box decoders etc, many of which are routinely left on standby overnight.

- As these ICT devices acquire more processing power, their requirements for power and for cooling, also rise. For instance, third generation (3G) mobile phones, which operate at higher frequencies and need more power than 2G ones (for instance, for Internet access, digital signal processing, polyphonic ringtones etc) and therefore more power is required to keep them charged.

- An increasing percentage of ICT usage might be regarded as "unnecessary", in the sense that it is spam email, SMS and voice calls, or the storage rather than deletion of old material.

ICT use will only grow over time, and it is important therefore that the industry takes steps now to curb and ultimately reduce its carbon emissions.

2. ICT use in monitoring climate change

The science of climate change, which has developed over the last century or so[5], has benefited greatly from the parallel development of ICTs. The typical locations for climate research—such as the polar ice caps, glaciers, volcanoes, the ocean bed or the upper layers of the atmosphere—are inhospitable, and remote monitoring and data collection using ICT-equipped sensors (telemetry) is essential for research. Even more useful has been the development of aerial photography, satellite imagery, grid technology and in particular the use of global positioning by satellite (GPS) for tracking slow, long-term movement, for instance of glaciers or ice floes (see Figure 3). The World Glacier Monitoring Service uses an integrative multi-level approach to document glacier

Figure 3: Retreat of the Trift Glacier, Switzerland
Source: Swiss Academy of Sciences. *Note:* The glacier retreated by around 200m between 2004 and 2005

changes that links satellite remote sensing and GPS data with aerial photography, in-situ measurements and computer modeling of glacial mass balance, with research spread over many decades.

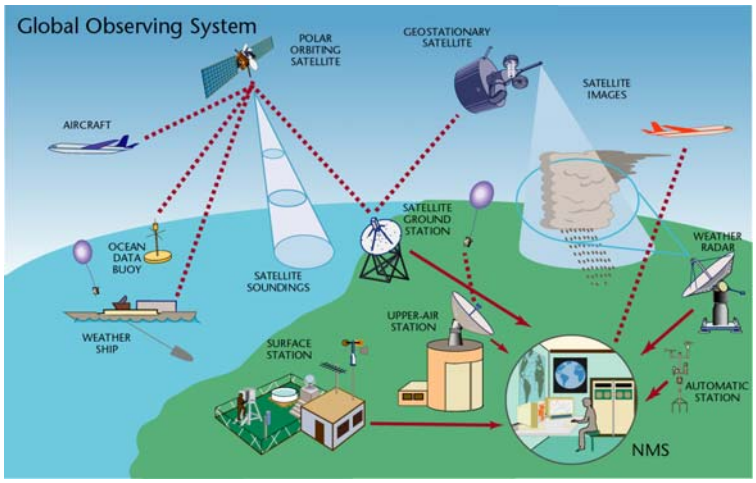

Figure 4: WMO Global Climate Observing System
Source: World Meteorological Organisation
Note: NMS = National Meteorological Service.

In addition to monitoring the effects of climate change, ICTs have also proved invaluable in computer modeling of the earth's atmosphere, beginning with the work of computer pioneer von Neumann in the late 1940s. Meteorological services are among the most demanding users of the world's fastest supercomputers, and produce progressively more sophisticated general circulation models of climate. For instance, the Hadley Centre for Climate Change in the United Kingdom runs a variety of climate models on a suite of NEC SX-6 supercomputers which have processing power equivalent to 1'000 times that of a top-of-the-range desktop PC. The numerical climate models are linked via Bracknell, one of 15 regional and three global telecommunication hubs of the World Meteorological Organization (WMO's) Global Telecommunications System (GTS)[6], which is linked to its World Weather Watch Global Climate Observing System (GCOS)[7] (see Figure 4). In addition, by using the unused processing cycles of thousands of linked computers[8], it is possible for scientists, and even amateurs, to conduct climate modeling experiments. Sophisticated computer systems also help run the system of tradable permits for carbon emissions which are one of the main implementation tools of the Kyoto Protocol.

3. ICTs for mitigating the local effects of climate change

The impact of global warming on the world's climate to date (see Figure 2) is relatively small compared with what can be expected in the future, even if the increase in GHG is stabilized. The IPCC, in its 4th assessment report, predicts a rise in average temperatures of 1.4-5.8°C[9] and a 3 per cent reduction in global GDP by 2030. However, the results are likely to be highly uneven in their distribution, with low-lying coastal areas (e.g., small island developing states, Bangladesh delta, Netherlands) at risk because of rising sea levels; sub-Saharan Africa at risk due to desertification; a growing number of environmental refugees and increased pressure on sources of fresh water and on vulnerable ecosystems such as coral reefs, tundra, coastal wetlands etc.

At the Antalya ITU Plenipotentiary Conference in 2006, Member States adopted Resolution 136 on the "*Use of telecommunications/ICTs for monitoring and management in emergency and disaster situations for early warning, prevention, mitigation and relief*" which, *inter alia*, calls upon the Directors of the Bureaux to continue their technical studies and to support the development of early-warning, mitigation and relief systems.[10] ITU-T's work in this field includes standardization of call priority in emergency situations (e.g., Recommendation E.106 on the International Emergency Preference System for disaster relief). ITU-T also leads the Partnership Coordination Panel on Telecommunications for Disaster Relief (PCP-TDR), which falls under the responsibility of ITU-T Study Group 2[11]. Its terms of reference include monitoring and promoting technical standardization work in this area.

One of the outcomes of ITU-T Study Group 2's work is the assignment of a special E.164 country code (888) to the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) for the purpose of facilitating the provision of an international system of naming and addressing for terminals involved in disaster relief activities. This might be used in an area of a country that has been cut off from the national telecommunications system of that country, or for natural disasters covering many countries, such as a tsunami (see Box 1). A number of regional and sub-regional workshops have been held on telecommunications/ICTs for disaster relief, and a Global Forum on 10-12 December 2007 in Geneva.

Box 1: Tsunami early warning systems: Message sent, but was it received?

A good example of the use of ICTs for disaster relief is the establishment of a tsunami early-warning and mitigation system for the Indian Ocean, following the tsunami of 26 December 2004, operating under the aegis of UNESCO's International Oceanographic Commission. A similar system has existed in the Pacific Ocean since 1965 and the Indian Ocean system is based on 25 seismic stations, 26 national tsunami centres and three deep ocean sensors, with messages sent by satellite phone. It became operational in June 2006. However, when it was needed for real the following month (see map), as a result of the Java earthquake, no message was relayed to coastal areas of Indonesia and hundreds of people were killed by the ensuing tidal wave. In a test conducted on 24 January 2007, the average delay between a message being sent (by SMS and email) and a response received back ranged between a minimum of two minutes (seven countries) and 31 hours (Indonesia), with three countries failing to respond at all. UNESCO has admitted that more coordination among governments is needed.

Source: Adapted from IOC/UNESCO[12] and BBC[13].

ICTs can also play a role in environmental protection, waste management and in environmentally-friendly supply chain management. These applications fall under Programme 3 of the Doha Action Plan of ITU-D, notably WTDC-06 Resolution 52. ITU-D will shortly publish a set of guidelines on technology and policy aspects of eEnvironment applications and practices in national development planning[14].

4. ICTs and concerted action against global warming

The key to combatting global warming is to stabilize and eventually reduce the emission of GHG. International success has been achieved with a reduction in ozone depleting substances (such as chlorofluorocarbon (CFC) gases) to 20 per cent of their 1990 levels by 2004, thanks to the 1987 Montreal Protocol. However, emissions of carbon dioxide have grown by around 80 per cent since 1970 and, despite the 1997 Kyoto Protocol, which set targets for a reduction by 5 per cent of 1990 levels by 2008-2012, there seems little sign of this rate of growth slowing. The next stop for the international community is the UN Climate Change Conference, in Bali from 3-14 December 2007, where it is hoped that a breakthrough can be made.[15]

Reducing carbon emissions will require changes in lifestyle and behaviour, but changes in management practices can also have a positive impact. New energy infrastructure investments are urgently required to move towards cleaner energy production, but there is also much that can be done in reducing energy consumption, in changing agricultural practices and through land-use change. Other longer-term, more high-tech solutions include ocean fertilization, creating a global sunshade and carbon sequestration. It is clear that any mitigation strategy must have multiple elements and ICTs can help with this, either:

- **Directly,** by reducing the ICT sector's own energy requirements (see Box 2 on next-generation networks). An example is provided by the members of the European Telecommunication Networks Operators' association (ETNO), who signed an environmental charter in 1996 on sustainability.

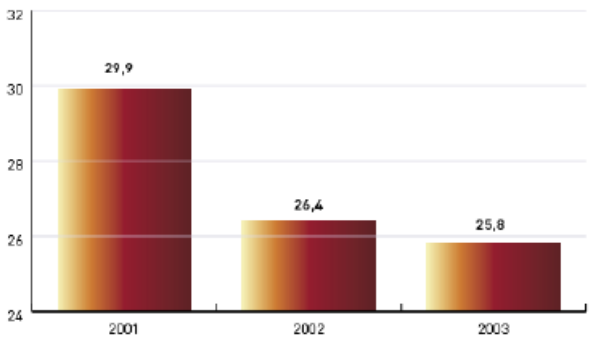

Figure 5: Reduction in grams of CO_2 per unit of turnover.
Source: ETNO. *Note:* Based on survey of 25 ETNO Member.

Box 2: Next-generation energy consumption for next-generation networks

The telecommunications industry is currently undergoing a major revolution as it migrates from today's separate networks (for voice, mobile, data etc) to a single, unified IP-based next-generation network (NGN). The savings will be achieved in a number of ways:

- A significant decrease in the number of switching centres required. For instance, BT's 21st Century Network (21CN) will require only 100-120 metropolitan nodes compared with its current 3'000 locations;
- More tolerant climatic range specifications for NGN switching locations, which are raised from 35 degrees (between 5 and 40°C) to 50 degrees (between -5 and 45°C). As a result, the switching sites can be fresh-air cooled in most countries rather than requiring special air conditioning.
- NGNs may make use of more recent standards, such as VDSL2 (ITU-T G.993.2), which specifies three power modes (full, low-power and sleep), whereas VDSL has only a single power mode (full power).

However, a particular concern relates to computer data centres, which have very demanding requirements for air-conditioning, electricity supply back-up etc. It is estimated that the five leading search companies use some two million servers. The total power required to run and cool these data centres amounts to around 5 GW and represents some 30 per cent of their total costs. Projects to reduce power consumption by data centres include the "Green grid" consortium involving AMD, Intel, Dell, Sun HP, IBM and others. Other initiatives to reduce power consumption include the "WattWatt" community website established by the IEC for sharing ideas on energy efficiency and the "GridWise" initiative of the US Dept of Energy which allows remote control of virtual thermostats via a web interface..

Sources: Adapted from various sources including Young (2007)[16], Schiwy (2005)[17], AMD[18], GridWise[19] and IEC[20].

Between 2001 and 2003, 25 ETNO member telcos succeeded in reducing their overall carbon emissions by 7 per cent and their carbon intensity (per unit of turnover) by 14 per cent (see Figure 5).

- **Indirectly,** through using ICTs for carbon displacement (see Box 3 on the ETNO/WWF initiative).
- **In a systemic way**, by providing the technology to implement and monitor carbon reductions in other sectors of the economy (see Box 4 on ICTs and intelligent transport systems).

This distinction between the direct, indirect and systemic value of ICTs in mitigating the effects of global warming provides a useful conceptual framework for analysis of what ITU-T is already doing in the field of climate change (section 5) and the options open to it in formulating a broader strategy (6).

5. What ITU-T is already doing on climate change

ITU-T is already very active, via its Study Groups, in standardization work and other studies that are relevant to climate change, in particular in the areas of energy efficiency, reduced power consumption, mitigation of the effects of climatic change and technologies for reducing carbon emissions. The following examples provide an insight into some of this work:

a) ITU-T's work focuses on the **reduction of power requirements of telecommunication equipment** including terminal devices and networking equipment. Energy efficient ICT equipment will reduce the production of GHG and hence reduce global warming. ITU-T Study Group 15 ("Optical and other transport network infrastructures") is in the process of initiating studies to investigate ways to reduce the power consumption of telecommunications equipment. Contributions on power saving for G-PON related studies are already being considered and a survey has been carried out under Q2/15.

b) A major focus of ITU's work in recent years has been on **Next-Generation Networks** (NGN), which are expected by some commentators (Dittberner Associates) to reduce energy consumption by 40 per cent compared to today's PSTN (see Box 2).

c) Two of the most promising technologies for improving energy efficiency are **radio-frequency identification (RFID) and sensors**, which can be combined together to form a ubiquitous sensor network (USN). This technology can be used in many different environmental applications, such as temperature control, efficient control of heating and lighting, telemetry etc. ITU-T has established a "Joint Coordination Activity on Network Aspects of Identification Systems (including RFID)" to coordinate work in this area.

d) ITU-T's mission, from the very earliest days, has included **telecommunications for disaster relief and for emergency services**, which are particularly important in mitigating the effects of climate change, for instance from flooding due to rising sea levels, or increased incidence of violent storms and hurricanes. Virtually all ITU-T Study Groups are active in this area, notably Study Group 2 which has the lead on telecommunications for disaster relief/early warning (see section 3 above).

Box 3: Saving the climate @ the speed of light

A joint initiative between the European Telecommunication Network Operators' association (ETNO) and the World Wide Fund for nature (WWF), called "Saving the climate @ the speed of light", is designed to show how ICTs can be used to displace carbon emissions within the European Union. The initiative sprang out of the World Summit on the Information Society (WSIS), following a conference on Telecommunications and Sustainability held in Budapest, 25-26 November 2004[21]. The partners have developed a two part roadmap:

- The first target is to reduce EU carbon emissions by 50 million CO_2 equivalent tonnes annually by 2010 through the strategic use of ICTs;
- The second would be a more ambitious target for 2020, to be set before 2010.

A number of areas in which ICTs can reduce carbon emissions have been identified:

- By reducing the need for travel through video- and audio-conferencing, and by facilitating remote participation in meetings. It is estimated that each 1 per cent reduction in business travel in the EU, amounting to around 50 million audio/video-conference calls, would save around one million tonnes of CO_2 emissions annually.
- Through flexible working patterns, such as telecommuting, facilitated by ICTs. Each one million EU telecommuters would save around one million tonnes of CO_2 emissions annually. A similar study in the United States, where commuting distances tend to be longer, found that today's 3.9 million telecommuters save between 10-14 million tonnes of CO_2 equivalent[22].
- By promoting sustainable consumption and development, through "dematerialization" (replacing atoms with bits), for instance through online phone billing (to save on paper bills), online submission of tax forms, by using IPTV to replace trips to the DVD store, by using e-commerce to reduce shopping trips etc.

Source: ETNO and WWF.[23]

e) In terms of **technologies for reducing carbon emission**, virtually every single application of telecommunications—from the telegraph to the telephone call to the email— might be considered as replacing the need for a physical journey. The work of ITU-T's Study Group 16, on multimedia, is of particular importance, notably in terms of standards for remote collaboration, such as the H series of ITU-T Recommendations on audiovisual and multimedia systems, including video-conferencing, which provide a means for people to collaborate at a distance without needing to travel. Higher performance systems, like telepresence, should help to reduce resistance to the use of these tools.

f) ITU is also active in the field of **intelligent transport systems**, which can help to reduce carbon emissions, for instance by reducing congestion (see Box 4).

g) Finally, greater use of **recycling** and the safe disposal of waste can assist in reducing global warming and the release of GHG. One area of study within ITU-T is "Environmental and Safety Procedures for Outside Plant" (ITU-T Study Group 6). Environmental protection procedures now in place in many countries will affect the selection of materials and mode of installation in outside plant. Study items include environmental aspects resulting from outside plant material recycling. Recommendations are being developed to implement these considerations while recycling copper and optical cables materials.

6. Options for and ITU-T strategy on climate change

Climate change is a concern for all of humanity and requires efforts on the part of all sections of society. ITU is called upon, *inter alia*, to "*promote, at the international level, the adoption of a broader approach to the issues of telecommunications in the global information economy and society*" (CS §9), and thus should exercise leadership in this area. There are a number of options where the Telecommunication Standardization sector (ITU-T) may take a lead:

a) **Organize a symposium** on the topic of ICT standardization and climate change, possibly in the first half of 2008. This symposium could assist in developing an ITU-T strategy and for identifying areas for future standardization work.

b) On the basis of the proceedings of the symposium, and on relevant standardization work, it may be useful to for ITU-T to issue a **handbook** on ICTs and climate change, in collaboration with ITU-D, focusing on best practice guidelines and assistance to developing countries.

c) In addition to those areas identified in section 5 above where work in ITU-T Study Groups is already proceeding, there may be other ways in which **standardization** work could be carried out. For instance on:
   - Energy efficiency, both for devices and for networks;

Box 4: ICTs and intelligent transport systems

In addition to reducing the direct effects of the ICT sector on climate change, and the indirect effects through using ICTs for displacement of carbon emissions, ICT-based technologies can also have a systemic impact on other sectors of the economy and of society, and can help in providing a basis for sustainable development. The potential systemic impact of ICTs is particularly apparent in the transport sector which, according to the Stern report[24], accounts for 14 per cent of total greenhouse gas emissions.

ICTs can be applied to transport through the development of Intelligent Transport Systems (ITS)[25]. Although the main focus of ITS is on the safety, management and efficiency of transport systems, ITS can also be used to reduce their environmental impact. For example:

- Parking guidance systems can lead motorists to the most appropriate parking space, and thereby reduce engine time;
- Similarly, GPS use for navigation or vehicle dispatch can reduce journey time;
- Road pricing schemes, such as the congestion charge in London, can encourage greater use of public transport and reduce congestion, thereby reducing journey times.

ITU's main efforts in this field are geared towards the annual "Fully Networked Car" workshops, organized jointly with ISO and IEC, the third of which will be held in Geneva, 5-8 March 2008. A particular focus of this event will be ICTs and climate change, with papers presented on:

- Cars as environmental sensors;
- Alternative route/transport planning;
- ICT-enabled energy efficiency
- Car-to-grid energy transfer.

Source: ITU-T Technology Watch Briefing Report #1.

  - Wider climatic tolerance for telecommunications/ICT infrastructure equipment, thereby reducing the requirement for air-conditioning;
  - Carbon displacement technologies, like TelePresence (see Technology Watch Briefing Report #2), video-conferencing and other remote collaboration tools, or on mitigating the effects of climate change, such as recycling of telecommunication waste and telecommunications for disaster relief.

d) One specific area for standardization work would be the development of a **standardized methodology for calculating the carbon footprint associated with the use of telecommunications/ICT equipment**. This could apply both to telecommunication service providers and for calculating the carbon displacement effect of ICTs. This project could be carried out with the assistance of a specialist carbon audit company, such as the Carbon Disclosure Project. ISO has already worked on this issue for other sectors of the economy, notably in the three-part standard ISO 14064:2006 which gives guidelines for measuring the release of greenhouse gases.

e) ITU-T may wish to give more emphasis to **facilitating remote participation**, for instance by using collaborative tools for broadcasting meetings or by changing participation rules to allow remote participants to make contributions in meetings etc.

f) ITU-T could seek **partnerships** for sustainable development. ITU was one of the founding partners of the Global e-Sustainability Initiative (GeSI), which sprang out of the Millennium Summit and which has specific working groups on climate change and eWaste. ITU has also recently joined the UN Environment Management Group[26]. ITU-T may also consider joining the ETNO/WWF partnership (see Box 3) which has been one of the most active in this area, or contributing to IEC's WattWatt website for electrical energy efficiency.

g) As a particular type of partnership, ITU-T may consider more active participation in the climate change efforts of **other UN agencies**, for instance in the preparations for the World Climate Conference-3, to be held in Geneva, October 12-16 2009. Ten UN agencies, led by WMO, already participate in the international organizing committee, and ITU could seek also to join this work. ITU-T may also seek a more active role in facilitating the work of WSIS action line C7 themes on e-Environment and e-Science, for which ITU was named by WSIS as a co-facilitator.

This Technology Watch Briefing Report is submitted to the Correspondence Group and to TSAG for discussion and for comments, which should be sent to tsbspd@itu.int.

Glossary of abbreviations and acronyms used in the document

21CN	Twenty-first Century Network
2G	Second Generation mobile communications
3G	Third Generation mobile communications
BOINC	Berkeley Open Infrastructure for Networked Computing
C	Centigrade
CALM	Continuous Air Interface for Long and Medium Range communications
CFC	Chlorofluorocarbon gases
CO_2	Carbon dioxide
CS	ITU Constitution
DVD	Digital Versatile Disc
ETNO	European Telecommunication Network Operators' association
EU	European Union
GCOS	Global Climate Observatory System
GDP	Gross Domestic Product
GeSI	Global eSustainability Initiative
GHG	Greenhouse Gases
G-PON	Gigabit Passive Optical Network
GPS	Global Positioning by Satellite
$GtCo_2$-eq	Gigatonnes of Carbon Dioxide equivalent
GTS	Global Telecommunication System
GW	GigaWatts
ICTs	Information and Communication Technologies
IEC	International Electrotechnical Commission
IOC	International Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IPTV	Internet Protocol Television
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication standardization sector
NGN	Next-Generation Network
NMS	National Meteorological Service
OCHA	Office for the Coordination of Humanitarian Affairs
PC	Personal Computer
PCP-TDR	Partnership Coordination Panel on Telecommunications for Disaster Relief
RFID	Radio Frequency Identification
SMS	Short Message Service
UN	United Nations
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USN	Ubiquitous Sensor Network
VDSL	Very high speed Digital Subscriber Line
WG	Working Group
WMO	World Meteorological Organization
WSIS	World Summit on the Information Society
WWF`	World Wide Fund for nature

Sources and Further Information

[1] UN Intergovernmental Panel of Climate Change (IPCC), Working Group 3 contribution on "Climate Change Mitigation" to the Fourth Assessment Report, 2007, available at: http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html.

[2] IPCC, Working Group 1 contribution on "The physical science basis" to the Fourth Assessment Report, 2007, available at: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.

[3] Speech by Mr Rajendra Pachauri, Chairman of the IPCC, to the UN High-level event on climate change, 24 September 2007, available at: http://www.ipcc.ch/Pachauri_240907.pdf and accompanying presentation at: http://www.ipcc.ch/UN_NYC_24thSep2007.ppt. .

[4] See "The impact of ICT on global emissions", report prepared by McKinsey for the UN Environment Group, 24 October 2007.

[5] For an account of the history of the science of climate change, see Spencer Weart's website at: http://www.aip.org/history/climate/index.html.

[6] For a description of the WMO's Global Telecommunication System, see: http://www.wmo.int/pages/prog/www/TEM/gts.html.

[7] The World Weather Watch programme is described at: http://www.wmo.int/pages/prog/www/index_en.html and the global climate observing system at: http://www.wmo.int/pages/prog/www/OSY/GOS.html.

[8] See for instance http://www.climateprediction.net/index.php which claims to be the world's largest experiment on climate modeling and uses a programme called BOINC (Berkeley Open Infrastructure for Networked Computing) for distributed computing.

[9] See "The heat is on", survey of climate change in *The Economist*, Sept 7 2006 edition, available at: http://www.economist.com/opinion/displaystory.cfm?story_id=7852924.

[10] All three Sectors are involved in activities related to emergency telecommunications, and an inter-sectoral task force has been established to coordinate this work. Relevant ITU-R Recommendations include F.1105 (2006), BO.1774 (2007), S1001 (2006), and a number of different Recommendations in the M series (mobile, radiodetermination, amateur and related satellite services).

[11] For more information on the PCP-TDR, see: http://itu.int/ITU-T/special-projects/pcptdr.

[12] For more information, see the IndoTsunami website, hosted by the Intergovernmental Oceanographic Commission of UNESCO, at: http://ioc3.unesco.org/indotsunami/.

[13] Indonesia tsunami system "not ready", BBC website, 19 July 2006 at: http://news.bbc.co.uk/2/hi/asia-pacific/5191190.stm.

[14] For more information on eEnvironment activities, see the ITU-D website at: http://www.itu.int/ITU-D/cyb/app/e-env.html/

[15] For more on the Bali conference, see the UN Framework Convention on Climate Change (UNFCCC) website at: http://unfccc.int/meetings/cop_13/items/4049.php. The call for a breakthrough in Bali was made by the UN Secretary-General at the conference "The Future in our hands", 24 September 2007 in New York, see: http://www.un.org/climatechange/2007highlevel/summary.shtml.

[16] See Young, Stephen, "Climate Change and ICT", presentation made at "Effective IT Summit", Cardiff, 24 January 2007, available at: http://www.effectiveit.com/__data/assets/pdf_file/0015/171402/Stephen_Young.pdf.

[17] SwissCom and T-Com "Energy optimization in the anticipated NGN switching", 2005, available at: http://re.jrc.cec.eu.int/energyefficiency/pdf/Workshop_May.2005/Broadband%20comunication/Schiwy.pdf.

[18] For more information on the Green Grid consortium, see: http://www.thegreengrid.org/.

[19] The GridWise website of the US Department of Energy's Pacific Northwest National Laboratory can be found at: http://www.gridwise.pnl.gov/.

[20] See the IEC community website on electrical energy efficiency at: http://wattwatt.com/.

[21] Proceedings of the conference "European Telecommunications and Sustainability" held 25-26 November 2004 in Budapest are available at: http://www.magyartelekom.hu/english/doc/konferencia_en.pdf.

[22] See "The energy and greenhouse gas emissions impact of telecommuting and e-commerce", report to Consumer Electronics Association by TIAX, July 2007, at: http://www.ce.org/Energy_and_Greenhouse_Gas_Emissions_Impact_CEA_July_2007.pdf.

[23] The report "Saving the climate @ the speed of light" is available at: http://www.etno.be/Portals/34/ETNO%20Documents/Sustainability/Climate%20Change%20Road%20Map.pdf, and the background report "Greenhouse Gas effects of ICTs" (2005) at: http://www.etno.be/Portals/34/events/VIS2005/projectdocu_Final.pdf.

[24] See "Stern Review: The Economics of Climate Change", available at: http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

[25] Intelligent Transport Systems, and in particular Continuous Air-interface for Long- and Medium-range communications (CALM), are the subject of the Technology Watch Briefing Report #1, available at: http://www.itu.int/ITU-T/spd/docs/002-tw-CALM.pdf./

[26] The UN environment management group website is at: http://www.unemg.org/.