Next-Generation Networks and Energy Efficiency

ITU-T Technology Watch Briefing Report Series, No. 7

Next Generation Networks (NGNs) are seen by many as the new network architecture that will unify today's fixed, mobile and broadcast networks. This innovative technology is expected to bring about greater energy efficiency than legacy networks. In turn, by improving the energy efficiency of Information and Communication Technologies (ICTs), NGN can potentially make a significant contribution in the battle against global warming.

The most reliable recent studies estimate that the ICT sector itself contributes around 2-2.5 per cent of global GHG emissions[1], and that this share will grow, mainly because of increasing demand for ICTs in developing countries. However, there is a huge potential for ICTs to mitigate GHG emissions in other sectors of the economy, such as transport, construction and supply chain management.

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.

Other reports in the series include:

#1 Intelligent Transport Systems and CALM
#2 Telepresence: High-performance video conferencing
#3 ICTs and climate change
#4 Ubiquitous Sensor Networks
#5 Remote Collaboration Tools
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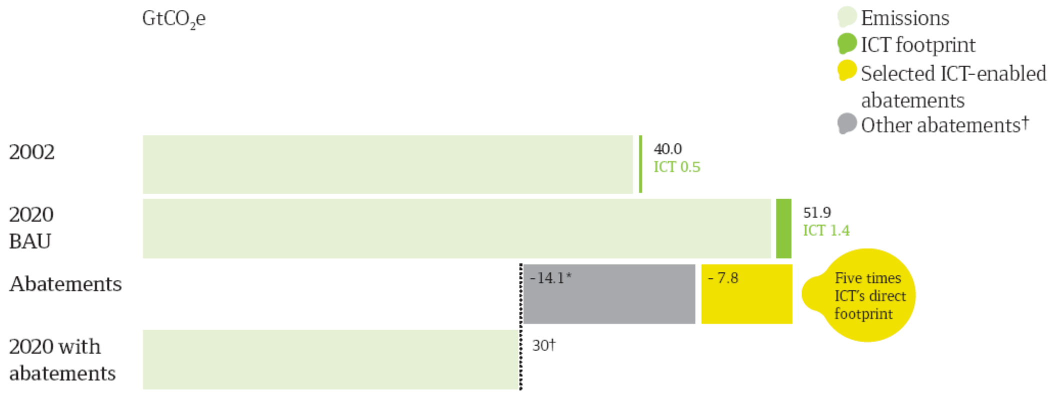
In December 2007, ITU-T issued a report in the Technology Watch Briefing Report series, entitled "ICTs and Climate Change" showing how ICTs are both a cause of global warming and also a major part of the solution. ICTs can be used to monitor, mitigate and adapt to climate change[2] through the promotion of carbon displacement technologies. This report was further discussed at two symposia on ICTs and climate change held in Kyoto, 15-16 April and in London, 17-18 June 2008. A more recent publication, "SMART 2020: Enabling the Low Carbon Economy in the Information Age" by the Climate Group and the Global e-Sustainability Initiative (GeSI), states that the use of efficient ICTs could reduce global CO_2 emissions by 15 per cent by 2020; which is five times the footprint of the ICT sector (see Figure 1). This will require that the ICT sector adopt a range of measures aimed at reducing its carbon footprint, especially for data centres, together with smart planning and logistics to make energy reductions through the use of ICTs in other sectors.

The ITU-T Telecommunication Standardization Advisory Group (TSAG) recently launched a work programme on ICTs and climate change. This work aims at limiting, and ultimately reducing, GHG emissions. It also seeks to foster sustainable development, promote energy efficiency in the development of Recommendations and Guidelines[3], and make users and operators aware of the possibilities of climate change mitigation through the use of ICTs. Reducing energy waste and increasing power efficiency is the optimal way to reduce CO_2 emissions and it also presents great advantages to telecom operators and service providers in terms of cost savings. Thus, it represents a "win-win" scenario.

This report examines the relationship between climate change and NGNs, by analyzing the improved energy efficiency and applications of these new networks. Specifically, the report presents an overview of the main characteristics of NGN (in section 1); looks at how NGN can minimize the power consumption of the network, (2). The report also looks at the likely increase in the number of data centres and what can be done to minimize their power requirements (3). It examines the energy savings that can be indirectly obtained from greater NGN usage, such as remote collaboration, amongst other applications (4), and ITU-T standardization work on NGN and climate change issues (5). Finally, some examples are presented in this report on possible emission savings that could be achieved with a better use of ICTs and NGN deployment. This report is the seventh in the series of ITU-T Technology Watch Briefing Reports and complements earlier reports that dealt with such environment topics as climate change, video-conferencing and remote collaboration.

Fig. 1 ICT impact: The global footprint and the enabling effect



* For example, avoided deforestation, wind power or biofuels
† 21.9 $GtCO_2e$ abatements were identified in the McKinsey abatement cost curve and from estimates in this study. Source: Enkvist P., T. Naucler and J. Rosander (2007), *'A Cost Curve for Greenhouse Gas Reduction'*, The McKinsey Quarterly, Number 1

In 2020 the global footprint is expected to reach 51.9 GtCO2e (Giga tonnes of CO2 equivalents). Of this amount, 1.4 Gt would be the direct contribution of ICTs. However by implementing good practices and use of ICTs, total emissions could be reduced in 7.8 Gt, e.g. 15 per cent of the expected amount.
Source: GeSI (2008) "SMART 2020: enabling the low carbon economy in the information age", available at www.gesi.org.

1. What are Next-Generation Networks?

The growing demand for ICTs, for new multimedia services, and the resulting expansion of digital traffic, is leading the telecommunications industry towards the convergence and optimization of traditional networks. The logical goal is the coming together of existing networks (fixed, mobile, Internet, broadcast etc) into a unitary network architecture which has been termed Next Generation Networks (NGNs). This emerging technology is a packet-based network able to make use of multiple broadband technologies, providing telecommunication services to users, with independence of service-related functions from transport technologies[4]. Main NGN characteristics and differences from traditional networks are presented in Box 1.

These characteristics appear to offer great potential for reducing the energy requirements and carbon footprint of ICTs by: (1) better equipment management and sharing of infrastructures, thereby reducing energy requirements for network and device operation, and (2) substituting travelling and the transport of goods, by the operation of new applications running over high-bandwidth NGNs.

NGNs are likely to contribute to a rise in the number of data centres, which will increase power consumption. But these data centres, and the applications they support, should lead to a major increase in the usage of ICT tools. This in turn should facilitate a process of the substitution of the transport of atoms by the transport of bits. NGN is therefore an essential part of any study of the effect of ICTs on climate change.

NGNs are expected to have effects not only on the environment, but also on social and economic elements, equivalent to earlier transitions in the telecommunication sector. This was the case in the early 1990s, with the creation of the World Wide Web, which brought the Internet into homes and workplaces and prepared the ground for the so-called 'digital revolution'[5]. A similar transformation occurred with mobile phones, which began provided a substitute for traditional fixed lines, offering users multiple services access including multimedia applications, anywhere and anytime.

NGN will require substantial investment, but the opportunities created will open up major expansion in both the scale and scope of the telecommunication sector. Some of these trends are already evident in the growth of broadband networks, the rise of Voice over IP (VoIP), multiple play offerings, fixed-mobile convergence and IP Television (IPTV). Some migration strategies will target NGN as a replacement of the core network, while others will replace the whole network including the access network, and some will overlap.

Some early NGN implementations -including field trials- were established in 2006 such incumbent operators as BT in the UK, NTT in Japan, and AT&T in the US. By the end of 2008, NTT expects to offer complete NGN services on a full scale[6], and BT has announced that it expects half of its customer base to have migrated by 2008, and the migration to be "substantially complete" by the end of the decade[7]. According to the ITU report “Trends in Telecommunication Reform: the Road to NGN” published in September 2007, it is predicted that full implementation of NGN in fixed line networks in developed countries will be deployed by 2012 and in mobile networks by 2020. Developing countries are also seeking to deploy NGN technology, although not necessarily following the same path as developed countries.

NGN are being developed using a number of different technologies, including wireless and mobile, fibre and cable, or by upgrades to existing copper lines. To implement several technologies in a unified infrastructure, standards development is needed to optimise the migration to the new network architecture. At ITU-T, the international standardization of NGNs is underway as part of the NGN Global Standards Initiative (NGN-GSI),[8] involving various standards organizations. The NGN-GSI focuses on developing the detailed standards (known in ITU as “Recommendations”) necessary for NGN deployment so that service providers can offer the wide range of services expected from NGN. NGN and climate change related standardization issues are presented in detail later in this report.

2. How do NGNs contribute to energy efficiency?

2.1 Internet Protocol Systems

The migration to NGN is expected to reduce power consumption by approximately 30-40 per cent by introducing Internet Protocol transmission, as compared with the current public switched telephone network (PSTN)[9]. The shift to IP-based routing and switching systems has improved the efficiency of the core network substantially over the past decade. This is especially true for the transmission of voice, where digital compression techniques have provided a 60–70 per cent reduction in transmission capacity requirements[10]. Furthermore, as networks converge in one platform, which may be fixed or wireless, this should reduce costs, and in turn reduce prices, thereby extending universal service.

An example of the use of IP for multiple services can be seen in third and fourth generation (3G and 4G) technology for mobile telephony services. They enable wide-area wireless voice telephony and broadband data services delivered to mobile phones and other portable devices. With a suitably-equipped mobile phone, one can make phone calls, check emails, and download videos and music at a very high speed. The use of higher frequencies makes this possible. The integration of several applications into a single device may contribute globally to reduce the manufacture of plastic and metallic equipment, which require a large amount of energy to manufacture.

OnRelay’s study, “Green Benefits of Mobile PBX” (released in June, 2008), reports that by replacing the majority of desk phones with existing mobile phones, a 74 per cent saving in power consumption by telephony equipment can be achieved. The availability to separate personal and business services in the same mobile phone permits a reduction in the number of mobiles carried and changed[11]. This could be possible with the unitary fixed/mobile networks enabled by NGN.

While there is the potential to achieve power savings with IP transmission systems, these advanced technologies will require high power consumption. New energy-saving algorithms are now appearing, for instance for VoIP services and multimedia applications, and this is helping to prolong battery life. Nevertheless, improving the energy efficiency of devices still represents one of the biggest challenges for technology research.

2.2. Introduction of multiple power modes

NGN-related technology may reduce energy by making use of more recent standards which specify multiple power modes, for instance full-power, low-power, stand-by and hibernation. Whereas traditional equipment, for instance DSL modems, has only two power modes (on and off), this differentiation among power modes can reduce the energy waste when the equipment is not in constant use.

With this objective, the European Commission, as part of a broader initiative to improve the energy efficiency of electrical equipment, has published five different Codes of Conduct[12] for ICT equipment, including the application of multiple power modes for broadband equipment.

2.2.1. Power modes in broadband equipment

Broadband is usually described as an "always on" service which requires a constant power supply. However a more precise description would be to say that it needs to be "always available". Making use of multiple different power modes can allow broadband connections to be accessible whenever they are needed, reducing energy consumption when the equipment is not in use. This contrasts to traditional DSL (the most common wired broadband access), which currently only offers full power mode. NGN foresees the achievement of universal broadband access, and therefore the introduction of power modes in broadband equipment may have a great impact in the total power consumption of the network (see standards for VDSL2 power modes in ITU-T Recommendation G.993.2)

The European Commission in its "Code of Conduct on Energy Consumption of Broadband Equipment"[13] presents an initiative to reduce the total energy consumption in end-use equipment, and network equipment required by broadband infrastructure. It proposes three power modes for the network equipment and two

Box 1: Legacy Networks vs. NGNs
Traditionally each telecommunication service has been built on its separate own network, with each of them having its own architecture. Today's operators generally run a number of different networks for different services which need to be interconnected. For example the public switched telephone network (PSTN) has been, to date, the main network for fixed line telephony. Similarly, the global system for mobile communications (GSM) has emerged as the main networks for mobile telephony, and the Internet (both on fixed and mobile platforms) is used for a range of different services. Unlike the other two, the Internet has always been packet-switched rather than circuit-switched. An NGN can be used as a basis for all these services, using the same platform and therefore presents important differences with legacy networks, as indicated below:

Legacy Networks

- Dedicated (controlled) network
- Multiple Circuit-switched and packet switched platforms
- Different signalling systems, low digitalization degree
- Separated services and transmission
- Routing
- Network independent
- Blurred boundaries multiple handoff situations creating blurred boundaries
- Dedicated trunk circuits
- Separate platforms for connection oriented and connection-less platforms
- Classical switches

Next Generation Networks

- Sharing same network
- All IP
- Converged Packet-switched network
- Converged services between Fixed/Mobile
- Network User centric service creation
- Clear network boundaries
- Multiple Routing of calls for resilience
- Single softswitch platform for connection-oriented or connectionless communications
- Softswitch: software-based call control
- Quality of Service enabled
- Generalized mobility: ubiquitous provision of services to users
- Improved energy efficiency

Compiled from different sources: ITU Study Group 13, NEC, NGN Final Workshop Brussels October power modes for end-user equipment (see Box 2), having a recommended power level for each power mode and for each element of the equipment.

According to the EU, the total European electricity consumption for broadband could reach 50 TWh per year by 2015, corresponding to 20 Mt of CO_2e emissions. However by implementing the general principles and actions in the broadband Code of Conduct (CoC) the (maximum) annual electricity consumption could be lowered to 25 TWh. The next challenge is to improve power management in each mode to reduce the minimum energy required, so that total consumption can be even further reduced (see Box 3).

This is one example of practical actions that can result in more efficient and economic use of energy in next generation technologies. For instance, The Home Gateway Initiative (HGI) announced on 27 May 2008 that it will be working towards a set of specifications that will outline energy saving solutions for the home gateway based on the CoC mentioned above, joining the EU initiative to reduce power consumption[14], for which HGI will work together with ITU-T and ETSI (European Telecommunications Standards Institute).

2.3. Energy savings for transmission systems

All forms of broadband consume more power than narrow band; however the introduction of low power modes should help to reduce energy consumption in the future. Moreover, the traditional digital subscriber line (DSL) is being substituted in many countries by optical transmission, which should ultimately offer lower energy solutions than DSL because the signal levels are lower. This section describes three different broadband transmission systems used by NGN and their relation to power saving.

2.3.1. Optical broadband access: a "green" transmission system

Optical transmission represents a significant element of the NGN architecture. For example, NTT is building an optical ring system to support its NGN. This is a large capacity optical network interconnecting nodes in a ring[15]. Remote control of nodes appears to be easier in this type of network; operations and maintenance are also easier. Moreover, optical fibres can replace all or part of the usual copper link that connects from the network termination point on the customer premises to the edge of the server cloud. But the big potential of optical systems is in the use of optic fibre to transport broadband access with highly effective transport capacity.

Box 2: Recommendations in the European Commission's Code of Conduct on Energy Consumption of Broadband Equipment

For the network equipment three power modes are proposed:
- Full-Power Mode L_0, applied to DSL equipment.
- Low-Power State L_2, applied to DSL equipment and to start-up from L_2 to L_0.
- Standby State L_3, applied to DSL equipment and to start-up from L_3 to L_0.

The network equipment includes DSL, cable and passive coherent location (PLC) modems, routers with up to 5 ports, small hubs and switches with up to 8 ports, WLAN, WIMAX, small printer servers connected to broadband, home gateway, telephone devices for VoIP, and the optical network termination. In addition to minimizing the power consumption, network equipment should contain chips that control multiple xDSL lines each, to control that lines are operating in a single mode. Eventually, DSL equipment should be able to decide autonomously whether change mode if a different state is needed.

For end-user equipment, two modes are established:
- On mode, where the equipment is connected to the power source and the network is in normal operation regarding the input and/or output of data of the network.
- Off mode, where the equipment is connected to the power source and is switched off, i.e. does not fulfil any function.

The end-user equipment includes DSL and combined ports, Wimax base stations, PLC & Cable service provider equipment and Optical line termination. Furthermore, end-users must be provided with information about the power consumption of end-use equipment and about guidelines for switching off the equipment when not in use.

For further information, see the EU CoC on broadband equipment released in 2007.

Because high speed wireless has a very limited speed range (typically 100 Mbit/s), optical fibre is necessary to back haul the traffic to major routing nodes, adding new features and services at lightning speed. (At present it is theoretically possible to transmit 14 Tbit/s on a single optical fibre. This means that it could transmit 140 high-definition movies in one second[16]). The network architecture that uses optic fibre to replace copper is known under the generic term "Fibre to the X" (FTTx), where x might be, for instance, the home (FTTH) or the central office.

Each fibre leaving the central office is generally shared by many customers. With passive optical networks (PONs), signals are carried by lasers and sent to their destination without the need for active electronics in the outside plant of the telecommunications network. Carriers can make significant savings through fibre sharing in the local loop, equipment sharing in the Central Office and by eliminating the dependence on expensive active network elements[17]. Moreover, this approach loses a lot less energy than copper-based cables and can be more economical with respect to materials[18]. A single strand of glass can carry as much data as several thousand copper cables, and it can do so over a longer distance without using repeaters; thereby avoiding the cost of transmitting electrical power to customers' premises and reducing energy costs.

An initial study of the power requirements of FTTH, published in February 2008, showed a positive impact on sustainable development. The study found that for the first 15 years of network implementation in Europe, GHG emission savings per user could be 330 kg equivalents of CO_2, the same amount emitted by a car travelling 2'000 kilometres[19]. The impact of FTTH network deployment takes into account production of passive and active equipment, transportation, deployment, and end of life recycling. Optical fibre can therefore be a sustainable transmission system (see Box 3).

Though its deployment can be expensive, new business models are offering the opportunity to underwrite the costs of deploying next generation broadband networks, including offering free next generation broadband connection with gas or electricity utilities. (For more information, see "The green-broadband blog[20]") However, one element that needs to be considered is the possible increase in use of communication services by customers as a consequence of the move to a flat rate tariff following a high speed broadband deployment.

2.3.2 Digital Subscriber Line: good prospects for reduced power requirements

DSL, the predominant technology used by traditional telephone companies to deliver broadband over twisted pair copper telephone wires, presents opportunities for power saving by optimizing service, transport, and physical (PHY) layer techniques. For example, BT plans to reduce energy at the PHY layer through reducing the transmitter power by[21]:

Box 3. Definition of terms and key facts.

- The consumption and production of energy is often measured in watt hours. If a 40-watt light bulb is lit for an hour, 40 watt hours of electric power is used. The power consumption of a household is normally measured in kilowatt hours, and for very big rates in **terawatt hours** (TWh, where TWh is a billion kilowatt hours). 50 TWh (5×10^{13} Wh) is approximately equivalent to the total energy consumption in Switzerland every year, including contribution from all sectors (industry, transport, etc).
- The combustion of all carbon containing fuels, such as petroleum (gasoline, diesel, kerosene, propane), coal, wood, etc will yield carbon dioxide. For example, the combustion of one litre of petrol produces about 2.3 kg CO_2, and approximately 86 per cent of the world's power consumption is derived from the combustion of fossil fuels. Therefore, power saving brings about direct reductions in CO_2 emissions.
- **Carbon dioxide equivalent** (CO_2e) is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. It can be defined as the concentration of carbon dioxide with the same global warming potential as a given type and concentration of GHG. In the case of a given FTTH network deployment in Europe, emission savings could have the same effect on climate change as saving 330 kg CO_2 per user.

Prefixes and units:
k = kilo = 10^3, M = mega = 10^6, G = giga = 10^9, T = tera = 10^{12}
Mt = mega tonne = 10^3 kilo tonnes = 10^6 tonnes = 10^9 kg

Sources: OECE glossary of statistical terms, US Energy Information Administration

- Using only sufficient power to meet transport rate requirements.
- Reducing power when there is little or no traffic to carry (for example by using multiple power modes, as mentioned above).
- Making responsible use of the DSL connection, for instance by turning off the Customer Premises Equipment (CPE) when not in use and reduce CPE power consumption[22].

The Multi Operator Power Save Initiative was created in 2007, involving several operators, with the objective to encourage standards bodies, in particular ITU-T, to deliver solutions to lower the power consumption of broadband. ITU-T Study Group 15, the DSL Forum and the European Telecommunications Standards Institute (ETSI) have all joined this initiative to contribute to reducing DSL power consumption and improving its functionality.

2.3.3 Mobile broadband

For developing nations, particularly those with large rural populations, mobile technologies present an especially atractive opportunity for building NGNs. Generally-speaking, the lower the wave frequency, the greater the distance it can travel without signal loss. For long distances, technologies like CDMA 450[23] or Wideband CDMA[24] are appropriate, while for shorter distances, WiMAX[25] and Wi-FI[26] are the predominant technologies for providing high-speed broadband. The wider availability of these technologies in rural and remote communities would enable:

- Remote collaboration, such as described later in this report.
- Electronic transactions, which use less energy than paper-based transactions.
- E-learning, which offers great development possibilities at lower energy costs. For higher education, e- learning may bring greater opportunities for collaboration and sharing knowledge.
- E-shopping, which according to the National Economic Research Associates will reduce car-based shopping travel by 10 per cent by 2010[27].
- Use of remote sensing and geo-positioning in agriculture, to better manage the environment and effects on global warming. The College of Engineering and Computer Sciences at the Australian National University[28] presented a study on solar water heaters, showing that a broadband-enabled smart controller can realise 20 per cent GHG savings for a conventional solar water heater and 75 per cent savings for an electrical water heater. In rural areas with limited infrastructure, satellite use can be quite efficient.

2.4 Unified network architecture

Network convergence, which is one of the principles inherent in NGN, involves a migration from multiple separate networks to a unique IP based network and requires a centralization of applications and services control. Traditional separate networks (for voice, video and data) have their own billing, management systems etc, which duplicates the same functionality, whereas the evolution to a unified network could allow telecom operators to share network equipment and management functions. This would dramatically reduce the required number of operations to execute the services, and consequently decrease energy costs. The centralization advantages of NGN, in terms of consumption of energy and resources, can include[29]:

- Dissemination of simpler terminals that are less energy and material intensive.
- Reducing manufacturing complexity and electronic waste: cables, installation space, etc
- Offering the possibility to share central, powerful, up-to-date computing resources in data centres
- Reducing the energy consumption of server farms.
- Increasing efficiency (eco-efficiency) by requiring fewer premises (see below).

This increase in efficiency is one of the main achievements of the ICT sector; the traffic per energy ratio measured in bits per Joule(bits/J)[30], has increased from 100bits/J in 1991 to 300bits/J in 2006, a factor of three in only 15 years[31] . Such metrics need to be treated with caution as the number of bits transmitted per annum has multiplied 1000 fold[32]. Being efficient is always a high priority for every company, but if it includes creating economic value and reducing environmental impact and resource use at the same time, then the value added is much higher. NGNs bring about a high operational efficiency and this reduces the carbon footprint, making communication technologies even more attractive to users while playing a bigger role in daily activities, and substituting for other activities that generate much bigger GHG emissions.

At the user level, NGNs appear to offer the possibility to access all applications from a smaller number of devices. This would allow connection to a broadband service such as IP over cable or DSL, providing high-speed access to a broad range of content, delivered to the user's computer, telephone, personal digital assistants (PDAs), or any other device through a shared router (see Figure 4). This can bring about great CO_2 savings in manufacturing, power maintenance, battery recharging, and in addition the saving of scarce materials which in many cases are petroleum-based plastics.

2.5 Reduction in the number of switching centres

Every communication network requires switching or routing centres to interconnect end users' equipment either via the service provider's network or via other providers' switching/routing centres, establishing the optimal route for a given information packet. Traditional networks require separate switching centres for fixed line, mobile phone line, TV, multimedia services, etc. all of which consume significant energy. An NGN architecture greatly reduces the number of centres required because of the use of higher capacity routers and higher speed transmission.

For example, BT currently maintains 16 separate communication networks, including the PSTN that carries voice calls. Moving to NGN, as part of BT's 21st Century Network (21CN) programme, will require only 100-120 metropolitan nodes compared with its current 3000 locations[33]. This will provide higher quality services and, more flexibility with the same coverage at reduced expenditures. Because infrastructure is shared, the requirements for heating, lighting, air-conditioning etc are reduced[34].

Most new technologies have the potential to reduce power consumption. For instance, today's Mobile Switching Centre Server (MSC-S) consumes around 35 per cent less power per subscriber than its predecessor. A single MSC-S node, capable of serving 1.3 million subscribers, can now be housed in one cabinet, occupying less than half a square metre of floor space, cooling and energy needs, whereas historically, several cabinets would have been needed[35]. NGN equipment may also offer a more tolerant climatic range specification: 35 degrees (between 5 and 40°C) for conventional equipment is raised to 50 degrees (between -5 and 45°C) for NGN. As a result, the switching sites can be fresh-air cooled in most countries rather than requiring special air conditioning. Nevertheless, the need for cooling represents an important challenge to reduce the energy consumption in switching and data centres.

Another of the advantages of NGN is that it eliminates the need for a close geographic link between the switching and data centre and users (with the possible exception of applications that need instant response times, like gaming or stock market prices). NGNs allow the data hosts (server farms) to be geographically distant from their users because IP based networks are tariffed in a distance-independent manner and unit costs for data transmission are close to zero. This means that power-hungry switching and data centres can be located where power is renewable (e.g. near hydro power sources) or where temperatures are lower (e.g. at northern latitudes) (see section 3).

2.6. Data centres and NGN

The growing number of Internet users worldwide, which now numbers over one billion, and their increasingly intensive use of broadband connections to access the Internet, results in increased power and energy consumption. A major component of this energy increase is in data centres (DCs), since data storage and the cooling of server farms represent two of the major ways in which ICTs consume energy. Moreover, the growth in the number of these centres is explosive. With an increasing demand for online services, which may be prompted in part by NGN deployment, this energy consumption will grow faster in the coming years. The GeSI study, cited above, estimates that DCs accounted for 14 per cent of all ICT GHG emissions in

2007, but this may increase to 18 per cent by 2020 (around 259 Mt of CO_2e). Indeed, it is expected that energy costs for the operation of servers will exceed the costs of the hardware by 2015[36]. Therefore, the reduction of DC power consumption has become one of the main challenges facing the ICT sector. (See Box 3)

Box 4: Key points on the greenhouse gas emissions of DCs

According to a McKinsey & Co study, the carbon footprint of DCs is surprisingly big and growing:

- DC electricity consumption is almost 0.5% of the global total, including custom-designed servers (e.g., Google, Yahoo, etc).
- The average DC consumes energy equivalent to 25'000 households.
- The energy consumption of DCs worldwide doubled between 2000 and 2006.
- The incremental US demand for DC energy between now and 2010 is the equivalent of 10 new power plants.
- Some 90 per cent of companies running large DCs need to install more power and cooling in the next 30 months.

Source: "Revolutionizing Data Centre Efficiency—Key Analyses" McKinsey & Company, April 2008.

The total power required to run and cool the leading search companies DCs worldwide is estimated to be around 5 GW and represents some 30 per cent of their total costs. Trends towards so-called "cloud computing" involve an increasing demand in data storage in DCs, using virtual servers and requiring enormous energy consumption[37]. For instance, the Google data centre in Oregon (US) consumes as much electricity each day as the city of Geneva, Switzerland, although the source is renewable hydro-power.

Mark Blackburn, in his report "Five Ways to Reduce Data Centre Server Power Consumption" for the Green Grid[38], claims that server energy consumption can be reduced without impacting ongoing operations, capital budgets or system reliability. He mentions the use of the commonly available tools by moving away from a mindset that all servers have to be powered on at all times regardless of use, to one where a service is always available regardless of server state. Identifying energy wasters, enabling power saving features, rightsizing, powering down underutilized servers and decommissioning legacy servers all represent a major boost towards energy reduction.

4. The potential climate impact of NGN applications

According to the GeSI report, the GHG elimination role of ICTs is five times greater in size than its own GHG emissions.
As mentioned above, one of the main ways in which ICTs contribute to reducing GHG emissions is through applications that run over an NGN platform and which promote the "dematerialization" of existing physical services. This concept refers to the substitution of activities that involve the physical movement of "atoms" (e.g., travel, transport of goods) by the transmission of "bits" of information. For instance, daily commuting and business travel can be substituted, at least in part, by remote collaboration using high-speed broadband access.

Automotive transport represents one of the main sources of GHG emissions, but the generalized availability of ultra-high-speed broadband access, with ubiquitous provision of services associated with NGN, would enable multiple tasks to be achieved simultaneously with minimum power consumption. Conferencing services and telework already contribute to a reduction of CO_2 emissions allowing people to work in a more flexible way while experiencing a richer family and social life. The improved efficiency of these services, due to network harmonization and broadband access facilitated by NGN, may increase telecommuting as well as other online services. The GeSI study posits that around 460 Mt of CO_2e emissions could be saved by 2020 by making use of telecommuting, videoconferencing, e-paper, e-commerce and online media. These new methods will become more available and affordable with the deployment of NGNs. Moreover, for developing countries, with limited travel budgets and rural areas with difficult geographic access, remote collaboration can accelerate development (see Figure 3). The following are a few examples of remote collaboration:

a. **Teleconferencing**: NGN architecture facilities, such as high speed broadband, offer enormous advantages to provide videoconferencing, one of the applications that offer the best potential for the reduction of travel. A video-conference allows multiple participants on a call to replace or complement face-to-face meetings, and it can reduce CO_2 emissions by up to 98 per cent compared with a common business meeting that includes commuting (according to research reported in 2008 by Telefonica I+D[39]). There are several web-hosted services (e.g., GoToMeeting, Acrobat Connect, OpenMeetings, WebEx Meeting Centre etc) that offer the possibility of having remote meetings via the Internet (see figure 4). For more information, see *ITU Technology Watch Briefing Reports* #5, "Remote Collaboration Tools" and "Telepresence"[40].

Figure 2: Teleconferencing

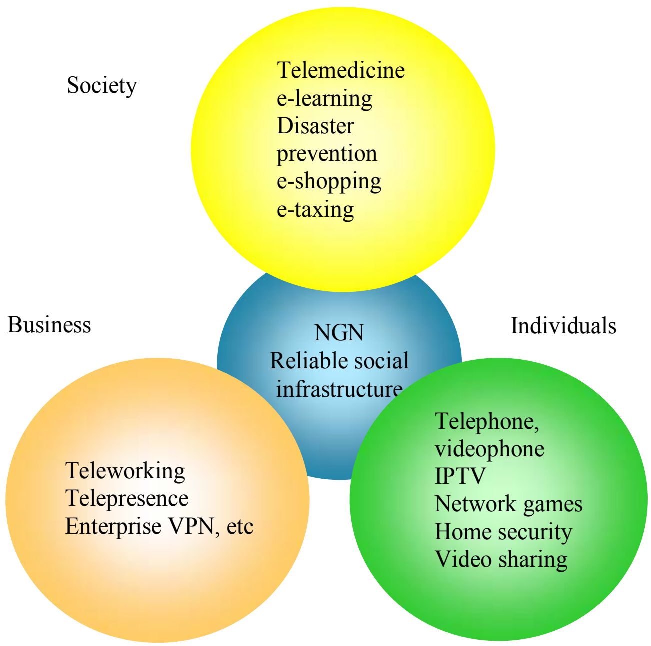
Source: *Courtesy of Cisco*

b. **Teleworking:** Several studies show how working from home can contribute to minimizing our daily carbon footprint by substituting work travel by teleworking. Over an extended period of time, this practice reduces demand for new office floor space and leads to further emissions reductions. On a global scale, it could lead to a huge reduction energy wasted in traffic jams. If a significant number of people worked from home more than three days a week, this could lead to energy savings of between 20 and 50 per cent, even taking into account the increase in energy used at home or in non-commuter travel[41]. For example, the US National Science Foundation (NSF)[42] reported in March 2008, that their teleworkers (51 per cent of the 1'200 employees with 32 per cent teleworking on a regular basis) each year collectively spare the environment more than 450 tonnes of GHG emissions. Furthermore, 94 per cent of NSF teleworkers use cable, DSL, or other high-speed Internet access capabilities at home. Some companies find teleworking makes it difficult for employees to collaborate.[43] However, technological improvements in the service could contribute to a more positive attitude towards the technology, and here is where NGN can play an essential role by providing new network facilities to operators and costumers.

c. **e-learning:** distance-learning has become a viable alternative option to traditional education and can be an effective tool in combating illiteracy in developing countries. More and more universities are offering the possibility of interactive participation in virtual classrooms, where the students receive all the necessary material without any waste in paper and using digital media. E-learning offers a great range of possibilities for students, since the only requirement is normally an Internet connection. With NGN and the extension of broadband service, the use of the web for educational purposes can only increase and reach a bigger number of users. One example is the ITU e-Learning Centre[44] established in 2002, which provides flexible access to training material for telecommunication staff worldwide, thereby reducing training costs.

d. **e-shopping**: electronic commerce has become a standard practice in many countries thanks to the widespread availability of online services. The use of the Internet and other computer networks

Figure 3: Application areas of the NGN (examples)



Source: Nippon Telegraph and Telephone to buy and sell products has dramatically increased over the last decade, particularly for products like books, plane tickets and electronic devices. Everyday one can find many kinds of new e-businesses opening, with virtual offices, where one not only saves CO_2 emissions in travelling to a traditional shopping centre, but also presents savings in the price of goods and services.

e. **Virtual worlds:** virtual newspapers, magazines, books are just a few of the examples where NGNs present big potential in material savings, because they allow convenient access from any device (mobile phone, PC, PDA etc). According to the WWF/ETNO report "Saving the planet at the speed of light", the mobile revolution has helped people to move straight to dematerialization and increased resource efficiency in many ways. The report also mentions that if just 10 million customers shifted from traditional to virtual answering machines, then 330 kilo tones of CO_2e could be saved.

Annex 1 presents a summary of data on CO_2 emission savings presented in this report. It presents some examples that may have both direct and indirect effects on global warming. The method utilised to make these calculations varies depending on the project, though the results should be the same using any of them. Nevertheless, it would be desirable to unify metrics and measurements methodologies to ensure that future results are consistent.

5. ITU-T Standardization work on ICTs and Climate Change.

NGN deployment represents a dramatic shift in the ICT landscape. Network convergence will require a solid base of international standards to allow a smooth and quick evolution. The development of global standards for NGN should be taking into account the need to combat climate change, as recognized by TSAG (see liaison statement #30, referenced in Annex C to R.22). Standardized equipment can play a key role in more efficient use of communication technology.

Functional requirements, architecture, and evolution to NGN are the main subjects of study of the ITU-T's Next-Generation Networks Global Standards Initiative (NGN-GSI), created in 2006, which focuses on developing the detailed standards (ITU-T Recommendations) necessary for NGN development and to give service providers the means to offer the wide range of services expected in NGN. NGN-GSI harmonizes, in collaboration with other standards bodies, different approaches to NGN architecture worldwide. Recommendations Y.2001, General overview of NGN and Y. 2011, General principles and general reference model for NGNs -- were issued in 2004 and subsequently some 200 Recommendations have been published, with ITU-T Study Groups 13 and 15 playing a leading role in the development of these standards.

ITU-T Study Groups can play their part in helping to reduce greenhouse gas emissions by taking account of energy consumption and savings in their standardization work programme and by focusing on the goals of reduced power consumption and energy efficiency:

- Study Group (SG) 13 leads ITU's efforts on NGN. Recent work includes a standard to provide inter-working between two dominant technologies in NGN, Ethernet and MPLS. SG 13 has also done work in the field of VPN, in particular on standards that will allow VPNs to work over all kinds of networks - optical, MPLS, IP etc. SG13's earlier work on global information infrastructure (GII) was an important precursor to today's NGN work[45].
- Study Group 15 is the main area for standards for DSL and also works on optical access and backbone technologies. A key concern for many operators is to maximize network capacity in the last-mile (between the exchange and the customer premises). SG 15 standards on DSL are one way of helping towards this goal. The latest DSL matters to be addressed are ADSL 2+ and VDSL2. Both can bring higher bandwidth to small businesses and residential customers[46]. Following the ITU tutorials on power saving in February 2008, experts in SG15 agreed to work towards a proposed percentage reduction of power consumption in broadband technologies.
- Study Group 16, which focuses on multimedia terminals, systems and applications, is of particular importance 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 provides a means for people to collaborate at a distance without needing to travel.

- Study Group 6 is considering, *inter alia,* environmental and safety procedures for outside plant, including the recycling copper and optical cables materials.
- Study Group 17 has developed a new recommendation X.1303, jointly with OASIS, which provides the basis for a common alerting protocol for use in advance of impending threats, such as tsunamis, typhoons or earthquakes.
- Study Group 2 is working on the standardization of call priority in emergency situations, including also those caused by climate disasters[47].

ITU-T SG 15 has approved the technical paper "Energy-saving checklist for standardization activities"; investigating ways to reduce the power consumption of telecommunications equipment (see Box 4). It is proposed that each new ITU-T Recommendation should contain a clause that identifies its impact on climate change and demonstrates the ways in which it contributes towards emission reduction, covering both production and the use of the equipment.

As part of the increased emphasis at ITU on the topic ICTs and Climate Change, the ITU organized two Symposia on ICTs and Climate Change, in Kyoto, 15-16 April 2008, and London, on 17-18 June 2008. These events brought together key specialists in the field, from top decision-makers to engineers, designers, planners, government officials, regulators and standards experts. Several guidelines and new ideas to reduce ICTs power consumption and improve energy efficiency emerged from these two events.[48].

Box 5: Optical and other transport networks: Checklist on Energy Saving for Standardization Activities

ITU-T SG 15, Working Party 1 has developed a checklist on energy standardization to assist standards developers. The main purpose of this checklist is to promote energy efficiency in the standardization and use of ICTs. The checklist is valid for standardization and specification activities for features in the Optical Transport and Access Networks, as developed by Working Party 1 (Access Network Transport) of ITU-T SG 15. However, it is hoped that it may also prove useful in other study group and focus group activities within ITU and in other standards development organisations.
According to the checklist, energy saving offers the following benefits:

- Reduces the cost of energy, for operators or end-users.
- Reduces the carbon footprint, where electricity is sourced from fossil fuel
- Reduces the size and cost of backup battery/generator, to support lifeline services during power outage.
- Low power makes new technology solutions feasible, such as DSL or Ethernet back-powered Optical Network Units (ONUs).

For more detail, see: *ITU-T Checklist on Energy Saving for Standardization Activities.*

5.1 Challenges ahead

Policymakers and members of standardization bodies need to be aware that ICTs can be a critical enabling technology to reduce GHG emissions in all sector, as well as the need for the sector to reduce its own emissions. To this end, ITU-T is promoting the adoption of energy efficient standards, processes, measurements and design and maintenance of ICTs. A key step should be to establish common definitions and methodologies to characterize the carbon footprint of the ICT sector.
Under the direction of (Telecommunication Standardization Advisory Group) TSAG, a new Focus Group on ICTs and Climate Change was created in July 2008, with the objective of developing methodologies to evaluate the impact of ICTs on climate change. For this task, the Focus Group intends to work with the other Sectors to achieve target reductions and make users and operators aware of the possibilities of climate change mitigation in ICTs.

Secondly, NGNs providers and manufacturers should commit to reducing power consumption through migration to NGN. Some of the actions to be taken could include:

- Maximizing Network capacity.
- Improving IP systems, reducing energy requirements of VoIP services and multimedia applications while maintaining the best quality.
- Lessening the number of electronic devices required in order to reduce emissions from the manufacturing and distribution of devices.

- Lowering the overall consumption of energy in data centres and developing energy efficiency servers.
- Monitoring power consumption in NGN devices to encourage most efficient use

6. Conclusion

NGNs represent a revolutionary change in the field of information and communication technologies; a migration towards a more advanced and modern platform for communications that will enable the offer of new services and applications with great potential for energy efficiency and effectiveness. As networks change, so do the ways in which people use them. Tomorrow's high-speed communication networks will employ packet switching technologies instead of circuit switching technologies. New access technologies will provide multiple alternatives to existing services. NGNs will be relatively invisible to customers; rather they will see only the multiple applications and harmonious inter-working that NGNs facilitate. During the transition period to NGNs, it is likely that they will co-exist with conventional networks. It is important, therefore, to keep the network changeover period as short as possible to avoid a dramatic increase of electricity consumption and CO_2 emissions from having dual networks in use.

NGNs appear to have a significant potential in reducing the carbon footprint of the ICT sector and, more importantly in reducing that of other sectors. These effects can be measured at two levels:

- the primary level is represented by the direct effects of the NGN architecture, and includes enhancing the efficiency of the network, reducing power requirements, cutting the number of switching centres and limiting the energy consumption of DCs.
- the second impact, whose magnitude is likely to be much larger, are the indirect consequence of the activities, services and technology that accompany the migration to an NGN infrastructure, such as remote collaboration, e-commerce, e-learning and several new services and applications that may emerge with the widespread adoption of an NGN backbone.

While the direct effects may be easier to measure, the indirect effects appear to have greater potential contributions to the reduction of the GHG emission in other sectors of the economy.

ITU will be working closely with its membership to lead efforts to achieve a climate-neutral ICT industry, promoting the use of more energy efficient devices and networks, exploring ways to reduce ICT power needs, dispose of – or, better, recycle -- ICT equipment in an environmentally responsible manner, and developing a standardized methodology for calculating the carbon footprint of ICTs. In this way, ICTs can become an integral part of national, regional and global strategies and policies to combat climate change.

This report has been prepared for the ITU-T Technology Watch Briefing Reports series. To comment on the report, or to recommend future topics for study, please write to TSBTechwatch@itu.int.

Annex 1: examples presented in this report, of emission savings that could be achieved with better use of ICTs and improved data centres, making use of NGNs technology

A. Actual Trials

Description of project	Emissions saving (period)	Source and website
▪ NGN architecture deployment	30-40 % compared to today's PSTN	"Protecting out changing world" BT presentation in ITU Symposia on ICTs and Climate Change, and Dittberner Associates International, www.dittberner.com/
▪ Telework program at the National Science Foundation (51% of 1'200 employees)	450 t GHG per year	US National Science Foundation (NSF), www.nsf.gov/
▪ Business traveling substitution by teleconferencing	98 % of average CO_2 emissions compared to face to face meetings	"Reducing greenhouse gas effect of travel business with video-conference", Telefonica I+D, www.tid.es
▪ CoolCenter50 project to reduce power consumption in Yokohama and Okayama data centres	50 % of total consumption (in 5 years)	Hitachi Ltd, www.hitachi.com/
▪ Fujitsu green policy for ICTs	760 Kt of CO_2e in four years (2007-2010)	Fujitsu Green Policy Innovation www.fujitsu.com/

B. Projections

Description of project	Emissions saving (period/date)	Source and website
▪ Smart use of ICTs in a global scale	15% of the total, equivalent to 7800 Mt CO_2e (by 2020)	"SMART 2020: Enabling the low carbon economy in the information age", www.smart2020.org/
▪ Multiple power modes for broadband equipment	25 TWh per year (by 2015)	European Commission Stand by Initiative http://sunbird.jrc.it/energyefficiency/html/standby_initiative_broadband%20communication.htm
▪ FTTH implementation in Europe	330 kg of CO2e (in 15 years)	FTTH Council Europe, www.ftthcouncil.eu/
▪ Unitary fixed/mobile telephony office network	74 % in telephony equipment	"Green Benefits of Mobile PBX", OnRelay report, http://www.onrelay.com/index.php?id=120
▪ Telecommuting, videoconferencing, e-paper, e-commerce and online media	460 Mt of CO_2e by 2020	GeSI report "SMART 2020: Enabling the low carbon economy in the information age", www.smart2020.org/
▪ 10 million customers shifted from traditional to virtual answering machines	330 Kt of CO_2e (in materials saving)	WWO/ETNO report "Saving the planet at the speed of light", , www.etno.be/
▪ Making use of broadband-enabled smart controller in water heaters	20 % GHG for conventional solar water heaters 75 % for electrical water heaters	"Broadband Communication Enables Sustainable Energy Services" Australian National University, http://cs.anu.edu.au/
▪ Improving cooling systems in DC	24 % reduction in energy consumption (by 2020)	"SMART 2020: Enabling the low carbon economy in the information age", www.smart2020.org/

Glossary of abbreviations and acronyms

AT&T	American Telephone & Telegraph,
BAU	Business as always
BPL	Broadband over Powerline
BT	British Telecom
21CN	Twenty-first Century Network
3G	Third Generation mobile communications
4G	Forth Generation mobile communications
C	Centigrade
CD	Compact Disc
CPE	Customer Premises Equipment
HCFCs	Hydrochlorofluorocarbons
CO_2	Carbon dioxide
DSL	Digital Subscriber Line
DC	Data Centre
EPA	U.S. Environmental Protection Agency
ETNO	European Telecommunication Network Operators' association
ETSI	European Telecommunications Standards Institute
EU	European Union
FTTH	Fibre to the Home
FTTx	Fibre to the "X"
GHG	Greenhouse Gases
GeSI	Global e-Sustainability Initiative
GSM	Global System for Mobile communications
Gt	Giga tonnes
$GtCO_2e$	Giga tonnes carbon dioxide equivalent
HGI	Home Gateway Initiative
ICTs	Information and Communication Technologies
IP	Internet Protocol
IPTV	Internet Protocol Television
ITU	International Telecommunication Union
Kt	Kilo tonnes
LAN	Local Area Network
MLS	Multiprotocol Label Switching
Mt	Mega tonnes
NGN	Next-Generation Network
NGN-GSI	NGN Global Standards Initiative
NTT	Nippon Telegraph & Telephone Corp.
ONUs	Optical Network Units
PC	Personal Computer
PDA	Personal Digital Assistants
PHY	Physical (layer)
PONs	Passive Optical Networks
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RSG	Residential Gateway
SIP	Session Initiation Protocol
SMS	Short Message Service
TSAG	Telecommunication Standardization Advisory Group
TWh	Terawatt hour
UPS	Uninterruptible Power Systems
VDSL	Very high speed Digital Subscriber Line
VoIP	Voice over Internet Protocol
VPN	Virtual Private Networking

WLAN	Wireless local area network
WiMAX	Worldwide Interoperability for Microwave Access
WMO	World Meteorological Organization
WTM	Wavelength Transmission Multiplexing
WWF	World Wide Fund for Nature

Notes, sources and further reading

1 See the GeSI study – SMART 2020: enabling the low carbon economy in the information age – the world's first comprehensive global study of the Information and Communication Technology (ICT) sector's growing significance for the world's climate, issued the 20th of June 2008, by the Climate Group and the Global e-Sustainability Initiative (GeSI). See the report at http://www.gesi.org.

2 See the major ITU initiative on the overall topic of ICTs and climate change, as part of ITU's concern with the role of telecommunications and information technologies in the protection of the environment. See http://www.itu.int/themes/climate/

3 See more about ITU work on ICTs and climate change at website http://www.itu.int/themes/climate/

4 See a general overview of NGN at ITU-T Recommendation Y.2001 (12/2004).

5 See http://www.clarin.com/suplementos/informatica/2005/08/17/f-00211.htm.

6 The NTT NGN field trials (which began in December 2006) included among other changes, integration technologies for integrating diverse services in an economical and efficient manner to achieve service convergence, see more www.ntt.com

7 See BT website http://www.bt.com/.

8 See Next Generation Networks Global Standards Initiative webpage, http://www.itu.int/ITU-T/ngn/index.html, and related study groups leaders of the different technologies.

9 Estimates of the precise energy savings vary. The estimate of 30 per cent comes from the implementation of BT's 21CN (see "Protecting out changing world", presentation by Donna Young (BT) at ITU symposium on ICTs and climate change, London, 17-18 June 2008, available at: http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F0000090007PDFE.pdf. The estimate of 40 per cent comes from Dittberner Associates International (http://www.dittberner.com/), who have constructed a number of models showing the benefits of NGN, which show an average 40 per cent saving in energy requirements as well as a 40 per cent saving in investment requirements and an 80 per cent saving in space requirements (see for instance presentation at: http://www.iee.org.hk/iee/files/58.pdf).

10 "Sustainable energy use in mobile communications" White Paper, August 2007, Ericsson www.ericsson.com/technology/whitepapers/sustainable_energy.pdf .

11 This power savings are though (by OnRelay) to come from the equipment sharing between fix and mobile line. If personal mobile telephones are usually on during working hours, by using these phones for business calls instead of having an extra device at the office it is expected to generate great power savings on manufacturing fixed line telephones, according to this report. OnRelay is a privately software company which is promoting power saving of telephony. Despite of the accuracy of this report, equipment sharing seems to bring about great power savings. See more on this study at http://www.onrelay.com/index.php?id=120.

12 A Code of Conduct is understood as a voluntary commitment of individual companies with the aim of reducing energy consumption of products and systems without hampering the fast technological developments and the service provided. See more about the European Commission Codes of Conduct in http://sunbird.jrc.it/energyefficiency/html/standby_initiative.htm.

13 See the Code of Conduct in Broadband equipment reported by EU: http://sunbird.jrc.it/energyefficiency/html/standby_initiative.htm.

14 Home gateway Initiative (HGI), at: http://www.homegatewayinitiative.org/.

15 From the article "Network Core Technologies for a Next Generation Network", Hideki Kasahara, Jun Nishikido, Kazuhiro Oda, Kunihiro Onishi, and Yoshio Kajiyama, NTT, available at: https://www.nttreview.jp/archive/ntttechnical.php?contents=ntr200706sf2.htm.

16 See the article "Evolving ICT and Challenges in R&D", by Takashi Hanazawa, NTT.

17 From ITU work on Optical Networks, see more at www.itu.int.

18 The Green Frog Silicon Valley (http://greenfrog.typepad.com/weblog/

19 Data based in European averages of broadband users. See more about fiber to the home at the FTTH council website http://www.ftthcouncil.eu/, and the main outcomes of this particular study at http://www.ftthcouncil.eu/documents/studies/Impact%20fibre%20optique%20UK%2026%2002%2008%20A.pdf.

20 See http://free-fiber-to-the-home.blogspot.com/.

21 www.itu.int/dms_pub/itu-t/oth/09/05/T09050000010003PDFE.pdf.

22 The topic "Opportunities and techniques for power saving in DSL" was presented by Les Humphrey, BT in the ITU tutorials held in February 2008 on energy savings on ICTs.

23 CDMA (code division multiple access) is a mobile digital radio technology. It allows several transmitters to send information simultaneously over a single communication channel, sharing a bandwidth of frequencies. To read more about this technology see for instance http://www.450world.org/.

24 Wideband Code Division Multiple Access, a type of 3G cellular network. It provides simultaneous support for a wide range of services with different characteristics on a common 5MHz of frequency carrier.

25 Worldwide Interoperability for Microwave Access, is a telecommunications technology that provides wireless data.

26 Wireless technology commonly used in home networks, mobile phones, video games etc

27 From Nera Ecoinomics Consulting, www.nera.com/.

28 See http://engnet.anu.edu.au/DEpeople/Haley.Jones/publications/DennisJonesTSA_Final.pdf.

29 From the book "Next Generation Networks, Perspectives and Potentials" Jinming Li Salina & Pascal Salina (2007), John Wiley& Sons, Ltd.

30 1 Joule (J) of power consumption is equivalent to 2.7778×10^{-4} watt hour.

31 Ibid.

32 See Dave Faulkner's presentation on "Access Network Transport, Energy Saving Checklist", from ITU Symposium on ICTs and Climate Change, Kyoto April 2008.

33 See BT's 21CN project to migrate to NGN in the UK, http://www.btplc.com/21cn/.

[34] See the presentation "The NGN age has arrived" by By Gao Xianrui & Zhou Yanqing, Huawei Technologies http://www.huawei.com/file/download.do?f=348.

[35] Ibid.

[36] See more of the IEE E-Server project in the Intelligent Energy Europe website http://ec.europa.eu/energy/intelligent/index_en.html.

[37] Cloud computing consist in a massive computer server farm linked to high speed networks. Cloud storage is a model of networked data storage that uses virtual servers. See InfoWorld article on cloud computing at http://www.infoworld.com/article/08/04/07/15FE-cloud-computing-reality_1.html and Errett Cord http://www.ecord.us/articles_cloud_computing.php

[38] See more of this report at: www.thegreengrid.org/gg_content/White_Paper_7_-_**Five**_**Ways**_to_Save_**Power**.pdf

[39] See Telefónica I+D website www.tid.es.

[40] See ITU TechWatch reports, http://www.itu.int/ITU-T/techwatch/.

[41] Ibid.

[42] See website of the National Science Foundation http://www.nsf.gov/.

[43] The SMART 2020 report mentions that in 2005, between 1-2% of the US workforce teleworked, and according to a survey by US teleworking coalition, TelCoa, 54% of companies thought that teleworking made it difficult for employees to collaborate and 46% thought it made it harder to manage employee performance which could be due to cultural barriers to adopt dematerialization technology, since technological barriers are not generally perceived as a major barrier.

[44] See more about ITU e-learning centre at http://www.itu.int/ITU-D/hrd/elearning/index.asp.

[45] http://www.itu.int/ITU-T/studygroups/com13/index.asp.

[46] http://www.itu.int/ITU-T/studygroups/com15/index.asp.

[47] See more on ITU-T Study Groups work at http://www.itu.int/ITU-T/studygroups/.

[48] See documentation of the symposia, background report, chairman's final report, presentations and videos in the website: http://www.itu.int/ITU-T/worksem/climatechange/index.html.