Sustainable ICT in corporate organizations

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Executive summary

The ICT sector has transformed the way organizations work, increasing productivity and driving increased economic output and trade across the globe. But there is a price to pay, and that is in the area of energy use.

The Smart 2020 report confirmed that the full life cycle carbon footprint of the ICT industry represents around 2% of worldwide emissions, and is growing at 6% compound annual growth. To balance this, ICT has an enabling effect where by other sectors benefit from increased energy efficiencies and energy use reductions. The scale of this ICT-enabled opportunity was found to be equivalent to 15% of all global emissions by 2020.

This document, part of the Toolkit on environmental sustainability for the ICT sector from ITU-T, focuses on the main sustainability issues that companies face in using ICT products and services in their *own* organizations across four main ICT areas: data centers, desktop infrastructure, telecommunications networks and broadcasting services.

Overall, the level of sophistication with sustainability metrics and management is highest in the area of data centers, with much more work needing to be done with desktop infrastructure, broadcasting and telecoms networks.

Data centers

Historically, the main objective of data center managers has been to maximize their computing performance and expand the availability of IT resources. The costs associated with delivering these capabilities, such as electric power and cooling, were generally accepted as a given cost of doing business. However, data center costs have risen extremely quickly as the rate of increase of data processing has outpaced the center's ability to support such systems. As a result, environmental factors such as energy and water have become the main limiting factor in the data center environment.

The key sustainability metric for data centers is PUE, or power usage effectiveness. This metric has been agreed upon by major industry bodies, as well as governments. It is a very useful relative metric and its greatest benefit comes from widespread sharing of such data. However, PUE takes account of the facility side only, not taking business use into consideration. As a result, this document outlines a number of other IT efficiency and utilization metrics that data center managers can use to enhance their sustainability performance.

A key benefit of using industry-wide definitions and standards of energy efficiency is the adoption of an agreed set of best practices. This document captures some of the best practice measures that data center managers can use. In line with the data center maturity model, these best practices are linked to suitable metrics to measure and manage performance.

Desktop infrastructure

Much of the energy consumed by IT equipment is wasted, mostly because computers are on with no one using them, such as during nights and weekends.

Power draw of PCs is a well-known factor impacting their energy consumption, but there are culprits beyond the PC, with energy consumed by the Ethernet link and the workgroup switch, which usually have no means of power management.

A 2004 study on office equipment power management found that an average office computer is active for 6.9 hours in a day, of which it is idle for 3.9 hours. The challenge is ensuring the computers are in low-power mode during idle periods, and off when not active. Apart from their direct power draw, PCs also have an indirect impact on their surroundings by heating them, causing a greater load on air-conditioning systems, for example.

This document outlines best practices on desktop infrastructure, covering the use of energy-efficient PCs, management of their power requirements, use of alternative data management techniques such as virtualization, and the use of software to measure and manage the environmental performance of desktop infrastructure.

Telecoms infrastructure and networks

Telecoms network infrastructure and devices are responsible for over a third of the ICT industry GHG emissions, according to the Smart 2020 report. Thanks to new technologies and energy-efficient products, the energy usage per device is improving. Further, the introduction of packet switching (a key feature of the Internet) is simplifying network topologies and lowering their energy requirements by 30-40%.

There are a number of metrics that can be used to measure power utilization in a network. ETSI recommends measuring the power consumption of DSLAM per subscriber line as well as the power needed to transport 1 Mbit/s of data over a kilometre. Recommendation ITU-Y.3021 takes the inverse approach to the ETSI measures by defining its metric as the throughput of networks divided by the power consumed. Similar metrics have been defined by GSMA for mobile infrastructure.

The adoption of the codes of conduct established for data centers and broadband networks could result in significant savings in energy consumption. A number of best practice issues emerge. These include server consolidation, virtualization, “switch-off” policies for redundant equipment, DC electricity and the use of software to understand and manage energy use.

Broadcasting services

Energy is a key consideration in an industry which uses bright lights, huge audio and video files, and widespread networks. Yet, it is estimated that around 80% of the industry’s carbon emissions relate to the in-use emissions of their customers in accessing the output of the broadcasting industry.

The industry has started exploring and using sustainability metrics relatively recently – so these metrics are not as sophisticated as their counterparts in, say, data centers. However, delivering a broadcasting service usually requires the use of desktop infrastructure, networking, data centers, and telecommunications. So, environmental improvements in any of those areas are potentially beneficial to the sustainability performance of a broadcasting service.

The toolkit

This document on Sustainable ICT in organizations is part of a set of documents that together form the Toolkit on environmental sustainability for the ICT sector. The toolkit is the result of an ITU-T initiative, carried out together with over fifty partners, which provides detailed support on how ICT companies can build sustainability into the operations and management of their organizations. The documents in the toolkit cover the following:

- Introduction to the toolkit.
- Sustainable ICT in corporate organizations, focusing on the main sustainability issues that companies face in using ICT products and services in their own organizations across four main ICT areas: data centers, desktop infrastructure, broadcasting services and telecommunications networks.
- Sustainable products, where the aim is to build sustainable products through the use of environmentally-conscious design principles and practices, covering development and manufacture, through to end-of-life treatment.
- Sustainable buildings, which focuses on the application of sustainability management to buildings through the stages of construction, lifetime use and de-commissioning, as ICT companies build and operate facilities that can demand large amounts of energy and material use in all phases of the life cycle.
- End-of-life management, covering the various EOL stages (and their accompanying legislation) and provides support in creating a framework for environmentally-sound management of EOL ICT equipment.
- General specifications and key performance indicators, with a focus on the matching environmental KPIs to an organization's specific business strategy targets, and the construction of standardized processes to make sure the KPI data is as useful as possible to management.
- Assessment framework for environmental impacts, explores how the various standards and guidelines can be mapped so that an organization can create a sustainability framework that is relevant to their own business objectives and desired sustainability performance.

Each document features a discussion of the topic, including standards, guidelines and methodologies that are available, and a check list that assists the sustainability practitioner make sure they are not missing out anything important.

1 Introduction

The ICT sector has transformed the way organizations work. Whether it is mobile phones, cloud computing or the Internet, the use of ICT has changed the processes, methods, products and services of business around the world. As a result of the use of ICT products and services, business has seen its productivity increase and the world has benefited from increased economic output and trade across both developed and developing countries.

But what impact do pervasive information and communication technologies have on the planet's environment? Does ICT help deal with sustainability problems or does it cause greater problems? The biggest price to pay is in the area of energy use. The Smart 2020 report[1] proved a seminal point in understanding the relationship between ICT and energy use. Since its publication in 2008 there have been country level versions in China, Germany, Portugal and USA. Smart 2020 confirmed that the full life cycle carbon footprint of the ICT industry represents around 2% of worldwide emissions and that the ICT footprint is projected to grow under business-as-usual (BAU) conditions at a 6% compound annual growth rate to 1.4 GTonnes of CO_2 by 2020.

Although its own emissions are rising, ICT's largest influence is expected to be through enabling increased energy efficiencies and energy use reductions in other sectors. In this context, Smart 2020 also provided the first ever comprehensive analysis of the capacity of ICT to reduce CO_2 emissions across the rest of the economy. The scale of this ICT-enabled opportunity was found to massive at 7.8 GTonnes of CO_2 by 2020 equivalent to 15% of all global emissions under the BAU projection. Corporate organizations can benefit from these efficiencies, but also have to learn to control the energy use of ICT products.

This document focuses on the main sustainability issues that companies face in using ICT products and services in their own organizations across four main ICT areas:

- data centers;
- desktop infrastructure;
- telecoms and networks;
- broadcasting services.

In each case there will be a number of sustainability impacts to consider. These include the raw materials (including hazardous substances, trace elements, etc.) and energy used in the manufacture of the components of the network, and end-of-life issues relating to the disposal or recyclability of equipment that is no longer used. These issues are treated elsewhere in Sustainability Toolkit, and therefore the focus of this section is on the single biggest sustainability impact of a network: the power consumed to operate it, and the consequent impacts relating to greenhouse gas emissions.

1.1 Objective and target audience

This document aims to help ICT professionals and business leaders understand the sustainability impacts of the digital products, services and technologies they use, so that they can measure those impacts, and manage them.

In each area, there is a focus on the key drivers impacting energy efficiency, and how they can be used as levers for changing energy efficiency in a business. Practical metrics are discussed, which can help in the process of measurement and management.

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[1] "SMART 2020: Enabling the low carbon economy in the information age," The Climate Group 2009.

The discussion, where possible, is grounded in the context of guidelines, regulations and best practices that already exist, or are in the process of being developed. One of the great advantages of using a standardized set of guidelines is that it makes comparability with other companies much easier, added to the experience gained from others.

Of the three areas covered, data centers demonstrate by far the greatest level of sophistication in terms of metrics, guidance and standards for managing energy consumption.

1.2 A note on digital convergence

One of the main challenges in putting together a document which ranges across all ICTs is the great deal of convergence that is occurring. Convergence means it is no longer easy to place ICTs into discrete categories and, in practice, businesses rarely, if ever, use just one category.

For example, IT is not separate to the telecommunications infrastructure, but is a component of it, and vice versa. A company with desktop infrastructure might also have one or more data centers, and use private and public networks for moving content around.

One of the consequences of this is that a technology such as virtualization, which could play out in the context of either desktop infrastructure or data centers, can (and does) feature in both sets of discussions. There is some redundancy in this, but the main goal is to make sure that each individual section is reasonably complete in itself, even if this does cause some duplication of discussion across the sections of this document.

2 Data centers

Historically, the main objective of data center managers has been to maximize their computing performance, and expand the availability of IT resources. The costs associated with delivering these capabilities, such as electric power and cooling, were generally accepted as a given cost of doing business. However, more recently, the rate of increase of data being processed and advancement of server technology has outpaced the data center's ability to support such systems.

As a result, energy is the main limiting factor in the data center environment, not only in terms of financial budgets, but also with respect to availability of grid connection capacity, and in terms of its environmental impact. The significant upswing in cloud computing is accelerating the growth of the data center, but is also creating sustainability challenges for the owners and operators of such facilities. This growth is particularly significant for those companies providing services such as Software as a Service, Platform as a Service or Infrastructure as a Service. From the perspective of corporate organizations that hire such cloud computing services, they benefit from a decrease in their own data center infrastructure.

There are a number of estimates of total global data center energy consumption and related carbon dioxide emissions. It is generally accepted that data centers are responsible for at least 0.25% of all CO_2 emissions; just over 10% of all ICT-related emissions. However, they are one of the fastest growing parts of the ICT sector. Even with new technologies allowing servers to do more with less power, the compound growth rate of data center energy consumption is racing ahead at around 10% per annum.[2]

[2] Tuppen, C.G., and Raub, C., "Are ICT emissions running ahead of expectations?," www.btplc.com/Responsiblebusiness/Ourstory/Literatureandezines/Publicationsandreports/PDF/Are_ICT_Emissions_Running_Ahead_of_Expectations.pdf.

As a result, the energy efficiency of data centers is receiving a lot of attention within the industry, and from environmental campaign groups such as Greenpeace[3].

2.1 The main components of a data center

A data center is a resilient facility the primary purpose of which is to securely house computing equipment. This network typically includes: IT equipment such as computing devices (e.g. servers, storage and networking equipment), cooling equipment such as air-conditioning units, power systems such as diesel generators (for backup purposes), uninterruptible power supplies, and supporting infrastructure. A data center may be wholly owned and occupied by one organization, or typically delivered 'As a Service' to many organizations.

A data center can occupy a single room in a building, or it can cover an entire building. Some data centers cover a campus of buildings. Most of the equipment is in the form of rack-mounted servers, with further infrastructure in the form of backup power, lighting, and environmental controls, dealing with temperature and humidity. Some of the infrastructure is designed to help manage the performance of both the IT and facility elements of a data center.

2.2 Drivers impacting energy efficiency of a data center

IT equipment energy consumption and cooling are related sustainability issues because they both require energy, which is increasingly expensive, and, when derived from fossil fuels, contributes to climate change.

Yet, it is only fairly recently that those IT managers have started to consider energy performance, or even thermal characteristics of their server equipment. Due to increases in power costs, energy has become one of the largest costs in the Total Cost of Ownership (TCO) of a data center. The rise in energy costs, future trends on energy, the additional regulatory costs of carbon now applied in certain countries such as Australia and across the EU, and the development of carbon policy mechanisms are all making data center managers and owners take this more seriously, from a business perspective.

As data center managers seek to improve their resource performance, here are some of the key issues they face:

- Improved monitoring – Many IT managers are not aware of the energy metrics relating to their IT equipment.
- Power-handling efficiency – When a server consumes electric power, it generates heat, which needs to be dealt with by the cooling infrastructure, which in turn needs energy to operate. Hence, improving the energy efficiency of a server has the potential of creating significant knock-on reductions in energy usage, but only if the facility power/cooling scales with IT power consumption.
- Cooling is a limiting factor – A data center may be able to add electric power instantaneously, if it is prepared to pay the price for more electricity, but providing more cooling infrastructure is much more difficult and takes more time.
- Power is also a constraining factor: is there power available in the grid, and even if there is, that power needs to be conditioned, typically using Uninterruptible Power Supplies (UPS). In effect, UPS resilient capacity ends up being a constraining factor, and requires investment even if it were possible to buy additional power from the grid.

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[3] For an example of a Greenpeace report on data centers, see www.greenpeace.org/international/Global/international/publications/climate/2011/Cool%20IT/dirty-data-report-greenpeace.pdf.

- Availability of low carbon electricity. As they strive to reduce their carbon footprint, data center operators are increasingly being located near renewable sources of electricity. However, this only benefits those who can choose their location site when building a new data center. Many organizations are constrained, due to existing facilities or other requirements, such as proximity to the customer or the business, etc.

2.3 PUE is the key sustainability metric

Although energy efficiency metrics are gaining common usage among data center owners and managers, it has proved difficult to apply the metrics clearly or consistently. However, there is now an agreement between major data center industry bodies and the US, EU and Japanese governments on the composition and measurement of Power Usage Effectiveness, usually referred to as PUE.[4]

Over the past few years, the key metric that has been gaining ground is PUE, which is the measurement of the total annual energy of the data center divided by the annual IT energy consumption. If the entire energy consumption of the IT resources in the data center also happens to be the energy consumption of the data center as a whole, then the PUE would be 1.0.

Figure 1: PUE metrics, sourced from the Green Grid[5]

PUE	Level of efficiency
3.0	Very inefficient
2.5	Inefficient
2.0	Average
1.5	Efficient
1.0	Very efficient

In practice, a data center consumes more energy than what it uses for its IT resources, in order to feed cooling systems, lighting, and power delivery components. If a data center has a PUE of 2.0, this indicates that for every 100 watts of power needed by the IT infrastructure, the data center needs to draw 200 W from the utility grid.

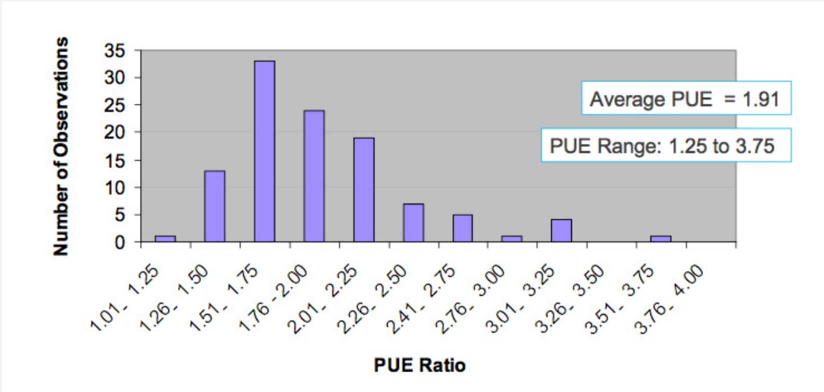
Unfortunately, there is no comprehensive, transparent, publicly available data set publishing accurate PUE statistics for data centers, though the move towards global harmonization should help improve matters. In 2010, the US EPA studied the PUE of 108 US data centers and published the following PUE distribution:[6]

4 "Recommendations for Measuring and Reporting Overall Data center Efficiency," Data center Metrics Task Force, May 2011.

5 www.thegreengrid.org/~/media/White_Paper_6_-_PUE_and_DCiE_Eff_Metrics_30_December_2008.ashx?lang=en.

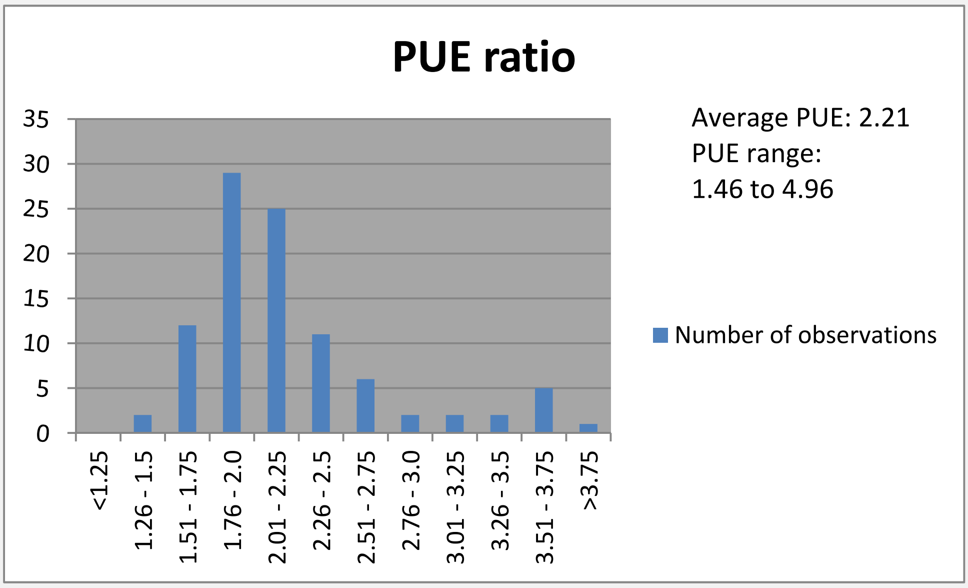
6 Sullivan, A., "ENERGY STAR® for Data centers," US EPA, ENERGY STAR, February 2010.

Figure 2: The distribution of PUE scores across 108 data centers. Source: US EPA



An HP study covering 97 sites (measured between 2008 to 2011, with 65 in the Americas, 21 in Europe, Middle East and Africa, and 11 in Asia Pacific and Japan) concluded that the PUE average for global data centers is higher than the average for US-based data centers.

Figure 3: HP data on the distribution of PUE scores across 97 sites



Although PUE is the standard measure, it is only part of the picture – it is a good relative metric but it takes account of the facility side only.[7] PUE does not take into consideration consumption; therefore, it does not at all account for actual business use.

When viewed in isolation, PUE can also cause unexpected results. For example, data centers which use virtualization techniques (where a number of physical servers are consolidated onto a single computing device) can end up with PUE scores that, perversely, are higher than those without virtualization, even

[7] For a full picture of data center efficiency, metrics relating to the IT side of the center need to be added to PUE, which is a metric relating to the facility side of a data center. See the discussion later in the document relating to the data center maturity model.

though the latter are less efficient. This example demonstrates that cooling and UPS equipment become less efficient at lower loads. As servers are turned off, power demand decreases and this result in more energy being used across the site. This is an example of the importance of an integrated approach to IT and facilities planning. Finally, increasingly, some of the latest cooling techniques, such as pumps and heat exchangers, or battery backup are built into the IT equipment itself, blurring the lines between facility equipment and IT equipment.

So is it worth pursuing such a metric?

The consensus in the industry is that it is not only worth measuring data center efficiency using such metrics, it is also worth sharing the results of the measurements, as it improves our understanding of what contributes to energy efficiency of IT resources.

Of course, PUE is not a static metric. It is undergoing developments led by The Green Grid, which enables greater granularity by breaking it down into the following components[8]:

PUE = Cooling Load Factor (CLF) + Power Load Factor (PLF) + 1.0

All the above factors are ratios:

- 1.0 represents the normalized IT load
- CLF is the total power consumed by chillers, cooling towers, computer rooms air conditioning, pumps, etc., divided by the IT load
- PLF is the total power dissipated by switch gear, UPSs, power distribution units, etc., divided by the IT load.

The PUE can also vary during a year due to changing weather conditions and so it is best to measure and publish 12 monthly average figures. This requirement is also emphasized by the global harmonization agreement on data center metrics.9 As cooling is heavily linked with the external environmental conditions (outside ambient temperature), data centers located in geographic areas that have higher average outside ambient air temperatures generally have higher cooling requirements and thus increased consumption of power. One choice is that the data center can be located in a cooler geographic area, and thus be able to utilize free cooling; however, the choice of the location is at times limited by business/operational constraints.

This is an important concept to embrace knowing that combinations of different cooling systems and locations will result in PUE values that can range from 1.30 to over 1.70.

2.4 Managing other sustainability metrics

Although there is wide industry support for PUE, using only one metric may not be an adequate measurement strategy, and may not lead to either cost savings, or resource efficiencies.

According to Rhonda Ascierto, senior analyst at Ovum, “PUE only measures the efficiency of a facility’s infrastructure, such as air conditioning and lighting. Judging a data center on PUE alone is akin to judging a company’s performance solely on earnings per share. The ways in which data centers consume resources are complex and multi-dimensional, and multiple metrics are needed to properly gauge their efficiency.”[10]

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[8] PUE and DCiE Efficiency metrics.

[9] “Harmonizing Global Metrics for Data Center Energy Efficiency,” Energy Star, 2010, www.energystar.gov/index.cfm?c=prod_development.server_efficiency.

[10] Ascierto, R., “From Money Pit to Profitability: The Business Case for Data center Efficiency,” April 2011.

The Green Grid itself points to metrics[11] that connect well with sustainability management needs:

- water usage effectiveness (WUE) – annual water usage divided by IT equipment energy, and expressed in litres/kilowatt-hour;
- carbon usage effectiveness (CUE);
- proxies for data productivity;
- data center maturity model.

Note that water and carbon/power metrics are related as water treatment itself can be an energy-intensive process. For example, desalination of sea-water uses far more energy than extracting water from a snowmelt-sourced reservoir. Also note that there are two variations to the WUE metric: $WUE_{site,}$ which relates to site consumption, and WUE_{source} which accounts for source consumption.

The data center maturity model is worth pointing to separately as it adds in a number of IT efficiency and utilization metrics, such as average monthly CPU (processor) utilization, IT power supply efficiencies, network utilization, and e-waste.

All of these metrics together help data center operators to quickly assess important sustainability aspects in their data centers, compare results, and determine opportunities to increase energy efficiency or reduce power consumption.

A metric that is more commonly used in networking relates to watts per user, or watts per gigabyte. Such a metric circumvents the problem where data centers end up with worsened PUE scores when they turn off unused compute capacity, even though such a practice is better in business terms. More work needs to be done to establish whether or not measure such as watts per user would have utility in the data center context.

Another metric worth considering aims at those facilities that have combined heat and power (CHP) plants – or the related combined cooling heat and power plants (CCHP). On-site power generation is better because power loss occurs over the transmission distance (anywhere from 7% to 30%). However, while a local power unit does not suffer from such losses, it could have lower efficiency than the big power plants. Provided the heat generated can be effectively used (e.g. co-tri-generation systems), this process can work for data centers as energy can be converted to cold air using efficient heat pumps.

For PUE calculations to be equitable, when data centers operate on-site electricity generation, IT managers need to take account of the IT source energy conversion factor (so they can benefit from the efficiencies of generating chilled water, for example) and the cogeneration input fuel assumption (the shares of input fuel from primary and secondary sources).[12]

Finally, there are other metrics that can be considered:

- ITEU (IT equipment utilization)
- ITEE (IT equipment energy efficiency)
- GEC (green energy coefficient), and
- DPPE (data center performance per energy).

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11 The Green Grid, "Water Usage Effectiveness: A Green Grid Data center Sustainability Metric," 2011.

12 "Recommendations for Measuring and Reporting Overall Data center Efficiency," Data center Metrics Coordination Task Force report representing 7×24 Exchange, ASHRAE, The Green Grid, Silicon Valley Leadership Group, US Dept of Energy Save Energy Now program, US EPA ENERGY STAR Program, US Green Building Council and Uptime Institute, May 2011.

Figure 4 shows how these different metrics compare with each other:

Figure 4: Comparing different data center metrics

Parameters used in the metrics	Type of information	PUE	ITEU	ITEE	GEC	DPPE
Total energy consumption of data center	Dynamic	✓			✓	✓
Energy consumption of ICT equipment	Dynamic	✓	✓			✓
Green energy produced and used in data center	Dynamic				✓	✓
Rated power of ICT equipment	Static		✓	✓		✓
Server capacity	Static			✓		✓
NW equipment capacity	Static			✓		✓
Storage capacity	Static			✓		✓

Currently, ITU-T is studying metrics for data centers. A new ITU-T Recommendation on metrics is expected to be approved by the end of 2012.

2.5 Guidelines on sustainability in data centers

Often the most common reason driving behavioural change in a business context is a change in regulation. However, there are no significant regulations that directly apply when it comes to driving sustainability performance in data centers. However, in a number of countries there will be general legislation addressing climate change and energy efficiency that affect data center operations. In addition, the motivation for managing sustainability performance will include other external forces, such as pressure from NGOs, investors, and customers. At the end of the day though, it just makes great business sense to curb the greatest cost inputs for some of the biggest financial investments a technology business can make.

EU Code of conduct

In 2010, the European Commission announced an EU Code of Conduct for Data centers, following on from codes of conduct that have been developed for external power supply units, uninterruptable power supplies, broadband and digital TV services.

A code of conduct is a voluntary commitment of individual companies, which own and operate data centers – including collocated centers – which aim to reduce their energy consumption, against a Business as Usual scenario, through the adoption of best practices in a defined timescale.

Companies that want to participate in the EU Code of Conduct need to submit an application, which covers an initial energy measurement, and an energy audit that identifies major energy saving opportunities. Once an action plan is accepted, participants need to deliver progress accordingly.

A McKinsey report found that a typical enterprise data center cost USD 150 m to build in 2003 and the costs had risen to many times that number over a five-year period.[13] By 2008, Google appeared to be spending nearly USD 3 000 per square foot on its data center in North Carolina, which is approximately three times

13 Kaplan, J., Forrest, W., Kindler, N., "Revolutionising Data center Energy Efficiency," McKinsey & Co, July 2008.

the expenditure of the average industry. Microsoft's Northlake, Illinois data center cost the company around USD 500 m in the same time period.[14]

Analyst Gartner points out that those high-density data centers, which usually require more cooling and power, need to modernize their operations, or risk doubling their energy costs every five years.[15]

When investments reach this scale, visibility is raised and approval is required from senior company executives and even Boards of Directors so that operational performance takes on greater importance. This is because legacy data centers are notorious for server utilization rarely exceeding an annual average of 6%.

So the best case for introducing sustainability metrics into the management process of a data center is that they offer an immediate understanding of some of the biggest drivers of cost and performance for key IT resources, while dealing with the negative developments associated with data center management. One example of such an interaction between business imperatives and energy savings comes from the move to high density computing, where racks which would have been rated at 4-8 kW of electricity in the past are now rated at 32 kW. The result of this kind of approach is that much more heat is generated, but some organizations are employing thermal monitoring, in products such as CA ecoMeter software, in order to re-provision virtual instances of infrastructure to a different physical location in the data center, when hotspots are created.

The US Environmental Protection Agency (EPA) has an Energy Star rating for stand-alone or large data centers.[16] Data centers can benchmark their energy performance against their peers, and the top quartile performers can earn the Energy Star award. The US Green Building Council's LEED program and BREEAM's data center programme are both good examples of an industry's response to the need to reduce energy use in data centers.

Further, a global taskforce of representatives from the US, European Union and Japan have been developing a harmonized set of global metrics which capture an agreed set of definitions for data center energy efficiency. An EU code of conduct for data centers exists, following on from codes of conduct developed for other ICT equipment.[17]

Finally, higher reliability systems generally have higher overall electrical system losses as compared to a lower reliability system. As a result, when calculating annual energy consumption of a data center, it is advisable to include a schedule on the IT load that more closely resembles the actual operational schedule of the IT equipment, thus providing a more accurate estimate of energy consumption. Such a schedule needs to contain the predicted daily or weekly operations of the computers on a network (based on historical workload data), but more importantly, it also needs the long-term ramp-up expected, of computers and their power requirements. This type of information makes the planning and analysis of overall annual energy consumption more accurate.

2.6 Best practices in data centers

One of the main advantages of using an industry-wide definition of energy efficiency is the adoption of an agreed set of best practices. Data center operators benefit from:

- A common and agreed vocabulary and terminology
- A shared understanding of the technology options available, and their relative merits

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14 Miller, R., "Google Data centers: $3,000 A Square Foot," Data center Knowledge, Nov. 2007.

15 See www.infoworld.com/d/mobilize/gartner-modernize-datacenters-or-risk-doubling-energy-costs-562.

16 www.energystar.gov/index.cfm?c=prod_development.server_efficiency.

17 http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_data_centers.htm

- The processes they need to establish in their own facilities, and with the administrators of the code of conduct
- The communication that is necessary across all participants
- Guidance on how to improve energy efficiency.

A detailed set of best practices for data centers, aimed at reducing their environmental impact, has been published by the ITU. Recommendation ITU-T L.1300[18] helps data center operators and owners build future facilities as well as improve existing ones.

The best practices identified cover the following areas of data center operation:

Table 1: Data center best practices

Issue	Notes
Data center utilization and management	Effective communications between different departments; resilience level and provisioning
ICT equipment	Selection, deployment and management of new and existing IT and telecom equipment
Cooling	Airflow design, cooling, free and economized cooling, cooling plant, CRAC units, reuse of waste heat
Data center power	Selection, deployment and management of data center power equipment
Other data center equipment	General practices
Data center building	Building physical layout and geographic location
Monitoring	Energy use and environmental measurement, data logging, reporting
Design of network	Requirements to connect equipment in the data center as well between data centers

The biggest challenge with green data centers is that the technical challenges and business challenges are interlaced together, with different lines of authority, responsibility and budget. Best practices have to stretch beyond just technical considerations. The Uptime Institute's white paper, Four metrics define data center greenness,[19] provides an excellent way of breaking up the formidable task of data center efficiency into manageable chunks.

The four metrics, which reflect the data center maturity model metrics, are:

1) IT strategy

   CIOs/CTOs should ask themselves, *How can we achieve our business objectives with less energy by considering different IT design, architecture, and hardware options to achieve computing and network availability, reliability and performance?*

2) IT hardware asset utilization, or average monthly CPU utilization

   CIOs/CTOs and senior data center executives should ask themselves, *How can I maximize the fraction of my IT hardware assets which are deployed productively and fully utilized?*

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[18] Recommendation ITU-T L.1300 – Best Practices for Green Data centers, International Telecommunication Union, Nov. 2011.

[19] Stanley, J., Brill, K.G., and Koomey, J., "Four metrics define data center 'greenness'," Uptime Institute.

3) IT energy and power efficient hardware deployment, including measures such as power supply efficiencies, and fan power improvements, for example

   IT architecture and capacity planning executives and purchasing managers should ask themselves, *How can I select and justify buying IT hardware that delivers the most effective computing performance per Watt of power consumption at the plug?*

4) Site physical structure overhead, based on PUE metrics

   Facilities and real estate decision makers should ask themselves, *How can I maximize the amount of useful power/energy delivered to the power plugs of IT hardware for each unit of power/energy consumed at the data center utility meter and thereby reduce site infrastructure "overhead?"*

So what specific strategies can data center managers use to further improve their sustainability performance? Energy Star proposes[20] the top twelve actions that data center managers can implement in order to benefit from energy efficiency. A summary is provided in Table 2 below:

Table 2: Top energy efficiency actions for data center managers

Action	Summary
Server virtualization	Consolidating multiple servers to a single physical server reduces energy consumption by 10-40%
Shut down unused servers	Save 15-30% by simply shutting down comatose servers, which continue to draw full power when not in use
Server consolidation	Bring lightly used servers tasks to a single server
Storage consolidation	Storage typically averages 30% utilization, yet companies typically hold the same information 20 times
Invest in energy efficiency	An Energy Star server draws around 30% less energy than a conventional one
Hot aisle/cold aisle layout	Physical arrangement of servers can reduce mixing of hot and cold air, improving efficiency
Aisle enclosures	Further reduction in mixing cold supply air with hot exhaust air
Airflow improvements	Decrease server inlet air temperatures and increase temperature of exhaust air to CRAC
Structured cabling	Reduce circulation of air around the servers
Seal off ducts	Use grommets to reduce air leakage
Adjust the temperature and humidity range	Most data centers run cool and dry. They can save 4-5% in energy costs for every 1° F increase in server inlet temperature
Variable speed fans in CRAC	Two-year payback on retrofitting fans that adjust speed according to cooling load
Air-side economizer	Bring cooler evening and winter outside air into the data center
Water-side economizer	Use a cooling tower to evaporate heat and produce chilled water during winter months

Source: Energy Star

Some improvements, such as aisle containment, can be retrofitted to existing data centers, whereas others, such as DC distribution, are more easily introduced when starting from scratch.

[20] www.energystar.gov/ia/products/power_mgt/downloads/DataCenter-Top12-Brochure-Final.pdf.

Aisle containment

Most data centers have standardized on a hot aisle/cold aisle layout as a strategy for more efficient cooling. A cold aisle has server racks aligned so that equipment air inlets are facing each other on opposite sides, while in the next aisle, both banks of server racks exhaust hot air. In theory, such a layout increases energy efficiency by allowing for higher temperature set points. By concentrating cooling air where it is needed most, computer room air conditioners (CRAC) and computer room air handlers (CRAH) can run a few degrees higher than what would otherwise be the case.

However, such techniques bring their own challenges to data center operators. The key problems occur when the cool air fails to enter the IT equipment (known as "bypass air"), or when heated exhaust air flows back into the cold aisle through over the tops of the racks, or through open rack space.

As a result of these challenges, hot aisle/cold aisle techniques have been refined to cover aisle containment strategies, where the goal is to capture the hot exhaust from IT equipment and direct it to CRAC or CRAH units as quickly as possible, using barriers such as curtains, cabinet-mounted chimneys and metal enclosures to separate the hot aisle. Aisle containment systems are economically viable if elevated air temperatures are supplied. High inlet temperatures can affect ICT equipment, a fact that is seeing greater attention from ICT equipment manufacturers and from ASHRAE (the American Society of Heating, Refrigerating and Air-conditioning Engineers).

DC distribution

In a typical data center, power arrives at the server room as AC, where it gets converted to DC in the uninterruptible power supplies. It is then converted back to AC to be transported to other parts of the facility and then back to DC again by the power supply inside each server, router, load balancer or other piece of network equipment.

Each time power is converted, energy is lost as heat with an associated cost. As a result, there is a lot of interest of getting data centers to run on DC power, just like telecom equipment has done for years. Of course, the biggest challenge with implementing DC power is converting equipment right across the data center to run on DC. What would also help are vendor standards for plugs, power cords, rectifier units and other DC gear.

As a result, standard specifications are now being developed by ITU and IEC working groups, covering the interface[21] of a DC power feeding system, and its architecture.[22] ETSI released EN 300 132-3-1 standard covering the use of 400 V DC as a power feed for a data center.

Fresh air cooling

Mechanical cooling devices are estimated to consume between 33-40% of a facility's energy consumption. So the idea that fresh ambient air can be introduced to supplement or circumvent cooling processes is an attractive one.

The basic concept of fresh air cooling is that outside air is brought into the data center facility and distributed via a series of dampers and fans. The servers take in the cool air, transfer heat and expel hot air to the room. Instead of being recirculated and cooled again, the hot air is simply directed back outside the

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21 Recommendation ITU-T L.1200 – Specification of DC power feeding system interface, International Telecommunication Union, May 2012.

22 Draft of architecture of DC power feeding systems (L.architecture), Study Group 5, TD 946 (GEN/5), International Telecommunication Union, September 2011.

building. If outside air is particularly cold, then the air economizer can mix inlet air and exhaust air in order to ensure that the resulting air temperature is suitable for use with the equipment.

How effective is such a process? For example, a Weatherite white paper[23] claims that, if a UK data center has cold aisle containment, the cooling system can be controlled to keep the containment to 27°C resulting in the data center being cooled 24/7 for the whole year using just outside fresh air based on UK average temperatures. This solution could be adopted in areas of higher ambient air temperatures if the IT equipment itself was designed to operate at higher temperatures. Work is being undertaken in standards organizations such as ETSI and ASHRAE as well as in other areas (e.g. EC Code of Conduct) to push for a wider and, in particular, a higher operating temperature range.

In addition to the direct air economizer systems described above, indirect air economizer systems are very efficient and offer an alternative approach, particularly where the use of outdoor air is not possible. These systems use wet and/or dry heat surfaces to exchange heat between outdoor air and indoor air without mixing the two airstreams.

Case study: Logicalis

Logicalis, part of the Datatec Group, is an international IT solution and managed services provider, based in the UK. As part of its services to its customers, Logicalis provides a number of data center hosting solutions: the customer runs their environment as one slice of a shared platform, or on a separate infrastructure.

Logicalis sees its work in sustainability as delivering against its own environmental goals as well as in improving business performance. As a result, the company maintains a hard business focus on its sustainability work.

Logicalis is constantly seeking new ways of measuring and improving its sustainability performance. Metrics such as PUE are seen to have delivered gains in data center efficiency, but much of the potential savings have already been achieved. Simon Daykin, chief technology officer at Logicalis, explains it this way: "If our focus is too high on PUE, we could simply turn on more computing capability but not use it. This does not make business sense. It is better to have a higher PUE with a lower capacity, when we don't need computing resources. The PUE score is not as good because there are fixed loads we cannot turn off."

Currently, Logicalis measures all sorts of performance metrics, including PUE: Watts per active server, server utilization, numbers of users, and measurements that meter the applications and infrastructure layers. The company uses software products from CA Technologies to monitor and capture sustainability data across the data center.

"The biggest challenge is pulling together a holistic view of the business from these many different siloed metrics," says Daykin. Logicalis' preference is to use measures such as Watts per gigabyte, or Watts per user, which it feels correlate better with business strategy. However, there is not a common set of standards based on such wider measures. And that is where the company feels there should be more attention from the standards-setting organizations, so that there is a common language for such business-aligned metrics so that benchmarks can be created, on the lines of the work done with PUE.

2.7 KPIs for data centers

The following key performance indicators (KPIs) have been listed in this document relating to data centers:

- PUE, which is the measurement of the total energy of the data center, divided by the IT energy consumption, sometimes expressed as PUE = Cooling Load Factor (CLF) + Power Load Factor (PLF) + 1.0;

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[23] "Direct Fresh Air Free Cooling of Data Centers," Weatherite white paper, July 2011.

- water usage effectiveness (WUE) – annual water usage divided by IT equipment energy, and expressed in litres/kilowatt-hour;
- carbon usage effectiveness, a measure which will differ from PUE to the extent that power is obtained from non-fossil fuel sources;
- data center maturity model metrics;
- other measures, such as ITEU (IT equipment utilization), ITEE (IT equipment energy efficiency), GEC (green energy coefficient), and DPPE (data center performance per energy).

3 Desktop infrastructure

Much of the energy consumed by IT equipment, especially desktop infrastructure, is wasted. For a start, somewhere around 50-60% of all desktop PCs in commercial buildings remain fully powered-on during nights and weekends, with existing power management almost always disabled. Since most office workers operate at their desks between 8 a.m. and 6 p.m., the rest of the working week, plus weekends together account for 75% of the total time that computers are on with no one using them.[24]

Energy Star estimates that organizations can save between USD 25 to USD 75 per PC per year, using desktop power management.[25] That is how organizations like GE and Dell are reporting annual savings of USD 2.5 m and USD 1.8 m, respectively.

But the PC that is left on overnight is not the only culprit. Even when a user is there, it is rarely working at full capacity. And beyond the PC, energy is consumed by the Ethernet link and the workgroup switch, which usually have no means of power management.

3.1 The elements of desktop infrastructure

The key piece of desktop infrastructure is the personal computer. In 2010 alone, a Gartner study found that 350 million PCs had been shipped worldwide. Till recently, most corporate IT infrastructure has focused on the PC, and peripherals, such as printers and networking components.

Over the past three years, the hegemony of the PC is being challenged by mobile equipment, particularly tablets and smartphones. This is creating new challenges for companies in terms of the infrastructure they need to provide support to such devices. Typically, they look for solutions that include virtualization and cloud computing as a way to enable them to integrate information and applications across PCs and mobile devices.

3.2 Sustainability drivers in desktop infrastructure

Power draw is a well-known factor impacting total energy consumption of desktops. The usage pattern of a computer can, however, be a far more significant factor,[26] as an energy-efficient computer that is always on consumes more energy than a less energy-efficiency computer that is regularly turned off.

A report by Forrester pointed to a number of factors as why companies are not implementing PC power management:[27]

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[24] Bray, M., "Review of Computer Energy Consumption and Possible Savings," Dragon Systems white paper, December 2006.

[25] Samson, T., "No good excuses not to power down PCs," InfoWorld, April 2009.

[26] Bray, 2006.

[27] Washburn, D., "How much money are your idle PCs wasting?" Forrester, Dec. 2008.

1) *The power used in turning on a PC negates any benefits from turning it off*

The average desktop draws 89 W, according to Forrester. If left on for 16 hours, it consumes 1.42 kW hrs of energy. For a 10-second power surge from turning a PC on to match that figure, the computer would have to draw in an excess of 2 000 amps, well over 150 times of what a typical mains outlet can provide.

2) *Screensavers save energy*

A screensaver displaying moving images consumes just as much electricity as an active PC, while certain graphics-intensive screen savers can cause a computer to burn twice as much.

3) *Turning a PC on and off reduces its performance and useful life*

While this may have been true some time ago, Forrester pointed to findings from the Rocky Mountain Institute showing that modern computers can handle 40 000 on/off cycles before failure.

4) *IT managers cannot run updates and patches on PCs that are asleep or off*

There are a number of technologies that are now in use, such as wake-on LAN and Intel vPRo that enables PCs that are asleep to be switched on by a remote administrator.

5) *PC users do not tolerate downtime due to power management*

The Forrester report acknowledges that users have very little patience for downtime, and have dealt with this problem by keeping their PCs permanently on. Companies like Microsoft and Apple have been addressing this problem by focusing on reducing the time it takes for a PC to start, plus there are dual benefits of low start-up time and lower energy costs from migrating to solid-state drives (SSDs) in our PCs.

Overall, the problems of perception about power management seem to be cultural and changing these factors will require more than just the imposition of new policies by the IT department. However, the benefits of changing the mind set of users are considerable, given that Gartner estimates that nearly a third of enterprise power is consumed by PCs and peripherals.[28]

Measuring power consumption of desktop infrastructure

Computers have a number of different power states, and their power draw can vary according to the power state they are in. For the purposes of this document, it is worth setting out three main power states:

- **Active**, refers to a computer that is turned on and ready for use
- **Low power**, covers a number of states commonly referred to as sleep or hibernation – usually, when a device has multiple low power settings, the low power term refers to the setting with the lowest power draw
- **Off**, refers to a computer that is turned off but still connected to a power outlet.

The key metric of energy is power draw, measured in watts (W), which is an indication of how much energy a device requires at any given moment. While it may be possible to obtain a figure for power draw from the manufacturer's specifications, it is likely to be more accurate to measure a computer's power draw in its in-use scenario.

The average power draw of a desktop computer has fallen over the last ten years, mainly due to the replacement of cathode ray tube (CRT) monitors with liquid crystal display (LCD) monitors, which have significantly greater energy efficiency. However, advances in energy efficiency are now being balanced out by upward trends in screen sizes.

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[28] Cole, A., "Greening the PC infrastructure," ITBusinessEdge, May 2009.

A seminal 2004 study on office equipment power management[29] found that in an average office a computer is active for 6.9 hours, of which it is idle for 3.9 hours. Ensuring computers are in low power mode during those idle periods further reduce their energy consumption. However, it is unrealistic to assume that a PC moves into low power mode as soon as it becomes idle. There is usually a specified delay before a computer enters low power mode. The length of the delay affects how much of the idle time is spent in active mode, and how much in low power mode.

Table 3: Effect of idle time delay on power state, assuming total idle time of 3.9 hours per day

Idle time delay (min)	Idle time in active mode (hours)	Idle time in low power mode (hours)	Time in lower power mode (%)
5	0.9	3	76
15	1.9	2	51
30	2.6	1.3	34
60	3.1	0.8	20

Source: Bray, 2006 referencing Kawamoto et al 2004

Another factor impacting power draw of the total desktop is the ongoing migration to mobile devices, mainly laptops but increasingly including tablets, which consume far less energy, and are more likely to be switched off on a regular basis.

Apart from the considerable direct contribution IT equipment makes to energy consumption, they also have an indirect contribution. A study quoted in Bray (2006) found that “office equipment increases the load on air conditioning by 0.2-0.5kW per kilowatt of office equipment power draw.” In effect, pretty much all the energy used by IT equipment ends up heating its surroundings, which in turn causes a greater load on air conditioning systems.

Also, the power draw of desktop infrastructure is impacted by the networking needed to connect the desktops together, in terms of the number of Ethernet links running through network switches. A study in the *International Journal of Network Management* found that network links cause switches to consume more power when operating at the 1 Gbit/s data rate by approximately 1.8 W per link. The study also found that if Gigabit Ethernet links ran at 10 Mbit/s or 100 Mbit/s, the energy consumption levels fell by around 4 W per link (2.7 W at the PC and 1.5 W at the switch).[30]

Although Gigabit Ethernet is increasingly common, most users do not require that level of speed for the network-based work they do, such as browsing, or require it for only very short periods of time. The mean bit rate on typical link is 1-3% of the available speed and most switches have no power management built into them.

As another example of over-capacity, analyses of local area network (LAN) link utilization demonstrates that not only users are only connected 1% to 5% of the time they’re powered up, a typical office is over-provisioned with connection points with the results that many connection points are powered but not used. As a result, the IEEE 802.3az Task Force has created an Energy Efficient Ethernet (EEE) Standard which defines mechanisms and protocols aimed at reducing power draw of network links during periods of low utilization, by transitioning network interfaces into a low-power state.[31]

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29 Kawamoto, K., Shimoda, Y., and Mizuno, M., “Energy Saving Potential of Office Equipment Power Management,” *Energy and Buildings*, pp. 915-923.

30 Gunaratne, C., Christensen, K., and Nordman, B., “Managing energy consumption costs in desktop PCs and LAN switches with proxying, slipt TCP connections, and scaling of link speed,” *International Journal of Network Management*, John Wiley 2005.

31 Frenzel, L.E., “IEEE and Broadcom bring forth Energy-Efficient Ethernet,” *Electronic Design*, Dec 2010.

The IEEE estimates that when IEEE 802.3az-compliant products have been fully deployed in new and existing Ethernet networks, energy savings could yield as much as USD 470 m per year, not including indirect savings in cooling or other equipment.

An additional IEEE specification defines the use of power over Ethernet (POE) technology where a single cable runs both power and data. POE provides low power to network components and peripherals so that they do not need to be plugged into the main grid. While POE, by reducing the overall requirement for AC wiring, brings defined benefits on infrastructure investments and operational expense, it is a point of debate whether it delivers energy efficiency benefits. POE has been encapsulated in the IEEE 802.3af standard.[32] It is typically used as the power source for voice-over-IP telephones, WiFi access points and other communications devices.

3.3 Regulations and guidelines

There are a number of guidelines and initiatives that have been put in place to enable computer users to benefit from energy efficient IT equipment. A quick summary of relevant guidelines are listed here:

- Energy Star is a joint program of the US EPA and the US Department of Energy – it offers energy-efficiency product labelling and advice
- EU Energy Star follows an agreement between the USA government and the EU on the co-ordination of voluntary energy labelling of office equipment – the activities of this programme are now part of the Intelligent Energy – Europe (IEE) programme
- Possible extension of the 92/75 directive covering mandatory labelling of home appliances
- The EUP Directive concerning ecodesign of Energy Using Products
- The framework directive on Performance of Buildings (approved 2002)
- The Energy Services directive.

3.4 Best practices on desktop infrastructure

Over the past five years, companies have moved from seeing energy efficiency as an optional feature in their IT equipment to it being a standard, must-have feature. In the past, companies were prepared to pay extra to gain energy efficiency benefits. Instead, "IT buyers are now expecting energy efficiency improvements, for example, in the same way that they expect improving price/performance ratios with each succeeding generation of technology they buy," according to the Forrester report on enterprise green IT adoption.[33]

IT buyers can also seek to incorporate EPEAT (Electronic Product Environmental Assessment Tool) guidelines on environmental assessment to their purchasing methods.[34]

Beyond hardware, the main focus in greening desktop infrastructure is in using software tools to manage eco-oriented goals at a granular level, in the data center but also across networking and desktop elements.

A powerful thread in this context is the application of virtualization techniques to the desktop. Virtual desktop infrastructure deploys a virtualized desktop on a remote central server, including all of the programs, applications processes and data. This enables users to run an operating system and execute

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[32] Details about the IEEE 802.3af standard is available on the IEEE website: www.ieee802.org/3/.

[33] Mines, C., "Market overview: The state of enterprise green IT adoption, Q4 2009," Forrester Research, Dec. 2009.

[34] EPEAT registration of electronic products covers environmental criteria, and is based on the IEEE 1680 family of Environmental Assessment Standards. www.epeat.net/.

applications from a device such as a smartphone or a thin client, which would normally exceed the capability of such hardware.

As of mid-2011, Gartner reports that at least 40% of x86 architecture workloads (based on Intel PC chips) have been virtualized on servers, and the installed base is expected to grow five-fold from 2010 to 2015 (as both the number of workloads in the marketplace grow, and as the penetration grows to more than 75%).[35]

So, is virtualization the goal of the IT team as they explore next steps in greening their IT infrastructure? Gartner feels that the server virtualization infrastructure provides the foundation for two important market trends: infrastructure modernization as well as cloud computing.

Clearly, organizations that are not exploring virtualization and cloud computing are missing out on the IT efficiency opportunities available through those methods.

The management challenge

While it is possible to define the energy used by a single device, the challenge for the organization is how to *manage* that energy consumption across its entire PC infrastructure. Most companies start with energy monitoring, but there is limited value in that approach. What an organization needs to be able to do is to control the devices that make up its infrastructure.

Desktop power management is an effective technology that businesses can use to improve the environmental footprint of their desktop infrastructure. The solutions are not seen to be expensive or disruptive, but "their introduction results in an immediate and sustained reduction in energy use by corporate IT," according to Andy Lawrence, research director at The 451 Group.[36]

Power management solutions are available from companies such as 1E, Verdiem, CA, JouleX and Greentrac which focus on enabling the IT administration to set policies for remote switch-off of computers. Increasingly, this capability is being stretched by keeping computers shut down or in sleep mode even during the day when they are not in use. Some of the solutions work by installing client software on PCs and Macs to directly monitor usage. Others implement companion solutions on smartphones so that the computer is only turned on when the user enters the building. JouleX is different in approach from the others in that it is agentless – it depends on the energy monitoring and monitoring capabilities of the device itself, with the information available via a management platform for which the company has developed a "connector" to obtain accurate real-usage data.[37]

One approach for managing desktop infrastructure is offered by CA ecoDesktop which allows an organization to build up an accurate understanding of the energy use of each individual machine on the network through remote polling. Information on the length of time a machine has been in a particular power profile can go back for 12 months. This enables an organization to create a baseline assessment, against which it can make decisions about how to save energy.

Such an approach enables an organization to also choose desktops from within their environment with energy characteristics that best fit the way the machine is actually used. Unfortunately, as of this writing, it is not possible to access EPEAT and Energy Star databases via the use of application programming interfaces (APIs); otherwise, it would be possible to create mashups that combine the power profile of an individual user with external data on machines that are best equipped to fit such a profile.

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[35] Bittman, T.J., Weiss, G.J., Margevicius, M.A., and Dawson, P., "Magic Quadrant for x86 Server Virtualisation Infrastructure," Gartner Research Note G00213635, June 2011.

[36] Lawrence, A., "Ecoefficient IT," The 451 Group, November 2008.

[37] Mingay, S., Stokes, S., Govekar, M., "Cool vendors in Green IT and Sustainability 2011," Gartner Research Note G00211310, April 2011.

Getting an organization to commit to a power conservation effort has a single unusual challenge: in a typical company, the facilities management department pays for the power consumed by desktop computers, while it is the IT department that can implement an energy-reduction plan.

For a desktop energy efficiency initiative to work, managers across the two departments need to agree on whose problem it is, whose budget will be spent on it, and who will get the benefits.

Typically, organizations need to carry out the following steps, which apply broadly to most IT energy-efficiency problems, but can be used effectively in managing desktop infrastructure as well:

1) *Establish a mandate for infrastructure modernization and energy efficiency*

   The IT department should decide that these issues are priorities and roll out projects to fit. Ideally, their plans will have the support of top management, especially once they have articulated a clearly defined goal for energy savings.

2) *Set up a green IT champions team*

   While a project of this sort needs an executive sponsor, the team needs green champions in other areas, such as facilities management or procurement.

3) *Figure out power metrics*

   Put together hard data on the energy and user data you need to track, such as computing usage patterns, power draw and an up-to-date asset inventory.

4) *Assemble and implement an action plan*

   Based on your initial metrics, figure out where you want the organization to get to, and what it will take to get there. Be clear which elements of the plan relate to setting up policies, and which relate to implementation and deployment.

5) *Optimize a strategy*

   Not everything will work as intended – this part of the plan gives you opportunities to figure out which machines in your infrastructure do not fit your plans or policies, and what you can do about them.

Case study – Politecnico di Torino

The monthly electricity bill at Politecnico di Torino now exceeds EUR 150 000, an increase of 218% since 1993, largely due to the proliferation of electronic systems across the campus. As a result, the institution set itself the goal of reducing power consumption across its networked devices.[38]

The institution started monitoring a number of TCP ports[39] in order to scan which devices were left on and idle. Analysis showed that, of a total of 9 000 registered devices, over 3 500 computing devices are on during the day, with as many as 1 840 of them were running during the night. While most Unix devices are left on, possibly due to the operation as a server, the largest category of devices, desktop PCs running either Windows or Linux, accounted for 30% of all active devices during the day, and 40% of active devices during the night. In effect, the devices turned on at night were consuming around 35-40% of the institution's total power consumption.

To reduce the number of PCs powered on, the institution implemented PoliSave, a centralized web-based architecture which allows users to automatically schedule the power state of their PCs. The server

[38] Chiaraviglio, L., Mellia, M., "PoliSave: Efficient power management of campus PCs," Politecnico di Torino, 2010.

[39] TCP stands for Transmission Control Protocol. Using this method, the computer sending the data connects directly to the computer it is sending the data it to, and stays connected for the duration of the transfer.

component remotely triggers power-up and power-down events by controlling local software that handles features such as wake-on-LAN (WoL) on network cards and hibernation.

The benefit is that the daily uptime of PCs managed by PoliSave is 9.7 hours, while the daily uptime for other PCs is 15.9 hours. The annual energy savings is 219 kW, which translates to over EUR 250 000.

Case study: Microsoft IT

Microsoft IT division, known as MSIT, developed an environmental sustainability (ES) plan aimed at changing the way that Microsoft uses power and to reduce the impact on the environment. The ES plan has two broad goals: to apply Microsoft's technology and engineering expertise to help solve the environmental challenges that everyone is facing, and to reduce Microsoft's carbon footprint.

To achieve these broad goals, MSIT identified four action areas:

- reduce Microsoft's electricity consumption;
- improve the utilization of the IT equipment in the data centers and labs;
- build more efficient applications;
- reduce Microsoft's carbon emissions by designing better data centers and by reducing overall travel, making use of unified communications (UC) technology for online meetings and telecommuting.

Organizational structure

MSIT also made organizational changes to help achieve the goals of the ES plan. As a result, MSIT:

- Identified an executive sponsor. The executive sponsor is responsible for the overall strategic plan, which will be carried out over a three-to-five-year period. Having an executive sponsor is essential for initiatives at Microsoft. The executive sponsor reports to the CIO
- Appointed a programme manager dedicated to the ES effort. The programme manager coordinates the entire programme and makes sure that the responsible members carry out the changes and report on the status
- Assembled a virtual team of departmental leads who report on activities and roadblocks. This virtual team works to attain commitments by communicating the issues
- Created an advisory board made up of senior-level IT executives as well as senior members from non-IT groups such as procurement, real estate facilities, and global foundation services.

Power PC management – challenges and opportunities

MSIT ran a few pilot projects to determine potential savings in the area of power PC management. The initial studies indicated a potential 30% savings, roughly equal to about 22 million kW hours, which is enough to operate about 2 200 homes. For example, although MSIT buys and delivers each PC at Microsoft with the power option set to Balanced, over 80% of MSIT's clients reset the power option to High Performance. It is a natural human response to want to run a machine at its highest performance level, but the typical knowledge worker at Microsoft does not need that much power. In fact, only 10% of the tasks at Microsoft require the full CPU performance capacity.

MSIT also determined that 70% of PCs at Microsoft are left on overnight. About 50% of the systems never go to sleep at all. There are often legitimate reasons for leaving PCs on. For example, many tests are run overnight. Running an SQL query[40] for hours at a time is another example of a legitimate reason to leave a

[40] An SQL query is a database enquiry using Structured Query Language.

PC on at night. But machines are very often left on unnecessarily either for technical reasons or simply because users have not been made aware of the environmental issues and potential savings.

Technical issues

Even if a user sets a PC to sleep mode, the PC may ignore those settings if an application is running in the background or if an application signals the operating system that it should not be shut down. Applications often do this, however, for invalid reasons. As a result, Microsoft is working with application providers and is also working on changes to the operating system to remedy this problem. An application has to be able to signal the operating system. Does the application really need to have the system stay awake or can the application be shut down?

There are also productivity issues related to turning a machine off. Microsoft is working on improving the boot time. For machines that are put to sleep rather than turned off, wake time is pretty simple and instantaneous, so that should not be a valid excuse for leaving a machine on.

MSIT believes that significant savings can be achieved by making Microsoft employees aware of the opportunity for energy savings. Microsoft employees are generally very environmentally conscious and the Seattle area is known as a green community. MSIT plans to use this consciousness and also the competitive nature of Microsoft employees to achieve ES goals.

MSIT is also piloting some third-party software solutions that offer reporting enhancements. MSIT is currently able to collect statistics at the aggregate IT level, but not at the departmental or client level. Third-party software offers solutions in this area.

MSIT uses preferences within the Group Policy object (GPO) in Microsoft Windows to reset power options to the Balanced setting on a company-wide basis. If a particular user really needs the High Performance power option, the user has permissions to change the setting; the Group Policy settings will not just rotate that user back to the Balanced setting. MSIT runs the preference periodically to push everyone back to the Balanced setting. For example, MSIT can run the preference monthly, quarterly, or yearly. Users that need higher performance can trickle back in and change their settings. Group policy can support a PC when it times out, when it goes to standby, or when it goes off. It cannot necessarily look at the different levels of CPU usage, so MSIT is evaluating third-party software for that functionality. MSIT is also looking at opt in/opt out tools. It is very important to acknowledge users who really need the higher power settings or who really need to keep their machines on all of the time.

3.5 Evaluation of the shift from one technology to another

A key consideration is the switch from one system to another and its consequences on the carbon economy (e.g. TV programmes delivered by the broadcast network versus download via the telecommunications network). One such shift that is worth examining is the move from on-premises systems to cloud computing.

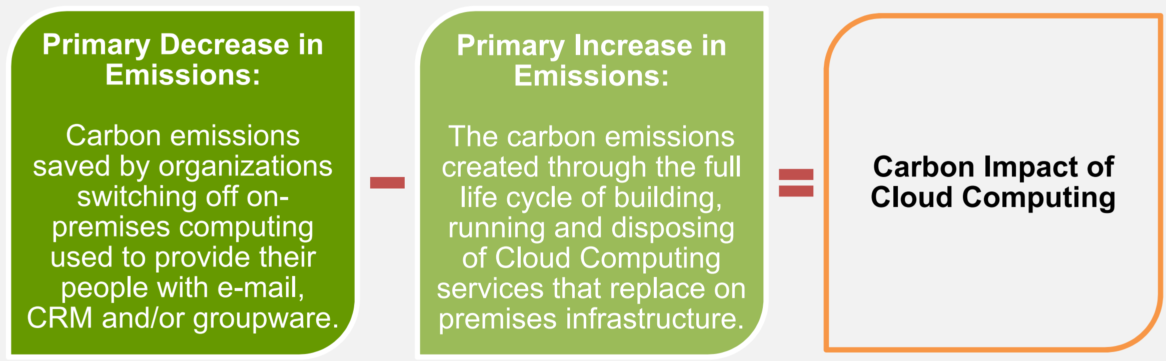
Cloud computing, in its emergent form, represents less a technological innovation and more a business model innovation within the ICT industry. Yet it has significant implications for the entire sector and its customers. It enables computing services (software, platforms and/or infrastructures) that are traditionally provisioned ‘on-premises’ within organizations, to be delivered from purpose-built data centers across Internet, in a utility or on-demand fashion[41].

[41] The enabling technologies of a low carbon economy, Imperial College London, 2011, www.enablingtechnology.eu/content/environment/resources/11_05_20_IT2ET_Summary_Technical_Deep_Dive_Analysis_for_Cloud_Computing.docx.

Further work is needed to include the energy impact of cloud services on telecommunications networks. Extra network infrastructure is needed such as routers and switches and their extra energy requirements.

The pragmatic way to understand the carbon abatement potential enabled by ICT is to focus upon the primary drivers of emissions. On this basis, cloud computing will enable carbon emissions abatement if it is used to replace less efficient on-premises servers, which are in turn permanently switched off. This latter behaviour – switching off on-premises servers – can be fundamental to the calculation of potential carbon savings from the move to cloud computing (see Figure 5).

Figure 5: Calculating the carbon impact of cloud computing



By comparison, additional primary carbon abating effects would not considered as primary drivers of emissions; hence, they are treated as out of scope. These include how the shift to cloud computing can reduce or eliminate materials and packaging, and reduce or eliminate travel/shipment as vehicles are used less frequently to distribute goods. Furthermore, and for the same reasons, secondary carbon abating effects can be treated as out of scope, such as the abatement resulting from the increased scale of adoption which enables future waves of additional cloud-based applications. Consideration may also be given to the potential primary and secondary rebound effects of cloud computing, though it is likely they would be offset by the additional primary and secondary abatement effects that had been placed out of scope.

The following best practices can be identified:

- When enterprises switch to the cloud, their now redundant on-premises servers must be switched-off; failure to do so will negate any potential carbon savings
- Applications need to consider small-/micro-sized firms. Nearly 60% of the savings potential relates to small-/micro-sized firms
- Energy mix may be more influential than power usage effectiveness (PUE); i.e. where a Cloud data center is located is more important in CO2 terms than the overall efficiency of the data center (measured by its power use effectiveness) – a cleaner energy source will more readily deliver better carbon savings that investing in efficiency
- Desktop infrastructure needs to be controlled to hibernate efficiently when not accessing cloud services.

3.6 Key performance indicators

The following KPIs have been listed in this document relating to desktop infrastructure:

- power draw, measured in watts, when active;
- power draw, in low power;
- power draw when off but connected to a power outlet;
- using Energy Star certified equipment;
- meeting EPEAT guidelines relating to environmental measures.

4 Telecoms infrastructure and networks

According to the Smart 2020 report (ref i), telecommunications network infrastructure and devices are responsible for over a third of ICT industry greenhouse gas emissions.

Over the next decade, billions of people in developed economies will move increasing amounts of information, images and video over the Internet and other networks. In addition, the World Bank expects the number of middle class consumers in low- and middle-income countries to grow from 400 million in 2005 to 1.2 billion by 2030,[42] many of whom will be going online for the first time. And then there will be the expected large increase in machine-to-machine communication, with the ongoing deployment of the Smart Grid being an excellent example. Cisco predicts there will be 25 billion devices connected to the Internet by 2015 and 50 billion by 2020.[43] If nothing is done to tame the energy usage of the ICT industry, this growth in overall usage will drive the industry way beyond today's 2% share of global emissions, possibly as high as 5% by 2020.

Of course the ICT industry is taking steps to reduce its own emissions as well as provide more energy-efficient products to its customers. Thanks to new technologies, the ICT industry's energy usage per device is generally improving. For example, the amplifiers and base stations used in mobile networks are now designed to consume less power, and fibre optic cables continue to lower energy consumption in fixed networks. Carbon emission reductions also happen when networks make greater use of solar and other renewable sources of energy. However, the problem is that energy increases due to growth in the number of devices and data usage outweigh energy reductions due to more efficient devices and techniques.

This section covers the sustainability impacts of the networks that are employed in telecommunications companies as well as in corporate organizations. It describes the components of networks, energy use and key environmental impacts. It also lays out guidelines and recommendations that telecoms and network operators can use to manage and improve their sustainability performance.

4.1 The building blocks of a network

Traditionally, the building blocks of a network were classified as either fixed or mobile, based on the degree of mobility available to the users of the system. With a fixed network, a call may only be initiated or received at the subscriber's premises, while a mobile call (or data) may be initiated or received by the subscriber's device at any place where the network is operational.

A fixed network consists of local access lines which connect individual subscribers to a local network node, usually referred to as an exchange, central office or point-of presence (PoP). A fixed network has one

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[42] Global Economic Prospects, World Bank, 2007.

[43] The Internet of Things, Cisco IBSG White Paper, 2011.

interface for every customer line and on broadband networks, the equipment joining each subscriber to Internet is known as the digital subscriber line access multiplexer (DSLAM). There will then be a transmission link from each local node to a major network node that aggregates and interconnects traffic from a number of exchanges. Major network nodes are then interconnected through the core transmission network that today mostly comprises fibre optic cables.

A mobile network, in contrast to a fixed network, is a multi-point network. A mobile device connects to the network through a cell site, using radio waves. Each cell site can support a number of users at the same time. The cells are joined together via a mobile switching center which also connects the mobile network to the fixed network.

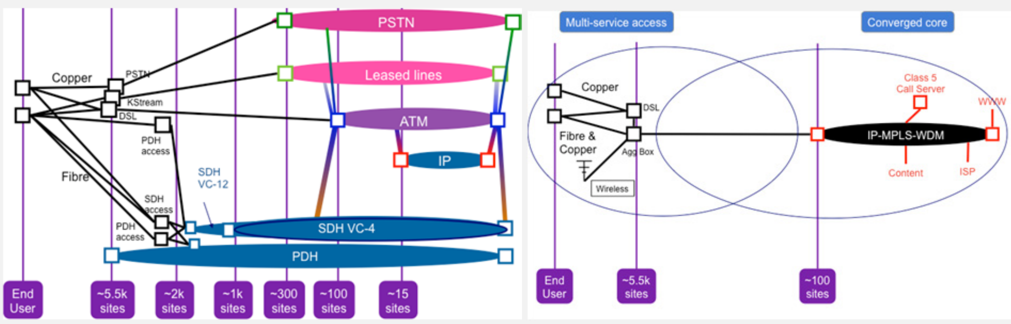
Corporate networks cover the hardware components, computers, software, and communications channels that a company may use to allow the sharing of information and resources within the boundary of the organization. Corporate networks often connect to public mobile and fixed networks as well, usually as part of their wide area network (WAN). However, some companies choose to build their own private networks to interconnect various company sites.

The telecommunication network started off life as a purely analogue based point-to-point voice communication system, and over the past ten decades the number of different services provided over the network has increased significantly. Early data connections used modulated sound signals, and public data systems such as Telex often had their own dedicated switching system, while individual organizations generally joined up their computer systems using private wires rather than going through the switched network.

When semiconductor-based switching took over from electro-mechanical systems, it became possible to move to all-digital communication. Analogue legacy systems are still being used in many areas such that by the turn of the century most of the big telecommunication companies were operating a wide variety of parallel digital and analogue customer connections, switching and transmission networks. In aggregate, these were termed the ‘telecommunication network’.

The introduction of packet switching (a key feature of the Internet) offers a completely different way of building the network. Instead of running many different parallel networks at the same time, all services are essentially designed to run over the Internet. This approach is termed the next generation network (NGN) and is expected to take around 30-40% less energy to run. The following diagrams (drawn from BT’s next generation networks) illustrate the simplicity (and hence energy efficiency) achieved with a NGN.

Figure 6: Traditional BT network is more complex and consumes more energy than next-generation network (NGN)



4.2 Sustainability impacts of a network

Different parts of the network contribute to the power consumption of the network as a whole. For example, when evaluating power consumption per byte of information accessed across the Internet, when the speed of data in the "last mile" is low, then the access network dominates power consumption. As access speeds grow, the core network routers increase their share of power consumption and some studies postulate future scenarios where these routers could dominate power consumption. Other data elements come into play as well. For example, the combined power consumption of data centers and content distribution networks is dominated by the power consumption of data storage for material that is infrequently downloaded, and by the transport of the data that is frequently downloaded.[44]

Measuring power consumption in a network

Given the importance of the power consumption in managing the sustainability impacts of a network, it is important to understand how power consumption is measured. This is particularly important as the European Code of Conduct for Broadband Equipment defines power consumption limits for such equipment.[45]

The European Telecommunications Standards Institute (ETSI) recommends measuring the power consumption of DSLAM (Digital Subscriber Line Access Multiplexer) in terms of the power consumption per line (in W) of the broadband network equipment being measured (P_{BBline}):

$$P_{BBLine} = P_{BBeq} / N_{subscrib\text{-}lines}$$

where:

P_{BBeq} is the power consumption (in W) of a fully equipped DSLAM, measured at the electric power input interface, placed at the premises of the operator or equipment supplier, which connects multiple broadband subscribers to a backbone.

$N_{subscrib\text{-}lines}$ is the maximum number of subscriber lines served by DSLAM.

ETSI has also defined a consequent metric, normalized power consumption (NPC). NPC is an indicator of the amount of power required to transport 1 Mbit/s of data over a 1 kilometre distance.

$$NPC = 1\,000 \times P_{BBline} / (bitrate \times line\ length)$$

where NPC is expressed in mW/Mbit/s/km, bitrate is in Mbit/s and line length is in km.

ETSI's technical NPC specification states that it is based on the bitrate and reach at full-power state of the equipment.[46]

At a more generic level, Recommendation ITU-T Y.3021 states that "network energy efficiency can usually be defined by the throughput of networks divided by the power consumed, that is, bit-per-seconds/Watt". Again it is expressed for maximum network capacity but interestingly takes an inverse approach to the ETSI measures.

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[44] Hinton, K., Baliga, J., Feng, M.Z., Ayre, R.W.A., Tucker, R.S., "Power consumption and energy efficiency in the Internet," March 2011, IEEE Journal Vol. 25, Issue 2.

[45] "Code of Conduct on Energy Consumption of Broadband Communication Equipment," European Commission Directorate-General, Joint Research Center; Final v2, July 2007.

[46] For a fuller discussion of the technical aspects of power consumption metrics, see "Environmental Engineering Measurement Methods and limits for Energy Consumption in Broadband Telecommunications Networks Equipment," European Telecommunications Standards Institute, ETSI TS 102 533, June 2008.

Another approach uses the number of bits transmitted divided by the joules of energy purchased, or its inverse, joules-per-bit. These are essentially identical to the other network metrics as a joule is simply a watt second.

For mobile radio networks, it is common to measure power efficiency (data rate / power consumption) instead of bit / joule as, in this instance, the achieved data rate is a more important factor for power and energy consumption. In addition to this capacity-specific KPI, it is important to have an additional KPI for the cases where coverage, rather than capacity is the limiting factor, as is typical for rural areas. ETSI specified a coverage KPI as area covered for a certain service per power consumption (square meter / Watt)[47].

For mobile networks, energy-efficient routing protocols are necessary and the GSMA has started a Mobile Energy Efficiency benchmarking service[48] to enable mobile operators to identify and quantify cost and greenhouse gas (GHG) savings.

The mobile benchmarks identified by the GSMA compare four energy KPIs, which are:

- mobile network energy consumption per mobile connection;
- mobile network energy consumption per unit mobile traffic;
- mobile network energy consumption per cell site;
- mobile network energy consumption per unit mobile revenue.

The GSMA benchmark service analyzes networks in operation. Further, standards are needed to benchmark new telecom equipment prior to deployment to give operators the tools to anticipate the power consumption of different solutions before they are in use.

ETSI's technical committee for environmental engineering (ETSI EE) has already created several standards in this area, and is in the process of adding further standards. For example, ETSI is finalizing a methodology for fixed networks (ES 203 184 Measurement Methods for Power Consumption in Transport Telecommunication Networks Equipment) and GeSI is working on a similar methodology for fixed networks.

4.3 Guidelines

The European Commission JRC Institute has published the Energy broadband code of conduct. The link provided to this code of conduct at the end of this document is well worth going through, as it provides resources on best practice guidelines in key sustainability areas. A large number of Europe's telecommunications companies have signed up to the codes of conduct, as well as a number of equipment vendors.

The driver for adoption is that energy efficiency is a priority in a number of different ways: commercially, economically and in environmental terms. As a result, European Commission Digital Agenda VP Neelie Kroes referring to both the broadband and data center codes of conduct was quoted in Computing saying: "Implementing these two codes of conduct will significantly reduce the EU's electricity consumption and could save as much as € 4.5bn per year."

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47 ETSI, TS 102 706 Environmental Engineering (EE) Measurement Method for Energy Efficiency of Wireless Network Equipment

48 Mobile energy efficiency benchmarking service, GSMA: www.gsmworld.com/our-work/mobile_planet/energy_efficiency.htm.

4.4 Best practice energy efficiency in networks

The management challenge with regard to energy impacts of networks is to understand what causes power consumption metrics to go up or down. A number of issues emerge.

A major problem with data networks, for example, is that the servers running them are under-utilized, sometimes as little as 6% of what they are capable of. However, the demand for more servers keeps growing, resulting in server sprawl. One way to deal with this problem is **server consolidation**, which reduces the total number of servers or server locations that an organization requires, through efficient usage of server resources.

A related technique is **virtualization**, which is the creation of a virtual (as opposed to actual) version of something, such as a server or network resource. Network virtualization combines available resources in a network by splitting up the available bandwidth into channels, each of which can be assigned to a particular server or device in real time. The usual goal of virtualization is to centralize network administrative tasks while improving scalability and work load. The benefit of efficient management of servers and networks is that energy efficiency improves. Recommendation ITU-T Y.3011 describes how virtualization concepts can be applied to future telecom networks.

One specific challenge with networks relates to legacy technologies. Although it is often possible to gain energy efficiency by introducing newer, more energy-efficient systems, a complete switchover rarely takes place, so that some customers are served on the new system and some on the old system. Companies tend to operate both systems in parallel as they anticipate this will lessen potential problems through redundancy, and thereby increase customer satisfaction. The result is that the gains in energy efficiency can be offset or totally lost because of this duplication of networks.

It is therefore important that companies introduce a rigorous 'switch off' policy and audit their network infrastructure to ensure they power down all redundant equipment.

Finally, energy consumption of most modern telecommunications equipment hardly changes with the level of traffic. In other words, although energy consumption is highest when the equipment is operating at maximum throughput, the consumption often does not fall by much when the equipment is underutilized. For example, a high speed broadband access network might be rated at 40 Mbit/s but it typically only functions at an average speed across the day of 15-20 kbit/s. The result is wasted energy while the network waits for the customer to use it at its maximum speed.

That is why a major focus in energy management is in power saving modes and how they operate to save energy. ITU and ETSI recommend:

- Power saving modes should be implemented in telecom systems, like L2 and L3 modes in DSLAM and modem equipment. Corresponding examples of power saving techniques for GSM/UMTS radio equipment are Standby power saving modes like TRX shutdown, HW/SW-triggered PA bias switching.
- As the subscriber equipment is in active use only a fraction of the time, it is imperative for every standard to make energy saving modes fully operable at low or no traffic periods. It is imperative to have a power management that effectively will activate the different power saving modes minimizing the power consumption.
- Traffic models indicating the typical traffic intensity and statistic behaviour over day and week are important tools to calculate the power consumption as a result of the combination of traffic pattern and power management behaviour. When defining the traffic models, the impact of subscription rate as well as impact from different services and use cases should be considered. A common use case is a computer that is always on – even when not in active use. The computer may send "keep alive" signals periodically. VoIP will be a future common use case, with a requirement for access "to the line" in <1 second. As the power saving effect of low power mode is also wanted, a solution would be to define a

low power mode that can transmit a low rate signal for control, “keep alive”, equalizing and VoIP start up. 100 kbps is proposed as relevant rate for such signalling.[49]

Further solutions are under investigation in research projects (e.g. the CELTIC-plus project OPERA-net / OPERA-net2 and EC-funded projects, such as ECONET, EARTH, TREND and STRONGEST) and in work from other standardization bodies such as the “IP proxying” study from ECMA.

The section on data centers has already indicated the considerable energy efficiency gains available from managing cooling as effectively as possible. They are not repeated here but the same principles apply to equipment room cooling for telecom companies: fresh air cooling, air economizing, water economizing, hot/cold aisles, variable speed cooling fans, and so on.

When discussing data centers, mention was also made of the way in which telecom companies use DC electricity to run their networks. By operating on 50V DC, telecom networks benefit from not having to suffer the losses associated with multiple AC/DC conversions. By operating the entire network on DC, the conversion from AC is carried out only once by large centralized power supply units, equipped with modern rectifiers, which improve the conversion efficiency. In comparison, the higher power requirements needed by data centers make the 50V DC solution impractical. Data centers require 300-400V DC system to avoid excessive voltage losses or the use of massive conductors. As a result, current standardization efforts for data centers are focussed on this higher value.

Cell stations are ideal candidates to use renewable energy generated on-site, especially where there is no, or unreliable grid connectivity. In such cases, cellular base stations are often powered using diesel generators with resultant fossil fuel related emissions. A number of the mobile equipment manufacturers are already experimenting with alternative clean technologies such as solar photovoltaic, wind power and locally grown biofuel. Although the viability of these systems from an economic standpoint may not be yet satisfactory, the anticipated increase in fuel costs and possible emissions caps or costs should make these systems more viable without taking into account the environmental benefits of lower emissions. In the meantime, manufacturers are developing optimized methods to use the diesel generators such as activating the generator for few hours (at full power) to charge batteries and then switching off the generator and running the base station on battery power.

Other power saving techniques being used or contemplated include:[50]

- an increase in the operational temperature of the equipment;
- the use of fresh air cooling instead of air conditioners;
- the use of geo-cooling.

Networks are, by their very nature, distributed, and a large telecoms network will have many thousands of separate buildings connected to the electricity grid. In such cases, energy consumption measurements may be no more than a few times per year at best. Smart energy meters are changing all that and provide frequent (typically half hour) readings. This not only allows a more detailed analysis of energy consumption patterns and more informed benchmarking between sites, but also means that all the energy readings can be brought together in real time at a single point. Automated analysis systems can spot anomalous behaviour and remedies instigated rapidly.

49 European Telecommunications Standards Institute, ETSI TR 102 530.

50 ETSI Energy Efficiency Report, www.etsi.org.

Case study – BT and Telecom Italia

BT says it will save GBP 13 million (USD 20.7 million) a year and shave 5% off its carbon footprint by fitting more than 22 000 smart meters and over 1 500 building management systems across its property portfolio. The installation programme is already underway and will be rolled out to 110 buildings a month, while an international expansion is planned for 2013.

BT is trialling a new 'sleep mode' for broadband connections that promises to slash energy use by broadband infrastructure by almost a third, delivering deep cuts in carbon emissions in the process. Dubbed Cool Broadband, the new system, is being piloted at the research and development center at Martlesham in Suffolk and a nearby exchange, and early indications are that it can cut energy use per line by around 30%.

BT's plan is to shift broadband from always on to always available. If the broadband line is operating at 20 Mbit/s, then Cool Broadband sends it into sleep mode where it is cut to 200 kbit/s, which is sufficient to support a phone call. Then it powers back up instantly when people want to use the full broadband connection.

Telecom Italia is replacing 100 000 lamps with LED ones and has laid down meters in most of the major sites. Plans are underway to cover the majority of its energy load. It has activated a centralized energy control room.

Case study: unified communications within Microsoft

Implementing unified communications internally within Microsoft has enabled employees to significantly reduce their environmental impact. Employees can telecommute more frequently and reduce the time spent on driving. Employees also frequently use web conferencing instead of travelling to meetings. Microsoft uses both the Office Live Meeting hosted service and Office Communications Server web conferencing to hold approximately 100 000 conferences every month.

Microsoft Travel estimates that employees have avoided flying more than 100 million miles annually when compared with travel in 2007, saving 17 000 metric tons of CO_2 annually. Microsoft UK reduced air travel by 21% since 2007, verified by the Carbon Trust Standard in April 2010. This shift was enabled largely by using technology to replace and supplement travel and a flexible work policy where 90% of staff takes advantage of unified communications, web- and videoconferencing.

Case study: GreenTouch

GreenTouch is a consortium of leading ICT experts from the industry, academia and research institutions, led by Alcatel-Lucent, which is focused on transforming the working of communications and data networks in order to significantly reduce their carbon footprint. The goal is to increase network energy efficiency by a factor of 1 000 from current levels.[51]

GreenTouch is focusing on those areas where there is greatest opportunity to deliver a transformative result with current targets being a 1000x improvement in wireless, 100X in wireline access, 100X in core routing and switching, and 10x in core optical networking and transmission.

An example of this approach is the Green Radio Network Architecture, which is expected to deliver a 1 000-fold improvement in the energy efficiency of wireless networks. Every element of the architecture is being rethought:

- Green air interface, featuring large scale antenna systems with high bandwidth

[51] www.greentouch.org.

- Network architecture, with dynamic management for energy efficiency, small cells and relays, and a new base station architecture using cloud computing
- New base station hardware, such as an ultra-low power base station on a chip, photonic enablers for RF systems, the use of renewable energy sources, and new architectures such as the lightRadio, which distributes intelligence throughout the network so that it can dynamically expand to meet growing demands.

Overall, GreenTouch is targeted on large-scale improvements in the energy per bit metric.

4.5 Evaluating the shift from one technology to another

The shift to new modes of communications from traditional means of communications needs to be considered in the light of its consequences on the carbon economy. One example of a switch in services that can have an impact on environmental impacts is the move to IP telephony. How green is IP telephony compared to a traditional phone system?

A voice over Internet Protocol (VoIP) system can broadly be classified according to two criteria: whether it is a primary line phone service replacing the public switched telephone network (PSTN), or whether it uses a client-server (c/s) or a peer-to-peer (p2p) architecture. Vonage and Google Talk are examples of c/s architectures, while Skype is an example of point-to-point (p2p) architecture. Of these, only Vonage is a primary-line phone service replacing PSTN service including access to emergency services.

A key finding of this work[52] is that "in c/s VoIP systems with always-on hardphones, the total power consumed is dominated by the power consumption of the hardphones." The typical power consumption of these phones was quoted at 5W.

PSTN, on the other hand, typically uses 0.3W for the line card and its share of the primary multiplexer. A wired handset connected directly to the line draws only 0.5W when off hook. A typical exchange line will operate of a traffic level of 0.1 Erlang (0.1 duty cycles) so the handset will on average draw 0.05W. The average power used per PSTN line is approximately 0.34W. More work is needed to understand the energy component of the transmission and switch network which could be as much as 50% of the total.

PSTN would therefore appear to be approximately 5-10 times more energy efficient than an equivalent VoIP system. However, many PSTN users operate cordless handsets which consume around 3W when the base station and charger is included, and so in this case the power consumption of IP- and PSTN-based telephony would be similar.

To establish best practice for energy saving in telephony, more work is needed to find out how VoIP telephony systems compare with mobiles and the PSTN taking account of the proportion of users that use conventional and cordless handsets. Separate studies of network energy and terminal types may be required.

Some general considerations emerge:

- If a user does not have broadband service, then using the PSTN is the most carbon efficient solution. Putting in a broadband line just for voice is inefficient because the processing power (especially customer premises equipment (CPE)) is much higher than that actually required. Therefore, avoid putting in new equipment to provide functionality that is already available.
- If a country runs a PSTN at its current capability, then all users, even those with broadband service, should use PSTN as the most carbon efficient solution because it is already there and additional

52 www.cs.columbia.edu/~salman/publications/greenvoip-gn10.pdf.

equipment would be needed to move people onto VoIP, i.e. additional call servers, although this would be a small part of the total consumption per user. Again, avoid putting in new equipment to provide functionality that is already available.

- If a country started to scale back PSTN to match its actual use, then all broadband users should use VoIP as the lowest carbon solution. This is because voice is a small proportion of the traffic, so the broadband (BB) line is being used more efficiently if all services run on the one line. VoIP call servers have a low energy consumption compared to PSTN, mainly because PSTN is 25 years old and technology has improved considerably, and the carbon footprint of PSTN is dominated by the in-use electricity.
- If we assume 20% of lines are voice only, it would save GHG emissions to close down PSTN and give all customers broadband for voice, even if you assume they use the full blown broadband CPE.
- For voice-only users, a network PSTN to VoIP conversion would be the best solution overall, as this saves on new CPE for those users.

4.6 Key performance indicators

The following KPIs have been listed in this document relating to telecoms and networking:

Wired access:

- Power consumption per network line, $P_{BBLine} = P_{BBeq}/N_{subscrib\text{-}lines}$
- NPC = 1 000 × P_{BBLine}/(bitrate x line length)
- Network energy efficiency: bits/Joule

Wireless access:

- Mobile network energy consumption per mobile connection
- Mobile network energy consumption per mobile traffic
- Mobile network energy consumption per cell site
- Mobile network energy consumption per unit mobile revenue.
- Network level efficiency based on coverage (for rural cases)
- Network level performance indicator based on data traffic (for urban cases).

5 Broadcast services

Broadcasting covers the distribution of audio and video content to the general populace, or a large subset of it. Originally, broadcasting featured analogue signals and analogue transmission techniques, using bespoke broadcasting hardware. However, the era of digital convergence is upon us. As a result, broadcasting uses increasingly digital signals and digital transmission. As well as radio-based broadcast, the same content is often also available over the Internet, with the user devices being computers or mobile phones rather than televisions or radios.

The volume of information broadcast across the world has more than quadrupled during the two decades from 1986 to 2007, from 432 exabytes to 1.9 zettabytes, where an exabyte represents a billion gigabytes, and a zettabyte is a thousand billion gigabytes.[53]

[53] Hilbert, M., and Lopez, P., "The World's Technological Capacity to Store, Communicate and Compute Information," *Science*, 2011.

5.1 The main activities of broadcasting

Although the process of content development for the purposes of broadcasting can be thought to start with the pitching of ideas and the writing of stories, this document starts with production, which is either done on location or in the studio. The output of the recording needs to be edited, tagged with metadata (for example, subtitling), scheduled, and then sent to the organizations that carry out transmission. As there are a number of methods of transmission, including terrestrial broadcasting, satellite, cable and online, the content needs to be reformatted for broadcasting medium.

Each broadcast medium has its own method of delivering the content to its audience, some using transmitters over the air, while others use cable and satellite. Traditionally, broadcasting was built around custom equipment only used by broadcasters or film/TV production companies. As digital convergence reaches into every nook and cranny of the broadcasting industry, the use of standard desktop, data storage and networking infrastructure is increasingly the norm.

As a result, although there is much that the broadcasting industry needs to do in the area of sustainability that is specific to the way it works, there is growing commonality regarding good practices, which can be borrowed from work done in other areas, including desktop infrastructure, networking and data centers.

5.2 The building blocks of broadcasting

Energy is a key consideration in an industry which uses bright lights, huge audio and video files and widespread networks. Yet, at the outset of this discussion, it is worth noting that around 80% of the broadcasting industry's carbon emissions, estimated at around 2% of global emissions, relate to the energy use of their customers in accessing the output of the broadcasting industry via their televisions, radios, satellite and cable boxes, and other equipment.[54]

A BBC study estimated the carbon footprint of watching broadcast television using digital terrestrial television and online delivery of video-on-demand. The carbon footprint for digital terrestrial television was found to be 0.088 kg CO_2e/viewer-hour and for online delivery of video-on-demand ranges from 0.030-0.086 kg CO_2e/viewer-hour. This was based mainly on the energy consumption in the use phase. Results were sensitive to the number of viewers per display. Program production contributes 12% to 35% and distribution contributes 10-28%. It was found that the audience size of a digital terrestrial channel and whether or not an aerial amplifier was used have a large effect on which distribution method appears to be the most energy efficient.[55]

As a result, the broadcasting industry can benefit from its own sustainability efforts if TVs and set-top boxes are more energy-efficient and use better power management in sleep and standby modes.[56]

As the broadcast industry transitions from analogue to digital, it finds that its energy use keeps rising, even when it seeks to use the most energy-efficient equipment available. For example, as broadcast and production companies digitize their archives, tapes that were once placed on a shelf, not using any energy,

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54 Carbon emissions from global telecommunications systems – mobile, fixed and communications devices, but excluding TVs and TV peripherals – currently approach 230MtCO_2e. TVs and related peripherals contribute of the order of 700 MtC02e, nearly as much as the total for global ICT emissions. Forster, C., Dickie, I., Maile, G., Smith, H., Crisp, M., "Understanding the environmental impact of communications systems," April 2009, http://stakeholders.ofcom.org.uk/binaries/research/technology-research/environ.pdf

55 Chandaria, J., Hunter, J., Williams, A., "The carbon footprint of watching television," Sustainable Systems and Technology, May 2011, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?reload=true&arnumber=5936908

56 Sky reports that it has cut the energy consumption of the Sky+HD set-top box by 29% compared to the previous model, and extended its auto-standby mode. As a result, it reports annual savings of 90,000 tonnes of CO_2e. "The Bigger Picture Review 2011," Sky.

are converted into digital files, which consume energy in their production and their storage. But the functionality associated with these files go up as well, as it is easier for their contents to be accessed by a wider number of people, they can be more easily reused, etc. Plus Sky reports that by digitizing 1.64 m tapes, it was able to eliminate the impacts relating to moving around 4 000 tapes a day.[57] So a straightforward power calculation could miss the benefits related to the greater functionality of dematerialized content.

Thanks to digital convergence, a number of areas of operation in broadcasting are easily understood in sustainability terms.

PC infrastructure is widely used in the broadcasting industry: on location and in the studio, in wrap and post-production, and in the back office. In this section, reference has already been made to the key sustainability impacts of PC infrastructure, and these are best captured by focusing on energy consumption. Broadcasting is no different from other industries in leaving computers fully powered up, even when not in use. As a result, the energy use of desktop infrastructure can be improved by the usual methods of using more energy-efficient computing devices, better power management, and the use of techniques such as virtualization.

The large size of audio and video files used in the broadcasting industry has resulted in many companies establishing **data centers** to simply digital storage and access. Again, power consumption is the key sustainability challenge in data centers, whether in feeding or cooling IT equipment. However, water, where used for cooling, is increasingly important as well.

Networking is another area of operation where lessons can easily be drawn from the experience of ICT companies. Every networking device consumes energy along the way, usually at full power draw even when not being used at full stretch. This is a similar situation that broadcasting companies have to deal with, either in terms of their own use of IT networks, or in relation to the use of terrestrial and cable networks. Although the telecom industry has done its homework in terms of knowing the relative impacts of the fixed and mobile networks, the broadcasting industry has not published information on the relative sustainability impacts of terrestrial, cable, satellite and online distribution channels. Clearly, this is an area where more work needs to be done.

Although ICT equipment may be found in many parts of the broadcast chain, the industry also uses some **equipment that is unique to this industry**, such as cameras, lighting, editing suites, transmitters, aerials, and so on. Due to the specialized nature of the kit, it is unlikely to have been purchased with energy efficiency in mind, nor would there be power management features. Further, the way equipment is used in the broadcasting industry, media professionals are usually unhappy to risk continuity of service by shutting equipment down, especially due to concerns that the equipment may come back on with different settings.

5.3 Measuring sustainability impacts in broadcasting

Given the widespread use of power (both from the grid as well as locally generated) in broadcasting, the industry is focusing on carbon emissions as a way of managing its sustainability performance.

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[57] http://corporate.sky.com/thebiggerpicturereview2011/environment-priorities.aspx#.

The BBC has developed a carbon calculator called Albert, which has since been shared with other programme-makers under the auspices of the British Academy of Film and Television Arts (BAFTA).[58] Albert works by asking production managers a series of questions relating to their production activities, such as studio usage and time spent in edit suites. The software then produces a series of charts showing the carbon impact of their work. Some measures included in Albert are:

- total CO_2 emitted during the course of a production;
- amount of CO_2 emitted per GBP 100 000 of budget;
- CO_2 per production hour.

In the US, the Producers Guild of America (PGA) has put together a Green Production Guide, in association with PGAGreen.org, aimed at the film and television industry, which covers best practices as well as a carbon calculator.[59]

Apart from the metrics focused on carbon as used in production, broadcasting organizations are also using sustainability metrics that cover more widely the activities of a broadcasting company, such as:

- share of renewable energy in total energy mix;
- CO_2e emissions per van or car in fleet;
- proportion of waste reused or recycled;
- water consumption per employee;
- CO_2 emissions per employee from business travel.

Separately, a broadcasting company can usefully employ the metrics discussed elsewhere in this sustainability toolkit:

- PUE of a data center;
- WUE of a data center;
- total power draw of PCs and peripherals in active and sleep modes;
- networking metrics such as bit-per-joule.

5.4 Guidelines and best practices

Currently, there are no formal regulations or guidelines that apply to sustainability impacts of the broadcasting industry. However, work on guidelines and best practices has started. For example, the European Broadcasting Union has a steering group working in the area of sustainability. This group is urged to explore the work already done in related areas of digital convergence, such as data centers, desktops and networks, in order to align with the recommendations that already exist for those areas. However, plenty of work needs to be done in the areas relating directly to broadcasting.

Industry groups have started collaborating on the development of best practices, and a number of guides are available:

- Green is Universal Film/TV production guides for NBC/Universal[60]
- PGA Green Production Guide[61]

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58 www.frontrowreviews.co.uk/news/bafta-launches-albert-today-or-how-to-measure-a-tv-programmes-carbon-footprint/10595.

59 www.greenproductionguide.com provides a carbon calculator as well as information on around 1600 green production vendors.

60 http://greenmediasolutions.com/pdf/greenmedia-tv-production-guide.pdf.

- Green Screen Program for the Canadian film and TV industry[62]
- Eco-scorecard from Green Media Solutions
- Fox Guide to Greening Production[63]
- BBC/Arup Low Energy Lighting Guide.[64]

Although energy is a key area of focus in these guides, they usually cover all sorts of other areas relating to sustainability in broadcasting, including the production office, locations, transport, set design, props, catering, lighting, wardrobe and post-production.

5.5 Broadcasting case studies

Cost and power consumption implications of digital switchover

A comparison of the respective carbon footprints of Digital Terrestrial TV and video-on-demand is included in an Ofcom study.[65]

The changeover from analogue to digital TV distribution is predicted to raise emissions initially by around 10 watts per user in the UK as they will require a digital-to-analogue convertor, as a set-top box. However, this additional power load will reduce as TV sets are replaced by more energy-efficient sets with an integral digital TV tuner. Note that the European Union Code of Conduct on set-top boxes specifies a maximum of 2 W on standby.[66,67]

The Ofcom study has shown that in the UK the analogue transmitter power (effective radiated power (ERP)) of the 5 terrestrial channels is approximately 75 MW. The total ERP post switchover is estimated be 18.2 MW. This is a reduction in power of approximately 75%. When antenna gain (10 dB) and transmitter efficiency are taken into account, the DC power to the transmitters is estimated to be 13 MW for the UK.

Comparing the carbon footprints of digital terrestrial television and video-on-demand

Recent studies[68] have estimated that television and related equipment account for 1.8% of GHG emissions and ICT is responsible for 2% of global GHG emissions. Both of these sectors are forecast to grow as the developing world increases its uptake of the technology.

This study estimates the carbon footprint of two different ways of watching television: using broadcast digital terrestrial television (DTT) and video-on-demand (VoD) over the Internet. It compares the two distribution methods and the corresponding consumer equipment. It uses the principles of life cycle assessment (LCA) to derive the carbon footprints using a bottom-up analysis of the system applied to the BBC's television services. This was the only environmental impact considered and was mainly from electricity use. Equipment manufacturing was not included.

The main results showed that broadcast DTT has a smaller carbon footprint per viewer-hour than VoD for average sized audiences, but not with small audiences or for homes using an aerial amplifier to boost DTT

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61 www.greenproductionguide.com/.

62 http://greenscreentoronto.com/green_practices/.

63 www.fox.com/greenitmeanit/.

64 http://downloads.bbc.co.uk/outreach/BBC_LEL_Guidelines.pdf.

65 http://stakeholders.ofcom.org.uk/binaries/research/tv-research/cost_power.pdf.

66 http://ec.europa.eu/energy/efficiency/ecodesign/doc/committee/2008_09_26_sstb_regulation_post_vote.pdf.

67 http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:036:0008:0014:EN:PDF.

68 http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP189.pdf.

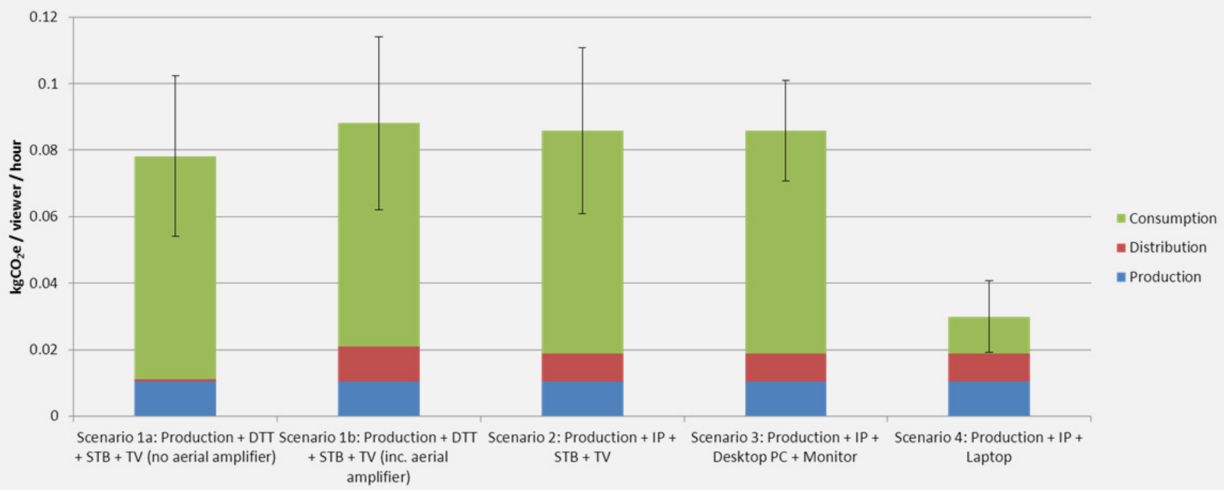
signals, as an aerial amplifier is always on and takes a significant power consumption. The largest environmental impact from watching television is from the consumer equipment. This amounts to 76% of the total for DTT and 78% and 37% for VoD using desktop and laptop computers respectively. The trend for larger screens could increase this although there is a parallel increase in viewing on small mobile devices. Program-making contributes 12% to 35% of overall GHG emissions.

Results were sensitive to the viewer numbers per display. Doubling the number of viewers per display reduces the carbon footprint by 44% for digital terrestrial television. For VoD, there was large uncertainty in the energy consumption data for the content delivery network and the Internet. However, this does not affect the main outcomes.

Figure 7 shows the results for the full end-to-end chain for a variety of scenarios. The production component, which is common to all, has the same value in all scenarios. Scenarios 1-3 have a carbon footprint of approximately 0.088 kg whereas scenario 4 (IP plus laptop) has a carbon footprint of only 0.030 kg CO_2e/viewer-hour.

The consumption component is the largest in all scenarios although the lower average energy consumption of laptop PCs is reflected in the results.

Figure 7: Overall comparison of the four different scenarios. The error bars show the 95% confidence interval



The trend to watching TV on laptops rather than TV sets may become more popular in the future as viewing habits change from ‘family’ to ‘personal’ viewing. Students and people on the move also use laptops or other handheld devices to watch TV.

Comparing music delivery services

In 2009, Microsoft and Intel Corporation commissioned a paper examining the energy and climate impacts of different music delivery methods. The study was carried out by a joint research team from Carnegie Mellon University, Stanford University, and the Lawrence Berkeley National Laboratory. It analyses six comparative scenarios regarding the publishing and delivery of traditional CDs and the production and digital use of online music. The study finds that in energy and CO_2 terms, online delivery can reduce customers’ footprint by between 40% and 80%. This reduction is due to the elimination of CDs, packaging, and the physical delivery of CDs to retailers and the household.

Sky's green initiatives

Satellite broadcaster Sky has set itself ten targets as part of its overall vision of reducing the company's environmental impacts.[69] These targets, including a 25% reduction in gross CO_2 emissions over three years, a 20% increase in energy efficiency, and 20% renewables use, are set in a context of continued business growth. Two years into the programme, the company has already achieved a 19% reduction in CO_2 emissions, and has exceeded the three-year target for energy efficiency.

Achieving these targets, as well as others relating to fleet emissions, business travel, water consumption and waste, has required considerable thought and action across the working of the company. An Environmental Steering Group (ESG) led by the chief executive of the company meets with twelve other executives leading individual departments to ensure that the company is operating in ways that will enable it to meet those targets.

The Sky Studios office in Isleworth, UK, has been built as Europe's most sustainable broadcasting facility, with an integrated wind turbine, an on-site combined cooling heat and power (CCHP) plant which provides at least 20% of the energy needed for the building's electricity and heating, and eight naturally ventilated studios.

The equipment for each studio was chosen so that a single switch can carry out an automatic shutdown of the entire studio, something that traditional broadcasting could never envisage. The lighting is based on energy efficient technologies and the building has regenerative lifts. The CCHP uses locally-sourced biomass, and harvested rainwater is used to flush toilets and irrigate the green spaces around the building. A green IT policy is in operation where power management is used to shut down computers at the end of each day, as well as the use of energy efficient centrally-located multifunction devices replacing individual scanners and printers.

BBC for Sustainable Production

Albert is a web-based carbon calculator designed to enable production staff, without any knowledge of sustainability or footprinting, to calculate the carbon impact of their programme. Emissions from the production office, studios and stages, travel, overnight accommodation, power generators and editing are all covered by the tool. The use of Albert is mandatory for the majority of BBC in-house production, and the tool has now been shared with the rest of the industry via a partnership with the British Academy of Film and TV Awards (BAFTA). Albert is free to use and more details can be found at www.bafta.org/albert.

"*Catwalk to Chaos*", a current affairs program made in Salford, has recently used Albert. Data was entered by the programme's production coordinator, Andrew Babbage. "Albert was very easy to use and understand", says Andrew. "The summary of the production carbon footprint was an eye-opener. Monitoring travel distances and methods during production helped me to make better decisions based on efficiency and cost". Motivated by both cost and carbon, Andrew says the production "actively reduced any unnecessary travel". Andrew intends to make use of Albert's "predict" function on his next production, meaning that the team will be able to compare how their expectations of the show's carbon footprint compare with the "actuals" entered in post-production.

The BBC has also launched a guide to using low energy lighting (LEL) on television productions. It is meant to act as a one-stop-shop for lighting directors, studio managers and production teams, helping them to cut carbon emissions and save on energy bills. The comprehensive 32-page guide – with graphics, statistics and product comparisons – leads the way in changing the industry's approach to sustainable productions. The guide is the first of its kind in the UK television industry and is available here: www.bbc.co.uk/outreach/media/BBC_LEL_Guidelines_Final_2011-07-08.pdf.

[69] http://corporate.sky.com/thebiggerpicturereview2011/data-data.aspx#tab5.

An LEL solution for a TV production is the combination of:

- efficient lighting equipment – light sources, luminaires (the optical system) and lighting controls;
- efficient design of the lighting installation;
- efficient lighting management of the lighting equipment during all the phases of the production, including 'dark' practices.

Although LEL lamps initially cost more to buy or hire, they last longer than traditional ones and save money and energy in the long run. For the programme '*The Bleak Old Shop of Stuff*' (BBC Two), the use of LEL led to energy savings of around 85%, a much cooler and more comfortable working environment, and praise for the lighting quality from the director of photography.

5.6 Key performance indicators

The following KPIs have been listed in this document relating to broadcasting:

- share of renewable energy in total energy mix;
- CO_2e emissions per van or car in fleet;
- proportion of waste reused or recycled;
- water consumption per employee;
- combined scopes 1 and 2 emissions / FTE employee and combined scopes 1 and 2 emissions / total revenue

Separately, a broadcasting company can usefully employ, where appropriate, the metrics discussed elsewhere in this document:

- PUE of a data center;
- WUE of a data center;
- total power draw of PCs and peripherals in active and sleep modes;
- networking metrics such as bit-per-joule.

6 Checklists

The aims of sustainability checklists are to:

- ensure resources are not exhausted (energy and raw materials);
- eliminate pollution (into soil, watercourses, atmosphere or oceans);
- eliminate damage to the environment (habitats, species endangerment, local or global);
- provide customers with information so that they can consider environmental impact when making choices between products or services.

An example "plain old telephone service" (POTS) inventory is given below. This is based upon a single customer service rather than the operator's total deployed infrastructure.

- customer's telephone apparatus;
- customer's internal wiring;
- customer's access line;
- customer's share of common infrastructure (duct and cabinet);

- customer's share of service provider's network (switching centers, core network and subsea network).

The environmental impact of the provision of a telephone service delivered in this way can be compared with alternative technologies such as VoIP delivered using personal computers, cellular telephony and satellite phones. When this work is completed, new users of the service will have the choice of which type of service to buy, depending on which has the lowest environmental impact. This choice will not necessarily be obvious as they may already have an existing service to which a new one is to be added on an incremental basis; an additional level of apportionment then needs to be considered. In the case of a single telephone line extension, the increment is more likely to be related to the product alone rather than the network utilization (e.g. a Digital Enhanced Cordless Telecommunications (DECT) phone). The user also needs to consider the amount of use that will be made of the product: its life span and duty cycle. The life span is the estimated time to replacement (e.g. 1-2 years for a mobile phone). Replacement has a cost in terms of raw materials and energy needed for manufacture and distribution. The duty cycle is the amount of time the service will be used (e.g. when a telephone handset is off hook). A higher duty cycle means more energy is likely to be needed to power it and a short life cycle means that it will soon need replacement.

It is therefore complex and beyond the capabilities of most users to compare different services on the basis of their sustainability.

A possible solution to this problem would be for all products to have an environmental sustainability cost included in the purchase price (e.g. a carbon tax). Products with a high cost (price plus environmental impact) would tend to be eliminated from the market by competitive forces. Legislation is required to make this happen, and this is being applied in some countries. Further consideration of the required legislation is beyond scope of this study.

In summary, different checklists are required for the service provider and for the purchaser of a service, who is normally (but not always) the end user. In theory, the purchaser should consider the likely environmental impact of the different service options before entering a purchase agreement and should be mindful that products claiming to be 'green' may not in fact provide the best environmental solution. In choosing a service, the 'green' purchaser should consider what the environmental impact is likely to be from the raw materials used, how much energy is needed to operate the service, and the eventual disposal or recycling. Currently this is an art, requiring judgement, rather than a science based on facts. Even so environmental labelling, technical specifications and best practices (e.g. the comparative examples given in this document) are sometimes available which make the choices between different products and services more tractable. However, because this is complex (and may not always be possible in practice), the service provider should also complete a checklist to ensure that the service is being provided in the most energy-efficient way possible.

6.1 Service provider checklist

A metric should be based on minimizing overall energy usage. This metric should provide a meaningful indication of progress towards a target level (to be set by regulators). A simple metric could be: "Average power per customer connected".

Figure 8: Example of service provider checklist[70] (not based upon any specific service provider's figures)					
Service type	Embodied carbon per user kg CO_2e	Standby power Watt	In use power Watt	Average power per user Watt	Assumptions
Telephony (POTS)	1	0.3	0.8	0.51	Single handset. 50% added to average power to allow for network power
cellular phone	0.5	0.1	0.1	0.2	at 0.1 duty cycle and 0.1W base station apportionment
VoIP	0.2	5	5.1	5.1	Head set needed. 10% apportionment for existing PC while 'On'
Satellite phone	2	0.02	2.0	0.22	at 0.1 duty cycle

However, this does not take into account the desirability of moving to non-fossil fuels and the use of renewable sources of energy. Therefore, this metric should be amended by users to take into account of the use of renewable energy sources. This is obtained when the emissions per annum are multiplied by the emission factor for the electricity generated (CO_2e/kWh). Emissions factors are time and country specific and are published with year-on-year updates to follow changes in the energy mix.

The environmental impact of an ICT service measured in terms of greenhouse gas emissions then becomes "the average carbon dioxide equivalent per customer connected per annum per service type".

6.2 End user checklist

An end user has to rely on energy consumption and raw materials usage figures provided by the service provider or some other independent entity (such as a consumer organization). Therefore, there must be audit, review and publication processes for these so that different service providers can be compared.

Figure 9: Example of a table comparing energy impacts of different services (not based upon any specific service provider figures)								
Service need	Duty cycle	Existing system Yes/No	Service provider Name	Embodied carbon per user kg CO_2e	Standby power Watt	Average power Watt	CO_2e intensity country g/Wh	Emissions per annum G
Telephony (POTS)	0.1	No	A	1	0.3	0.51	0.52	688
Cellular phone	0.1	No	B	0.5	0.1	0.2	0.52	810
VoIP	0.1	No	C	0.2	5	5.1	0.52	20 500
Satellite phone	0.1	No	D	2	0.02	0.22	0.52	736

70 10% apportionment for VoIP services has been made in the case of the PC used for the VoIP example. Note the PC cannot be in standby mode if it is to receive incoming calls.

6.3 *Data center energy checklist*

Here is a handy checklist that a data center manager can use to improve their facility's sustainability performance:

1. Measurement of the facility's energy performance, using a number of metrics, including PUE, WUE, CUE, data productivity proxies and the data center maturity model, which itself includes a number of IT efficiency and utilization metrics.
2. Implementation of data logging and reporting capabilities, which can be applied to servers, network and storage utilization.
3. Reduction of physical space and servers by consolidating multiple servers through virtualization.
4. Selection and deployment of new ICT equipment that meets energy efficiency performance standards, such as Energy Star, LEED and SFY.
5. Cooling for the facility to cover airflow design (such as a hot aisle/cold aisle layout), free cooling such as the use of fresh air, economized cooling, CRAC units (with variable speed fans), and reuse of waste heat. Usage of air-side and water-side economizers to take advantage of favourable outside weather conditions, where appropriate.
6. Increase data center operating temperature and relaxation of humidity controls to reflect allowable temperature and humidity ranges of equipment. Implementation of energy and environmental monitoring of the data center, and industry standard reporting approaches, such as IPMI[71], DCMI[72] and SMASH[73].
7. Selection and deployment of power for the facility, with management in place to exploit low carbon grid and non-grid power sources. Also, consideration of the kind of power equipment needed to minimize losses, including DC distribution and equipment that runs on DC power.
8. For managers of new build facilities, consideration that the geographic location and physical layout of the building contributes to its long-term performance.
9. Minimization of energy losses that take place in the network due to transmission.
10. Shutting-down of unused servers, and unnecessary cooling equipment.
11. Consolidation of storage to improve utilization, but also to reduce redundant storage of the same information.
12. Reduction of the circulation of air around servers through structured cabling.
13. Design of an efficient topology, DC interconnection and energy conservation policies for network devices in order to manage the energy used by the network.

[71] IPMI (Intelligent Platform Management Interface) is a standardized computer system interface used by administrators to manage a computer system and its operation.

[72] DCMI, or Data center manageability interface, is based on IPMI 2.0 and helps administrators manage server assets in a data center.

[73] SMASH, or System Management architecture for Server Hardware, is an industry standard for managing server hardware.

6.4 Telecoms and networks energy checklist

Here is a handy checklist that a manager can use to improve the sustainability performance of the organization's telecoms and network infrastructure:

1. Measure the power consumption of the networking infrastructure using ETSI metrics, which measure the power required to transport a certain amount of data over a specified distance. Alternatively, the measures in Recommendation ITU-T Y.3021 define the inverse approach to the ETSI measures, defined by the throughput of the network per unit of power consumed.
2. On mobile networks, use the Mobile Energy Efficiency service from the GSMA to benchmark energy KPIs.
3. For broadband networks, use the Energy broadband code of conduct from the JRC Institute to lay out best practice guidelines in key sustainability areas.
4. For data networks, use server consolidation to reduce network sprawl.
5. Virtualization is a related technique that saves energy while simplifying network administration. Now virtualization can be applied to telecom networks as well.
6. Rigorously apply "switch off" policies to ensure that redundant equipment is powered down and unused legacy technologies are permanently switched off.
7. Use lower energy-intensive power saving modes so that energy that is wasted, when networks are not in use, is minimized.
8. Use DC power distribution and DC equipment to avoid losses associated with multiple AC/DC conversions.
9. Consider the use of renewable energy sources, particularly for mobile cell stations and other mobile networking infrastructure.
10. Use smart grid solutions to enable more detailed analysis of energy consumption patterns, as well as benchmarking between sites.

6.5 Desktop energy checklist

Here is a handy checklist that an IT manager can use to improve the sustainability performance of the organization's desktop infrastructure:

1. Implement group policies regarding the setting of power options on computer kit, including sleep and hibernation settings, and keeping machines turned off at night.
2. Purchase equipment that meets specifically EPEAT, Energy Star or Intelligent energy – Europe guidelines for environmental performance.
3. Use specialized power management software applications to extend power usage data collection and reporting capabilities.
4. Work with staff to help them understand and be aware of the opportunity for energy savings in their interactions with computers.
5. Since network switches consume more power when running at gigabit Ethernet speeds, consider running the links at 10 or 100 Mbit/s.
6. Use virtualization techniques to deploy desktops on remote central servers, so that lower power devices can be used as thin clients.
7. Managing desktop infrastructure impacts a number of non-IT groups, including facilities, procurement and business services. It is important to bring together a team that represents all these interests.

8. Identify an executive sponsor who is responsible for the overall strategic plan regarding the greening of desktop infrastructure. Set up a green IT champions team to work under the executive sponsor.
9. Use energy data, usage patterns, power draw and an up-to-date asset inventory to optimize the desktop infrastructure.

6.6 Broadcasting checklist

Here is a handy checklist that a manager can use to improve the sustainability performance of the organization's broadcasting infrastructure:

1. Since computers are now widely used as tools in broadcasting, there should be clear group policies regarding the energy management of PCs, including power management profiles, "switch-off" policies and the purchase of more energy-efficient devices.
2. A number of broadcast organizations have established data centers and should employ PUE-based metrics to understand and manage their energy use.
3. Broadcasting data centers should also manage heating and cooling, through use of hot/cold aisles, fresh air cooling, use of structured cabling to prevent heat build-up, and water-based cooling methods.
4. With media professionals unhappy to risk continuity of service, much broadcasting equipment stays on. Broadcasters need to build switching off policies and practices for non-PC equipment as well as PC equipment.
5. Use industry-wide carbon calculators, such as the BBC's Albert, and green production guidelines, such as the guide from the Producers Guild of America, to measure and manage the carbon impact of your work.
6. Consider the use of renewable energy sources, as well as combined cooling Heat and power plants.
7. For data networks, use server consolidation to reduce network sprawl.
8. Virtualization is a related technique that saves energy while simplifying network administration.
9. Use lower energy-intensive power saving modes so that energy that is wasted, when networks are not in use, is minimized.
10. Use modern lighting equipment which is colour-corrected but low-energy in consumption.

7 Conclusions

The original Smart 2020 analysis only considered known technologies in determining both the direct and enabling pathways. In the case of the ICT sector direct footprint, if it does grow to 1.4 Gtonnes by 2020 and the total global economy was to reduce its footprint to 30 Gtonnes in line with McKinsey abatement cost curve projections, then the ICT sector would represent 4.7% of total emissions. If this were to happen, not only would the sector find itself under considerable scrutiny but, as a consequence, it could also find it increasingly difficult to market the enabling solutions.

Although the ICT industry is well used to radical and rapid technology change, so far it has not fully applied its innovation capabilities to deliver new ICT technologies for transformational energy reduction. There are a number of transformational advances in ICT technology that should be investigated. Some, such as quantum and optical computing, and polymeric semiconductors that are based on plastics in place of silicon and other inorganic materials, will help in the production of new, more efficient ICT devices. Others, of more direct relevance to this chapter, will help reduce the energy consumption of ICT at a system, rather than a product level. The ITU project on Future Networks has also explored many of these issues and Recommendation ITU-T Y.3021 presents a very good overview of potential game changers.

Fibre optics has already transformed the efficacy of high bandwidth data transmission. The more data that can be manipulated, switched and transmitted as light rather than electrons, the more energy efficient the whole system will become. This is because light has an inherently higher carrying capacity and also because energy is used every time there is a light/electronic conversion. As fibre becomes more prominent in the local loop the possibility of completely eliminating the need for local exchange infrastructure becomes apparent, with light consolidators taking the traffic directly to a main network node. In principle, a whole country could be connected in this way with only a handful of core network nodes.

As demonstrated a number of times in this document, many ICT systems today are designed to respond to their maximum data or processing demand but that their energy consumption often does not fall in response to falling demand. The introduction of energy proportional computing and networks would address this issue head on. It requires hardware and software working in harmony to make power consumption proportional to data processing demand.

At a network level it could be further developed such that traffic would be routed in a way that minimizes system-wide energy consumption. This may include traffic processing such as traffic aggregation, multiple path routing, and network coding and will require an active sleep mode in network node equipment.

7.1 Suggestions for ITU-T SG 5

The scope of this document covers a wide number of uses of technology in modern ICT organizations. What is clear that each type of ICT organization has its own set of recommended practices, check lists and key performance indicators. However, there is much more work that needs to be done.

A number of areas have been identified where there is need for initial or further studies in order to develop standards of practice. ITU-T Study Group 5 is working on a series of activities relating to ICTs and climate change[74]. A number of issues listed in this document deserve further work, and it is our recommendation that ITU-T SG 5 initiates studies in these areas:

- Of the four areas under consideration in this document, much more work has been done on creating a set of metrics and standards for data centers than for desktop infrastructure, broadcasting services and networks. The latter areas need the same level of definition, industry-wide acceptance and adoption of metrics and standards as has been achieved so far with data centers.
- A new ITU-T Recommendation on metrics for data centersis needed which integrates energy consumption metrics with metrics relating to business strategy and business use. It is possible to turn off sections of the data center in line with business needs and yet improve the PUE score. This feels counter-intuitive with good business strategy. We need to see metrics in this regard where better metric scores align with better business practice. Could the use of metrics based on watts per gigabyte of data, or watts per user provide metrics that align better with business practice?
- Standard specifications are needed on the interface of a DC power feeding system and its architecture.
- There are considerable energy efficiency gains in the area of cooling, including fresh air cooling, direct air economizers and indirect air economizers, but further studies are needed to show how these benefits can be introduced and managed in data centers. As ETSI and ASHRAE are developing work items in this area, one possible way might be for ITU-T SG 5 to work jointly with these bodies.
- Organizations that are seeking to manage desktop infrastructure can benefit from access to energy consumption data regarding ICT equipment, particularly if this data can be integrated into their energy

[74] Study Group 5 is the ITU-T Study Group responsible for studies on methodologies for evaluating ICT effects on climate change and publishing guidelines for using ICTs in an eco-friendly way. Under its environmental mandate, SG 5 is also responsible for studying design methodologies to reduce environmental effects, for example, recycling of ICT facilities and equipment. www.itu.int/net/ITU-T/info/sg05.aspx.

management applications. However, data from organizations such as Energy Star and EPEAT are currently not available via API access. ITU-T SG 5 can define standards by which such data can be shared in open formats.

- Most metrics relating to desktop infrastructure apply to individual machines as opposed to a divisional or organizational footprint, where much work needs to be done, both in terms of metrics and on best practice frameworks.
- Thanks to a number of studies, it is possible to understand what good practice looks like in terms of energy utilization in data centers. However, there is no such depth of information available when it comes to benchmarking of desktop infrastructure. A possible model could be the information available to mobile operators through GSMA's Mobile Energy Efficiency benchmarking service.
- Metrics and frameworks for best practice are needed on energy stations needed to power mobile network nodes.
- Although next generation networks (NGN) are expected to deliver 30-40% energy savings compared to traditional networks, a study is needed to capture the sources of energy savings in NGNs so that their benefits are not lost.
- Although there are metrics relating to energy consumption of DSLAMs, there is a need for energy metrics that apply across an entire network.
- Network equipment needs power saving modes which can be fully operable at low or no traffic periods. Standards are needed for such modes to be implemented fully across networks.
- A study is needed on energy savings possible through the use of alternative power schemes in cellular base stations, including alternative energy sources as well as optimized methods where diesel generators are run for a few hours at full power to charge batteries, and then the generator is switched off at other times while the station runs on battery power.
- A study is needed on the energy efficiency metrics applicable in the broadcasting industry, covering production, lighting, storage, post-production, transmission and networking.
- A study is needed on the relative sustainability impacts of terrestrial, cable, satellite and online distribution channels.
- For further work, guidance could be provided on a solution to the following problem: a person or organization needs to procure a basket of ICT services – what is the best combination of transmission system(s) to choose from in order to meet the service requirements and have the least environmental impact? The available technologies include: broadcast services (TV and radio), mobile cellular (2,3, and 4G), fibre (passive optical network and point-to-point), twisted pair, Ethernet (LAN), WLAN and cable (TV) networks.
- Overall, the broadcasting industry has not benefited from the sort of wide-ranging work that has been done in other sectors, such as data centers where there is considerable sophistication in measuring and managing environmental performance.
- A study is needed on the energy efficiency metrics applicable in the broadcasting industry, covering production, lighting, storage, post-production, transmission and networking.
- A study is also needed on the relative sustainability impacts of terrestrial, cable, satellite and online distribution channels.

8 Glossary

API	Application Programming Interface
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
BAU	Business-As-Usual
BREEAM	Building Research Establishment Environmental Assessment Method
CCHP	Combined Cooling Heat and Power plants
CLF	Cooling Load Factor
CPE	Customer Premises Equipment
CRAC	Computer Room Air Conditioning unit
CRAH	Computer Room Air Handlers
CRM	Customer Relationship Management
CUE	Carbon Usage Effectiveness
DCMI	Data Center Manageability Interface
DECT	Digital Enhanced Cordless Telecommunications
DPEE	Data center Performance Per Energy
DSLAM	Digital Subscriber Line Access Multiplexer
DTT	Digital Terrestrial Television
EPA	US Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
GEC	Green Energy Coefficient
GHG	Greenhouse Gas Emissions
GPO	Group Policy Object
GSMA	GSM Association
IPMI	Intelligent Platform Management Interface
IPTV	Internet Protocol Television
ITEE	IT Equipment Energy efficiency
ITEU	IT Equipment Utilization
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environment Design, a rating system for the design, construction and operation of high performance green buildings
NGN	Next Generation Network
NPC	Normalized Power Consumption
P2P	Peer-to-peer, or point-to-point
PLF	Power Load Factor

POE	Power Over Ethernet
PoP	Point of Presence
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
PUE	Power Usage Effectiveness
PUE	Power Usage Effectiveness
SMASH	System Management Architecture for Server Hardware
SSD	Solid-State Drive
UPS	Uninterruptible Power Supplies
VoD	Video on Demand
VoIP	Voice over Internet Protocol
WBCSD	World Business Council on Sustainable Development
WOL	Wake-on LAN
WRI	World Resources Institute
WUE	Water Usage Effectiveness
WUE_{site}	Water Usage Effectiveness, related to consumption at a site
WUE_{source}	Water Usage Effectiveness, related to source consumption

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