European Commission

# Best Environmental Management Practice in the Telecommunications and ICT Services Sector

*Background Report for the development of an EMAS Sectoral Reference Document*

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# Abstract

This background report provides an overview of techniques that may be considered **Best Environmental Management Practices** (BEMPs) in the telecommunications and ICT services sector. It is intended to provide a basis for discussions between the European Commission and experts from the sector with the aim to develop an EMAS Sectoral Reference Document for the sector.

The proposed BEMPs are intended to support the efforts of all Telecommunications and ICT services providers to improve their environmental performance across all significant environmental aspects (energy consumption, resource consumption, etc.). Techniques are applicable at different lifecycle stages (planning and design, installation, operation, end-of-life management, etc.) and on different ICT assets (software, data centres, etc.). The report gives a wide range of information (environmental benefits, economics, indicators, benchmarks, references, etc.) for each of the proposed best practices, which are grouped as follows:

- Cross-cutting measures, which are applicable by any company of the sector: environmental management system, procurement of sustainable services and products, waste management, optimisation of end-user device energy consumption, etc.
- Data centre related measures, which are specific to data centre operators (and their suppliers) or server owners, mainly to reduce their energy consumption: cooling and airflow management, server virtualisation, data management, etc.
- Telecommunications network related measures, which are specific to telecommunication operators (and their suppliers) and aim at better managing existing networks, at installing greener network equipment and reducing the impact of building or renovating network infrastructures.
- "Greening by ICT" measures, which refer to solutions developed by software developers and telecommunication service providers to improve the environmental performance in other sectors of the economy.

# Résumé

Ce rapport présente une revue des techniques qui peuvent être considérées comme **meilleures pratiques de management environnemental** (MPMEs) dans le secteur des télécommunications et des technologies de l'information et de la communication. Il entend fournir une base de discussion entre la Commission Européenne et des experts du secteur dans le but de développer un document de référence sectoriel EMAS pour ce secteur.

Les MPMEs décrites dans ce rapport visent à soutenir les efforts des entreprises du secteur, en vue d'améliorer leurs performances environnementales en ce qui concerne tous les aspects environnementaux significatifs (consommations d'énergie et de ressources, production de déchets, etc.). Le rapport présente un large éventail de données (bénéfices environnementaux, coûts, indicateurs, benchmark, références, etc.) pour chacune des meilleures pratiques proposées. Elles peuvent être mises en œuvre à différentes étapes du cycle de vie (développement, installation, gestion de la fin de vie, etc.) et concernent différents types d'actifs informatiques (logiciels, centres de données, etc.). Ces MPMEs sont regroupées de la manière suivante :

- Mesures transversales, pouvant être adoptées par n'importe quelle entreprise du secteur: système de management environnemental, achats responsables, gestion des déchets, etc.
- Mesures pour les centres de données (leurs gestionnaires, les propriétaires des serveurs, etc.), principalement en vue de réduire leurs consommations d'énergie : gestion des données, virtualisation de serveur, optimisation de la ventilation et du refroidissement, etc.
- Mesures pour les réseaux de télécommunication (leurs opérateurs, leurs installateurs, etc.), visant à mieux gérer les réseaux existants, à installer des équipements plus performants au niveau environnemental et à réduire les impacts liés à la création de nouvelles infrastructures.
- Mesures d'amélioration de la performance environnementale d'autres secteurs économiques par le biais des solutions proposées par des développeurs et opérateurs télécom.

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# List of Abbreviations

| | |
|---|---|
| AC | Alternative Current |
| ADEME | Agence De l'Environnement et de la Maîtrise de l'Energie |
| ASIP | Application Specific Instruction Processor |
| BAT | Best Available Technique |
| BEMP | Best Environmental Management Practice |
| BIOS | Basic Input Output System |
| BREF | Best Available Technique Reference Document |
| BSC | Base Station Controller |
| BSS | Business Support Systems |
| BT | British Telecom |
| BTS | Base Transceiver Station |
| CAPEX | Capital Expenditure |
| CF | Compress and Forward |
| CHP | Combined Heat and Power |
| CO | Central Office |
| CO2 | Carbon Dioxide |
| CoMP | Coordinated Multi-Point |
| CPU | Central Processing Unit |
| CRAC | Computer Room Air Conditioners |
| CRAH | Computer Room Air Handlers |
| CUE | Carbon Usage Effectiveness |
| DAS | Distributed Antenna System |
| DC | Direct Current |
| DCeP | Data centre Energy Efficiency |
| DCiE | Data centre Infrastructure Efficiency |
| DEMS | Data centre Management System |
| DF | Decode and Forward |
| DMIMO | Distributed Multiple-Input Multiple-Output |
| DSL | Digital Subscriber Line |
| DSLAM | Digital Subscriber Line Access Multiplexer |
| DTX | Discontinuous Transmission |
| EARTH | Energy Aware Radio and neTwork tecHnologies |
| EbUA | Energy per bit and Unit Area |
| EC | European Commission |

| | |
|---|---|
| EDGE | Enhanced Data for GSM Evolution |
| EEE | Electronic and Electrical Equipment |
| ELV | Exposure Limits Value |
| EMAS | European Eco-Management and Audit Scheme |
| EMF | Electromagnetic Fields |
| EPA | Environmental Protection Agency |
| EPEAT | Electronic Product Environmental Assessment Tool |
| ETSI | European Telecommunications Standards Institute |
| EU | European Union |
| FTTN | Fibre To The Node |
| GEC | Green Energy Coefficient |
| GeSI | Global e-Sustainability Initiative |
| GHG | Green House Gas |
| GHz | Giga Hertz |
| GIFAM | Groupement Interprofessionnel des Fabricants d'Appareils d'Equipement Ménager |
| GPON | Gigabit Passive Optical Network |
| GPRS | Global Packet Radio Service |
| GSM | Global System for Mobile communication |
| GSM | Global System for Mobile Association |
| HFC | Hybrid Fibre Coaxial |
| Hz | Hertz |
| ICNIRP | International Commission on Non-Ionising Radiation Protection |
| ICT | Information and Communications Technologies |
| IEA | International Environment Agency |
| IED | Industrial Emissions Directive |
| IMS | IP Multimedia System |
| IP | Internet Protocol |
| IREC | Institut de Recherche Economique Contemporaine |
| IT | Information Technologies |
| ITU | International Telecommunication Union |
| JRC | Joint Research Centre |
| kWh | kilowatt hour |
| LCA | Life Cycle Assessment |
| LPI | Low Power Idle |
| MIMO | Multiple-Input Multiple-Output |
| MSC | Mobile Switching Centre |

| | |
|---|---|
| MWh | megawatt hour |
| NACE | Nomenclature Statistique des Activités Economiques dans la Communauté Européenne |
| NIC | Network Interface Card |
| NRDC | Natural Resources Defense Council |
| NREL | National Renewable Energy Laboratory |
| NTT | Nippon Telegraph and Telephone Corporation |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| OLT | Optical Line Terminal |
| ONU | Optical Network Unit |
| OPEX | Operational Expenditure |
| ORC | Organic Rankine Cycle |
| OSS | Operational Support Systems |
| OXC | Optical Cross-Connects |
| PA | Power Amplifier |
| PBB | Polybromobiphenyls |
| PBDE | Polybromodiphenylethers |
| PON | Passive Optical Network |
| PPE | Power to Performance Effectiveness |
| PtP | Point-to-Point optical |
| PUE | Power Usage Effectiveness |
| QoS | Quality-of-Services |
| RAT | Radio Access Technology |
| RF | Radio Frequency |
| ROADM | Reconfigurable Optical Add-Drop Multiplexers |
| ROI | Return On Investment |
| SCF | Store-Carry-and-Forward |
| SiNAD | Signal to Noise and Distortion |
| SNR | Sub Network Router |
| SPUE | Server Power Usage Effectiveness |
| SRD | Sectoral Reference Document |
| SSD | Solid State Drive |
| TDM | Time Division Multiplexing |
| TWG | Technical Working Group |
| UK | United Kingdom |
| UMTS | Universal Mobile Telecommunications System |
| UNEP | United Nations Environment Programme |

| | |
|---|---|
| UPS | Uninterruptible Power Supply |
| US | United States |
| VDSL | Very high bit-rate Digital Subscriber Line |
| WEEE | Waste Electrical and Electronics Equipment |
| Wh | Watt hour |
| WiMAX | Worldwide Interoperability for Microwave Access |
| WUE | Water Use Efficiency |

# Preface

## Introduction

This background report provides an overview of techniques that may be considered **Best Environmental Management Practices** (BEMPs) in the telecommunications and ICT services sector. The document was developed by Ernst and Young and Associés (France), under a contract with the European Commission's Joint Research Centre (JRC), on the basis of desk research, interviews with stakeholders and discussions with technical experts via the forum of a Technical Working Group (TWG) comprising experts from industry, academia, NGOs and public administration.

This background report is intended to provide a basis for further discussions between the JRC and the TWG. The final findings will be presented in a best practice report produced by the JRC ("JRC Scientific and Policy Report on Best Environmental Management Practice in the Telecommunications and ICT services Sector"). Its technical content will then be used for the development of an EMAS Sectoral Reference Document (SRD), as illustrated below. The whole structured process is outlined in the guidelines on the *"Development of the EMAS Sectoral Reference Documents on Best Environmental Management Practice"* (European Commission, 2014), which are available online[1].

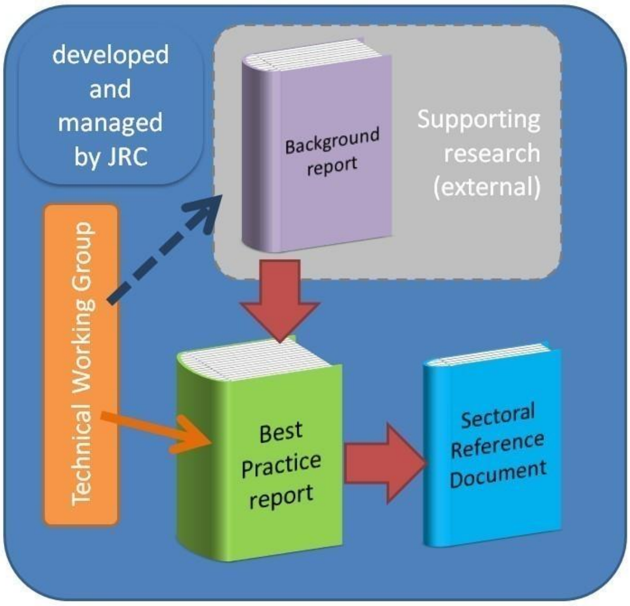


**Figure 1: The present background report in the overall development of the Sectoral Reference Document (SRD)**

Companies from the telecommunications and ICT services sector interested in implementing best practice to improve their environmental performance are recommended to refer to the final Best Practice Report that will be available on-line[2] as soon as it is finalised and published.

1 http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf

2 The Best Practice Report will be available online at: http://susproc.jrc.ec.europa.eu/activities/emas/telecom.html

## Background

EMAS (the EU Eco-Management and Audit Scheme) is a management tool for companies and other organisations to evaluate, report and improve their environmental performance[3]. To support this aim, and according to the provisions of Art. 46 of the EMAS Regulation (EC No. 1221/2009), the European Commission is producing SRDs to provide information and guidance on BEMPs in several priority sectors, including the telecommunications and ICT services sector.

Nevertheless, it is important to note that the guidance on BEMP is not only for EMAS participants, but rather it is intended to be a useful reference document for any relevant company that wishes to improve its environmental performance or any actor involved in promoting best environmental performance.

## Content

This background report describes proposals of BEMPs for the telecommunication and ICT services sector.

BEMPs encompass techniques, measures or actions that can be taken to minimise environmental impacts. These can include technologies (such as more efficient equipment) as well as organisational practices (such as staff training).

An important aspect of the BEMPs proposed in this document is that they are proven and practical, i.e.:

- They have been implemented at full scale by several companies (or by at least one company if replicable/applicable by others);
- They are technically feasible and economically viable.

In other words, BEMPs are demonstrated practices that have the potential to be taken up on a wide scale in the telecommunication and ICT services sector, yet at the same time are expected to result in exceptional environmental performance compared to current mainstream practices.

A standard structure is used to outline the information concerning each BEMP, as shown in Table 1.

**Table 1: Information gathered for each BEMP**

| Category | Type of information included |
|---|---|
| **Description** | Brief technical description of the BEMP including some background and details on how it is implemented. |
| **Achieved environmental benefits** | Main potential environmental *benefits* to be gained through implementing the BEMP. |
| **Environmental indicators** | Indicators and/or metrics used to monitor the implementation of the BEMP and its environmental benefits. |
| **Cross-media effects** | Potential *negative* impacts on other environmental pressures arising as side effects of implementing the BEMP. |

[3] Further information on EMAS is available at www.emas.eu.

| | |
|---|---|
| **Operational data** | Operational data that can help understand the implementation of a BEMP, including any issues experienced. This includes actual and facility-specific performance data where possible. |
| **Applicability** | Indication of the type of facilities or processes in which the technique may or may not be applied, as well as constraints to implementation in certain cases. |
| **Economics** | Information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, decreased waste charges, etc.). |
| **Driving force for implementation** | Factors that have driven or stimulated the implementation of the BEMP to date. |
| **Reference organisations** | Examples of organisations that have successfully implemented the BEMP. |
| **Reference literature** | Literature or other reference material cited in the information for each BEMP. |

Proposals of sector-specific Environmental Performance Indicators and Benchmarks of Excellence are also derived from the proposed BEMPs. These aim to provide organisations with guidance on appropriate metrics and levels of ambition when implementing the BEMPs described.

- Environmental Performance Indicators represent the metrics that are employed by organisations in the sector to monitor either the implementation of the BEMPs described or, when possible, directly their environmental performance.
- Benchmarks of Excellence represent the highest environmental standards that have been achieved by companies implementing each related BEMP. These aim to allow all actors in the sector to understand the potential for environmental improvement at the process level. Benchmarks of excellence are not targets for all organisations to reach but rather a measure of what is possible to achieve (under stated conditions) that companies can use to set priorities for action in the framework of continuous improvement of environmental performance.

Conclusions on sector-specific Environmental Performance Indicators and Benchmarks of Excellence are drawn by the TWG at the end of its interaction with the JRC. Therefore the proposals for indicators (and, eventually, for benchmarks) contained in this background report are to be considered no more than preliminary proposals from the authors of this background report.

### Sources of information and development of the document

This background report was elaborated between June 2015 and October 2016, and it includes inputs from the technical working group established for this sector, which had its kick-off meeting in November 2015.

This background report was developed by Ernst & Young France. Many technical descriptions were consulted in the scientific literature and from relevant technical reports, which are publicly available. Further information were obtained directly from telecommunications and ICT services providers.

### Structure

Following a brief description of the context and scope of this document, Chapter 1 ('General information about the Telecommunications and ICT Services sector') provides some background information on the Telecommunications and ICT Services sector:

- Section 1.2 regarding general information on the sector (Telecommunications and ICT Services uses, turnover and employment)
- Section 1.3 regarding environmental issues (direct and indirect aspects, environmental pressures)
- Section 1.4 regarding the use of environmental management systems in the sector.

The main content of this document are the best environmental management practices (BEMPs) for the Telecommunications and ICT Services sector, described in Chapters 2 to 5:

- Chapter 2 **"Cross-cutting measures"** gathers practices that can be implemented by any actor of the telecommunications and ICT services sector (implementation of an environmental management system, deployment of a green procurement policy, prevention and management of Waste Electrical and Electronic Equipment, use of renewable energy);
- Chapter 3 **"Data centres"** focuses on techniques specific to data centres (cooling and airflow management, server virtualisation, etc.) and referenced within the CENELEC Technical Report *CLC/FprTR 50600-99-1*;
- Chapter 4 "**Telecommunication networks**" deals with techniques aiming at better managing existing networks (in terms of energy consumption and electromagnetic field issues), at installing more energy-efficient network equipment and reducing the impact of building or renovating network infrastructures;
- Chapter 5 "**Improving the environmental performance in other sectors ("Greening by ICT")**" demonstrates how ICT can reduce environmental impacts in other sectors based on real examples from companies in the telecommunications and ICT service sector.

Chapter 6 "**Applicability**" is developed in three sections.

The first section explains the relations between the BEMPS, and give an overview of the applicability of the BEMPs to organisations (telecommunication operator, data centre operator, etc.), lifecycle stages (planning and design, installation, operation, end-of-life management, etc.) and ICT assets (software, data centre, etc.).

The purpose of the second section is to facilitate use of this document by small and medium sized enterprises (SMEs).

The third section summarises the environmental pressures tackled by the different BEMPs.

## List of BEMPs and indicators

The table below (Table 2) summarises the different BEMPs that are described in this background report, as well as the recommended performance environmental indicators. The number given before the title of each BEMP refers to the chapter and section number.

**Table 2: Overview of the different BEMPs and environmental performance indicators**

| BEMP | Short description | Recommended indicator |
|---|---|---|
| **2. Cross-cutting measures** | | |
| 2.2 Making the best use of an environmental management system | ICT facilities have important environmental impacts through energy consumption, water consumption and waste generation. It is particularly important for telecommunication and ICT services companies to monitor their environmental impacts and implement an environmental management system to systematically minimise these impacts. It is considered best practice to:<br>• Define the organisation's needs and audit the existing ICT equipment, services and software.<br>• Measure, monitor and manage the environmental performance of ICT equipment infrastructure and facilities.<br>• Set objectives and action plans based on benchmarking and best practices. | • Implementation of an asset management system certified ISO 55001 (Y/N)<br>• Share of facilities or sites with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS verified, ISO 14001 certified<br>• Share of facilities or operations measuring and monitoring energy use and water consumption as well as waste management<br>• Share of staff provided at least once with information on environmental objectives and training on relevant environmental management actions<br>• Energy use (in kWh) per unit of turnover (€) or network traffic (Terabyte) (for telecommunication network operators)<br>• Power Usage Efficiency (PUE) (for data centres)<br>• WEEE generation (in kg or tonnes) per unit of turnover (€)<br>• Water consumption (m3) per unit of turnover (€) or building surface (m2)<br>• Total carbon emissions (in tCO2eq.) for scope 1 and 2<br>• Total carbon emissions compensated (in tCO2eq.) through Clean Development Mechanisms (CDM)<br>• Carbon emissions (in tCO2eq.) for scope 1 and 2 per unit of turnover (€) |
| 2.3 Procurement of sustainable ICT products and services | The selection and deployment of ICT products and services needs to be based on an integrated strategy to tackle their inherent environmental impacts, such as their energy consumption and the use of specific materials such as rare metals and chemicals. It is considered best practice to:<br>• Assess the existing assets of ICT equipment and the needs in the | • Share of products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, top class energy label, Energy Star, etc.)<br>• Share of equipment purchased by the company complying with internationally recognized best practices or requirements (e.g. EU Codes of Conduct) |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | procurement process preparation.<br>• Include in the call for tender required specific environmental criteria to be met.<br>• Ensure proper use by end-users when deploying ICT equipment through asset management, communication and training.<br>• Establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact. | • Share of packaging purchased by the company made from recycled materials or awarded the Forest Stewardship Council label<br>• Share of the grade given to environmental criteria in calls for tenders<br>• Share of suppliers that have an environmental management system or energy management system in place (e.g. EMAS verified, ISO 14001 or ISO 50001 certified)<br>• Share of ICT products and services provided by the company to customers for which environmental information is available to customers |
| 2.4 Optimising energy consumption of end-user devices | There is a large potential to reduce the energy consumption of end-users equipment used within the offices and facilities of telecommunication and ICT services companies thanks to specific power management measures. It is best practice to:<br>• Adopt technical solutions:<br>o Installing appropriate devices in terms of energy performance and functionalities depending on the needs of users;<br>o Properly configuring equipment to minimise unnecessary functionalities and power consumption;<br>o Performing regular energy audits to check devices configuration and powered-off devices;<br>o Developing power management solutions using different types of power management modes (manual, default, through software) or using dedicated devices (smart power strip, etc.).<br>• Adopt organisational solutions:<br>o Assessing individual user acceptance;<br>o Raising users' awareness. | • Electricity use of offices (kWh) per unit of turnover or number of employees (excluding HVAC and lightning if possible)<br>• Share of end-user ICT devices having been configured by a power management specialist<br>• Share of end-user ICT devices audited on power management during the year<br>• Share of end-user ICT devices audited on power management at least once during their lifetime<br>• Share of staff trained at least once on energy savings |
| 2.5 Use of renewable energy | ICT facilities have high carbon footprint due to intensive energy use. Electricity generation from renewable sources such as biomass, solar, wind and geothermal cooling systems, significantly reduces their carbon footprint. It is considered | • Share of renewable electricity purchased (with Guarantees of Origin) out of the total electricity use (%)<br>• Share of renewable electricity produced on site out of the total electricity use (%) |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | best practice to:<br>• Purchase third-party green electricity.<br>• Produce one's own electricity, either on or off-site.<br>• Store electricity on-site in an efficient way. | • Green Energy Coefficient (GEC) = renewable energy use / total energy use (%)<br>• Carbon Usage Effectiveness (CUE) = CO2-eq. emissions from the energy consumption of the facility (kgCO2eq) / total ICT energy consumption (kWh) |
| 2.6 Waste management of ICT equipment | Waste management in the ICT sector is important because of the use of specific materials that need to be properly treated at end-of-life to avoid damage to human health and the environment. It also offers a large potential for limiting resource depletion through recycling. Specific waste management techniques can be implemented in order to improve waste management at each stage of the waste hierarchy in ICT companies. It is considered best practice to:<br>• Develop a waste prevention plan.<br>• Promote LCA-based eco-design through procurement.<br>• Increase the service life and limit the obsolescence of ICT equipment.<br>• Implement systems to enable re-use of ICT equipment.<br>• Ensure traceable collection and proper sorting of end-of-life ICT equipment. | • Share of facilities or sites with a certified zero waste management system or with a certified asset management system (% of facilities/sites)<br>• Average service life of ICT equipment to be calculated for different product groups (e.g. servers, routes, end-user devices)<br>• Share of WEEE generated from own operations recovered for reuse or refurbishment or sent for recycling<br>• Share of WEEE generated from clients recovered for reuse or refurbishment, or sent for recycling |
| **3. Data centres** | | |
| **3.2 BEMPs related to existing data centres** | | |
| 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment) | The energy consumption of data centres is responsible for a major share of their environmental impacts. It is therefore important for data centre operators to have a clear and detailed view on energy consumption at the appropriate granularity levels, and to systematically exploit all opportunities to minimise it. It is considered best practice to:<br>• Implement an energy management system (e.g. ISO 50001 or through EMAS).<br>• Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified to maximise any unused capability prior to new material investment.<br>• Install metering equipment capable | • Energy use of the data centre per floor area (kWh/m²)<br>• Power Usage Effectiveness (PUE)<br>• $KPI_{DCEM}$ Global KPI for Data Centre according to ETSI standard<br>• Share of facilities having an energy management system certified according to ISO 50001 or integrated in EMAS, or complying with the EU Code of Conduct on Data Centre Energy Efficiency or the "expected practices" of CLC/FprTR 50600-99-1.<br>• Share of ICT, cooling or power equipment with specific metering equipment (for measuring their use, energy consumption, temperature or humidity conditions)<br>• Share of staff provided with |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | of measuring energy consumption and environmental parameters at different levels (row, cabinet, rack, or ICT device level).<br>• Monitor and report key performance indicators on equipment utilisation, energy consumption and environmental conditions. | information on energy objectives or training on relevant energy management actions during the year |
| 3.2.3 Define and implement a data management and storage policy | Minimising the quantity of data stored onto drives and the computing capacity required to run applications, databases and services is a key measure to reduce the energy consumption of data centres by reducing the number of powered hardware (servers and storage devices). It is considered best practice to:<br>• Implement an effective data management and storage policy to minimise the share of stored data either unnecessary, duplicated or does not require rapid access.<br>• Deploy grid and virtualisation technologies to maximise the use of shared platforms.<br>• Consolidate existing services and decommission unnecessary hardware to reduce the number of highly resilient and reliable hardware powered (servers, networking and storage equipment).<br>When properly implemented, these techniques lead to a reduction of the hardware purchased which also results in significant material resources savings. | • Energy use (kWh) per rack<br>• Server PUE (SPUE) = (Server Input Power) / (Computation Useful Power)<br>• Average storage disks space utilisation (%)<br>• Average server utilisation (%)<br>• Share of servers virtualised (%)<br>• Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services |
| 3.2.4 Improve airflow management and design | The reliability of IT systems depends on environmental conditions (temperature, humidity, dust, etc.) that must be ensured by appropriate control of the indoor air quality. Airflow management for data centres aims at avoiding air recirculation and mixing of cooling air supplied and hot air rejected from equipment. It is considered best practice to:<br>• Implement a hot aisle / cold aisle configuration for ICT equipment to ensure that hardware shares an air flow direction without mixing cold and hot air.<br>• Ensure aisles separation and containment to avoid the recirculation of air around the servers.<br>• Segregate ICT equipment according to their environmental requirement (mainly humidity and temperature) and provide appropriate airflows to separate environmental areas. | • Air flow efficiency (fan power in kWh / fan airflow in m3/hour)<br>• Return Temperature Index (identification of air recirculation)<br>• Flow performance of the air handler<br>• Thermal performance of the air handler<br>• Rack cooling index (difference between allowable intake temperature and the one recommended by ASHRAE)<br>• Share of racks installed with hot aisle/cold aisle configuration (with containment)<br>• Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding airflow management and design, and installation of ICT equipment to optimise airflow management. |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | • Improve the floor and ceiling design to reduce bypass air flow, to prevent re-circulated air, and to reduce obstructions created by cabling or other structures.<br>• Adjust volumes and quality of supplied cooled air to the IT equipment needs (function of heat produced and environmental requirements), and provide a slight oversupply of air to minimise heated air recirculation.<br>Improved airflow management increases both the efficiency and the capacity of the cooling equipment, reduces the utilisation of fans and humidifiers (and their energy consumption) and minimise the production of waste heat. | |
| 3.2.5 Improve cooling management | Cooling is needed to remove the heat produced by ICT equipment in a data centre or a network room and to ensure the right operating conditions for ICT equipment to perform reliably. Sizing the necessary cooling system of a data centre depends on the environment where the data centre is located, on the efficiency of the IT equipment used in the data centre and on the airflow management performance. It is considered best practice to:<br>• Maintain the cooling system close to its original condition to preserve its efficiency.<br>• Review and adapt the cooling system capacity by shutting down unused equipment and better taking into account specific equipment operating requirements.<br>• Optimise and automate the cooling system output by connecting CRAC units or suing smart and multifactor units. | • COP (coefficient of performance): average cooling load (kW) / average cooling system power (kW)<br>• Share of data centre total energy use dedicated to the cooling system (%)<br>• Power Usage Effectiveness (PUE)<br>• Carbon Usage Effectiveness (CUE)<br>• Water Usage Effectiveness (WUE)<br>• Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency (parts 5.2, 5.4 and 5.5) or the Expected Practices of CLC/FprTR 50600-99-1 regarding cooling management |
| 3.2.6 Review and adjust temperature and humidity settings | ICT facilities are often overcooled, and the server intake temperature set point can be raised within the recommended or allowable temperature ranges (given in the manufacturer specifications) in order to reduce the cooling capacity and the energy consumption of the cooling system. A similar situation is generally observed regarding humidity, and the energy and water consumption of humidifiers can be reduced by allowing a broader range of humidity levels.<br>It is therefore considered best practice to:<br>• Review and raise temperature set | • Airflow Efficiency (fan power in kWh / fan airflow in m3/hour)<br>• Return Temperature Index (RTI)<br>• Share of facilities or sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding temperature and humidity settings |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | points of cooling systems if practical, to reduce cooling needs and maximise the use of economisers.<br>• Review and change humidity settings of cooling systems if practical, to reduce the needs for humidifiers. | |
| **3.3 BEMPs related to selecting and deploying new equipment for data centres** | | |
| 3.3.2 Selection and deployment of equipment for data centres | The selection and deployment of ICT devices as well as cooling and power supply equipment needs to be based on an integrated strategy to minimise their overall environmental performance (energy use, water use, embodied energy, resource efficiency). It is considered best practice to:<br>• Implement a green procurement policy specific to data centres equipment, from process preparation to bid evaluation.<br>• Select and install environmental-performant servers and storage equipment; i.e. equipment with enable power management features, equipment suitable for the data centre power density and cooling delivery capabilities, equipment meeting the expected environmental conditions (temperature and humidity), etc.<br>• Select environmental-performant cooling equipment; i.e. equipment with high CoP or variable speed controls, appropriately sized cooling units, centralised cooling systems, economisers, etc..<br>• Select environmental-performant power equipment; i.e. highly efficient UPS, modular UPS, etc. | • Share of ICT products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, Energy Star, Blue Angel, etc.)<br>• Share of suppliers that have an environmental management system or energy management system in place (e.g. EMAS verified, ISO 14001 or ISO 50001 certified)<br>• Share of facilities that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding the selection and deployment of new ICT equipment / of cooling system / of new power equipment / of other data centre equipment.<br>• Average energy efficiency of UPS (given by manufacturers)<br>• Average COP of cooling equipment (given by manufacturers) |
| **3.4 BEMPs related to the deployment of new ICT services and software** | | |
| 3.4.2 Developing new ICT services and software minimising servers utilisation | While software does not directly consume energy, it greatly influences the energy efficiency of the ICT hardware on which it runs. However, a large share of software code does not take into account energy consumption, and opportunities exist to optimise software and reduce the energy consumption of servers. It is considered best practice to:<br>• Select energy efficient software that minimises power consumption of ICT equipment while running.<br>• Develop internally or outsourced energy-efficient software that uses the least energy to perform the | • Share of new acquired software for which energy performance has been used as a selection criteria (%)<br>• Share of new developed software for which the energy consumption has been used as a development criteria (%)<br>• Share of existing software which has been refactored (%)<br>• Share of software for which the energy use has been assessed (%)<br>• Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | required task.<br>• Monitor the energy consumption of software to assess the real performance of the acquired software, or to assess the opportunity of improving the energy efficiency of existing software.<br>• Refactor existing software to improve its energy efficiency. | 50600-99-1 regarding the development and deployment of new IT services. |
| **3.5 BEMPs related to new build or refurbishment of data centres** | | |
| 3.5.2 Planning of new data centres | When building or upgrading a data centre, the planning phase offers the most significant opportunities to ensure its environmental performance. Data centres are often oversized to allow future extensions, which generates energy inefficiencies. In many cases, the building can prevent the data centre from upgrading to new and more energy efficient equipment. It is considered best practice to:<br>• Limit the level of physical infrastructure resilience and service availability according to business requirements.<br>• Build a modular data centre to avoid oversizing and maximise infrastructure efficiency under partial and variable load conditions. | • Energy use of the data centre per floor area (kWh/m²)<br>• Power Usage Effectiveness (PUE)<br>• Share of sites that have implemented the best practices on the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres |
| 3.5.3 Reuse of data centre waste heat | As any electrical equipment, IT equipment requires power supply and produces waste heat while running. Data centres produce large quantities of waste heat, which is an opportunity for heat reuse. It is considered best practice to:<br>• Re-use the waste heat produced in some rooms of the data centre to provide low grade heating to industrial or office space (including other areas of the data centre). | • Energy Reuse Factor (ERF) (Total energy – Reused Energy ) / IT energy<br>• Energy Reuse Effectiveness (ERE) = Reuse energy / Total energy<br>• Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding reuse of data centre waste heat |
| 3.5.4 Design of the data centre building and physical layout | The physical layout of the data centre influences significantly its cooling system performance, since cooled areas (where racks are located) may be unnecessarily located close to internal heat sources (such as mechanical or electrical equipment) or in areas heated by external sources (e.g. solar radiation). It is considered best practice to:<br>• Minimise direct solar heating of the cooled areas of the data centre, in order to minimise cooling requirements.<br>• Locate cooling equipment in appropriate areas of the data centre, | • Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre building physical layout |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | such as areas with free air movement, areas with sufficient space to optimize cooling performance, areas free of obstructions and free of equipment generating heat. | |
| 3.5.5 Selecting the geographical location of the new data centre | The geographical location of the data centre has great influence on its future carbon and environmental impacts. It is considered best practice to:<br>• Select a location with environmental conditions improving the performance of side-economisers, offering opportunities for installing equipment for the production of renewable energy or limiting threats and natural disasters (such as flooding).<br>• Locate the data centre close to energy, cooling and heating sources, to minimise energy losses due to energy transport and to offer opportunities for the of carbon emissions (consumption of renewable energy, waste heat or free cooling).<br>• Minimise impacts of the building on the environment (noise, aesthetic impacts, needs for telecommunication networks and other infrastructures, etc.). | • Share of new facilities with free cooling solutions (air-side economisers, geothermal cooling, etc.)<br>• Share of new facilities with renewable energy production on site (photovoltaic panels, wind turbine, etc.)<br>• Share of new facilities with heat reuse systems<br>• Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre geographical location |
| 3.5.6 Use of alternative sources of water | Water is used in data centres for two purposes: cooling and humidification, which are intimately linked. In particular, evaporative chillers require significant amount of water. It is considered best practice to:<br>• Monitor water consumption from all sources in all data centre spaces.<br>• Limit impact on potable water resources by using non-potable water sources (rainwater, wastewater, etc.). | • Share of water consumed in data centres by source, such as mains water, rainwater or non-utility water sources<br>• Water consumption of the data centre per floor area ($m^3$ consumed /$m^2$ of data centre)<br>• Water Usage Effectiveness (WUE)<br>• Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding water sources |
| **4 Telecommunication networks** | | |
| 4.2 Improving the management of existing telecommunication networks | Due to end-user demand variability, traffic loads on telecommunication networks vary significantly over time and space. The energy consumption of modern telecommunications equipment is the highest when the equipment is operating at maximum traffic load, but it does not decrease much when the equipment is underutilised. A large part of the daily network energy | • Power consumption per customer or subscriber in kWh / customer or subscriber<br>• Mobile Network coverage Energy Efficiency (the area covered by the mobile network / the energy consumption) in $m^2$ / J<br>• Mobile Network data Energy Efficiency (the data volume delivered / the energy consumption) in bit / J |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | consumption is thus spent for providing full system capacity, even when the actual traffic demand is much lower. It is best practice to:<br>• Measure the energy consumption of network elements by using smart energy meters and automated analysis.<br>• Use smart stand-by functions to implement network energy management, and switch as many devices as possible to low consumption mode when the traffic load is low to adapt the overall capacity of the network to the demand.<br>• Use dynamic power scaling opportunities to adapt the operation mode of network equipment to low or moderate traffic period times.<br>• Take advantage of dynamic scheduling transmission to better manage data traffic, and to control the amount and the timing of data packet transmission.<br>• Provide energy-aware services to reduce the traffic demand at peak load, as well as the overall capacity of the network. | • Network minimum power consumption divided by network maximum power consumption (in %)<br>• Share of network nodes for which energy consumption is measured (in %)<br>• Share of network nodes for which dynamic power solutions (such as dynamic power scaling or dynamic scheduling transmission) are implemented (in %) |
| 4.3 Improving risk management for electromagnetic fields through assessment and transparency of data | Electromagnetic fields (EMF) are a public concern in relation to the growing telecommunication networks. Strict regulations have been defined and intense research works have been carried out to tackle this issue. It is best practice for telecom operators to:<br>• Improve risk management for electromagnetic fields through assessment and transparency of data on EMF exposure. | • Percentage of sites assessed for compliance with EMF limits;<br>• Percentage of the public expressing concerns about EMF from telecommunication networks. |
| 4.4 Selecting and deploying more energy-efficient telecommunication network equipment | Both mobile and wireline networks use ICT equipment that require electricity and specific environmental conditions to properly function. Telecommunication operators have the opportunity when selecting and deploying such materials within their networks to improve its energy efficiency by selecting and configuring appropriate equipment. It is best practice to:<br>• Privilege selection and deployment of the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks (more energy efficient technology, power management features, etc.). | • Percentage of broadband equipment meeting the Broadband Code of Conduct requirements in terms of energy consumptions<br>• Share of base stations with multi-standard solutions<br>• Average UPS System Efficiency<br>• Average COP of cooling systems<br>• Share of base stations with a Remote Radio Head or Active Antenna System |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | • Privilege deployment of integrated and multi-standard solutions, instead of multiple single-standard systems running in parallel and not properly configured.<br>• Privilege selection and deployment of the most energy-efficient cooling systems in base stations (e.g. passive cooling, simple fans, heat exchangers, etc.) and central offices (e.g. hot aisle / cold aisle blanking plates, hot air containments, air ducting, etc.).<br>• Privilege selection and deployment of the most energy-efficient UPS (e.g. high efficient UPS, modular UPS, etc.) in base stations and central offices.<br>• Privilege design of telecommunication sites maximising energy-efficiency by migrating distributed functions to central servers in wireline networks, moving radio equipment closer to the antenna, and using an appropriate design of UPS.<br>• Use software enabling energy savings all along the network, to implement virtualisation (for increasing equipment sharing and reducing the number of needed hardware equipment) or networking functions (for allowing a greater flexibility and efficiency of the network). | |
| 4.5 Installing and upgrading telecommunication networks | Beyond the installation of new energy efficient equipment on network sites, organisational solutions can deliver significant energy savings, for instance, by ensuring that unused equipment is plugged off and power and cooling supply are not oversized and optimised to the actual current needs. It is best practice to:<br>• Take advantage of technology transition (e.g. deploying 4G technology in existing base station sites) to optimize network sites (decommission of unused equipment, replacing of obsolete equipment, proper configuration of cooling systems, etc.) through the integration of such practices in a management process focused on upgrading base station sites. | • Mobile Network data Energy Efficiency (EEMN,DV)<br>• Mobile Network coverage Energy Efficiency (EEMN,CoA)<br>• Average lifetime of ICT equipment in network sites<br>• Share of ICT equipment decommissioned and removed from base station sites each year |
| 4.6 Reducing the environmental impacts when | Telecommunication and broadcasting infrastructures generate neighbourhood nuisances (aesthetic impact, noise from | • Percentage of sites shared with other operators<br>• Spread between the maximum |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| building or renovating telecommunication networks | generators and cooling system, etc.) and are responsible for land-use (potentially associated with biodiversity disturbance). To limit such impacts when building new infrastructures or when renovating existing ones, it is best practice to:<br>• Colocate ICT infrastructures, in order to limit the number of different infrastructures.<br>• Locate network infrastructures (fixe-lined, antennas, buildings, etc.) close to existing access roads and out of conservation areas<br>• Install noise reducing solutions, such as barriers, absorptive material or muflers. | legally authorised sound value in an area and the sound emitted by the equipment of a base station site (power generator and air conditioning system, in dB)<br>• Noise Reduction Coefficient (from 0 to 1) of the material used to lower the transmission of sound from the base station to the surroundings |
| 4.7 Minimising data traffic demand through green software | To minimise the environmental impacts of telecommunication networks operation and to avoid a rebound effect, a reduction in the growth rate of data traffic can play a significant role. This BEMP is dedicated to practices that can be implemented: either when developing new software or when optimizing existing software, and for both mobile applications (for smartphones and tablets) and computer software (for laptop and desktop), as well as web portals and web-based applications. It is best practice to:<br>• Design demand-adaptive software based on the assessment of end-users needs, in order to avoid energy over-consumption at usage phase and to limit the obsolescence of existing ICT devices.<br>• Assess software environmental impacts through LCA at development phase and performance measurement (CPU, RAM and energy utilisation) at usage phase.<br>• Develop more energy efficient software; e.g. providing different image resolutions, preferably connecting mobile devices via LAN or WLAN (rather than mobile network), or implement mobile apps' solutions when developing software for stationary equipment. | • Amount of data transferred in relation with software utilisation (bit / web page view or bit / min of mobile application use)<br>• Share of demand-adaptive designed software among the portfolio dedicated to internal or external use (published software)<br>• Share of software for which a LCA has been carried out among the portfolio dedicated to internal or external use (published software)<br>• Share of software for which the energy performance has been measured among the portfolio dedicated to internal or external use (published software)<br>• Share of existing software which has been refactored toward higher efficiency among the portfolio dedicated to internal or external use (published software) |
| **5 Improving the energy and environmental performance in other sectors ("greening by ICT")** | | |
| 5.2 Digitalization and dematerialization | It is best practice for telecommunication and ICT services providers to develop services to support digitalization and dematerialization of activities | • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Number of face to face meetings |

| BEMP | Short description | Recommended indicator |
|---|---|---|
| | (communication, transportation, etc.). ICT solutions such as video conferencing and online e-commerce services help organisations in any sector improve the efficiency of their activities by saving time and reducing expenses. These drastic changes offer opportunities for reducing the environmental impacts of many activities by reducing the consumption of resources and the emission of pollutants (including GHG). | avoided each year through the use of videoconferencing by clients<br>• Share of clients' employees using telecommuting solutions<br>• Share of periodical documents completely digitalized (e.g. invoices, administrative documents, journals, etc.) by clients<br>• Share of products and services sent online (in terms of turnover) by clients |
| 5.3 Data collection and communication | It is best practice for telecommunication and ICT services providers to develop data management systems that collect, aggregate, analyse and display information aimed at improving efficiency. Such solutions have supported organisations in all sectors improve decision-making process. These systems have been used for better managing energy demand, water supply, transportation, and farming inputs, leading to reducing resources consumption and related environmental impacts. | • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Annual energy savings (kWh) of clients<br>• Annual water consumption savings ($m^3$) of clients<br>• Annual reduction of consumables of clients<br>• Number of smart meters connected at clients' place |
| 5.4 System integration | It is best practice for telecommunications and ICT services providers to develop smart solutions in different sectors leading to more and more integrated infrastructures: energy grid, roads, buildings, etc. ICT technologies help connect the various systems in an integrated and dynamic system and can reduce environmental impacts by reducing energy consumption and the use of resources. | • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Annual energy savings (kWh) of clients<br>• Number of units connected to the grid (number of EVs, wind turbines, etc.) by clients<br>• Share of renewable electricity produced by clients integrated on grid |
| 5.5 Process activity and functional optimisation | It is best practice for telecommunications and ICT services providers to develop intelligent simulation, automation, redesign, or control modelling software to support companies optimise processes, activities, functions or services and help reduce environmental impacts by reducing energy consumption and the use of resources. | • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Annual energy savings (kWh) of clients<br>• Amount of material saved (kg) by clients<br>• Share of clients' products (€ turnover) using modelling to reduce use of materials |

# Executive summary

This background report provides an overview of techniques that may be considered **Best Environmental Management Practices** (BEMPs) in the telecommunications and ICT services sector. The document was developed by Ernst and Young and Associés (France), under a contract with the European Commission's Joint Research Centre (JRC), to support the development of an EMAS Sectoral Reference Document for the telecommunications and ICT services sector.[4]

This background report is intended to provide a basis for further discussions between the JRC and technical experts and stakeholders from the sector via the forum of a Technical Working Group (TWG). The final findings will be presented in a best practice report produced by the JRC ("JRC Scientific and Policy Report on Best Environmental Management Practice in the Telecommunications and ICT services Sector")[5].

### Target group

The proposed best environmental management practices (BEMPs) described in this report were identified as best practices that can support the efforts of all Telecommunications and ICT services providers, i.e. telecommunication operators, ICT consultancy firms, data processing and hosting companies, software developers and publishers, broadcasters, installers of ICT equipment and sites, etc. Large organisations that store and process large quantities of data of their clients, supply chain and / or products (e.g. public administrations, hospitals, universities, banks, etc.) can also find of relevance several of the proposed BEMPs.

### Scope

The document covers core business activities of organisations in the Telecommunications and ICT Services sector. It focuses on the following elements which are inter-linked:

- Data centres (servers, cooling equipment, power systems, etc.)
- End-user devices (computers and other peripheral equipment)
- Telecom infrastructure and networks (base stations, landlines, satellites, etc.)
- Software (programming, internet websites, applications, etc.)
- Broadcasting services (radio, television, internet, etc.)

Practices in the scope of other EMAS Sectoral Reference Documents and related Best Practice reports are excluded from this document, such as: the manufacturing, retailing, repairing and waste management of ICT equipment, the management of offices, and mobility (business travel and employee commuting).

Within the report, a distinction is made between:

- BEMPs that minimise the environmental impacts of Telecommunications and ICT Services providers, referred as "greening of ICT" practices;

[4] Further information on what are the EMAS Sectoral Reference Documents and how these are developed can be found in the guidelines on the "Development of the EMAS Sectoral Reference Documents on Best Environmental Management Practice" (European Commission, 2014), which are available online at http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf.

[5] The Best Practice Report will be available online at: http://susproc.jrc.ec.europa.eu/activities/emas/telecom.html

- BEMPs that refer to the solutions provided by Telecommunications and ICT Services companies to minimise the environmental impacts of other sectors, referred as "greening by ICT" practices.

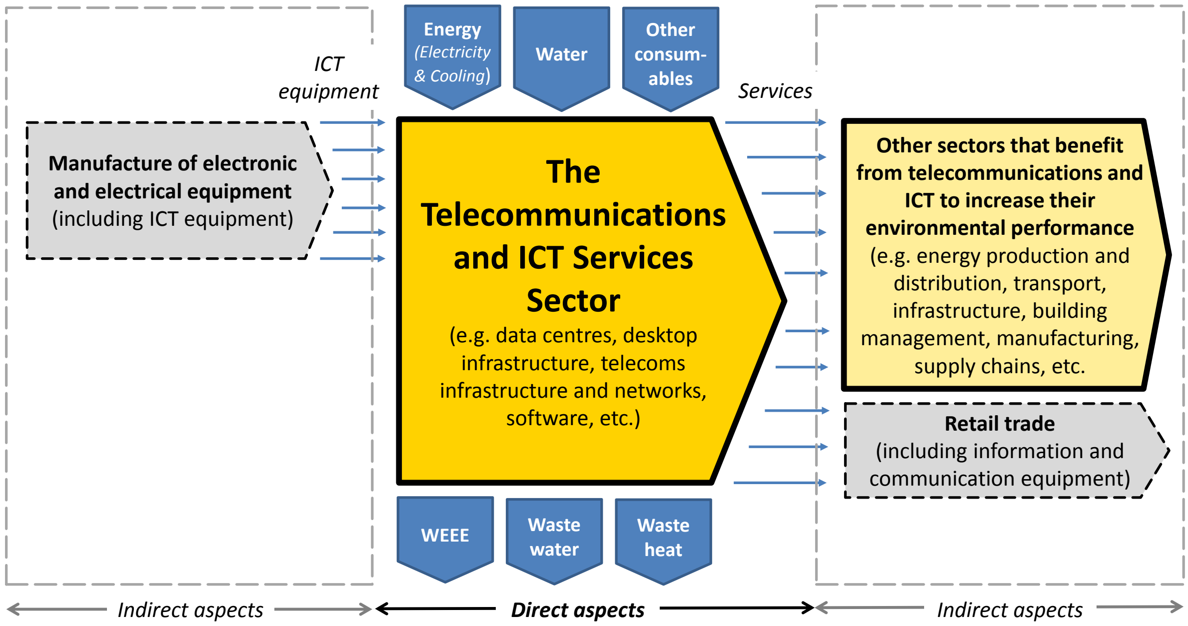


**Figure 2: Overview of the scope of the document**

The main environmental aspects and associated environmental pressures for the telecommunication and ICT services sector are presented in Table 3 (below). These environmental aspects were selected as the most relevant in the sector and are those that are covered in this document. However, the environmental aspects to be managed by specific organisations should be assessed on a case by case basis.

**Table 3: Main environmental aspects and environmental pressures related to the Telecommunications and ICT Services sector**

| Service / Activity | Main environmental aspects | Main environmental pressures |
|---|---|---|
| Data Centre | - ICT equipment (servers, storage devices, etc.)<br>- Software (processors)<br>- HVAC and power supply<br>- Buildings | - Electricity consumption and GHG emissions<br>- Resources consumption and WEEE generation<br>- Water consumption and waste water<br>- Noise emissions (generators and cooling compressors) |
| Telecommunication infrastructure and networks | - ICT infrastructure (antennas, cables, fibres, landlines, etc.)<br>- ICT equipment (transceivers, routers, switchers, etc.)<br>- HVAC and power supply<br>- Buildings (central offices, base stations, etc.) | - Energy consumption and GHG emissions (network equipment, cooling systems, transportation, etc.)<br>- Resources consumption and WEEE generation<br>- Electromagnetic Field exposure<br>- Noise emissions (generators and |

| | | |
|---|---|---|
| | - Terminals (phones, computers, modems, set-top boxes, etc.)<br>- Software (processors, controls, etc.) | cooling compressors)<br>- Changes to the landscape and habitats due to infrastructure deployment |
| End-user devices | - ICT equipment (computers, peripheral devices, etc.)<br>- Software | - Electricity consumption to power hardware and GHG emissions<br>- Resources consumption and WEEE generation |

## Content of the document

The proposed Best Environmental Management Practices are grouped into 4 areas:

### *A. Cross-cutting measures*

The cross-cutting measures are Best Environmental Management Practices that can be implemented by any actor of the telecommunications and ICT services sector. These BEMPs offer guidance on the design, implementation and monitoring of management frameworks for environmental issues. These frameworks are helpful in order to identify and to optimise environmental impacts across multiple processes, bearing in mind potential trade-offs between different impacts and lifecycle stages.

- **Making the best use of an Environmental Management System (EMS)** with the implementation of specific techniques to systematically minimise the environmental impact of ICT facilities by benchmarking existing use, and measuring and monitoring environmental performance.
- **Procurement of sustainable ICT products and services** which refers to the development of specific environmental criteria and their integration at each stage of the procurement process to minimise the environmental impact of ICT products and services. The implementation of a procurement process covers both upstream measures related to the purchase of ICT products and services and downstream measures with the development of environmental criteria for products provided to final users.
- **Optimising the energy consumption of end-user devices** used within the offices and facilities of telecommunication and ICT services companies by implementing technical solutions in the installation, configuration and use of such devices. The successful implementation of technical solutions also requires organisational measures to ensure individual acceptance and top management commitment.
- **Use of renewable and low-carbon energy** help ICT facilities reduce their environmental footprint by reducing GHG emissions associated with fossil fuel energy. It applies mainly to data centres and base stations facilities and can be implemented by using biomass co-generation, solar power, wind power or geothermal cooling systems. When renewable energy based system are not technically or economically feasible, natural gas based CHP can be considered.
- **Considering the ICT equipment end-of-life through waste prevention and fostering of reuse and recycling**, both for company's own ICT equipment and end-user devices that the company provides to its clients along with the services it sells. Specific effective measures include the promotion of eco-design through LCA and procurement, the increase of ICT equipment service life through thorough maintenance and controls, and the effective collection and sorting of end-of-life equipment.

### *B. Data Centres*

These are techniques specific to data centres. The structure of the BEMPs is based on the CENELEC Technical Report *CLC/FprTR 50600-99-1*, which is a development of the best practices identified in the EU Code of Conduct for Energy Efficiency in Data Centre[6]. In addition to energy aspects, the BEMPs also cover other relevant environmental aspects, e.g. resource consumption, land use, water use, or noise:

1. **BEMPs related to existing data centres** provide practice-oriented information to data centre operators that wish to improve the energy performance of their existing data centres. Only the direct aspects of energy, i.e. those controlled by the data centre operator, are covered and the focus is mainly on the operation of data centres. Colocation providers and customers as well as other suppliers and customers of ICT services may also find the BEMPs useful to support the procurement of services that meet environmental or sustainability criteria. The following measures are considered best practice:
    - Implement an energy management system for data centres (including measuring, monitoring and managing equipment)
    - Define and implement a data management and storage
    - Improve airflow management and design
    - Improve cooling management
    - Review and adjust temperature and humidity settings
2. **BEMPs on selecting and deploying new equipment and services for data centres** give key technical information to implement a policy for the procurement of sustainable ICT services and products when purchasing ICT devices (servers, storage disks, network interfaces, etc.), as well as cooling and power supply equipment for existing or new build data centres. The main goal of data centre operators and their clients (which can own servers) is to minimise the number of hardware used and their direct and indirect energy consumption. However, these measures must carefully consider relevant trade-offs. For instance, some energy-efficient cooling technologies have significant water use and replacing existing equipment causes resource and embodied energy consumption. It is therefore very important that the selection and deployment of ICT as well as power and cooling equipment is based on an integrated strategy to minimise their overall environmental performance (energy use, water use, embodied energy, resource efficiency).
3. **BEMPs on deployment of new ICT services and software** are dedicated to software. If it does not directly consume energy, it greatly influences the energy efficiency of the ICT hardware on which it runs. However, a large share of software code does not take into account energy consumption, and opportunities exist to optimise software and reduce the energy consumption of servers. A company can select software which uses the least energy to perform the required tasks, as well as develop energy efficient software.
4. **BEMPs on new build or refurbishment of data centres** focus on planning and designing data centre in a way that minimises its future energy and water consumption when operating. Data centres are often over-dimensioned with large tolerances for operational and capacity changes. This leads to inefficiencies. If not properly located and designed, opportunities for deploying waste heat reuse, renewable energy production and consumption or free

[6] The EU Code of Conduct for Energy Efficiency in Data Centre is available online at: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

cooling, or for minimising other environmental impacts (aesthetic impacts, noise, etc.) can be limited. The following measures are considered best practice:

- Consider environmental aspects in the planning of new data centres
- Reuse of data centre waste heat
- Design of the data centre building and physical layout minimising direct solar heating of cooled areas and appropriately locating the cooling equipment
- Selecting the geographical location of the new data centre to exploit opportunities for waste heat reuse, renewable energy and free cooling and to minimise environmental aspects
- Use alternative water sources

### *C. Telecommunication networks*

These are techniques specific to telecommunication operators (and their suppliers). They aim at better managing existing networks, at installing more environmental friendly network equipment, at reducing the impacts of building or renovating network infrastructures and at minimising data traffic through the following techniques:

- **Improving the energy management of existing telecommunication networks**, with a better knowledge of the energy consumption of the network, and several technical solutions that intend to minimise data traffic peak loads (to avoid network oversizing) and to reduce the energy consumption of the network in low or moderate traffic times.

- **Improving risk management for electromagnetic fields (EMF) thanks to monitoring and transparency of data**, since this is still a public concern despite the implementation of strict regulations and intense research works.

- **Selecting and deploying more energy-efficient telecommunication network equipment**, which covers ICT equipment (radio, telecommunication, broadband and IT devices), as well as cooling systems and UPS. Further energy-efficiency improvement can be achieved while designing telecommunication sites (integrated and multi-standard solutions, remote antennas, etc.) or using software enabling energy savings.

- **Installing and upgrading telecommunication networks** refers to the opportunity of taking advantage of technology transition (e.g. deploying 4G technology in existing base station sites) to optimize network sites regarding their energy consumption (decommission of unused equipment, configuration of power and cooling supply equipment, etc.).

- **Reducing the environmental impacts when building or renovating telecommunication networks**, with colocation, and appropriate location or equipment which can minimise building aesthetic impact and land-use, or noise from generators and cooling system.

- **Minimising data traffic demand through green software** which intends to use eco-design principles and techniques when developing new software or optimizing existing software. This is applicable for mobile applications (for smartphones and tablets) and computer software (for laptop and desktop) as well as for web portals and web-based applications.

### *D. Improving the environmental performance in other sectors ("Greening by ICT")*

These BEMPs aim at inspiring telecommunications and ICT services companies to develop and deploy solutions that result in environmental benefits for their clients, as well as to demonstrate the environmental benefits of such solutions. Compared to the

BEMPs from the three other chapters, the BEMPs on greening by ICT solutions are framed at a more general level and intend to show in which broad areas green ICT companies have contributed the most to reduce the environmental impacts of different economic sectors on the basis of concrete initiatives implemented by companies of the ICT services sector in partnership with companies belonging to different sectors (power, transport, etc.).

These solutions can be grouped according to four main change levers for reducing GHG emissions and improving environmental performance in general that have been identified by the GeSI initiative (GeSI, 2012 and GeSI, 2015)[7]:

- **Digitalization and dematerialization**, which allow substitution and elimination of products or processes consuming large amounts of energy and resources (transport, printed documents, etc.).
- **Data collection and communication**, which allow real-time data analysis and feedback, in order to enable better decision-making, to reduce risks and to enhance the coordination with stakeholders (suppliers, consumers, etc.).
- **System integration**, which helps to manage the use of resources, by facilitating the use of low-carbon energy and reducing emerging consumption at system level (building, company, grid, etc.).
- **Process, activity, and functional optimisation**, which improve efficiency through simulation, automation, redesign or control of process activity and services.

From an ICT company perspective and for each of these four main levers, it is best practice to:

- keep on developing new solutions that offer opportunities to reduce environmental impacts (through R&D investments, partnerships with companies from other sectors, etc.);
- help companies deploying such solutions into their operations and business (by specifically design the solution to its client needs, by providing training and communication, etc.);
- internally deploy these solutions, if relevant.

[7] The reports are available online at: http://gesi.org/smarter2020 and http://smarter2030.gesi.org/

### Applicability

**Most of the BEMPs are only applicable to specific lifecycle stages: service development, planning and designing, selection and procurement, installation and upgrades, operation and management, or end-of-life management. The**

Figure 3 shows that there is at least one BEMP applicable for each lifecycle stage of any ICT asset (data centre, telecommunication network and end-user device).

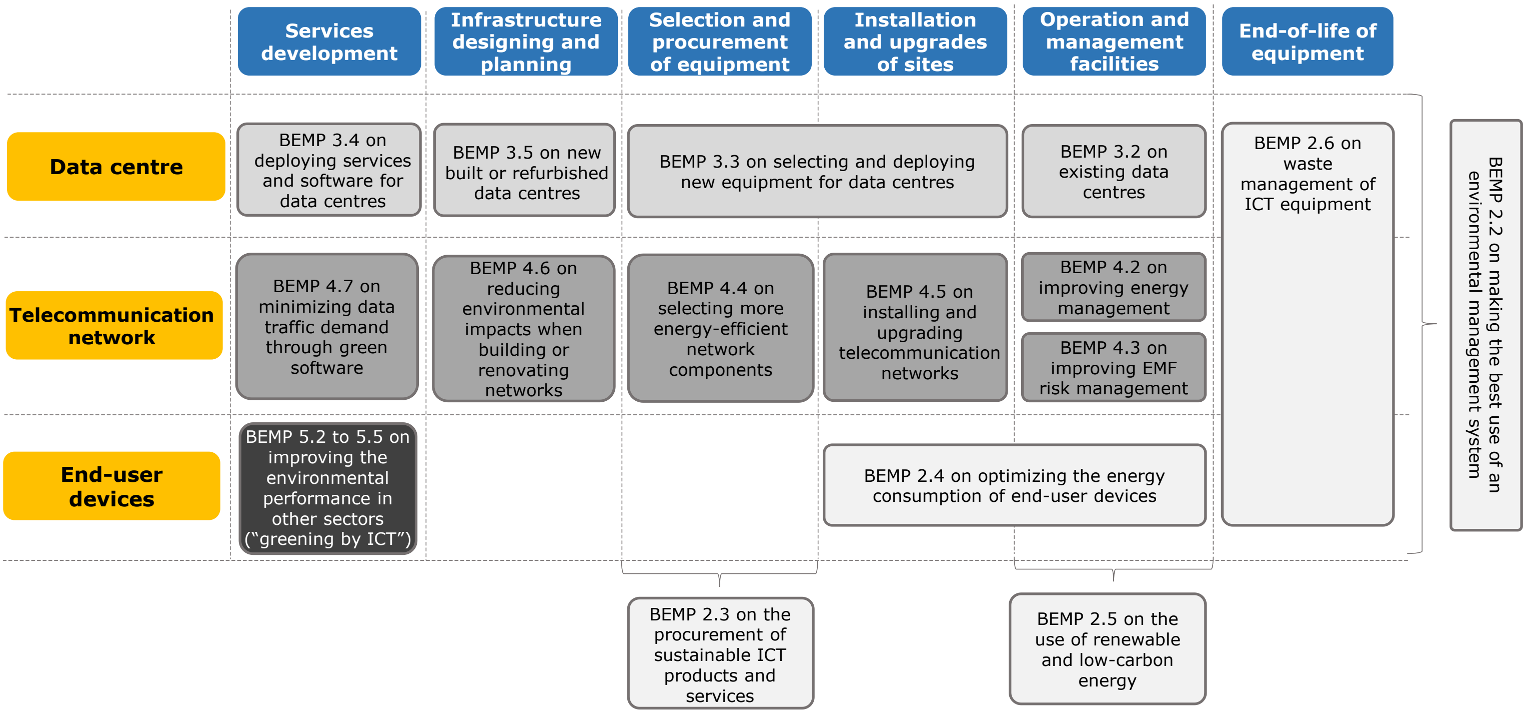


**Figure 3: Overview of the BEMPs applicability**

The main environmental pressure of the Telecommunications and ICT Services sector is its energy consumption and direct and indirect emission of greenhouse gases (GHG), tackled by most of the BEMPs developed within this document. Some BEMPs focusing on ICT equipment, and other equipment that can be found in ICT and Telecommunication facilities (power supply, cooling system, etc.), deal also with resource consumption issues. Water consumption is very specific to only certain types of cooling systems in data centres, while all the other significant environmental aspects (noise emissions, land-use, aesthetic pollution, EMF exposure, etc.) are almost exclusively related to telecommunication infrastructures and facilities. Only certain BEMPs are dealing with all the environmental pressures: environmental management systems for sites and facilities and the procurement of sustainable ICT and other equipment. Finally, the BEMPs on "greening by ICT" solutions are quite different from the other ones since they refer to the minimisation of the environmental impacts of other sectors.

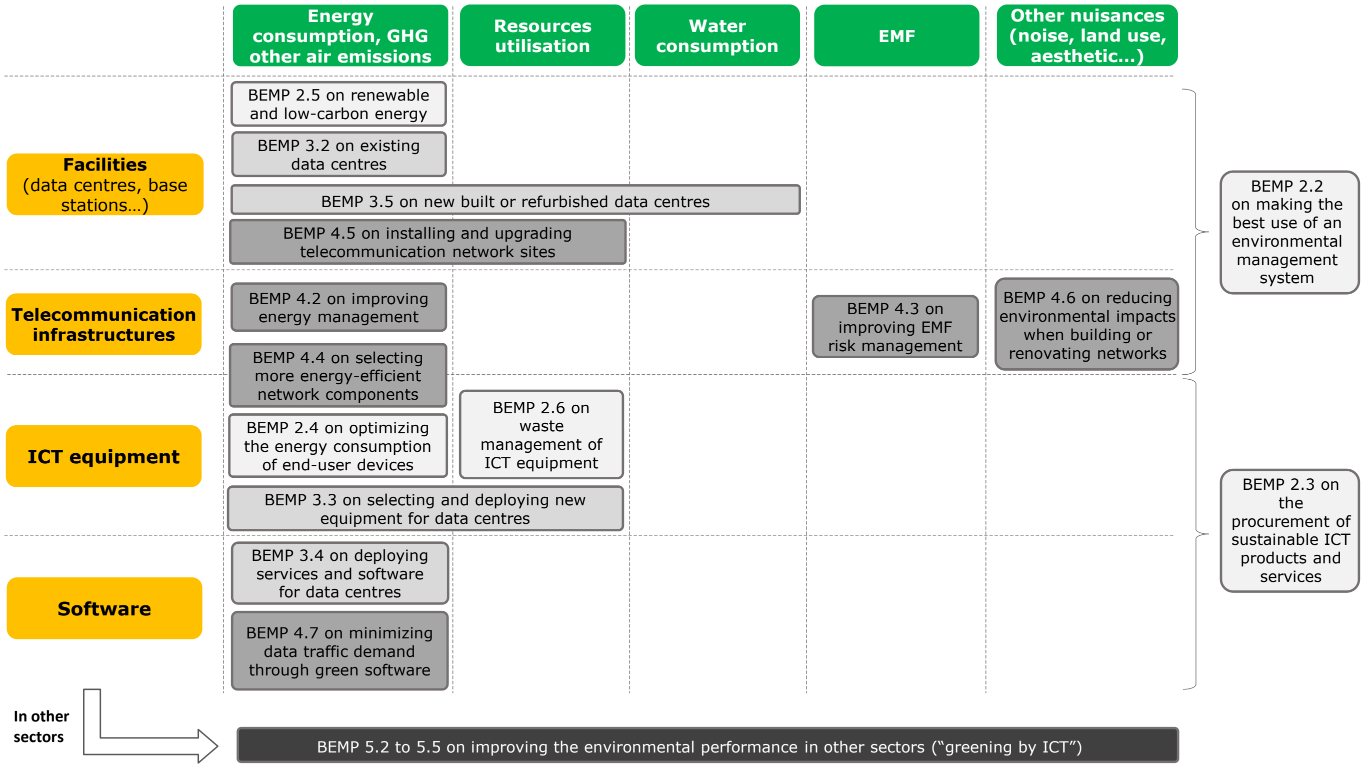


**Figure 4: Overview of the main environmental aspects and impacts addressed by the BEMPs**

## Way forward

This background report proposes a series of best environmental management practices, for each of the relevant covered aspects, as well as a set of environmental performance indicators that can be used by telecommunications and ICT services companies to report their performance. Where available, ranges of environmental performance are also given in the detailed description of each technique.

Based on these, further research by the European Commission, and all the information provided by the experts involved in the process, the Technical Working Group will conclude on the final set of BEMPs and environmental performance indicators as well as on a series of Benchmarks of Excellence to be included in the final best practice report and, ultimately, in the SRD.

Any expert or stakeholder interested to be involved in the process is welcome to contact the European Commission's Joint Research Centre at JRC-IPTS-EMAS@ec.europa.eu

# Synthèse

Ce rapport présente une revue des techniques qui peuvent être considérées comme les meilleures pratiques de management environnemental (MPMEs) dans le secteur des télécommunications et des technologies de l'information et de la communication (TIC). Ce document a été développé par EY et Associés (France), sous contrat avec le centre commun de recherche de la Commission Européenne (appelé JRC), en vue de soutenir le développement d'un document de référence sectoriel EMAS pour ce secteur[8].

Ce rapport vise à fournir une base de discussion entre JRC et des experts et parties prenantes du secteur au travers du groupe de travail technique (appelé TWG). Les résultats finaux seront présentés dans un rapport de bonnes pratiques produit par le JRC ("JRC Scientific and Policy Report on Best Environmental Management Practice in the Telecommunications and ICT services Sector")[9].

### Cible

Les meilleures pratiques de management environnemental (MPMEs) proposées dans ce rapport ont été identifiées comme les meilleures pratiques pouvant soutenir les efforts de l'ensemble des fournisseurs de services en matière de télécommunications et de technologies de l'information et de la communication (TIC), à savoir les opérateurs télécom, les cabinets de conseil en TIC, les entreprises en charge du traitement et du stockage de données, les développeurs et éditeurs de logiciels, les diffuseurs média, les installateurs d'équipements et de sites télécom, etc. Les grandes organisations qui stockent et traitent des quantités importantes de données relatives à leurs clients, leurs produits ou leurs fournisseurs (administrations publiques, hôpitaux, universités, banques, etc.) peuvent également trouver pertinents plusieurs des MPMEs proposées.

### Périmètre

Le présent document couvre les activités principales d'organisations du secteur des télécommunications et des technologies de l'information et de la communication (TIC). Il adresse plus particulièrement les éléments suivants qui sont interconnectés :

- Centres de données (serveurs, équipement de refroidissement, alimentation en énergie, etc.) ;
- Equipment des utilisateurs finaux (téléphones mobiles, ordinateurs et autres périphériques, etc.) ;
- Infrastructures et réseaux télécoms (station de base, lignes téléphoniques, satellites, etc.) ;
- Logiciels (programmation, sites Internet, applications, etc.) ;
- Services de diffusion des médias (radio, télévision, Internet, etc.).

Toutes les pratiques présentes dans le périmètre d'autres documents de référence sectoriels EMAS sont exclues de ce document, comme : la fabrication, la vente, la réparation et la gestion des déchets d'équipements des TIC, la gestion de bureaux, et la mobilité (voyages d'affaires et navettage).

[8] Plus d'informations sur ces documents de référence sectorielle EMAS and sur leurs modalités d'élaboration peuvent être trouvées dans les procédures suivantes "Development of the EMAS Sectoral Reference Documents on Best Environmental Management Practice" (European Commission, 2014), disponibles en ligne à l'adresse suivante : http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf.

[9] Le rapport sur les bonnes pratiques sera disponible en ligne à l'adresse suivante : http://susproc.jrc.ec.europa.eu/activities/emas/telecom.html

Au sein du rapport, une distinction a été faite, entre :

- Les MPMEs qui visent à réduire les impacts environnementaux du secteur des télécommunications et des TIC, et dénommées « pratiques de verdissement des TIC » ;
- Les MPMEs qui font référence à des solutions fournies par des compagnies du secteur des télécommunications et des TIC afin de réduire les impacts environnementaux d'autres secteurs, et dénommées « pratiques de verdissement par les TIC ».

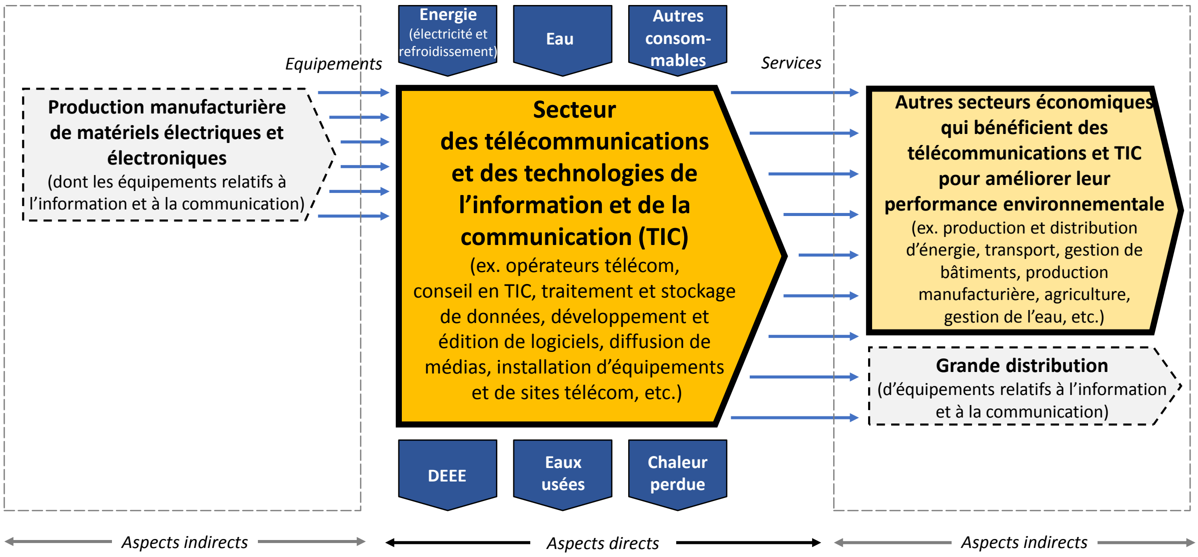


**Figure 5: Vue d'ensemble du périmètre du document**

Les principaux aspects environnementaux et pressions environnementales associées pour le secteur des télécommunications et des TIC sont présentés dans la Table 3 (ci-dessous). Ces aspects environnementaux ont été sélectionnés comme les plus pertinents pour le secteur et sont ceux qui sont couverts dans ce document. Cependant, les aspects environnementaux devant être gérés par chaque organisation doivent être évalués au cas par cas.

**Table 4: Principaux aspects et pressions en termes environnementaux relatifs au secteur des télécommunications et des TIC**

| Services / Activités | Principaux aspects environnementaux | Principales pressions environnementales |
|---|---|---|
| Centres de données | - Equipements des TIC (serveurs, solutions de stockage, etc.)<br>- Logiciels (processeurs)<br>- Chauffage, Ventilation et Refroidissement<br>- Alimentation électrique<br>- Bâtiments | - Consommations d'électricité et émissions de gaz à effet de serre (GES)<br>- Consommations de ressources et production de DEEE<br>- Consommation d'eau et production d'eaux usées<br>- Nuisances sonores (générateurs et compresseurs des climatiseurs) |
| Infrastructures et réseaux de télécommunication | - Infrastructure réseau (antennes, câbles, fibres, lignes téléphoniques, etc.)<br>- Equipment TIC (émetteurs- | - Consommations d'électricité et émissions de gaz à effet de serre (GES)<br>- Consommations de ressources et production de DEEE) |

| | | |
|---|---|---|
| | récepteurs, routeurs, etc.)<br>- Chauffage, Ventilation et Refroidissement<br>- Alimentation électrique<br>- Bâtiments (bureau central, station de base, etc.)<br>- Terminaux (téléphones, modems, décodeurs, ordinateurs, etc.)<br>- Logiciels (processeurs, etc.) | - Exposition aux ondes électromagnétiques<br>- Nuisances sonores (générateurs et compresseurs des climatiseurs)<br>- Modification des paysages et habitats du fait du déploiement d'infrastructures |
| Equipement des utilisateurs finaux | - Equipment TIC (ordinateurs, périphériques, etc.)<br>- Logiciels | - Consommations d'électricité et émissions de gaz à effet de serre (GES)<br>- Consommations de ressources et production de DEEE |

## Contenu du document

Les meilleures pratiques de management environnemental (MPME) proposées sont regroupées selon 4 catégories :

### *A. Mesures transversales*

Les mesures transversales sont des MPMEs susceptibles d'être mises en œuvre par n'importe quel acteur du secteur des télécommunications et des TIC. Ces MPMEs fournissent des lignes directrices pour la conception, la mise en place et le suivi de cadres de management des enjeux environnementaux. Ces procédures de gestion sont utiles pour identifier et minimiser l'impact environnemental d'activités se traduisant par des processus multiples, et aux effets potentiellement contraires selon les thématiques environnementales et les étapes du cycle de vie étudiés.

- **Optimiser l'utilité d'un système de management environnemental (SME),** par le déploiement de techniques permettant de minimiser de façon systématique l'impact environnemental de sites à forte utilisation des TIC. Cela se traduit par la réalisation d'analyses comparatives des usages existants et par la mesure et l'évaluation des performances environnementales.
- **Acheter des produits et services TIC respectueux de l'environnement,** via l'élaboration de critères environnementaux spécifiques et leur intégration à chaque stade du processus d'achat de sorte à minimiser leur impact environnemental global. Une politique d'achats responsables peut aussi bien concerner les produits et services utilisés par l'entreprise elle-même, que ceux qu'elle vend à ses clients.
- **Optimiser la consommation énergétique des appareils des utilisateurs des TIC** en développant des solutions techniques pour l'installation, la configuration et l'utilisation de ces appareils. Un déploiement réussi de ces solutions techniques exige également des mesures organisationnelles permettant de faciliter leur acceptation individuelle et d'assurer un engagement des dirigeants.
- **Utiliser des énergies renouvelables et à faibles émissions de GES** dans les centres de données et sites de télécommunications principalement. Cela peut être mis en pratique via l'achat garanti ou la production sur site de ce type d'énergie (cogénération de biomasse, panneaux photovoltaïques, éoliennes, géothermie, etc.), et au travers de la mise en place de solutions de stockage d'énergie sur site.

- **Optimiser la gestion de l'équipement TIC en fin de vie,** au travers d'une mise en place de pratiques de prévention, de réutilisation et de recyclage. Des mesures spécifiques à ce secteur sont présentées, comme la promotion de l'écoconception des équipements des utilisateurs (dont la réduction de leur obsolescence), la mise en place de solutions de réutilisation d'équipements, et le renforcement de ses relations avec les prestataires en charge de la collecte, du tri et du traitement de ces déchets spécifiques.

### *B. Centres de données*

Par rapport aux mesures précédentes, ce sont des techniques spécifiques aux centres de données (ou data centres). La structure du document s'appuie sur le rapport technique de la commission européenne pour la standardisation électrotechnique ou CENELEC (CENELEC Technical Report *CLC/FprTR 50600-99-1)*, qui est un développement des meilleures pratiques identifiées dans le Code de Conduite de l'Union Européenne pour l'efficacité énergétique des centres de données[10]. Au-delà des enjeux énergétiques, les MPMEs couvrent d'autres aspects environnementaux significatifs, comme l'utilisation des sols, les consommations d'eau ou les nuisances sonores :

- **Les MPMEs relatives à la gestion des centres de données** fournissent des informations pratiques aux gestionnaires des centres de données désireux d'améliorer leurs performances énergétiques. Seuls les aspects directs de la consommation d'énergie, c'est à dire ceux contrôlés par l'exploitant, sont couverts par ces MPMEs, et l'attention est principalement portée sur le fonctionnement de ces centres de données. Les clients, les prestataires proposant de la colocation, ainsi que d'autres fournisseurs et clients de services TIC peuvent également trouver un intérêt dans ces MPMEs, dans la mesure où elles soutiennent l'achat de services répondant à leurs standards en matière de respect de l'environnement. Les mesures suivantes sont considérées comme les meilleures pratiques à mettre en œuvre :
  - Déployer un système de management de l'énergie pour les centres de données (incluant la mesure, le contrôle et la gestion des équipements).
  - Définir et déployer un système de gestion des données traitées et stockées
  - Améliorer la conception et la gestion des systèmes de circulation d'air
  - Améliorer la gestion du refroidissement des serveurs
  - Revoir et ajuster les réglages de température et d'humidité

- **Les MPMEs concernant la sélection et le déploiement de nouveaux équipements pour les centres de données** présentent des informations techniques cruciales pour mettre en place une politique d'achat de biens et services TIC durables lors de l'achat d'appareils TIC (serveurs, disques de stockage, interfaces réseau, etc.), d'équipements de refroidissement et d'alimentations électriques pour les centres de données déjà existants ou en construction. L'objectif principal des gestionnaires de centres de donnée et de leurs clients (qui sont parfois propriétaires de leurs propres serveurs) est de minimiser le volume de matériel informatique utilisé et leurs consommations énergétiques directes et indirectes. Cependant, ces mesures doivent être

[10] Le Code de Conduite de l'Union Européenne pour l'efficacité énergétique des centres de données est disponible en ligne à l'adresse suivante : http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

étudiées de manière attentive et globale, au regard des effets non souhaités qu'elles peuvent générer. Par exemple, certaines technologies de refroidissement peuvent être très consommatrices en eau, et remplacer des équipements existants nécessite une consommation de ressources et d'énergie pour leur fabrication. Il est ainsi particulièrement important de fonder la sélection et le déploiement d'équipements des TIC, ainsi que de refroidissement et d'alimentation électrique, sur une stratégie globale et intégrée permettant de réduire leur empreinte environnementale globale (consommation d'énergie, consommation d'eau, utilisation d'énergie et de ressources pour la fabrication).

- **Les MPMEs concernant le déploiement de nouveaux services TIC et de logiciels**. Si les logiciels ne consomment pas directement de l'énergie, ils impactent grandement l'efficacité énergétique du matériel utilisé dans les TIC et sur lequel ils sont exécutés. Cependant, une grande part des codes des logiciels ne prend pas en compte la consommation énergétique, et il existe des opportunités pour les optimiser et réduire la consommation énergétique des serveurs. Une entreprise peut sélectionner les logiciels qui utilisent le moins de puissance et de capacité (et indirectement d'énergie) pour accomplir les tâches requises, ou tout aussi bien développer ses propres logiciels plus efficients sur le plan énergétique.

- **Les MPMEs relatifs aux centres de données en cours de construction ou de rénovation** adressent les phases de planification et de conception de centres de données, de sorte à minimiser leurs futures consommations en énergie ou en eau lorsqu'ils seront en fonctionnement. Les centres de données sont souvent surdimensionnés pour permettre des changements importants en termes de fonctionnement et de capacité dans le futur. Cela conduit généralement à manque d'efficience à l'instant présent. S'ils ne sont pas localisés de façon appropriée et conçus correctement, les opportunités de déploiement d'un système de réutilisation des pertes de chaleur, de production et de consommation d'énergies et de refroidissement renouvelables ainsi que de minimisation des impacts environnementaux des bâtiments (pollution visuelle, nuisances sonore, etc.) peuvent être limitées. Les mesures suivantes sont considérées comme les meilleures pratiques à mettre en place dans ce cadre-là :

  - Considérer les aspects environnementaux dans la planification de nouveaux centres de données
  - Réutiliser les pertes de chaleur des centres de données
  - Concevoir des bâtiments minimisant l'exposition au soleil des zones refroidies et optimisant la localisation de climatiseurs
  - Sélectionner la localisation géographique des nouveaux centres de données de manière à exploiter des opportunités de réutilisation de la chaleur perdue, de production d'énergie renouvelable et de minimiser les impacts environnementaux
  - Utiliser de ressources d'eau alternatives

### *C. Les réseaux de télécommunications*

Il s'agit de techniques propres aux opérateurs télécoms (et à leurs sous-traitants). Elles visent à améliorer la gestion des réseaux existants, à installer des réseaux plus respectueux de l'environnement, à réduire les impacts des travaux de construction et de rénovation des infrastructures réseaux et à minimiser le trafic de données par les techniques suivantes :

- **Améliorer la gestion énergétique des réseaux de télécommunication,** avec une meilleure connaissance de la consommation énergétique du réseau, et différentes solutions techniques qui visent à minimiser les périodes de pic du trafic de données (pour limiter le besoin de réseaux surdimensionnés) et à réduire les consommations énergétique du réseau en périodes de trafic plus modérés.
- **Améliorer la gestion des risques relatifs aux champs électromagnétiques au travers de l'évaluation et de la communication des valeurs d'exposition**, étant donné que cela est toujours source d'inquiétude pour le grand public, malgré l'adoption d'une régulation stricte et d'intenses travaux de recherche sur le sujet.
- **Sélectionner et déployer des équipements plus efficaces sur le plan énergétique au sein des réseaux de télécommunication**, tant au niveau des équipements des TIC (radio, télécommunication, Internet, etc.), que des systèmes de refroidissement et des alimentations électriques (nommés UPS). Au-delà de la phase d'achat, il est possible de réaliser des économies d'énergie supplémentaires lors de la conception des sites de télécommunication (utilisation de solutions intégrées et multistandards, d'antennes spécifiques, etc.) ou via l'utilisation de logiciels permettant des économies d'énergie.
- **Installer et moderniser les réseaux de télécommunication** avec l'opportunité de tirer parti des transitions technologiques (ex. déploiement de la 4G sur des stations de base existantes) pour optimiser les sites télécoms en ce qui concerne leur consommation d'énergie (désinstallation de l'équipement inutilisé, reconfiguration des systèmes de refroidissement et d'alimentation électrique, etc.).
- **Réduire les impacts environnementaux lors de la construction et la rénovation des réseaux de télécommunication,** par le biais de la collocation, du choix d'une localisation appropriée ou de l'installation d'équipements qui minimisent les impacts du bâtiment (pollution visuelle, nuisances sonores, occupation du sol, etc.).
- **Réduire la demande en trafic de données via l'utilisation de logiciels « verts »**, développés ou revus sur la base de principes d'écoconception. Cette mesure s'applique aux applications mobiles (pour smartphones et tablettes), aux logiciels (pour ordinateurs portables ou fixes) et aux portails web, tant en développement que déjà en utilisation.

### *D. Améliorer les performances environnementales dans d'autres secteurs (« Verdissement par les TIC »)*

Ces MPMEs ont pour objectif d'inspirer les fournisseurs de services télécom et TIC en vue du développement et du déploiement de solutions qui résultent en bénéfices environnementaux pour leurs clients, mais aussi pour démontrer les bénéfices environnementaux de ces solutions. Comparés aux MPMEs des trois précédents chapitres, celles-ci sont définies à un niveau plus macro et visent à présenter les principales directions dans lesquelles des entreprises du secteur des TIC ont le plus contribué à la réduction des impacts environnementaux d'autres secteurs économiques. Ce résultat s'est appuyé sur les initiatives concrètes développées par des entreprises du secteur des services en TIC en partenariat avec des entreprises appartenant à d'autres secteurs (production d'électricité, transport, etc.).

Ces solutions peuvent être regroupées selon quatre leviers majeurs de changement pour réduire les émissions GES et améliorer la performance environnementale en général qui ont été identifiés par l'initiative GeSI (GeSI, 2012 ; GeSI, 2015)[11] :

- **La digitalisation et la dématérialisation** qui permettent la substitution et la suppression de produits ou de procédés consommateurs d'énormes quantités d'énergie et de ressources (transport, impression de documents, etc.).
- **La collecte de données et la communication** qui permettent une analyse de données et un retour d'information en temps réel, afin de permettre une meilleure prise de décision, de réduire les risques et d'améliorer la coordination avec l'ensemble des parties prenantes (fournisseurs, consommateurs, etc.).
- **L'intégration de systèmes** permettant de mieux gérer l'utilisation des ressources, en facilitant l'utilisation d'une énergie bas carbone et en réduisant la consommation à l'échelle du système (bâtiment, entreprise, réseau, etc.).
- **L'optimisation des processus, activités et fonctionnalités**, permettant d'améliorer l'efficacité à travers la modélisation, l'automatisation, la refonte ou le contrôle d'activités et de services.

Du point de vue d'une entreprise du secteur des TIC et pour chacun de ces quatre leviers majeurs, les bonnes pratiques sont de :

- Continuer à développer de nouvelles solutions porteuses d'opportunités pour réduire les impacts environnementaux (à travers des investissements R&D, des partenariats avec des entreprises du secteur, etc.) ;
- Aider les entreprises à déployer de telles solutions dans leurs opérations et activités (en concevant des solutions spécialement adaptées à leurs besoins, en proposant des formations et de la communication, etc.)
- Déployer ces solutions en interne, si cela s'avère pertinent.

[11] Les rapports sont disponibles en ligne aux adresses suivantes : http://gesi.org/smarter2020 et http://smarter2030.gesi.org/

### Applicabilité

La plupart des MPMEs sont seulement applicables à certaines étapes du cycle de vie des équipements et sites : développement de services, planification et conception de sites, sélection et achat d'équipements, installation et modernisation d'infrastructures, opération et management, gestion de la fin de vie des équipements, etc. La Figure 6 permet de mettre en évidence qu'il y a au moins une MPME applicable pour chacune des étapes du cycle de vie de n'importe quel actif des TIC (centre de données, réseau télécom et équipement d'utilisateur).

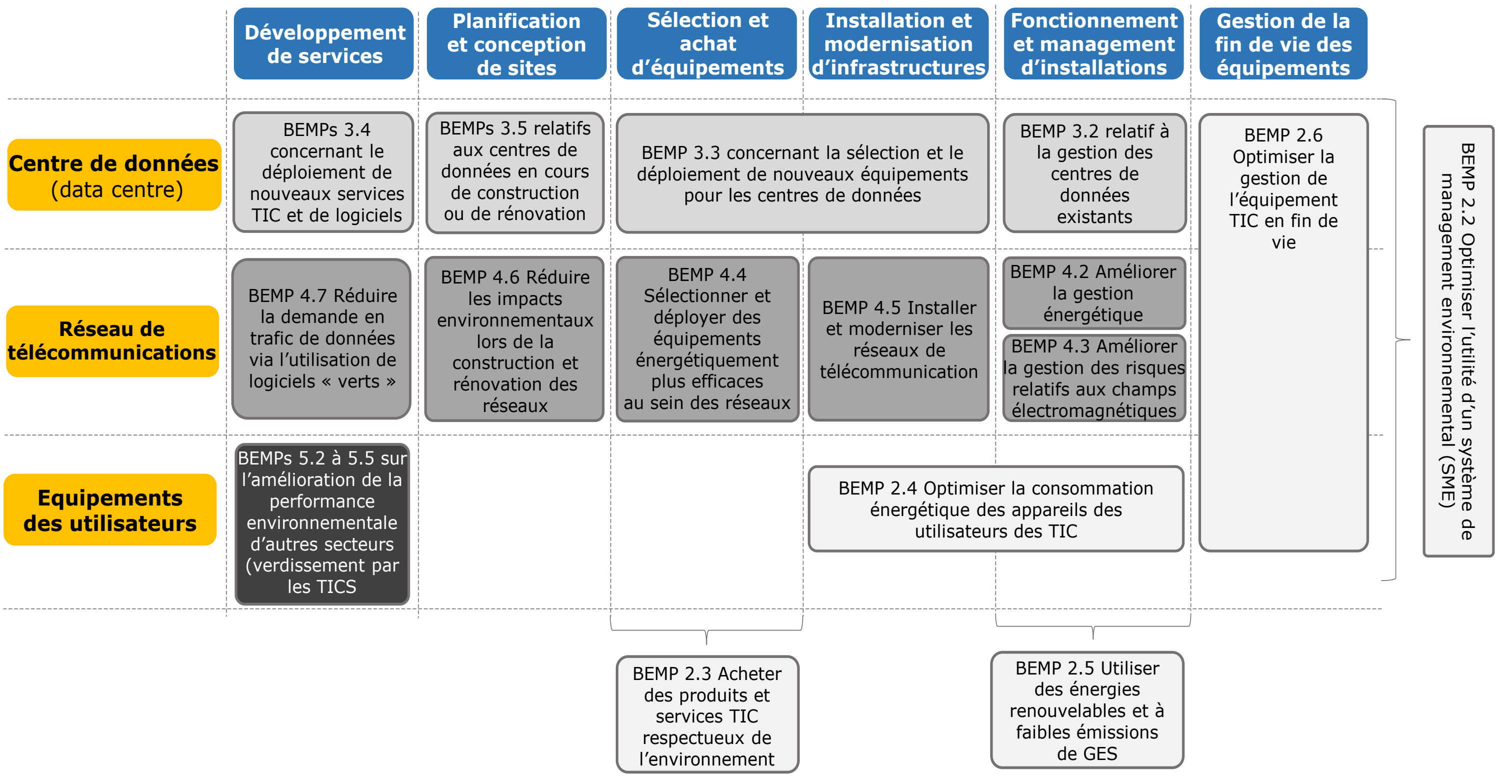


**Figure 6: Vue d'ensemble de l'applicabilité des MPMEs**

La principale pression environnementale causée par le secteur des services en télécommunications et TIC est constituée par sa consommation d'énergie, ainsi que par les émissions de GES et d'autres polluants atmosphériques qui y sont liés. La plupart des MPMEs développées dans ce document traitent de cet enjeu. Certaines MPMEs dédiés aux équipements des TIC, ainsi qu'aux autres types d'équipements spécifiques qui peuvent être trouvés sur les sites étudiés (centres de données, sites télécom, etc.), traitent des enjeux de consommation de ressources. L'enjeu de consommation d'eau est uniquement lié à certains types de systèmes de refroidissement qui peuvent être trouvés dans certains centres de données, tandis que les autres enjeux environnementaux significatifs (nuisances sonores, pollution visuelle, exposition aux ondes électromagnétiques, etc.) sont presqu'exclusivement liés aux infrastructures et sites de télécommunication. Seuls certaines MPMEs sont suffisamment transversales et traitent de l'ensemble des pressions environnementales (système de management environnemental, politique d'achats responsables, etc.). Enfin, les MPMEs relatives au verdissement par les TIC sont assez différentes des autres puisqu'elles font référence à la réduction des impacts environnementaux d'autres secteurs que celui des services en télécommunications et TIC.

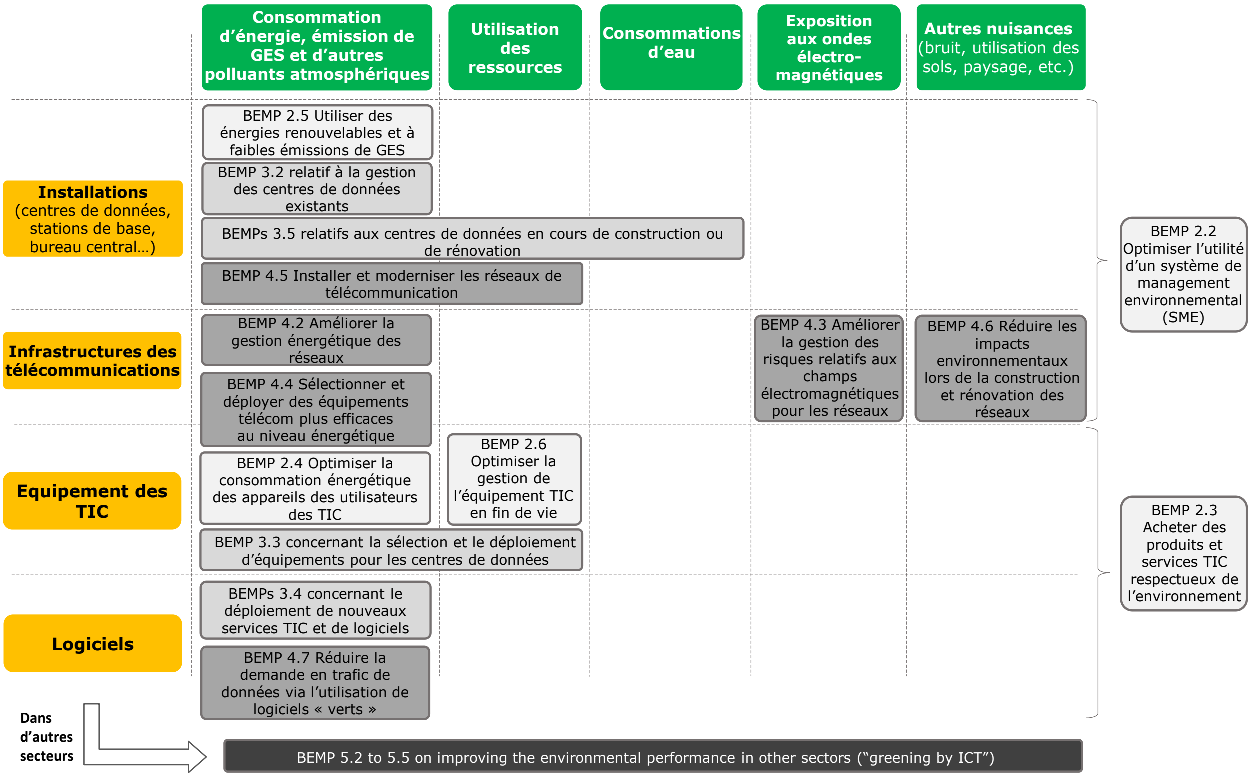


**Figure 7: Vue d'ensemble des principaux aspects et impacts environnementaux traités au travers des MPMEs**

## Prochaines étapes

Ce rapport documentaire présente une liste des meilleures pratiques de management environnemental pour chacun des aspects environnementaux significatifs adressés, mais également des indicateurs de performance environnementale qui peuvent être utilisées pour piloter et reporter cette performance. Lorsqu'ils sont disponibles, des niveaux de performance environnementale sont également fournis dans la description détaillée de chaque technique.

En s'appuyant sur ce document, sur des recherches approfondies menées par la Commission Européenne, et sur l'ensemble des informations fournies par les experts engagés dans le processus, le Groupe de Travail Technique conclura sur l'assortiment final des MPMEs et des indicateurs de performance environnementale, ainsi que sur une série d'Analyses Comparatives d'Excellence (benchmark of excellence) qui seront présentées dans le rapport final sur les meilleures pratiques du secteur et, en dernier lieu, dans le document de référence sectoriel (DRS).

Tout expert ou partie prenante intéressé par une implication dans le processus est invité à contacter le Centre Commun de Recherche (JRC en anglais) de la Commission Européenne, à l'adresse suivante : JRC-IPTS-EMAS@ec.europa.eu

# 1 General information about the Telecommunications and ICT Services sector, its environmental relevance and EMAS implementation in the sector

## 1.1 Scope of the document

### 1.1.1 Target group

The Telecommunications and ICT Services sector covers a wide variety of services and businesses including, but not limited to:

- **Telecommunications**: the transmission of voice, data, text, sound and video using electrical signals (both analogue and digital) using wires or cables (wired / fixed) or electro-magnetic waves (wireless / mobile).
- **Professional use of information and communication technology (ICT) equipment and infrastructure**: the design, construction, operation, maintenance, upgrading and dismantling of information and telecommunication infrastructure and networks at local, regional and international level. This includes data processing, hosting and related activities (e.g. data centres);
- **Broadcasting**: the distribution of audio, video and/or data content to a dispersed audience (i.e. radio and television) via any electronic mass communications medium such as over-the-air, via satellite, via a cable network or via the Internet.
- **Software development and publishing:** the development (e.g. designing, programming, modifying, documenting, testing and bug fixing) and publishing of software products (e.g. operating systems, search engines, applications, databases, web pages, video games, etc.).
- **ICT consultancy**: planning, designing, installing, maintaining and upgrading ICT systems that integrate computer hardware, software and communication technologies and other professional and technical ICT-related activities.

These organisations are typically included in the section J (Information and Telecommunication) of the statistical classification of economic activities set out in Annex I of Regulation 1893/2006/EC (NACE Rev.2). However, the NACE definitions and classification of the ICT sector has been subject to discussion as the sector is still developing rapidly (JRC, 2012a). In their Guide to Measuring the Information Society, the OECD makes a distinction between ICT producers and production (ICT supply) and ICT users and uses (ICT demand) as well as a distinction between ICT infrastructure, ICT products (goods and services) and 'content and media products' (OECD, 2011). In line with the OECD's classification, the production of content and media products is not included in the scope of BEMPs for the Telecommunications and ICT Services sector.

The following NACE codes are included in the scope of the present background report for Telecommunications and ICT Services sector:

- Only certain sub-categories of publishing activities (NACE Code 58):
  - 58.21 Publishing of computer games
  - 58.29 Other software publishing
- All the sub-categories of telecommunications activities (NACE Code 61):
  - 61.1 Wired telecommunications activities
  - 61.2 Wireless telecommunications activities
  - 61.3 Satellite telecommunications activities
  - 61.9 Other telecommunications activities

- All the sub-categories of computer programming, consultancy and related activities (NACE Code 62):
    - 62.01 Computer programming activities
    - 62.02 Computer consultancy activities
    - 62.03 Computer facilities management activities
    - 62.09 Other information technology and computer service activities
- Only certain sub-categories of information service activities (NACE Code 63):
    - 63.11 Data processing, hosting and related activities
    - 63.12 Web portals

Other types of organisations classified under the NACE J section are partially included in the scope of the present background report, because of their increasing digitalisation:

- Publishing of books, newspapers, journals etc. (NACE Code 58.1) via Internet
- Motion picture, video and television programme production, sound recording and music publishing activities (NACE Code 59)
- Broadcasting via Internet (NACE Code 60)
- News agency activities (NACE Code 63.91)
- Other information service activities n.e.c. (NACE Code 63.99)

As mentioned, the content and media production related to these activities is excluded from the scope.

Organisations from other NACE code sections and which are directly connected to the previous Information and Telecommunication activities are also included in the scope because of their similarities:

- Reproduction of software (NACE Code 18.20)
- Activities of call centres (NACE Code 82.20)

Other organisations that have to manage or operate large data storage and processing as a vital part of their activities are also considered, e.g.:

- Architectural and engineering activities and related technical consultancy (NACE Code 71.1)
- Technical testing and analysis (NACE Code 71.20), and especially Research and experimental development on natural sciences and engineering (NACE Code 72.1)
- Libraries, archives, museums and other cultural activities (91.0)
- and also large organisations that store and process large quantities of data of their clients, supply chain and / or products such as public administrations, hospitals, universities, banks, manufacturers, retailers and other service companies.

The Telecommunications and ICT Services sector covers only a specific part of the value chain, since some activities are covered by other background reports:

- ICT manufacturing industries (NACE Code 26.A, 26.2, 26.3 and 26.8), ICT trade industries (NACE Code 46.5), Installation of mainframe and similar

computers (NACE Code 33.20) and recycling, reuse and repair of ICT equipment (NACE Code 95.1) are covered by the best practice report for the electrical and electronic equipment manufacturing sector[12];

- ICT retail trade (NACE Code 47.1 and 47.4) can be considered covered by the best practice report for the retail trade sector[13].

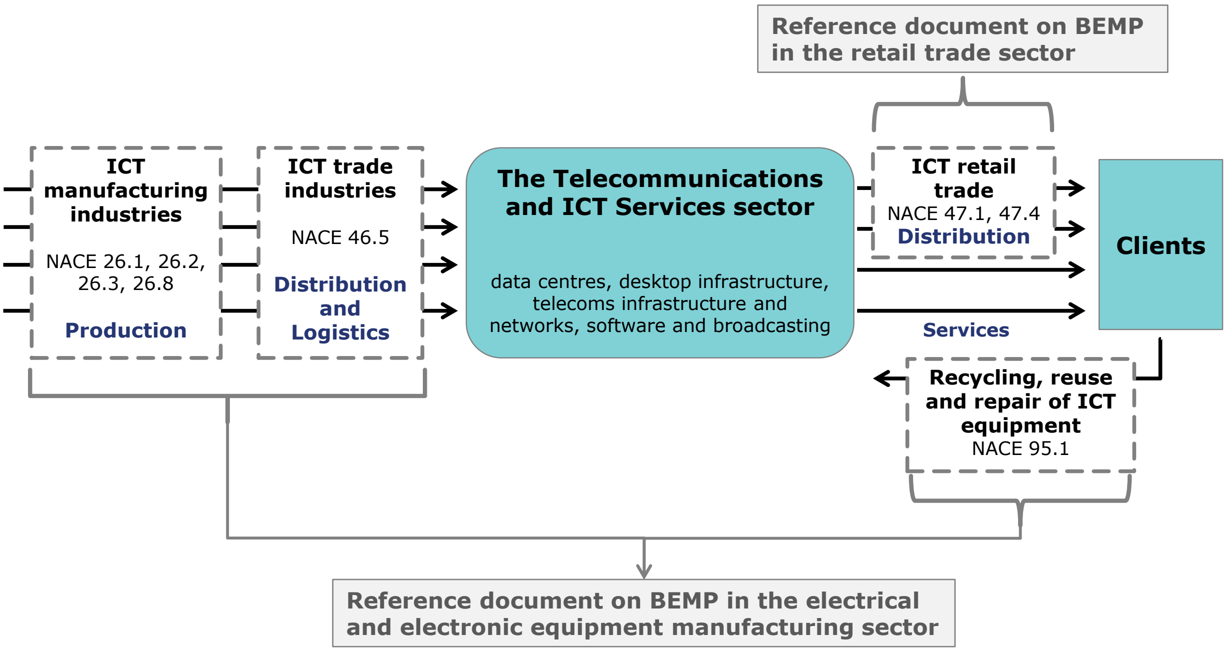


**Figure 8: Coverage of the Telecommunications end ICT Services supply chain by other best practice report and related sectoral reference documents**

### 1.1.2 ICT assets on which BEMP can apply

The scope of the BEMPs for the Telecommunications and ICT Services sector focuses on the following elements which are inter-linked:

- Data centres (servers, cooling equipment, power systems, etc.)
- End-user devices (computers and other peripheral equipment)
- Telecom infrastructure and networks (base stations, landlines, satellites, etc.)
- Software (programming, internet websites, applications, etc.)
- Broadcasting services (radio, television, internet, etc.)

[12] The best practice report for the electrical and electronic equipment manufacturing sector is under development and will be available on-line at: http://susproc.jrc.ec.europa.eu/activities/emas/eeem.html

[13] The best practice report for the retail trade sector is available on-line at: http://susproc.jrc.ec.europa.eu/activities/emas/retail.html

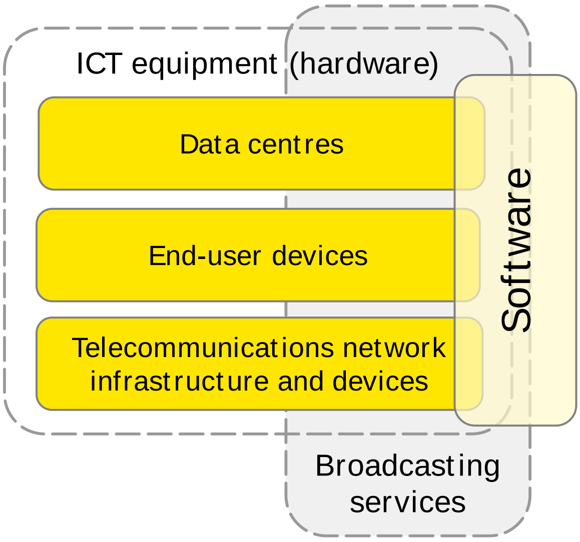


**Figure 9: The main assets of Telecommunications and ICT Services considered in this study**

NB: These terms are defined within the introductive section of the chapters describing BEMPs.

### 1.1.3 Activities covered by the BEMPs

This document covers the core business activities of organisations in the Telecommunications and ICT Services sector. The manufacturing, retail and recycling of ICT equipment are not included in this study as they are covered in the documents on BEMP for other sectors. Moreover, only practices that telecommunication and ICT services providers can implement themselves are developed within this report. For example, practices that promote the use and sale of more environment-friendly ICT equipment (e.g. establishing environmental criteria during procurement of ICT equipment, providing information to customers on the energy consumption of devices provided to them) or the collection and sorting of used ICT equipment at their end of life are included, while waste management (recycling, disposal, etc.) are not part of the scope.

The management of offices and general company transport are also not included as these are common for all types of organisations and not specific to organisations in the Telecommunications and ICT Services sector. Besides, the best environmental management practices (BEMPs) related to mobility (business travel and employee commuting) and sustainability practices in offices are already developed in the document on BEMP in the Public Administration Sector[14]. No BEMP that is specific to the Telecommunications and ICT Services buildings and transportation was identified in these areas.

[14] The best practice report for the public administration sector is available on-line at: http://susproc.jrc.ec.europa.eu/activities/emas/public_admin.html

This background report distinguishes between:

- BEMPs that minimise the environmental impacts of organisations in the Telecommunications and ICT Services sector, referred as "greening of ICT" practices;
- BEMPs that organisations in the Telecommunications and ICT Services sector can implement in order to minimise environmental impacts of other sectors beyond the Telecommunications and ICT Services sector, referred as "greening by ICT" practices.

An overview of the scope of the BEMPs for the Telecommunications and ICT Services sector is given in Figure 10.

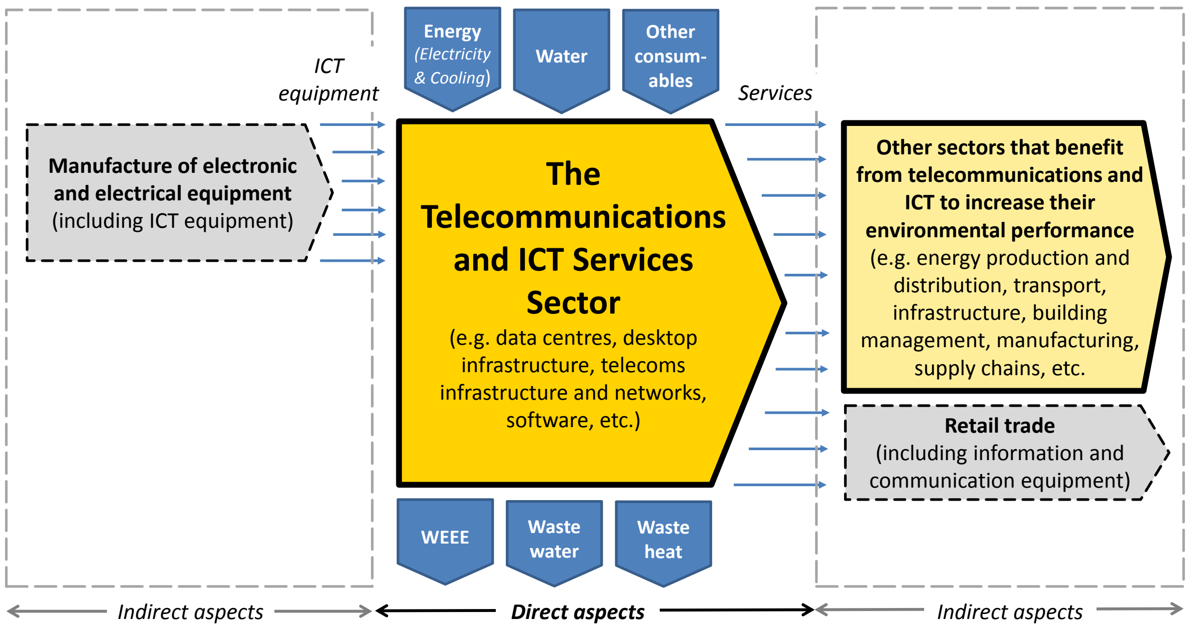


**Figure 10: Overview of the scope of the document**

## 1.2 Key economic data of the sector

The description of the Telecommunications and ICT Services sector in the EU (e.g. annual turnover, number of companies and employment) is based on Eurostat data. The NACE codes identified in the previous section (see 1.1 Scope of the document) as referring to organisations belonging to the Telecommunications and ICT Services sector were used to perform such assessments. Nevertheless, this method presents some limits, inherent with the quality of the Eurostat data base (in terms of completeness, redundancies, etc.) and with the selection of certain NACE Codes.

Based on this study's scope definition, the relevant NACE codes[15] and Eurostat database[16] it was estimated that:

- the Telecommunications and ICT Services sector in the EU-28 was made up in 2012 of about 730,000 companies, or about 3.9% of total number of companies (financial sector excluded)[17];
- the sector employed more than 4 million people, that to say 3.5% of the total number of employees in the global non-financial business economy of the EU 28;
- these companies generated a turnover of around EUR 850 billion in 2012, which represented 3.2% of the turnover generated by the global non-financial business economy.

The Telecommunications and ICT Services sector is a growing market, with an annual average 2% increase in turnover for the companies in this sector in the EU-28 (Eurostat, 2012a).

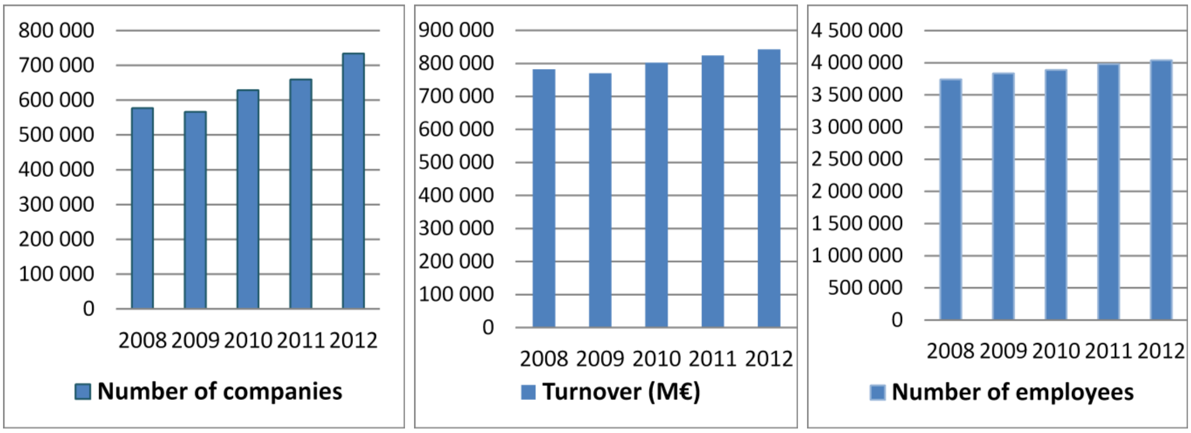


**Figure 11: Evolution of the number of Telecommunication and ICT Services sector (Source: Eurostat, Annual detailed enterprise statistics for services)**

15 The Telecommunication and ICT Services sector is mainly covered by section J of the NACE classification, with the complete telecommunications (division 61), the complete computer programming, consultancy and related activities (division 62), as well as information service activities (division 63), content production excluded. Other NACE codes refer entirely to the Telecommunication and ICT Services sector: software publishing (division 58.2) and reproduction of software (division 18.20), activities of call centres (division 82.20) and installation of mainframe and similar computers (division 33.20).

16 See the Eurostat database: Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) [sbs_na_1a_se_r2], available http://ec.europa.eu/eurostat/fr/data/database

17 Only non-financial companies were studied since data related to turnover are specific for financial companies, and the same perimeter was used for calculating the number of companies, the number of employees and the turnover (i.e. excluding the financial sector).

About 77% of the companies in the Telecommunications and ICT Services sector belong to the computer programming, consultancy and related activities (NACE Code 62) (Eurostat, 2012a). If telecommunications services (NACE Code 61) represented only 5% of the total number of Telecommunications and ICT Services companies, they employed 23% of the employees of the sector and generated 44% of its global turnover.

**Table 5: Turnover and employment statistics per NACE Code (Source: (Eurostat, 2012a))**

| | Companies | | Turnover | | Employees | |
|---|---|---|---|---|---|---|
| | number (2012) | | billion EUR (2012) | | number (2012) | |
| 58.21 Publishing of computer games | 1 257 | 0,2% | 3,56 | 0,4% | 7 400 | 0,2% |
| 58.29 Other software publishing | 18 072 | 2,4% | 19,75 | 2,2% | 120 500 | 3,4% |
| 61.10 Wired telecommunications activities | 11 000 | 1,5% | 155,41 | 17,1% | 360 000 | 10,2% |
| 61.20 Wireless telecommunications activities | 6 027 | 0,8% | 133,82 | 14,7% | 187 000 | 5,3% |
| 61.30 Satellite telecommunications activities | 800 | 0,1% | 9,07 | 1,0% | 20 500 | 0,6% |
| 61.90 Other telecommunications activities | 25 190 | 3,4% | 104,63 | 11,5% | 251 000 | 7,1% |
| 62.01 Computer programming activities | 230 850 | 30,8% | 152,46 | 16,8% | 857 500 | 24,4% |
| 62.02 Computer consultancy activities | 230 644 | 30,7% | 161,39 | 17,8% | 863 000 | 24,6% |
| 62.03 Computer facilities management activities | 20 000 | 2,7% | 33 | 3,6% | 145 000 | 4,1% |
| 62.09 Other information technology and computer service activities | 87 500 | 11,7% | 73 | 8,0% | 360 000 | 10,2% |
| 63.11 Data processing, hosting and related activities | 73 101 | 9,7% | 42,09 | 4,6% | 239 000 | 6,8% |
| 63.12 Web portals | 20 010 | 2,7% | 7,83 | 0,9% | 43 000 | 1,2% |
| 63.99 Other information service activities n.e.c. | 26 000 | 3,5% | 12,1 | 1,3% | 60 000 | 1,7% |
| Total | **750 451** | **100%** | **908,11** | **100%** | **3 513 900** | **100%** |
| Source: Eurostat database (2012) | | | | | | |

The table above illustrates that wired, wireless and satellite telecommunications companies (NACE code 61.1, 61.2 and 61.3, respectively) have the highest average number of employees per company (32.7, 31.0 and 25.6, respectively), while all the other activities employ less than 10 employees.

The Telecommunications and ICT Services sector is made of a large majority of micro-sized firms, with 93% of the total number of companies in the sector employed less than 10 people in EU-28 in 2012 (Eurostat, 2012b). There were around 2,000 large-sized companies in the Telecommunications and ICT Services sector in the EU-28 in 2012, less than 9,000 medium-sized companies and about 44,000 small-sized companies.

The major countries in terms of turnover were the United Kingdom, Germany, France, Italy, Spain, Sweden, Belgium, Poland, Ireland and the Netherlands: these 10 countries generated almost 90% of the turnover of this sector in 2012 in the EU-28. They employed more than 80% of the people employed in the sector in the EU-28 in 2012. These countries also represent more than 75% of all Telecommunications and ICT Services companies in the EU-28.

Beyond the size of the country, the specializations of each economy explain these figures:

- The United Kingdom, Sweden, the Netherlands and Luxembourg were the countries where the Telecommunications and ICT Services providers represented in 2012 the largest share of the total non-financial companies (more than 5%);

- Ireland, Luxembourg, the United Kingdom and Sweden were the countries where the turnover generated by the Telecommunications and ICT Services represented the largest share of the global non-financial business turnover (more than 4%);
- Sweden, Luxembourg, Denmark, Finland and France were the countries where the Telecommunications and ICT Services providers employed the most people (more than 4.5% of the total number of employees in the non-financial business sector).

**Table 6: Turnover and employment statistics per country aggregated for the Telecommunications and ICT Services sector (Source: (Eurostat, 2012a))**

| | **Entreprises** | **Turnover** | **Employees** |
|---|---|---|---|
| | number (2012) | million EUR (2012) | number (2012) |
| Belgium | 21,856 | 27,558.3 | 79,259 |
| Bulgaria | 6,582 | 3,127.7 | 57,974 |
| Czech Republic | 5,963 | 5,717.2 | 28,684 |
| Denmark | 11,318 | 14,901.6 | 76,836 |
| Germany | 73,557 | 173,172.7 | 768,605 |
| Estonia | 2,502 | 11,46.9 | 11,712 |
| Ireland | 3,368 | 19,354 | 32,461 |
| Greece | 6,835 | 7,948.7 | 45,335 |
| Spain | 10,083 | 39,914.5 | 165,987 |
| France | 91,459 | 142,850.4 | 637,199 |
| Croatia | 4,018 | 2,704.5 | 23,104 |
| Italy | 82,021 | 89,011.7 | 419,948 |
| Cyprus | 680 | 989.8 | 6,454 |
| Latvia | 3,530 | 1,353.3 | 17,816 |
| Lithuania | 2,142 | 1,332.2 | 19,742 |
| Luxembourg | 1,594 | 7,631.2 | 13,411 |
| Hungary | 24,887 | 7,644.2 | 71,650 |
| Malta | 32 | NA | 1,652 |
| Netherlands | 47,516 | 19,004.9 | 185,967 |
| Austria | 14,089 | 15,587.2 | 69,827 |
| Poland | 54,306 | 20,661.1 | 162,180 |
| Portugal | 10,133 | 10,176.8 | 64,887 |
| Romania | 13,558 | 7,166.7 | 119,587 |
| Slovenia | 4,938 | 2,371.1 | 14,840 |
| Slovakia | 9,816 | 4,786.2 | 35,639 |
| Finland | 6,719 | 12,088.2 | 65,165 |
| Sweden | 40,353 | 36,120.1 | 148,471 |
| United Kingdom | 131,457 | 177,340.5 | 693,453 |
| European Union 28 | **734,270** | **843,365** | **4,037,845** |
| Source: Eurostat 2012 | | | |

*NB: The total numbers of this table are different from those in Table 5 related to turnover and employment statistics per NACE Code because values for the EU-28 can be different from the sum of 28 EU Member States in the Eurostat database. The difference between these values is about 2%.*

## 1.3 Environmental aspects of the telecommunication and ICT services sector

### 1.3.1 Direct and indirect aspects

According to EMAS Regulation (EC 1221/2009), an 'environmental aspect' is an element of an organisation's activities, products or services that has or can incur an impact on the environment, both the natural environment and people. Environmental impacts arise from pressures generated by environmental aspects, such as the emission of greenhouse gases or air pollution (Table 7). Environmental aspects may be classified into:

- Direct environmental aspects: elements of an organisation's activities, products or services over which the organisation has full management control, and can thus influence directly.
- Indirect environmental aspects: elements of an organisation's activities, products or services over which the organisation does not have full management control, but can influence indirectly.

The Telecommunications and ICT Services sector is positioned after the production supply chain of ICT equipment and media contents and in direct contact with clients. Every stage of this chain, from raw material production, through manufacturing, storage, distribution and use, to dealing with waste, has environmental impacts. Direct aspects are the ones related to the Telecommunication and ICT Services sector only, whereas indirect aspects originate from all the other actors except Telecommunication and ICT Services providers, i.e. ICT manufacturers, wholesalers, retailers and consumers.

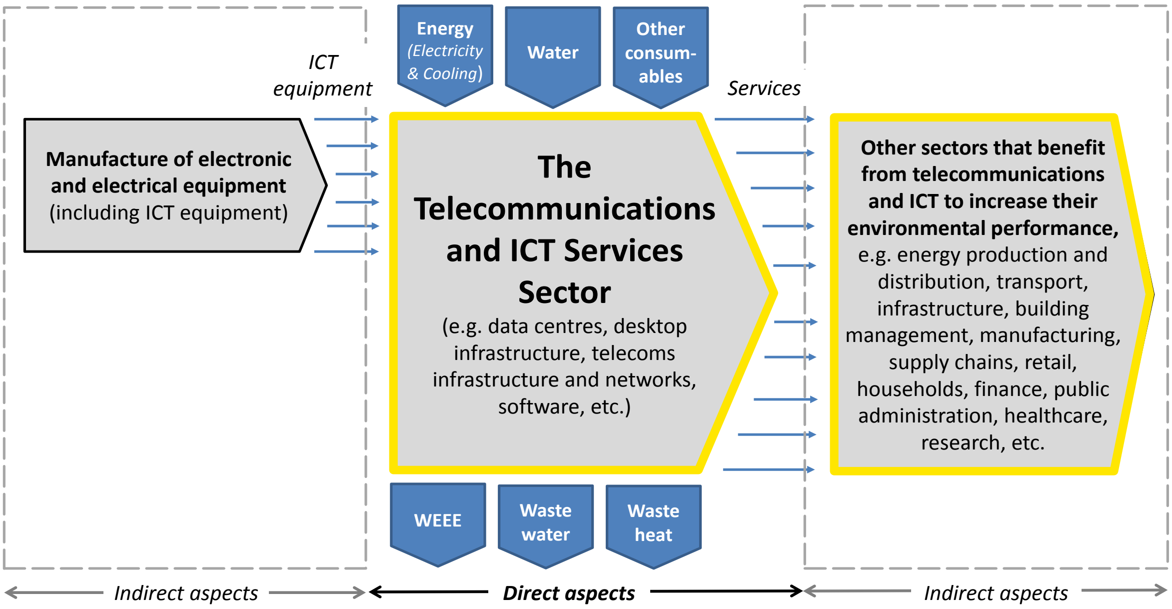


**Figure 10: Overview of the scope of the document**

Publishing software, providing broadcast services, managing data centres, running end-user devices (e.g. computers and other ICT equipment) and deploying telecommunications infrastructure and networks are the key activities that give rise to direct environmental impacts specifically associated with the Telecommunications and ICT Services sector. Other aspects, such as offices and building management,

transport and other operations (e.g. paper consumption), are general activities that are of high relevance for several sectors and for which BEMPs are already available in the document on BEMP in the Public Administration Sector[18].

The major indirect environmental aspects are associated with the production and end-of-life of ICT equipment as well as with the use of outsourced ICT services. Considered that most aspects of the ICT equipment supply chain (raw material supply, manufacturing, wholesale and retail, treatment of waste electrical and electronic equipment) are covered in other documents on BEMPs (electrical and electronic equipment (EEE) manufacturing sector and retail trade sector), the indirect aspects this reference document focused on result from the use of applications and ICT services, e.g.:

- Data processing and analysis (big data analysis in health, economics and other fields);
- Data modelling (design of products and services, solutions for smart cities, transport, distribution and logistics);
- Changing the way of communicating (work organisation, digitalisation, etc.).

Table 7 lists the main environmental aspects and associated environmental pressures arising from Telecommunications and ICT Services.

**Table 7: Main environmental aspects and environmental pressures related to the Telecommunications and ICT Services sector**

| Service / Activity | Main environmental aspects | Main environmental pressures |
|---|---|---|
| Data Centre | - ICT equipment (servers, storage devices, etc.)<br>- Software (processors)<br>- HVAC<br>- Power supply<br>- Buildings | - Energy and water consumption<br>- Generation of WEEE and waste water<br>- GHG emissions from electricity production and refrigerant leakages |
| End-user devices | - ICT equipment (computers, peripheral devices, etc.)<br>- Software | - Energy consumption to power hardware<br>- Generation of WEEE<br>- GHG emissions from electricity production |
| Telecommunication infrastructure and networks | - Buildings (central offices, base stations, etc.)<br>- Nodes (antennas, satellites, routers, etc.) | - Electricity consumption from network equipment and cooling systems<br>- Fuel consumption related to transportation |

[18] The best practice report for the public administration sector is available on-line at: http://susproc.jrc.ec.europa.eu/activities/emas/public_admin.html

| | | |
|---|---|---|
| | - Links (cables, fibres, landlines, etc.)<br>- Terminals (phones, computers, modems, etc.)<br>- Software (processors, controls, etc.) | - Generation of WEEE<br>- Electromagnetic waves generation<br>- GHG emissions from electricity production<br>- Changes to the landscape and habitats due to infrastructure deployment |
| Broadcasting services | - Buildings (base stations)<br>- Transmitters (antennas, satellites, etc.<br>- Links (cables, fibres, etc.)<br>- Terminals (radios, TVs, etc.)<br>- Software (processor) | - Energy consumption<br>- Generation of WEEE<br>- Electromagnetic waves generation<br>- GHG emissions from electricity production<br>- Changes to the landscape and habitats |

The following paragraphs provide some further feedback on the main environmental aspects for the sector covered in this document.

### *ICT equipment (hardware)*

Telecommunications and ICT services depend on a wide range of different types of hardware. For example, besides computers, data centres use servers and storage devices, end-user devices include peripherals (printers, copiers, etc.), telecommunication networks use terminals (phone, modems, etc.) and broadcasting uses antennas. The use of ICT equipment implies similar direct environmental pressures: electricity consumption and waste of electrical and electronic equipment (WEEE) mainly. The use of ICT equipment indirectly leads to environmental pressures related to the use of energy (GHG and other air emissions), to the manufacturing of ICT equipment (embodied energy, raw material consumption, etc.) and to its end-of-life management (soil or water pollution when not properly treated).

### *Software*

ICT equipment typically needs software such as operating systems, web browsers and mobile phone applications to function. Although software does not directly consume electricity, the hardware on which they are hosted does, and not well designed software can lead to an increase of the device's consumption. Software can be used to monitor and control ICT and other electric and electronic equipment and therefore plays an important part in determining the energy consumption of Telecommunications and ICT Services.

### *Heating, Ventilation and Air-Conditioning (HVAC)*

ICT equipment consumes electricity that often results in excess heat. In order to maintain a suitable working environment and insuring the integrity of hardware, the excess heat has to be removed. Due to the density of hardware and a high sensitivity of equipment to temperature and humidity, data centres are particularly concerned with ventilation and air conditioning, but also central offices in wireline networks and base stations in mobile networks. The excess heat requires specific cooling systems (composed of cooling plants, conditioners, humidifiers, etc.) which consume a significant amount of energy to operate. Cooling systems functioning leads to GHG

emissions: indirectly (from electricity consumption) and directly (due to refrigerant leakages). Some cooling systems also consume water, which is released into the environment after use. Significant level of noise may also be emitted by certain cooling equipment (due to the compressor action).

### Power supplies

ICT and other electrical and electronic equipment (e.g. computers, cooling systems, transceivers, etc.), require an electrical power supply to function. Electrical losses can occur due to line losses and power conversions (from alternative current to direct current, or reverse). Power supplies directly drive energy consumption, and indirectly GHG emissions (due to electricity production). This is particularly relevant for data centres and antenna that convert electricity from AC to DC. Back-up generators can also be responsible for fuel consumption and a source of noise emissions.

### Buildings and infrastructure

Data centres are sometimes as big as entire buildings and sites of their own. Telecommunication infrastructure such as radio towers, base stations and central offices can also be large structures. The construction and maintenance of large data centres and network infrastructure has an effect on landscapes and land use. Impacts depend on the size of the structure and its location.

### Wireless transmitters

Wireless communication, used for providing both telecommunications and broadcasting services, uses radio wave emissions (with a spectrum from 3 kHz to 300 GHz) as signals, which are captured by receivers (phones, satellites, modems, etc.). All radio transmitters create electromagnetic fields (EMF).

Moreover, telecommunications and broadcasting infrastructure can have a visual impact on the character and amenity of the local environment depending on the perception of the local community as well as the aesthetic value assigned to the landscape, both in urban and in rural contexts.

### Wirelines

Wireline communication relies on the use of thousands of kilometres of electric cables and optical fibres. These infrastructures contribute to electrical losses and effects on landscape (with aerial landlines).

### Transportation

The maintenance and management of network infrastructures raise the issues of transport. Materials and employees can be brought far away when performing such works. Besides, special vehicles – often with low fuel efficiency - can be required, depending on the type of equipment to be replaced or repaired.

## 1.3.2 Environmental pressures

The following paragraphs present the main environmental pressures that can result from the provision of telecommunications and ICT services. Nevertheless, a same activity can generate different environmental pressures, and implementing a best environmental management practice for reducing one major environmental pressure can lead to an increase of other environmental pressures. For example, the reuse of IT equipment can be beneficial from a raw material point of view, but not necessarily with regards to energy consumption (e.g. energy savings resulting from the use of a newer and more energy-efficient server are often greater than the energy required to

produce new equipment). Such aspects are identified and described for each BEMP, within the section entitled "cross-media effects".

### *Greenhouse gases emissions and energy consumption*

The main environmental pressure of the Telecommunications and ICT Services sector is its energy consumption and direct and indirect emission of greenhouse gases (GHG). Various studies have estimated the contribution of ICTs (excluding manufacturing and broadcasting) to climate change at between 2% and 3% of total global $CO_2$ emissions (Malmodin, 2010), (ITU, 2009), (Gartner, 2009). This ICT footprint is expected to increase significantly over the next few years according to several studies (Corcoran, 2013), (GeSI, 2012). The greenhouse gases emissions reported by the companies of the ICT sector (NACE codes 61, 62 & 63) are far lower, with only 0.2% of the total emissions at the EU-28 level.

A quantitative analysis of the different estimates of the ICT's sector energy consumption in Europe revealed that the ICT sector (excluding manufacturing and broadcasting) was directly responsible for the consumption of 214 TWh of electricity in 2011 (Öko Institute, 2013). This represented 7.7% of the total consumption in EU-27, and resulted in 88.3 million tonnes of $CO_2$e. These figures are expected to increase to 259 TWh in 2020 or 8.1% of the total consumption of electricity in the EU.

While the use of fixed ICT products at home and at the office represented 2/3 of the total electricity consumption of the sector in 2011, this will decrease both in absolute and relative terms due to the increased use of mobile phones and the energy efficiency improvements of ICT equipment. However, the end-user devices related energy-consumption highly depends on the way of use. A significant growth of electricity consumption is expected for data centres and telecommunication networks (35% and 150%, respectively), because of increased use of the internet and cloud services.

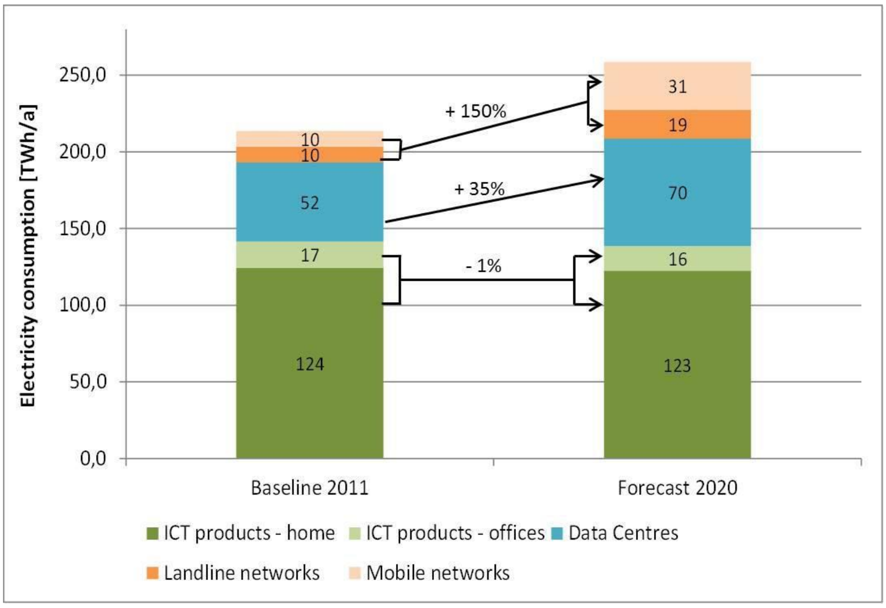


**Figure 12: Comparison of the ICT-related electricity consumption in EU-27 in 2011 & 2020, excluding ICT manufacturing and broadcasting. Source: (Öko Institute, 2013).**

### *Raw material consumption and WEEE production*

Another main environmental pressure related to the Telecommunications and ICT Services sector is its contribution to demand for ICT equipment and the production of e-waste (or Waste of Electrical and Electronic Equipment). ICT equipment contains a great number of different metals and other materials, some of them valuable (gold, copper, iron, etc.) and others harmful (lead, cadmium, chromium, PCBs, etc.). While the reuse or material recovery of the equipment may generate a source of income, inappropriate treatment of WEEE may generate health risks due to the inhalation of toxic fumes or the accumulation of chemicals in soil, water and food.

In 2012, more than 650,000 tonnes of wasted IT and telecommunications equipment[19] was collected[20] in EU-28 (Eurostat, 2012c). At the same time 1,275,000 tonnes of products were put on the market and about the same quantity of waste was produced (Eurostat, 2012c). While the number of products put on the market has decreased slightly since 2007 (an average of -3% each year), the quantity of waste collected started decreasing after 2010.

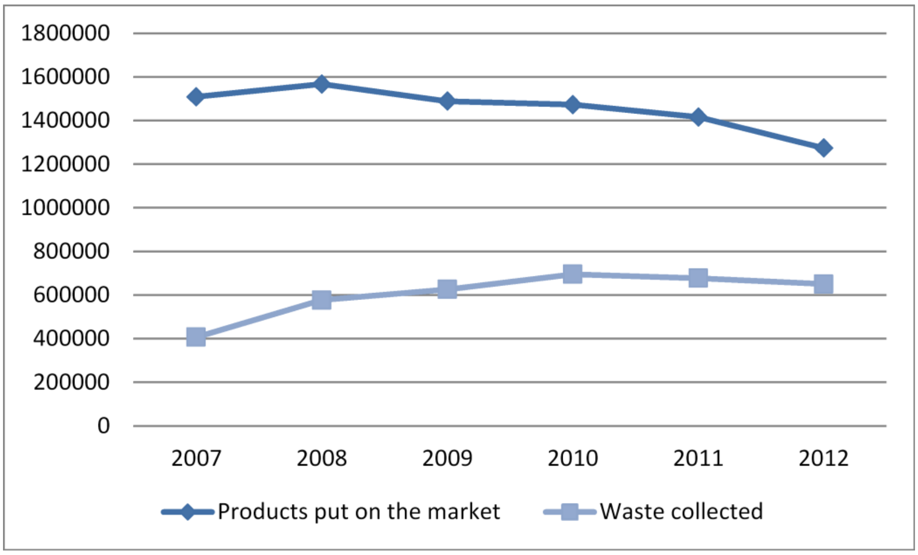


**Figure 13: Evolution of IT and telecommunications equipment put on the market and collected as waste in EU-28, in tonnes (source: Eurostat, 2012c)**

In EU-28, most of the wasted IT and telecommunication equipment is collected from households (89.5% according to Eurostat, 2012c). The majority of this waste is treated in the Member State where it was collected (83.5%), and 73.2% is recycled or reused (Eurostat, 2012c).[21] According to the European Commission, only one third of e-waste in the EU was reported as appropriately treated (European Commission, 2009a). The other two thirds were sent to landfills or potentially to sub-standard

[19] The WEEE Directive defines the IT and telecommunications equipment as: centralised data processing, mainframes, minicomputers, printer units, personal computers (CPU, mouse, screen and keyboard included), laptop computers, notebook computers, printers, copying equipment, electrical and electronic typewriters, user terminals and systems, facsimile, telex, telephones (including pay telephones, cordless telephones and mobiles, answering systems, pocket and desk calculators and other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means.

[20] 650,871 tons of IT and telecommunications equipment (Eurostat, 2012c). In Italy only the quantity of waste collected from households is included (data for waste collected from other sources was not available).

[21] Calculation made on the basis of data given by the Eurostat database for 2012 in the EU28, except for the United Kingdom (data related to recycling were not available).

treatment sites in, or outside the EU. In this regard, illegal trade of electrical and electronic waste (including ICT equipment) to non-EU countries was estimated to be widespread, 12% of waste streams detected in transport violations were WEEE, even if most illegal shipments appear to be intra-EU movements[22].

### *Water consumption and wastewater production*

Some data centres use water for cooling their ICT equipment. The quantity and the quality of water used (fresh water, "grey" water, etc.) depend on the type of cooling system. While liquid-based cooling systems are considered more energy-efficient than air-based cooling systems, they use water. The water consumption of data centres is only an issue in water stressed regions. Regarding the production of wastewater, the main pressure relies on the discharge in the natural environment of warmer water, which can affect the local ecosystem.

### *Electromagnetic radiation*

Exposure to non-ionising electromagnetic fields is growing, due to the deliberate use of radio waves and microwaves for telecommunication and broadcasting, and due to indirect production (by the electricity supply grid for example). This is a cause of concerns for citizens and organisations. Exposure limits have been set up in the EU, on the basis of the guidelines of the International Commission on Non-Ionising Radiation Protection (ICNIRP). While absorption of electromagnetic field energy[23] leads to heating of body tissue at typical telecommunication frequencies, the effects of long-term exposure on human health or wildlife are difficult to assess (European Commission, 2005). The latest opinion of the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) on Potential health effects of exposure to electromagnetic fields (EMF) was state as following:

> *"Overall, the epidemiological studies on mobile phone RF EMF exposure do not show an increased risk of brain tumours. Furthermore, they do not indicate an increased risk for other cancers of the head and neck region. […] Epidemiological studies do not indicate increased risk for other malignant diseases, including childhood cancer. Overall, there is a lack of evidence that mobile phone RF EMF affects cognitive functions in humans."* (SCENIHR, 2015)

However, according to the WHO, the current level of knowledge on EMFs is significantly higher than for most other health related topics (WHO, 2015). The current levels of EMFs from telecommunication infrastructures are usually well below the levels identified by research as potentially damaging.

### *Changes to landscapes, land use and habitats*

Telecommunications and broadcasting infrastructures are composed of different structures such as telephone lines, antennas, dishes, radio masts, towers, base stations and buildings, which may have a visual impact on the character and amenity of the local environment as well as the aesthetic value assigned to the landscape, both in urban and in rural contexts. The need to integrate ICT infrastructures in an urban

[22] For more information, see: http://www.impel.eu/transboundary-enforcement-actions-project-results-in-17500-inspections/#

[23] Levels of absorption of electromagnetic radiations depend on the transmission frequency and the distance from the source (transmitting antenna, mobile phones, etc.).

landscape without defacing existing buildings is a real challenge for network operators. In a rural context, terrestrial and aquatic habitats may be altered primarily during the construction of telecommunications infrastructure depending on the type of infrastructure component and proposed location. Potential impacts on biodiversity may be more significant when creating long distance fibre optic cables, and access roads to transmission towers and other fixed infrastructure. In both contexts, the acceptance of the infrastructure by stakeholders (including inhabitants and local authorities) can vary considerably. A low acceptance by local stakeholders can be damaging for the network operators and results in complaints and reputational issues.

### *Other environmental pressures*

The Telecommunications and ICT Services sector also contributes to other environmental pressures such as:

- air pollution (from diesel generators to power base stations),
- ozone depletion (from leakage of some types of refrigerants of cooling systems and fire extinguishers),
- noise (from generators and compressors),
- heat rejection (in the form of warmer water or steam generated by cooling systems), and its effects in terms of increasing the temperature of the local environment and disturbing ecosystems.

## 1.4 Use of Environmental Management Systems in the Telecommunication and ICT Services sector

### 1.4.1 EMAS deployment in European companies of the sector

The EU Eco-Management and Audit Scheme (EMAS) is a management tool developed by the European Commission for companies and other organisations to evaluate, report and improve their environmental performance. EMAS is open to every type of organisation committed to these goals. It spans all economic and service sectors and is applicable worldwide. Currently, almost 3,000 organisations and approximately 9,750 sites are EMAS-registered in EU-28, including many multinational companies and smaller companies as well as public authorities[24]. This study as well as the Sectoral Reference Document (SRD) that will be developed by the European Commission is carried out under the EMAS regulation.

According to the EMAS registration database (23 July 2015), 42 different organisations were registered under the NACE codes relevant for the Telecommunications and ICT Services sector.[25] The sites registered belong to the following activity groups (NACE codes):

- 18.20 - Reproduction of recorded media (1 site)
- 33.20 - Installation of industrial machinery and equipment (4 sites)
- 58.29 - Other software publishing (2 sites)
- 61.10 - Wired telecommunications activities (5 sites)
- 61.20 - Wireless telecommunications activities (2 sites)
- 61.90 - Other telecommunications activities (3 sites)
- 62.01 - Computer programming activities (8 sites)

[24] See EMAS website: http://ec.europa.eu/environment/emas/index_en.htm

[25] See EMAS register website: http://ec.europa.eu/environment/emas/register/search/search.do

- 62.02 - Computer consultancy activities (7 sites)
- 62.03 - Computer facilities management activities (5 sites)
- 62.09 - Other information technology and computer service activities (14 sites)
- 63.12 - Web portals (1 site)
- 63.99 - Other information service activities n.e.c. (4 sites)
- 82.20 - Activities of call centres ( 4 sites)

Additionally, it should be noted that many companies are registered for more than one activity, and that different sites of a same organisation may be registered in the EU EMAS register.

Most of the sites registered as Telecommunications and ICT Services under the EMAS regulation are in Spain (32 sites) and Italy (20 sites). The other countries are Austria, Germany and the United Kingdom with two sites each, and Portugal and Belgium with one site each.

### 1.4.2 ISO 14000 family of standards

The ISO 14000 family addresses various aspects of environmental management. It provides practical tools for companies and organisations looking to identify and control their environmental impact and constantly improve their environmental performance. ISO 14001:2015 and ISO 14004:2015 focus on environmental management systems. The other standards in the family focus on specific environmental aspects such as life cycle analysis, communication and auditing[26].

Though many companies have declarations on their websites as well as in public environmental reports as to the various standards that they apply (including ISO standards), there is no public registry of companies certified with ISO 14001. Therefore, it could not be clarified how common this practice effectively is.

However, reports of the larger firms show that many of these recognise the importance of applying such schemes, declaring how wide ISO 14001 certification is in their facilities and often publishing information on their certification under the environmental sections of their websites. From the companies reviewed, some reported on having at least one of the above mentioned environmental management schemes in place, some having both.

[26] For more information, see http://www.iso.org/iso/iso14000.

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# 2 Cross-cutting measures

## 2.1 Introduction / scope

This chapter focuses on cross-cutting measures which could apply to all types of organisations in the telecommunication and ICT services sector at different levels (data centres, telecommunication networks, end-user devices, etc.).

These BEMPs offer guidance on the design, implementation and monitoring of management frameworks for environmental issues. These frameworks are helpful in order to identify and to optimise environmental impacts across multiple processes, bearing in mind potential trade-offs between different impacts and lifecycle stages.

*For BEMPs specific for data centres, see Chapter 3 and for telecommunication networks see Chapter 4.*

The following four BEMPs can be implemented in any type of organisation in the telecommunication and ICT services sector:

- **Making the best use of an Environmental Management System (EMS):** An EMS is a tool that provides organisations with a method to systematically manage and improve the environmental aspects of their operations (European Commission, 2016). It helps organisations to achieve their environmental obligations and performance goals. The International Standards Organisation (ISO) defines an EMS as *"the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy"* (UNEP, 2016). There is an ISO standard for EMS (ISO 14001[27]) as well as a European scheme set by EU legislation (EMAS[28]) including the ISO 14001 standard as well as additional elements. This report focuses on the environmental performance related aspects of EMS implementation, in particular the identification of relevant environmental aspects, effective performance monitoring and benchmarking, and targeted BEMP prioritisation. It provides users of this document with guidance on how to identify the most relevant BEMPs and associated benchmarks of excellence. Readers are referred to existing guidance documentation for specific cross-sectoral compliance requirements of EMAS and other EMS schemes. For data centres, see also the BEMP regarding the implementation of an energy management system (Section 3.2.2).
- **Procurement of sustainable ICT services and products:** it refers to the process which aims at procuring goods and services with a reduced environmental impact throughout their life cycle when compared to products or services with the same primary function (Buy Smart +, 2012). This report focuses on specific environmental procurement criteria related to selection and purchasing of ICT equipment. For equipment specific to data centres, see the BEMPs 3.3 on the selection and deployment of new equipment for data centres. For telecommunication networks, see the BEMP 4.4 on Selecting and deploying more energy-efficient telecommunication network equipment.

[27]For more information, see: http://www.iso.org/iso/iso14000

[28] Further information on EMAS is available at www.emas.eu.

- **Optimising the energy consumption of end-user devices:** Energy consumption of ICT equipment depends on two main factors: energy requirements, or the energy required to run the equipment and usage pattern, or the way the equipment is used (duration, activity, load, etc.). This report focuses on ICT equipment, devices and peripherals used by telecommunication and IT companies, such as:
    - Data centre equipment (servers, cooling equipment, uninterruptible power supplies, etc.);
    - Network equipment (antennas, switching systems, etc.);
    - Personal computers (desktop and laptop);
    - Mobile devices (smartphones, mobile, tablets, etc.);
    - Other peripherals (monitors, scanners, copiers, fax machines, etc.).
- **Renewable and low-carbon energy:** using renewable energy sources such as biomass, solar, wind, geothermal and hydro technologies reduces significantly the carbon footprint of electricity production compared to conventional energy generation in the form of the combustion of fossil fuels (coal, natural gas, oil, etc.). This report focuses on the renewable energy sources and technologies most relevant for telecommunication and ICT equipment and facilities.
- **Waste management:** refers to the best practices related to the different stages and the hierarchy of waste management (prevention, reuse, recycle, recovery, refurbishment and disposal) in order to reduce impacts on human health and the environment (ITU, 2012b). This report focuses on the asset management and end-of-life management of telecommunications and ICT equipment under direct control of organisations in the telecommunications and ICT services sector.

**Table 8: Scope of BEMPs related to cross-cutting measures**

| BEMP | Description / Scope | Related BEMPs |
|---|---|---|
| **2.2 Making the best use of an environmental management system** | <u>Techniques:</u><br>• Define the organisation's needs and audit the existing ICT equipment, services and software.<br>• Measure, monitor and manage the environmental performance of ICT equipment infrastructure and facilities.<br>• Set objectives and action plans based on benchmarking and best practices.<br><br><u>Applicability:</u><br>• Facility level (data centre, base station, etc.)<br>• Network level<br>• Company level<br><br><u>Environmental aspects:</u><br>• All environmental aspects (especially energy efficiency) | *Specific for energy management of data centres:*<br>⊠ Implement an energy management system for data centres (including measuring, monitoring and managing equipment) – see Section 3.2.2 |
| **2.3 Procurement of sustainable ICT products and** | <u>Techniques:</u><br>• Assess the existing assets of ICT equipment and the needs in the | *Specific for equipment and services in data centres:*<br>⊠ Selection and deployment |

| | | |
|---|---|---|
| **services** | procurement process preparation.<br>• Include in the call for tender required specific environmental criteria to be met.<br>• Ensure proper use by end-users when deploying ICT equipment through asset management, communication and training.<br>• Establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact.<br><br><u>Applicability:</u><br>• Network equipment (antennas, switching systems, etc.)<br>• Servers and storage equipment<br>• Personal computers (desktop and laptop)<br>• Mobile devices (smartphones, mobile, tablets, etc.)<br>• ICT equipment used by customers (routers, set-top boxes)<br>• Other peripherals (monitors, scanners, copiers, fax machines, etc.)<br>• Power supply equipment (UPS)<br>• Software<br><br><u>Environmental aspects:</u><br>• All environmental aspects (especially energy efficiency and raw material consumption) | of equipment for data centres – see Section 3.3<br>☒ Energy efficient software – see Section 3.4.2<br><br>*Specific for equipment and services in telecommunication networks:*<br>☒ Selection and deployment of equipment networks – see Section 4.4 |
| **2.4 Optimising the energy consumption of end-user devices** | <u>Techniques:</u><br>• Adopt technical solutions:<br>  ○ Installing appropriate devices in terms of energy performance and functionalities depending on the needs of users;<br>  ○ Properly configuring equipment to minimise unnecessary functionalities and power consumption;<br>  ○ Performing regular energy audits to check devices configuration and powered-off devices;<br>  ○ Developing power management solutions using different types of power management modes (manual, default, through software) or using dedicated devices (smart power strip, etc.).<br>• Adopt organisational solutions:<br>  ○ Assessing individual user acceptance;<br>  ○ Raising users' awareness.<br><br><u>Applicability:</u><br>• Facility level (data centre, base station, etc.)<br>• Network level<br>• Company level | *Specific for energy management of data centres:*<br>☒ Implement an energy management system for data centres (including measuring, monitoring and managing equipment) – see Section 3.2.2<br>☒ Define and implement a data management and storage policy – see Section 3.2.3<br><br>*Specific for equipment and services in telecommunication networks:*<br>☒ Improving the energy management of existing telecommunication networks – see Section 4.2 |

| | | |
|---|---|---|
| | <u>Environmental aspects:</u><br>• Energy efficiency | |
| **2.5 Use of renewable and low-carbon energy** | <u>Techniques:</u><br>• Purchase third-party green electricity.<br>• Produce one's own electricity, either on or off-site.<br>• Store electricity on-site in an efficient way.<br><br><u>Applicability:</u><br>• Facility level (data centre, base station, etc.)<br>• Company level<br><br><u>Environmental aspects:</u><br>• GHG emissions | *Specific for data centres:*<br>• Selecting the geographical location of the new data centre (Section 4.5.5)<br><br>*Specific for free cooling of data centres (i.e. the use of a ground source for cooling):*<br>• Use alternative water sources (Section 4.5.6) |
| **2.6 Waste management of ICT equipment through prevention, reuse, recovery and recycling** | <u>Techniques:</u><br>• Develop a waste prevention plan.<br>• Promote LCA-based eco-design through procurement.<br>• Increase the service life and limit the obsolescence of ICT equipment the reduction of the obsolescence.<br>• Implement systems to enable re-use of ICT equipment.<br>• Ensure traceable collection and proper sorting of end-of-life ICT equipment.<br><br><u>Applicability:</u><br>• All ICT equipment (networks, data centres, end-user devices, customer devices…)<br><br><u>Environmental aspects:</u><br>• Raw material consumption<br>• Waste generation<br>• Hazardous waste | |

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## 2.2 Making the best use of an environmental management system

**SUMMARY OVERVIEW:**

**ICT facilities have important environmental impacts through energy consumption, water consumption and waste generation. It is particularly important for telecommunication and ICT services companies to monitor their environmental impacts and implement an environmental management system to systematically minimise these impacts. It is considered best practice to:**

- **Define the organisation's needs and audit the existing ICT equipment, services and software.**
- **Measure, monitor and manage the environmental performance of ICT equipment infrastructure and facilities.**
- **Set objectives and action plans based on benchmarking and best practices.**

**ICT components**

| | | | | |
|---|---|---|---|---|
| **Data centre** | **Telecommunication network** | Broadcasting | Software publishing | **End-user devices** |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| Design and installation | **Selection and procurement of the equipment** | **Operation and management** | Renovation and upgrades | **End-of-life management** |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | **Resources consumption** | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- Implementation of an asset management system certified ISO 55001 (Y/N)
- Share of facilities or sites with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS verified, ISO 14001 certified
- Share of facilities or operations measuring and monitoring energy use and water consumption as well as waste management
- Share of staff provided at least once with information on environmental objectives and training on relevant environmental management actions
- Energy use (in kWh) per unit of turnover (€) or network traffic (Terabyte) (for telecommunication network operators)
- Power Usage Efficiency (PUE) (for data centres)
- WEEE generation (in kg or tonnes) per unit of turnover (€)
- Water consumption (m3) per unit of turnover (€) or building surface (m2)
- Total carbon emissions (in tCO2eq.) for scope 1 and 2
- Total carbon emissions compensated (in tCO2eq.) through Clean Development Mechanisms (CDM)
- Carbon emissions (in tCO2eq.) for scope 1 and 2 per unit of turnover (€)

**Cross references**

| | |
|---|---|
| **Prerequisites** | • N/A |
| **Related BEMPs** | • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment) |

| | |
|---|---|
| | • 2.3 Procurement of sustainable ICT products and services<br>• 2.6 Waste management of ICT equipment through waste prevention, reuse and recycling |

### 2.2.1 Description

An environmental management system (EMS) provides an organisation with a framework for managing its environmental responsibilities efficiently and to reduce environmental impacts. It is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating effectiveness. An environmental management system can be informal internal practices as well as be based on internationally recognised standards such as the ISO standard 140001 or on the European scheme EMAS and follows the principle of continuous improvement with the Plan – Do – Check – Act cycle (Figure 14). It also provides the organisation with a framework to monitor key environmental performance indicators.


**Figure 14: The principle of continuous improvement of environmental management systems through the Plan-Do-Check-Act cycle (European Commission, 2016)**

The main objectives of an EMS are the following:

- Reviewing the organization's environmental goals
- Analysing environmental impacts and legal requirements
- Setting environmental objectives and targets to reduce environmental impacts and comply with legal requirements
- Establishing programmes to meet objectives and targets
- Monitoring and measuring progress in achieving the objectives
- Ensuring employees' environmental awareness and competence

- Reviewing progress of the EMS and making improvements.

The implementation of EMS in organisations in the telecommunications and ICT services sector helps reducing the environmental impact of their operations and activities. It can be adapted to different types of facilities:

- **Data centres**: composed of power equipment, uninterruptible power supplies (UPS), transformers, air management and cooling systems, IT equipment such as servers and storage devices, routers, switches and cabling.
- **Telecommunication network infrastructure:** composed of telecommunication network components such as routers, cabling, and optical fibres.
- **Offices**: composed of PCs, notebook computers, monitors, multifunctional devices such as printers, servers.
- Call centres.
- Film and television production sites.

Other environmental aspects, such as the fleet vehicles of the organisation, can also be taken into account.

The main environmental impact of organisations in the telecommunication and ICT services sector is related to energy consumption which can be managed by the overall environmental management system or by a specific energy-focused EMS such as ISO 50001 Energy Management Systems (see the BEMP on energy management systems for data centres in Section 3.2.2). However, in order to adopt an integrated vision of environmental impacts, overall EMS allow to take into account other impacts such as waste generation and water consumption at the same time.

Other related ISO standards are:

- ISO 14004 provides guidance on the establishment, implementation, maintenance and improvement of an environmental management system and its coordination with other management systems.
- ISO 14006 is focused on the integration of eco-design into other management systems.
- ISO 14064-1 specifies principles and requirements at the organizational level for the quantification and reporting of greenhouse gas (GHG) emissions and removal.

Other standards, such as ETSI standard (ETSI ES 202 336-12 V1.1.1, 2015) on Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks), can also be used.

This BEMP explains how environmental management can be implemented and applies at site or company level. It is based on an iterative sequence which facilitates continuous improvement and allows those responsible to be proactive. The general guidelines provided on the implementation of EMSs allow considerable freedom in terms of the environmental criteria concerned. While EMSs are generally applicable to all types of organisations, in the telecommunication and ICT services organisations, it is best practice to:

- **Define the organisation's needs and audit the existing ICT equipment, services and software.**

  It involved the collection of data and information to understand the use of ICT equipment to assess the needs for replacement and new devices and services.

- **Measure, monitor and manage the environmental performance of ICT equipment infrastructure and facilities.**

  This can be implemented by:

  - Installing automated metering equipment to collect and log environmental performance data;
  - Implementing real time monitoring of environmental and energy performance;
  - Involving employees and customers to change habits when using ICT equipment.

- **Set objectives and action plans based on benchmarking and best practices.**

  The analysis of monitoring process and the benchmark of best practices help define action plans and objectives. Moreover, this report on BEMP in the telecommunication and ICT services sector gives a set of best practices and related benchmarks of excellence for the sector. It can be used as a reference to benchmark best practices to implement for different ICT assets (End-users devices in BEMPs in chapter 2, Data centres in BEMPs in chapter 3, Telecommunication networks in BEMPs in chapter 4) and to position company's performance for each solution with a view to set objectives and an action plan to reach them.

### 2.2.2 Achieved environmental benefits

The implementation of an environmental management system can lead to different types of environmental benefits. The first step of an EMS implementation results in the identification of the most relevant environmental stakes for the organisation. The review of the organisation's environmental goals, environmental impacts and legal requirements and the setting of environmental objectives and targets will lead to the prioritisation of the objectives according to potential benefits and results.

In regards to environmental issues concerning the telecommunication and ICT sector defined in the Chapter 1.1, the environmental benefits cover:

- **Energy reduction**: putting in place energy management and monitoring is expected to have a twofold environmental benefit. First, a more thorough monitoring is expected to reduce the energy consumption of ICT infrastructure, which is much larger than the actual energy needed to operate the equipment. For instance, in a data centre, the energy consumed is split between servers (which do directly useful work) and the power, cooling, and networking infrastructure that supports the correct functioning of servers. It is estimated that, in average, for every Watt of energy being consumed by servers, about 0.5 W is needed to cool them (Hancock, 2009). Another source of additional energy consumption is the powering of idle resources. In facilities without appropriate energy monitoring practices, servers consume almost as much energy when idle or lightly loaded, as when heavily loaded (Meisner, 2009). The problem is exacerbated by the fact that most data centres, being provisioned for peak rather than average load, are very lightly loaded on average — considerably less than 50% typically. The consequence of this lack of appropriate energy monitoring is that, while a PUE of 1 would signal a 100% energy efficiency, the current industry average is estimated to be somewhere between 1.6 and 1.8 (Geet, 2014). The performance varies very much from one data centre to another and considerable inefficiencies exist. Putting in place energy measurement tools can allow the identification of energy inefficiencies, and the adoption of processes to monitor energy use.

For office devices, the optimisation of existing assets can be done by auditing and adapting the equipment to the user's needs. For instance, laptop computers consume between 50% and 80% less energy than workstations (Buy Smart +, 2012). The optimisation of the number of devices used through the use of multifunction devices (such as printers that also makes copies, faxes and scans) will also impact the energy consumption. Multifunction devices consume 50% less energy than the consumption of four separated devices (Buy Smart +, 2012).

Telecommunication networks that are properly monitored with management tools allow the optimisation of equipment and reduce the energy consumption throughout the network from the customer premises equipment, the remote node or base station and the terminal unit.

Reducing energy consumption is often directly linked to a **reduction of $CO_2$ emissions**.

- **WEEE and waste reduction**: EMS will allow for other direct environmental benefits through the reduction of waste generated and the extension of service life of equipment. It reduces the emission of waste and hazardous waste. The implementation of the EMS ISO 14001 standard can lead to an increase in the amount of equipment sent for recycling and refurbishment of about 30% (Afnor, 2016).
- Other environmental benefits such as **water consumption reduction**. The implementation of ISO 14001 can lead to the reduction of 15% in water consumption (Afnor, 2016).

### 2.2.3 Appropriate environmental performance indicators

There are different types of performance indicators that can be used when implementing environmental management systems:

- Outcome-oriented indicators (measure the environmental performance of the organisation):
    - energy use (in kWh) per unit of turnover (€) or network traffic (Terabyte), for telecommunication network operators;
    - Power Usage Efficiency (PUE) (for data centres) which is defined as the ratio of the total power to run the data centre facility to the total power drawn by all IT equipment. PUE is the most common energy performance indicator for data centres (more details are available in section 3.2.2.3 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment));
    - WEEE generation (in kg or tonnes) per unit of turnover (€) to analyse the waste management system performance;
    - water consumption (m3) compared to the turnover (€) or building surface ($m^2$) to analyse the water management system performance;
    - total carbon emissions in tCO2eq. for scope 1 and 2;
    - total carbon emissions compensated in tCO2eq. through Clean Development Mechanisms (CDM). The best practice is to be carbon neutral, including green electricity and compensation. Frontrunners like KPN and Telenet mobile telecommunications companies, reach carbon neutrality using about 90% of green electricity and 10% of compensation projects.

  - carbon emissions in $tCO_2eq$. for scope 1 and 2 per unit of turnover (€);
- Process-oriented indicators (measures the implementation of environmental management):
  - the implementation of an asset management system certified ISO 55001;
  - the share of facilities or sites with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS verified, ISO 14001 certified;
  - the share of facilities or operations measuring and monitoring energy use and water consumption as well as waste management;
  - the share of staff provided at least once with information on environmental objectives and training on relevant environmental management actions.

### 2.2.4 Cross-media effects

An environmental management system is a holistic approach, which considers all major environmental aspects and takes into consideration the needs and specificities of organisation and sites, so that actions result in improving the overall environmental performance.

Some environmental aspects can be conflicting. For instance, the development of energy management objectives involves renewing the ICT equipment by investing in more energy efficient devices but this will generate more waste by dismissing previous generation equipment. An EMS provides a framework to prioritise actions and manage these trade-offs. The typology of the sites and equipment, stakes and objectives must be analysed to determine the best approach and maximise the outcome.

### 2.2.5 Operational data

Frontrunner organisations have third-party certified or verified environmental management systems such as EMS based on ISO 14001[29] and EMAS covering all their facilities and operations.

General guidance on the implementation of EMAS is available on the internet:

- General guidance (http://ec.europa.eu/environment/emas/index_en.htm), which can be used in conjunction with the sector-specific guidance in this document.
- Organisations with non-standardised EMS can find step-by-step information on how to move to the more ambitious EMAS system in the "Step up to EMAS" study.[30] This provides specific information for 20 of the most commonly used EMS)
- For small and medium sized enterprises (SMEs), a simplified system – EMAS easy (http://www.emas-easy.eu/) – has been developed that allows EMAS to be implemented in a way that is proportional to the size and capabilities of smaller businesses.

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[29] ISO 14001 was revised in 2015. For more information on ISO 14001, see http://www.iso.org/iso/iso14000.

[30] Available at http://ec.europa.eu/environment/emas/documents/StepUp_1.htm

**Define the organisation's needs and audit the existing ICT equipment, services and software**

The first step to improve environmental management is the audit of existing ICT equipment and assets in relation to the needs of the organisation. It involves the collect of data and information to understand the use of the ICT equipment and the current environmental performance.

This step for environmental management requires the mapping of the activity and the identification of types of equipment, person in charge of controlling the equipment and of the existing tools and methods used to manage the equipment.

The audit of existing ICT equipment, services and software also allows the evaluation of the needs for new and more efficient equipment, services and software. For equipment that needs to be replaced, it will help determine if the equipment can be reused, repaired or recycled according to the most appropriate waste management option (see the BEMP on waste prevention and management (and asset management) - section 2.6). For services, cloud computing may be a more energy efficient solution when compared to organisations operating their own servers and data centres (see the BEMP on procurement - section 2.3). For software, organisations may select or develop software that uses the least energy to perform the required tasks whilst meeting the organisation's needs and constraints (see the BEMPs on energy efficient software – Section 3.4.2.1 and Section 4.7).

Asset management can also lead to the decommissioning of old equipment, in order to improve energy efficiency.

**Measure, monitor and manage the environmental performance of ICT equipment infrastructure and facilities**

The measuring and monitoring stage of an EMS implies the collection of data and the analysis of the information to track the environmental performance. In order to do this, organisations should:

- **Install automated metering equipment to collect and log environmental performance data**: The collection of data can be done either with periodic manual readings of the data provided by the metering equipment, occurring at regular times (ideally at peak load), or with automated daily readings, enabling more effective monitoring. There are specific technologies and equipment to collect and measure data, but most ICT equipment have the ability to measure, monitor and communicate their energy performance. For example, there are several different types of meters that can be designed into a data centre, ranging from high precision power quality meters to embedded meters (i.e. in a UPS or PDU). Each has different core functions and applications (see Table 9). Real time interactions between the equipment and the control system allow a self-awareness of the system, which means that it can adapt its activity to a given context.

  There is a risk of over-metering since deploying a lot of sensors and meters can produce large quantities of data which are not analysed. It is better to have sensors placed in the right location and acting on the data that is gathered than trying to monitor everything. It is very important to define the right balance between the number of sensors and the target of monitoring, by using an iterative process (few sensors at the beginning, and the sub-monitoring can be increased if necessary).

**Table 9: Application and cost comparison of different types of electrical meter devices used in data centres (Kidd & Torell, 2013)**

| Type of meter | Applications | Installed cost per meter* |
|---|---|---|
| Power quality meters | • power quality monitoring<br>• electric utility bill verification<br>• power circuit loading & balancing<br>• energy management<br>• maintenance activity support | €4500 – €10000*** |
| Power meters | • power circuit loading & balancing<br>• energy management<br>• cost allocation / billing<br>• maintenance activity support<br>• critical incident alarming | €500 - €3000 |
| Digital relay embedded meters** | • protective device for medium voltage equipment<br>• power circuit loading & balancing<br>• maintenance activity support<br>• critical incident alarming | ~€1000 |
| Electronic trip unit embedded meters** | • protective device in low voltage circuit breakers<br>• power quality monitoring<br>• power circuit loading & balancing<br>• energy management<br>• maintenance activity support<br>• critical incident alarming | €500 - €11600 |
| Uninterruptible power supply (UPS) embedded meters | • engineering data support<br>• PUE monitoring<br>• critical incident alarming | Included in UPS price |
| Power distribution unit (PDU) embedded meters | • PUE monitoring<br>• management of power capacity<br>• cost allocation<br>• critical incident alarming | Included in PDU price |
| Rack PDU embedded meters | • most accurate “IT load” measurement per Green Grid<br>• load balancing<br>• rack level power capacity management | €0.04-€0.05 / watt premium over basic rack PDUs |

** Based on typical pricing in US market and assumes that the metering is ordered with, and installed into, the power distribution equipment*
*** Cost to add metering functionality to protective devices*
**** Large price range due to functionality differences in embedded meters; low end trip unit meters are basic power meters whereas high end trip unit meters are power quality meters with breaker diagnostics*

- **Implement real time monitoring of environmental and energy performance**: Real time monitoring of environmental performance encourages the analysis of the evolution of the performance (daily, monthly, quarterly and annually). The installation of smart meters can help users when managing their ICT equipment. Data needs to be reported to be of use in managing the environmental performance of the facility. ICT equipment and systems allow an automated environmental or energy reporting console instead of manually collecting, logging and analysing data. Analysing data allows the infrastructure

management team to set objectives for the facility, and to check the variation of its performance over time. To help the target setting process, the management team can estimate its position among industry peers Google uses machine learning techniques that learn from actual operations data to model data centre performance and predict PUE (Gao, 2014). This allows them to understand and optimise energy efficiency.

- **Involve employees and customers to change habits when using ICT equipment**: a key step in the implementation of environmental management system is the staff involvement (IT2Green, 2014), but also customers. For example BT, has an ambition to help their customers reduce their carbon emissions (BT, 2015). As for users, the objective is to encourage them to question their habits on the use of ICT equipment. For staff managing ICT equipment and analysing data, training on the management tools used is needed. The best practice is to provide all employees with information on environmental objectives and training on relevant environmental management actions.

**Set objectives and action plans based on benchmarking and best practices.**

For the environmental management system to allow continuous improvement, objectives and action plan must be determined. Measurement and monitoring of environmental performance helps determining objectives. Benchmarking sectorial performance levels also supports the establishment of relevant objectives compared to competitors and best practices. Objectives shall be determined over different timeframe: short-term, mid-term and long-term objectives.

Table 10 shows examples of benchmark on targets that major telecommunication companies have set themselves. Action plans must be defined to answer these objectives in time. The evaluation of the completion of the objectives can be done quarterly and annually to ensure their achievement.

**Table 10: Examples of energy and carbon targets set by major telecommunication companies in Europe**

| Company | Sourcing renewable electricity | Increasing energy efficiency | Carbon reduction target | Enabling the energy saving-potential of ICT |
|---|---|---|---|---|
| **Proximus** | Objective 100% (achieved in Belgium) | | -30% $CO_2$ emissions (2015/2025) | - |
| **Orange** | - | - | -50% $CO_2$ emissions per customer use (2006/2020) | - |
| **Deutsche Telekom** | | | -20% $CO_2$ emissions (2008/2020) | |
| **BT** | Objective 100% (achieved in the UK) | | -80% carbon intensity of business (1997/2020) | 2020 ambition: 3 :1 Help customers reduce carbon by three times BT's own emission |
| **Telenet** | Objective 100% (achieved) | | Carbon neutral in 2015, including compensation (achieved) | - |
| **KPN** | Objective 100% (achieved in the NL) | -25 % absolute energy consumption | Carbon neutral in 2015, including compensation | Save as much energy with our products as our own energy |

| | | | | |
|---|---|---|---|---|
| | | (2010/2025) | (achieved) | consumption in 2020 |
| **Vodafone** | - | | Reduce $CO_2$ emissions by 50% against the 2006/07 baseline by March 2020 for mature markets<br><br>Reduce CO2 per network node by 20% against a 2010/11 baseline by March 2015 for emerging markets[31] | By March 2018: enabling customers to reduce their carbon emissions by twice the amount of carbon generated by Vodafone |

*Source: 2015 Annual or CSR reports from Proximus, Orange, Deutsche Telekom, BT, Telenet, KPN and Vodafone*

### 2.2.6 Applicability

The implementation of an EMS requires time and resources for the initial setup as well as ongoing maintenance. It applies to any company but the resources and means allocated to the process must be adapted to the size and the environmental impact of the site or the company. For small and mid-size companies, efforts needed must be assessed and validated.

After a few years, when processes have reached maturity, companies can step back from maintenance improvements, which are usually minor at this point. It may no longer worth investing further into the EMS maintenance.

It is very important to purchase EMS technology and software that can be easily integrated into the company's own business management systems and offer data exchange interfaces that connect data sources to reporting system in an automated way.

An EMS can be implemented at site level or company level.

### 2.2.7 Economics

The costs of introducing a standardised (e.g. ISO 14001 or EMAS) EMS are likely to be higher compared to non-standardised systems due to the need for verification. For smaller companies, the costs tend to be proportionally higher, and therefore a simplified EMAS system is available for SMEs. Ongoing costs are likely to be lower once the required systems are in place and staffs become familiar with their obligations.

The main interest economic benefit of environmental management is an increased profitability, due to lower costs in energy, water or waste combined with increased business levels. A decrease in energy consumption can deliver substantial cost savings over time. It is estimated that implementing energy practices in data centres, and consolidating applications onto fewer servers, could reduce data centre energy usage by 20% (Universal Electric Corporation, 2010). When taking into account the use of

[31] Objective achieved with a reduction of 28% baseline 2011.

newer servers and best practices that include real time power monitoring, the improvement could reach 45%.

**Table 11: Cost and benefits of implementing EMAS, (European Commission, 2009b)**

| Organisation size | Potential efficiency savings (€) | Implementation costs (€) | Annual costs (€) |
|---|---|---|---|
| Micro | 3,000 to 10,000 | 22,500 | 10,000 |
| Small | 20,000 to 40,000 | 38,000 | 22,000 |
| Medium | Up to 100,000 | 40,000 | 17,000 |
| Large | Up to 400,000 | 67,000 | 39,000 |

*Notes: Potential annual efficiency savings are based on energy savings only, and do not include resource efficiency savings.*

### 2.2.8 Driving force for implementation

Several driving forces for the implementation of energy monitoring practices can be identified:

- **Reduce costs** through energy savings (see economics section).
- Identify and implement opportunities to **improve operational effectiveness** and provide **performance measurements** against set targets.
- **Manage environment-related risks** and liabilities and address key management challenges around resource effectiveness, climate protection and corporate social responsibility.
- Demonstrate **compliance with legal requirements**[32] and anticipate potential future regulations
- Demonstrate **environmental commitment to customers and other stakeholders** and **improve employee and other stakeholder engagement** in environmental protection.

### 2.2.9 Reference organisations

Capgemini[33] (part of the Capgemini Group), is the only UK company in the IT and consulting sector to currently hold EMAS certification. Capgemini has achieved the following environmental improvements, among others, compared with the base year of 2008:

- an increase in data centre effectiveness of over 20%, achieved three years ahead of plan;

[32] For example, the wiring regulation in the UK requires all equipment using 16A or more to be monitored individually.

[33] http://ec.europa.eu/environment/emas/news/index_en.htm

- a reduction in carbon emissions of 17.5%, excluding data centres, putting the company on track to achieve its target (20% reduction by the end of 2014) by the end of 2012, two years ahead of plan;
- a 25% reduction in office energy emissions;
- a 34% reduction in tonnage of waste generated;
- reduction in tonnage of waste sent to landfill.

Novacroft, a leading software development company, has been committed to standards and holds ISO 14001 certification (BSI, 2016). The company has increased its recycled waste from 50% to 75% and reduced waste to landfill from 50% to 25%. Energy management is tackled head on and considered in every decisions. For instance, it was considered for the new office to ensure it was fit for purpose in terms of adhering to ISO 14001 requirements.

IBM have a single worldwide registration to the ISO 14001 EMS standard. IBM has expanded its global ISO 14001 registration since 1997 to cover its chemical-using research locations and several country organisations. Additionally, several business functions such as product design and development, Supply Chain, and Global Asset Recovery Services also have obtained ISO 14001 certification (IBM, 2016).

### 2.2.10 Reference literature


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## 2.3 Procurement of sustainable ICT products and services

**SUMMARY OVERVIEW:**

**The selection and deployment of ICT products and services needs to be based on an integrated strategy to tackle their inherent environmental impacts, such as their energy consumption and the use of specific materials such as rare metals and chemicals. It is considered best practice to:**

- **Assess the existing assets of ICT equipment and the needs in the procurement process preparation.**
- **Include in the call for tender required specific environmental criteria to be met.**
- **Ensure proper use by end-users when deploying ICT equipment through asset management, communication and training.**
- **Establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact.**

**ICT components**

| | | | | |
|---|---|---|---|---|
| **Data centre** | **Telecommunication network** | Broadcasting | Software publishing | **End-user devices** |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| Design and installation | **Selection and procurement of the equipment** | Operation and management | Renovation and upgrades | End-of-life management |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | **Resources consumption** | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental indicators**

- Share of products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, top class energy label, Energy Star, etc.)
- Share of equipment purchased by the company complying with internationally recognized best practices or requirements (e.g. EU Codes of Conduct)
- Share of packaging purchased by the company made from recycled materials or awarded the Forest Stewardship Council label
- Share of the grade given to environmental criteria in calls for tenders
- Share of suppliers that have an environmental management system or energy management system in place (e.g. EMAS verified, ISO 14001 or ISO 50001 certified)
- Share of ICT products and services provided by the company to customers for which environmental information is available to customers

**Cross references**

| | |
|---|---|
| **Prerequisites** | • N/A |
| **Related BEMPS** | • 2.2 Making the best use of an environmental management system<br>• 3.3.2 Selection and deployment of green equipment for data centres<br>• 4.4 Selecting and deploying more energy-efficient telecommunication network equipment |

### 2.3.1 Description

The definition of a policy regarding the procurement of sustainable ICT products and services is the first step to environmental performance in ICT equipment. The integration of environmental requirements into the procurement process involves setting criteria in the assessment process. The criteria identified should be regularly reviewed and updated depending on market and technology review.

The definition of environmental criteria can cover different aspects of environmental performance of ICT equipment (i.e. focused on the environmental performance of products) or the supply chain or supplier (i.e. focused on the environmental performance of organisations):

- Energy efficiency.
- Improve the circular economy (reduce waste and increase re-use, repair, disassembly, refurbishment and recycling) and the life cycle management of equipment and consider the environment at the design stage (Design For Reliability and DFE design for Environment).
- Reduce the use of raw materials, embodied energy and water used during the manufacturing of ICT equipment.
- Increase the use of sustainable materials.
- Reduce or eliminate the use of certain chemicals.

Other types of criteria can be defined to assess the environmental performance of software or services such as green cloud computing.

The European Commission has developed a handbook on Green Public Procurement, available at: http://ec.europa.eu/environment/gpp/index_en.htm. This handbook presents the inclusion of clear and verifiable environmental criteria for products and services in the public procurement process and can be used as a tool to develop a procurement of sustainable products and services.

This BEMP presents technical specifications for ICT equipment to integrate sustainability criteria at each level of the procurement process. It covers both upstream and downstream supply chain of ICT companies.

It is best practice to:

- **Assess the existing assets of ICT equipment and the needs in the procurement process preparation**.

  It covers the assessment of the existing assets of ICT equipment and of the needs compared to the different equipment and new technologies available on the market.

  - Assess the needs to buy appropriate technological requirements, to buy the right amount of ICT equipment needed or the appropriate software and service.
  - Benchmark existing equipment according to the needs and the type of ICT equipment or software and services needed.

- **Include in the call for tender required specific environmental criteria to be met**.

  It can include required environmental criteria to meet in the call for tender process.

  - Technical criteria: the call for tender can include technical requirements on the technical specificities for the ICT equipment: type of used materials, included functionalities, and included services such as maintenance to extend the service life or repair the equipment. These

different services are further developed in the BEMP on waste (see Section 2.6).

- Environmental criteria: specific environmental criteria can be determined to require a threshold of environmental performance to reach. It can be specific criteria on energy efficiency, embodied energy and recyclability. These criteria can be based on a life cycle assessment to determine the environmental performance of the product throughout its lifecycle. For the purchase of green software or green cloud computing environmental criteria displayed by the vendor can be benchmarked.
- Specific requirements: tools such as Type I, II and III eco-labels and energy label can be used to benchmark energy performance of ICT equipment.

- **Ensure proper use by end-users when deploying ICT equipment through asset management, communication and training:** the next step after purchasing hardware, software or services is to ensure that it is deployed internally or externally depending on the final use of the ICT equipment or service. Internal deployment requires the training of employees and raising awareness on environmental performance. External deployment through the selling of the ICT equipment will require appropriate communication and the display of environmental criteria.
- **Establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact:** it ensures that customers will be offered products which meet specific environmental criteria to help them reduce their environmental footprint. ICT companies can develop scorecards to rate the environmental performance of the products they sell.

The sustainability criteria must be defined according to the global environmental policy and the type of activities and ICT equipment used. The criteria used will be adapted for office devices, data centres equipment and network equipment. The following table shows the different procurement options by type of ICT equipment.

**Table 12: An overview of the main priority equipment, software and services relevant for the procurement of sustainable ICT products and services**

| Type of facility | ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|---|
| Data centres | Servers and storage equipment | • Benchmark performance of the environmental performance of equipment<br>• Select more energy efficient equipment, e.g. purchasing ecolabelled equipment such as EnergyStar<br>• Select equipment that have extended operating temperature and humidity ranges that allow use of free cooling<br>• Select equipment with power management features and allows | • Energy consumption (and $CO_2$ emissions)<br>• Material consumption and waste management<br>• Toxicity |

| Type of facility | ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|---|
| | | external control of energy use<br>• Select equipment suitable for the data centre airflow direction<br>• Select equipment with power and inlet temperature reporting capabilities<br>• Purchase of products easily reparable or recyclable with less hazardous materials<br>• Purchase renewable energy sources | |
| | Power supply equipment | • Select more energy efficient equipment, e.g. purchasing ecolabelled equipment such as EnergyStar[34] or following the EU Code of Conduct[35] for external power supplies and Uninterruptible Power Systems (UPS)<br>• Select equipment containing high effectiveness AC/DC power converters (rated at 90% power effectiveness) | • Energy consumption (and $CO_2$ emissions) |
| | Cooling system equipment | • Select appropriately sized cooling units<br>• Select more energy efficient equipment such as:<br>◦ chillers with high Coefficient of Performance<br>◦ equipment with variable speed (or frequency) controls for compressors, pumps and fans<br>◦ direct liquid cooled devices<br>• Select equipment that use natural refrigerants or with low ozone depleting potential | • Energy consumption (and $CO_2$ emissions)<br>• Ozone depleting substances and GHG emissions (from refrigerants) |
| | Air handling equipment | • Select appropriately sized air handling units<br>• Select more energy efficient equipment such as equipment with variable speed (or frequency) controls for fans | • Energy consumption (and $CO_2$ emissions) |

[34] An international standard with criteria to rank the most energy efficient equipment. Available at: https://www.eu-energystar.org/

[35] The European Code of Conduct for Energy Efficiency in Data Centre is a voluntary initiative. The aim is to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner without hampering the mission critical function of data centres. Available at: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

| Type of facility | ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|---|
| Telecom-munication network | Cabling | • Select cables that minimise transmission losses<br>• Select chlorine and halogen free cables and those with insulation that does not produce dioxine if burnt | • Energy consumption (and $CO_2$ emissions)<br>• Heavy pollutant emissions |
| | Broadband network equipment (routers, DSL Optical, RBss and Wi-Fi) | • Select energy efficient equipment, e.g. respecting the EU Code of Conduct on Energy Consumption for Broadband Equipment | • Energy consumption (and $CO_2$ emissions) |
| | Broadband equipment (routers, DSL, etc.) and Set-top boxes | • Select energy efficient equipment, e.g. respecting the EU Code of Conduct for digital TV Service Systems | • Energy consumption (and $CO_2$ emissions) |
| | Antennas, switching systems, etc. | • Select energy efficient equipment, e.g. respecting the EU Code of Conduct on Energy Consumption for Broadband Equipment and the EU Code of Conduct for digital TV Service Systems | • Energy consumption (and $CO_2$ emissions) |
| Offices | Personal computers (desktop and laptop) | • Benchmark performance of the environmental performance of equipment<br>• Select more energy efficient equipment, e.g. purchasing ecolabelled equipment such as EU Ecolabel[36] and EnergyStar or follow the EU Green Public Procurement Criteria for Office IT equipment[37]<br>• Lease products or require take-back services<br>• Purchase of products easily reparable or recyclable with less hazardous materials (Brominated Flame Retardants, mercury and lead)<br>• Purchase packaging made from recycled material or Forest Stewardship Council label[38] | • Energy consumption (and $CO_2$ emissions)<br>• Material consumption and waste management<br>• Toxicity |

[36] Refer to section 2.3.5 on Operational data.

[37] The EU Green Public Procurement develops criteria for office IT equipment on technical specifications and ecolabel criteria. Available at: http://ec.europa.eu/environment/gpp/index_en.htm.

[38] For more information, see: https://ic.fsc.org/en/certification/national-standards/europe-russia.

| Type of facility | ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|---|
| | Mobile devices (smartphone, mobile, tablets) | • Benchmark performance of the environmental performance of equipment<br>• Select more energy efficient equipment<br>• Lease products or require take-back services<br>• Purchase of products easily reparable or recyclable with less hazardous materials | • Energy consumption (and $CO_2$ emissions)<br>• Material consumption and waste management<br>• Toxicity |
| | Other peripherals : printers, monitors, scanners, copiers, fax machines | • Benchmark performance of the environmental performance of equipment<br>• Select more energy efficient equipment, e.g. purchasing ecolabelled equipment such as EU Ecolabel and EnergyStar or follow the EU Green Public Procurement Criteria for Office IT Equipment or Imaging Equipment<br>Lease products or require take-back services<br>• Purchase of multifunction products (e.g. printer/copier/scanner/fax) so to minimise the number of equipment<br>• Promote paperless activities and cloud printing<br>• Purchase of products that have low power/sleep modes<br>• Purchase of products easily reparable or recyclable with less hazardous materials | • Energy consumption (and $CO_2$ emissions)<br>• Material consumption and waste management<br>• Toxicity |
| General | Software | • Select software which uses the least energy to perform the required tasks | • Energy consumption (and $CO_2$ emissions) |
| | Cloud computing | • Select ICT service providers that have energy efficient servers and data centres, services and support | • Energy consumption (and $CO_2$ emissions) |
| | Electricity | • Select electricity from renewable energy sources, e.g. Guarantee of Origin | • $CO_2$ emissions |

### 2.3.2 Achieved environmental benefits

A policy for the procurement of sustainable products and services will help achieve different environmental benefits depending on the sustainability criteria used to select ICT equipment.

Selecting energy-efficient ICT equipment is expected to primarily reduce **direct energy consumption** from ICT equipment in companies. Energy label programmes such as Energy Star set the level required to obtain the label by selecting effectiveness levels reflective of the top 25% of models available on the market. The criteria and specifications are reviewed every three years when the market share of qualified products reaches about 35% (Aebischer and Hilty, 2014).

Assessing the impact of energy label programmes is difficult since technology evolves rapidly and the market has known significant growth. However, energy label programs certainly speeded up the adoption of energy-efficient equipment.

Besides direct energy savings, the selection of energy-efficient ICT devices creates **indirect energy savings**. Energy-efficient devices produce less heat which indirectly leads to reduce the use of air-conditioning and the associated energy consumption.

Using eco-labelled equipment reduces other environmental pressures, for instance it decreases **direct greenhouse gases emissions**.

A case study (PrimeEnergyIT, 2012a) demonstrates and measures the environmental benefits of choosing energy-efficient equipment in a data centre. The data centre in the case study is located in Germany and benefited from a new energy-efficient cooling system with the use of a CHP unit combined with an adsorption chiller. This change of technology resulted in substantial electricity savings of 78% and reduced the CO2 emissions by 47%.

Other environmental criteria than energy-efficiency have different environmental benefits. Criteria on the **reduction of the use of hazardous substances** and chemicals help reduce toxics materials use. The purchase of ICT equipment containing less toxic materials and fewer substances results in the **reduction of generated WEEE** and generated hazardous substances. It will also allow the reduction of the amount of natural resources needed for the project manufacturing.

The definition of technical and environmental criteria and life cycle analysis can lead to significant reduction in primary materials used and water consumption.

The different environmental benefits can be listed as follow (EPEAT, 2011):

| Metric | Reductions |
|---|---|
| Electricity | 9 million megawatt hours |
| Primary Materials | 16 million metric tons |
| Air Emissions (including greenhouse gases) | 36 billion kg |
| Greenhouse Gas Emissions | 1.6 million MTCE* |
| Water Emissions | 77 million kg |
| Toxic Materials (incl Hg) | 1,156 metric tons |
| Solid Waste | 31,992 metric tons |
| Hazardous Waste | 59,525 metric tons |

**Figure 15: Estimated environmental benefits from 2010 Worldwide EPEAT Purchasing**

### 2.3.3 Appropriate environmental performance indicators

In the framework of the procurement policy for ICT equipment, organisations can set environmental performance indicators to evaluate the environmental performance of the procurement policy.

The following indicators are used to monitor the integration of sustainable criteria in the procurement of equipment and services:

- Share of products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, top class energy label, Energy Share of equipment purchased by the company complying with internationally recognized best practices or requirements (e.g. EU Codes of Conduct);
- Share of packaging purchased by the company made from recycled materials or awarded the Forest Stewardship Council label;
- Share of the grade given to environmental criteria in calls for tenders. Environmental criteria. Environmental criteria cover overall environmental policy, energy efficiency, CO2 limitation, natural resource use and eco-responsible design measures. The best practice is to dedicate 10% of the bid notation to environmental performance when purchasing ICT equipment. For instance (European Commission, 2016).
- Share of ICT products and services provided by the company to customers for which environmental information is available to customers.

To assess the environmental performance of the procurement policy, it is also important to monitor suppliers' performance:

- Share of suppliers that have an environmental management system in place (e.g. EMAS, ISO 14001, ISO 50001, etc.). The best practice is to ensure that all suppliers with a high environmental impact has an EMS in place to minimise

the impact of their operations on the environment. For instance, BT requires all its suppliers to attain a minimum standard of environmental management and encourage its suppliers to reach ISO 14001 accreditation. The approach is risk based requiring the highest level of environmental management from suppliers presenting high environmental risk. Therefore, BT differentiates suppliers who are disposing of waste, suppliers of products and suppliers of services (BT, 2016).

### 2.3.4 Cross-media effects

If the procurement of more sustainable ICT equipment is focused only on a limited number of environmental aspects this may lead to trade-offs in other areas. Therefore, best practice within the procurement phase is to incorporate a broad range of environmental issues considered on a lifecycle basis to mitigate against this risk.

The switch to more energy efficient devices will ultimately generate WEEE. The waste created shall be monitored and proper end-life management implemented. Programs of refurbishment, donation or recycling can be considered.

The generation of additional waste can be contained by a proper procurement process. The establishment of a Green procurement policy shall not imply the renewal of all ICT equipment. It shall be based on the assessment of the needs and the usage patterns in order to avoid unnecessary purchases and therefore WEEE.

Using more energy-efficient products also implies using more powerful devices. The purchase of energy efficient devices will lead to more modern equipment and technologies using more complex components. But because they are faster and more powerful, they can be using more energy in the end (Carbon Trust, 2006). Increases in energy demand should only be acceptable when the increase in processing power responds to a substantial increase of the service offered, this can be measured as Mbit/s, Mflops etc.

In general, eco-labelled products such as the EU Ecolabel have been assessed as environmental front-runners across a range of relevant environmental criteria, and are not associated with significant cross-media effects.

The policy for the procurement of sustainable ICT products and services shall be integrated into an overall environmental policy which helps prioritise the different environmental challenges to ensure an overall improvement of environmental performance.

### 2.3.5 Operational data

This section covers operational data and implementation techniques at each procurement levels introduced in section 2.3.1.

The European Commission Green Public Procurement criteria are a useful reference to facilitate the inclusion of green procurement in public tender documents (see http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm). Specific technical specifications for office IT equipment have been detailed.

**Assess the existing assets of ICT equipment and the needs in the procurement process preparation**

Before the selection of suppliers and ICT equipment, the first step is to assess the existing ICT equipment consumption and identify the needs for energy-efficient ICT equipment. This stage can be integrated in an EMS which primarily aims at auditing and reviewing the equipment (refer to BEMP 2.2).

Defining the actual needs for new equipment, software or service is a crucial step to avoid all unnecessary purchases and cross-media effects. Renewing ICT equipment and workstations should not be proceeded systematically but consider different criteria. It should be based on the age and use patterns of the equipment and on its capability to fulfil the (new) service demand. Users' needs should also be evaluated.

The French Public Procurement Code (Article 5) gives guidance on the methodology to assess the needs (Buy Smart +, 2012). It is based on the analysis of overall energy consumption. The mapping of overall environmental performance of the ICT equipment can take into account different criteria (Orange, 2016):

- CO2 limitation and energy efficiency: manufacturing, transport, use (usage modes, power draw, device annual electricity consumption) end of life;
- Resource preservation: limitation of the presence of rare metals and non-renewable resources;
- Eco-design: specific measures to reduce environmental impact and limitation of use of sensitive:
  - Packaging and documentation optimisation
  - reparability
  - presence or recycled plastics in device shells;
- Existing services for maintenance and repair.

The assessment of ICT equipment used in data centres must take into account specific criteria in addition to the ones used for office equipment:

- ensure that the temperature and humidity ranges are compatible with the data centre indoor environment;
- evaluate the data centre power density and cooling capabilities;
- analyse the data centre room design to allow good air flow and to select hardware and cooling systems with the right dimensioning;
- select hardware with an efficient AC/DC converting system.

While selecting IT equipment for data centre, purchasers shall make sure not to compromise the security requirements of the room. A security check can also be carried out especially on fire protection and water protection.

The assessment of telecommunication network equipment takes into account the end-users connected to the network and the performance of the final user utilisation. It can be based on the evaluation of the final user energy consumption and the energy efficiency of the different areas served by transceiver stations.

The assessment of green software or green cloud computing can be based on the benchmark of existing software and services and their environmental performance regarding energy efficiency and $CO_2$ emissions.

**Include in the call for tender required specific environmental criteria to be met**

<u>Defining specific criteria to achieve environmental performance</u>

The definition of technical specificities depends on the type of equipment and facilities (data centres, telecommunication network components or offices components). The assessment of needs performed will help determined the criteria needed for the optimal use of the ICT equipment.

Technical criteria can be set on:

- The functionalities of the equipment (multifunction devices, improved software, etc.) which will allow energy efficiency through the use of one device for different functions instead of several devices.
- The services associated to the product. Services of maintenance and repair will extend the service-life of the equipment.
- Eco-conception of the product with the use of recyclable materials, reduced primary materials and through making the product repairable or specific components easily replaceable.

In addition to technical criteria related to the ICT equipment, environmental performance criteria related to the supplier can be added to the requirements. Environmental performance criteria can focus on different aspects related to the supply chain:

- Suppliers to have verified or certified environmental management systems such as ISO 14001 and EMAS in order to qualify for purchasing agreements.
- Energy efficiency: reduced embodied energy in the production process.
- Water efficiency: reduced water consumption during the production process.

The different topics will need to be prioritised according to the type of equipment, the functionalities required and the use.

The selection criteria for environmental performant IT equipment can be more specific for data centres' equipment such as servers and hardware components (processor, throttle drive, etc.) (refer to BEMP 4.3.2 Selection and deployment of equipment for data centres for more information). IT equipment shall be selected to be suitable for data centre characteristics:

- hardware with operating temperature and humidity ranges compatible with the data centre indoor environment;
- IT equipment suitable for the data centre power density, cooling capabilities and room design (to allow good air flow);
- hardware with an efficient air conditioning converting system.

The selection of telecommunication network equipment is also specific. It can be based on the Code of Conduct on Energy Consumption of Broadband Equipment (JRC, 2015) criteria (refer to BEMP 4.4 Selecting and deploying more energy-efficient telecommunication network equipment for more information). The Code of Conduct defines power consumption targets to reach for:

- DSL network equipment (ADSL2 and VDSL2),
- Optical Line Terminations (PON and PtP),
- Interfaces (with narrowband network equipment),
- Cable equipment (I-CMTS, M-CMTS).

Using EU Ecolabels and energy label as tools to reach environmental performance

The benchmark of the existing technologies on the market can help determine the level of environmental performance required. The identification of environmental performant products can be made by referring to the different ecolabels. The

International Organisation for Standardisation (ISO) classified labels into three categories (Buy Smart +, 2012):

- Type I labels: awarded by an independent third party based on product compliance with required defined criteria;
- Type II: labels: environmental information is provided by the manufacturer or the distributor without third party oversight;
- Type III: standardised information.

The Type I label is the most reliable from a procurement stand point being based on an independent process of verification.

The different relevant ecolabels are the following:

- **Energy Star** is an international standard created by the US Environment Protection Agency and the Department of Energy in 1992. The EU coordinates with the energy labelling of office equipment through the EU Energy Star Programme (managed by the European Commission).[39] The criteria are established in order to reach 25% of the most efficient equipment available on the market. It includes the energy consumption during standby mode and turn off time. Energy Star products relate to a set of criteria that is imposed through public procurement policies. It can be recommended as a minimum standard (Buy Smart +, 2012). The Energy Star website (https://www.eu-energystar.org/products.htm) provides a database of labelled products.
- The **EU Ecolabel** covers a wide range of product groups. It is based on the consultation with the European Union Ecolabelling Boards (EUEB, the, Member States, Competent Bodies and other stakeholders. It applies to electronic equipment such as imaging equipment, personal computers and notebook computers. It takes into account criteria on energy efficiency and power suppliers and other criteria on hazardous and chemical substances used and on the recyclability of the ICT equipment. See the EU Ecolabel website (http://ec.europa.eu/environment/ecolabel/products-groups-and-criteria.html) for more information.
- **The Blue Angel** label is another internationally recognised environmental label created at the German Environment Ministry's request. Criteria take into account: recyclability, pollution mitigation during manufacturing, chemical emissions, noise and energy consumption reductions including during standby mode.

  The requirements to meet in terms of energy efficiency for workstations are based on the Energy Star programme. Contractor must meet all applicable Energy Star criteria and specify the admissible maximum value based on the Typical Energy Consumption equation (RAL, 2014). For more information, see the Blue Angel website (https://www.blauer-engel.de/en/get/producttypes/all).
- The **Nordic Ecolabel**, the official Ecolabel in the Nordic countries, established in 1989 by the Nordic Council of Ministers to provide environmental labelling scheme. It applies to a large range of products including computers. Criteria focus on power consumption, design and materials. For more information, see the Nordic Ecolabelling website (http://www.nordic-ecolabel.org/criteria/product-groups/).

[39] For more information, see: http://www.eu-energystar.org/

- **TCO** is a Swedish label which focuses on office computer equipment. It includes ergonomic and Electromagnetic Field emissions criteria in addition to energy consumption. Energy efficiency criteria are aligned with the Energy Star programme.
- **EPEAT** is an American ecolabel aiming at helping customers to evaluate IT equipment impacts on the environment. It was created by the Green Electronics Council (GEC) in the framework of the International Sustainability Development Foundation (ISDF). EPEAT tackles different criteria on hazardous resources reduction, end-life management and energy savings. The lowest energy consumption requirements are also based on the Energy Star criteria.

Ecolabels can mainly be used for energy efficiency criteria but some ecolabels also include other specific criteria on the topics described before. The Buy Smart + report (2012) summarises the differences on the different ecolabels in the following table:

**Table 13: Ecolabel comparison (Buy Smart +, 2012)**

| | Energy Star | Blue Angel | Ecolabel | TCO |
|---|---|---|---|---|
| Label characteristics | In Europe, office computer equipment only | Nearly all office equipment | Computer hardware for individual households, office equipment | Office equipment, supplies, telephones |
| Consumption in operating mode | Yes | No | Yes | No |
| Consumption in sleep mode | Yes | Yes | Yes | Yes |
| Consumption in standby | Yes | Yes | Yes | Partially |
| Workplace security | No | Yes | Yes | Yes |
| Noise emissions | No | Yes | Yes | Yes |
| Mandatory / optional | Optional | Optional | Optional | Optional |
| Cost of the labelling application | No | Yes | Yes | Yes |
| Geographic zone of coverage | Worldwide | Germany, also open to foreign producers | Worldwide | Europe and North America |

### Table 14: European Ecolabel criteria for electronic equipment (European Commission, 2011)

| | Display | Keyboard | Personal computer |
|---|---|---|---|
| Energy savings: computer | | | X |
| Energy savings: display | X | | X |
| Power management requirements | X | | X |
| Power supplies: internal | | | X |
| No mercury in display backlights | X | | X |
| Hazardous substances, mixtures, plastic parts | X | X | X |
| Noise | | | X |
| Recycled content | X | X | X |
| User instructions | X | X | X |
| Design for disassembly | X | X | X |
| Repairability | X | | X |
| Lifetime extension | | | X |
| Packaging | X | X | X |

### Table 15: Comparison of the key non-energy Eco labelling criteria for ICT Office equipment (European Commission, 2011)

| Criteria for Desktops | TCO'05 | The Swan | Blue Angel | EU Ecolabel |
|---|---|---|---|---|
| Environmental Responsibility | | | | |
| Company's environmental Responsibility | X | X | | |
| Environmental hazards | | | | |
| Mercury, cadmium, and lead | X | X | X | X |
| Flame retardants | X | X | X | X |
| Chlorinated plastics | X | X | X | |
| Preparation for Recycling | | | | |
| Material coding of plastics | X | X | X | X |
| Variety of plastics | X | X | X | X |
| Metallisation of plastics | X | X | X | X |
| Material recovery of plastics and metals | | X | X | X |
| Design for recycling - Mercury lamps | X | X | X | X |
| Easy to dismantle | | X | X | X |
| Recycling information for customers | X | X | X | X |
| Guarantee and spare parts | | | | |
| Guarantee | | X | X | |
| Supply of spare parts | | X | X | |
| upgradability/performance expansion | | X | X | X |
| Packaging | | | | |
| Requirements regarding packaging materials | | | X | X |

Besides eco-label, energy label can be used to benchmark energy performance of ICT equipment. The Energy Labelling Framework Directive (2010/30/EU) gives guidance on energy labelling with regard to energy-related products on the internet. The label scale (currently from A to G, A+++ to D, etc.) help choose more energy-efficient product. It is best practice to select the products in the top class of the energy label.

Using standards or benchmarks to require environmental performances

At present, there are no official eco-labels applying for every ICT product or service.

Performance based procurement criteria can be defined, as:

- the energy-consumption at full and partial loads;
- the coefficient of performance (COP) for cooling equipment;
- the percentage of recycled materials;
- etc.

To set up such environmental performance targets, the purchase department has two main possibilities:

- **Using standards** developed by recognised organisations, such as:
    - ITU’s informative values (e.g. L.1340 : Informative values on the energy efficiency of telecommunication equipment) ;
    - ETSI standards;
    - EU Code of Conducts, and in particular:
        - Code of Conduct on Energy Efficiency of External Power Supplies
        - Code of Conduct on Energy Efficiency of Digital TV Service Systems
        - Code of Conduct on energy efficiency and quality of AC Uninterruptible Power Systems (UPS)
- Code of Conduct on Energy Consumption of Broadband Equipment **Benchmarking** environmental performance of products or services:
    - Vendors can display the environmental performances of the products they are selling.
    - The Standard Performance Evaluation Corporation (SPEC) website provides relevant performance benchmarks.

Total Cost of Ownership

The Total Cost of Ownership (TCO) shall be used to assess the offers (including energy savings related to the installation of more energy-efficient equipment that might be more expensive). This way the buyer does not only rely on the purchasing price but integrates the operating costs and disposal costs. For many products, costs occurring during the use and disposal are higher than purchasing cost. These costs are evaluated over the expected useful lifetime of the product. The different costs may be treated by different departments and the procurement procedures will require the cooperation of different internal authorities.

**Ensure proper use by end-users when deploying ICT equipment through asset management, communication and training**

After having established a procurement policy which takes into account environmental criteria, the next step is ensuring the use of purchased ICT equipment.

- Internal deployment: through asset management to ensure the use of the ICT equipment. Asset management is further detailed in the BEMP Implement an EMS (see section 2.2). Raising awareness of users is important to ensure the proper use of the ICT equipment.

- External deployment: through communication and environmental criteria display, scorecard display to raise customers' awareness and facilitate their choice.

**Establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact**

Companies from the telecommunication sector can ensure to offer products which meet specific environmental criteria to help customers improve their environmental footprint. The selection of the product can be integrated in a green procurement policy. In order to reduce the environmental impact, the different impacts throughout the product life-cycle must be assessed. Specific LCA standards have been developed for the ICT and telecommunications sector (ETSI ES 203 199 and ITU-T L.1410 standards).

In the same way, Vodafone presents its analysis of mobile life-cycle as follow:

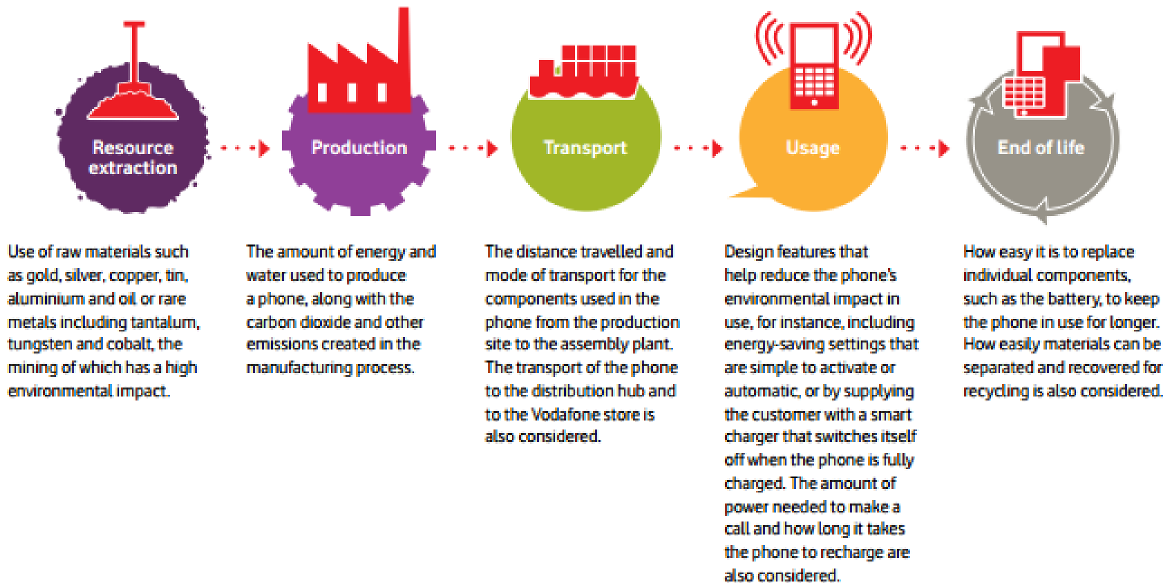


**Figure 16: Mobile phone life cycle stages (Vodafone)**

These different stages must be assessed to reduce the overall environmental impact and different solutions can be implanted:

- **Select energy-efficient products**: the main challenge regarding mobile phone energy efficiency is to improve batteries performance and reduce the energy consumption during standby mode (refer to section 5 for more details on energy-efficient IT equipment).
- **Select products composed of sustainable materials**: mobile phones are composed of rare and hazardous materials. The ecodesign of the equipment is an important stage to reduce the environmental impact. Ecodesign can reduce the amount of material used for the production of a device. Sustainable materials can also be used such as polylactic acid plastic made entirely from corn starch or glucose, renewable and biodegradable.
- **Select product for easy disassembly and repair**: many mobile phones are designed to stop users from opening them and replacing specific parts by gluing parts together and putting special crews. Prevent those elements will prevent planned obsolescence. Some materials put together are difficult to

recycle. The variety of different plastics used in ICT equipment makes plastic recycling particularly difficult. The goal is to minimise mixing of materials such as metals embedded in plastics.

- **Reduce packaging and accessories:** the environmental impact can also be diminished during the conditioning of the product. The reduction of the material used and the reduction of the number of accessories are key solutions to reduce the overall impact. Many buyers already have compatible chargers when they buy a new mobile phone, some accessories such as chargers may be unnecessary.
- **Select standardised components and accessories:** Telecom operators and broadcasting companies can have a great influence on manufacturers through product specifications. The aim is to encourage the greater use of universal equipment (e.g. chargers, modems, etc.), in order to reduce the need for new products and parts.
- **Implement virtualized solutions**: Telecom operators can propose virtualised set-top boxes to their clients, in replacement of hardware equipment. Such shift aims at reducing material consumption (1.8 kg per end-user according to Deutsche Telekom) and $CO_2$ emissions (20.44 kg of CO2 saved per year according to Deutsche Telekom).

Environmental criteria can be set on the IT equipment service providers offer to customers. On alignment with the design and procurement policy, environmental criteria can be set to evaluate the environmental performance of products. Telecommunication service providers can create an internal evaluation grid to measure the environmental performance of the products they offer to their customers.

Products rating can be based on the different stages of the product life-cycle. The rating requires that the telecommunication company works with the manufacturers to obtain the information needed to establish the evaluation. No global methodology has been developed but some telecommunication companies have established their own methodologies. The eco-rating scheme primarily aims at informing the customers on environmental information to help them making more sustainable choices, but it will also improve the sustainability throughout the supply chain. It will encourage manufactures to improve their environmental impacts and the eco-rating will promote the sustainability performance of their handsets. The methodology for the eco-rating can be based on questionnaires sent to the manufacturers who must provide supporting evidence.

In order to ensure the reliability of the rating, the evaluation process requires the intervention of an independent third-party. The third-party can be an NGO or a national institution focusing on environmental impacts. The methodology can be based on official and standard baseline established by international institutions such as ISO standards (ISO 14 0140 and ISO 14 044 for life cycle analysis). For instance, Orange developed its environmental performance evaluation in partnership with WWF based on ADEME environmental impact analysis and reviewed by the consulting firm Bio Intelligence service. Vodafone's questionnaires to manufactures are verified by two independent third parties, BUREAU VERITAS and SKM Enviros. The best practice is to cover 100% of products and services with environmental information available to customers. For instance, 100% of Orange mobile phone have environmental score.

Telecommunication companies can also use ecolabel to communicate on the environmental performance of products. LCA and other tools can be used to better inform customers on the environmental impacts of the products they purchase (e.g. PEP ecopassport (http://www.pep-ecopassport.org/)). When communicating on these

issues, a great attention should be paid to make the analysis and results understandable for customers.

The energy label created under the EU's Energy Labelling Directive can also be used to inform customer on the energy performance of the product.

To support the eco-rating or energy labelling approach, other techniques to encourage customers to consider environmental impacts can be developed when selling the products. Service providers can offer contracts to improve the useful life of the product. Customers often change mobile phone even when their old one is still working. Telecommunication companies can offer longer contracts and options of fixing or leasing products.

### 2.3.6 Applicability

The implementation of a policy for the procurement of sustainable ICT services and products is applicable in any company but will require specific skills on sustainability. Large organisations have greater potential to leverage influence over their suppliers, but SMEs may exert considerable influence over local suppliers.

The range of office equipment considered and covered by the different labels is the following:

**Table 16: Types of equipment by ecolabels**

| | Energy Star | Blue Angel | TCO | EPEAT |
|---|---|---|---|---|
| **PCs** | x | x | x | x |
| **Notebook computers** | x | x | x | x |
| **Monitors** | x | | x | |
| **Multifunctional devices** | x | x | x | |
| **Servers** | x | x | | |

EU Codes of Conduct cover different types of ICT equipment:

- Code of Conduct on Energy Efficiency of External Power Supplies
- Code of Conduct on Energy Efficiency of Digital TV Service Systems: equipment for the reception, decoding and interactive processing of digital broadcasting
- Code of Conduct on energy efficiency and quality of AC Uninterruptible Power Systems (UPS)
- Code of Conduct on Energy Consumption of Broadband Equipment

Comparing different ICT products (from different companies, different countries, etc.) can be complex and is not considered as totally reliable yet. However, it may be feasible to use it internally in a company.

### 2.3.7 Economics

Establishing a green procurement policy requires investing in human resources and skills.

In some cases the procurement of sustainable ICT services and products may induce additional costs through, for example, developing and enforcing new environmental requirements, purchasing eco-labelled products, working with suppliers. In other cases, costs may be decreased, for example by shifting to energy-efficient equipment. It is important that cost implications are considered alongside possible lifecycle benefits. As specified in the previous section (2.3.6) a life cycle cost analysis must be performed to consider the purchasing price and the operating costs. For IT equipment the following CAPEX and OPEX shall be looked at:

| CAPEX | OPEX |
|---|---|
| • IT hardware purchase and installation<br>• Software licenses and installation | • IT equipment energy costs<br>• IT equipment maintenance<br>• Software operation and maintenance<br>• IT operation |

**Figure 17: IT equipment CAPEX and OPEX (PrimeEnergyIT, 2012)**

The table below gives an overview of costs and return estimates for each best practice.

| Best practice | Operating costs | Investment costs | Annual Cost Savings |
|---|---|---|---|
| **Assessment of ICT equipment and technological specificities** | | | |
| Auditing ICT equipment to identify unused equipment and assess the fleet performance (see BEMP section 2.2) | Man hours depending on the facility/site size | NA | NA |
| Purchase the optimised number of devices | Man hours | NA | NA |
| Renew the right level of devices | Depends on the level of renewed equipment | Depends on the level of renewed equipment | Depends on the level of renewed equipment |
| Carry out a Life Cycle Assessment analysis | Man hours | Specific tools or information to acquire | Depends on the type of equipment |
| **Defining specific criteria to achieve environmental performance** | | | |
| Defining technical criteria | Man hours | NA | NA |
| Defining environmental criteria | Man hours | NA | NA |
| Using eco-label referencing | Man hours | Depends on the number of equipment purchased<br>To be defined | Replace 5,000 computers and monitors with ENERGY STAR qualified products and activate power management |

| | | | |
|---|---|---|---|
| | | | (EPA, 2011):<br>• US$290,21 (EUR 255,000)<br>• US$663,428 (EUR 583,000) |
| Using other specific criteria | Man hours | Depends on the number of equipment purchased | NA |
| Bid evaluation | Man hours | NA | NA |
| **Deploying ICT devices** | | | |
| Internal deployment: training and raising awareness of users | Man hours<br>Requires the involvement of managers | Investment in training sessions | NA |
| External deployment: communication and environmental criteria display, scorecard display | Man hours<br>Requires the involvement of managers | Marketing and communication costs | NA |

### 2.3.8 Driving force for implementation

- **Economic benefits for the enterprise from product and service rationalisation**: energy cost savings and life-cycle cost savings are the main drivers force for implementing a green procurement policy. Integrating in the procurement process criteria for energy efficiency will ultimately result in electricity consumption savings. Implementing a green procurement policy will encourage the monitoring of energy savings data and will systematise the need assessment process and the benchmarking of products. It will also lead to a decrease in maintenance costs. Energy-efficient products have longer productive lifetime than les efficient products. It helps reducing the number of time product needs to be replaced.
- **Demand for capacity increase** drives the replacing of servers by new more-energy-efficient ones.
- **Expectations of stakeholders**, including customers and shareholders.
- **Risk aversion** with respect to dependence on unsustainable supply chains (future cost and reputation) and **business security** through the establishment of long-term viable suppliers.
- Demonstrate **compliance with legal requirements** and anticipate potential future regulations. The procurement process involves the development of formal process for reviewing suppliers' offers. This can answer potential regulations on due diligence responsibility.

### 2.3.9 Reference organisations

- The ITU report Guidance on green ICT procurement (2013) puts into relief the best practices from front runners in the sector. The reference organisations identified are:

    - Telefonica (Spain)
    - Telecom Italia (Italia)
    - Deutsche Telekom (Germany): the company put in place a supplier development program aiming at improving environmental standards in the supply chain. Mandatory requirements on CSR criteria are set for suppliers' pre-qualification and procurement KPIs are monitored. CSR criteria account for 10% of the bid notation. Measures implemented with the suppliers in this program helped save 160,000 metric tons of CO2 in two years.
- Atos implemented assessment of suppliers into the procurement process as a requirement to enter the panel, for sourcing decisions and for performance reviews. Atos required its suppliers to provide feedback on CSR practices through the Ecovadis platform (Ecovadis, 2016). Atos won the Procurement excellence award in 2015 of the World Procurement Awards organised by Procurement Leaders ® (Procurement Leaders, 2015).
- BT won the CSR award at the World Procurement Awards organised by Procurement Leaders ® (Procurement Leaders, 2015).
- The following companies use Energy Star certified ICT equipment:
    - Dassault Systèmes uses EU Energy Star certified ICT equipment (Dassault Systemes, 2015)
    - IBM uses EU Energy Star ICT equipment. IBM had certified seven IBM Power® servers and three storage machine types to the Energy Star requirements (IBM, 2015).

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## 2.4 Optimising the energy consumption of end-user devices

**SUMMARY OVERVIEW:**

**There is a large potential to reduce the energy consumption of end-users equipment used within the offices and facilities of telecommunication and ICT services companies thanks to specific power management measures:**

- **Adopt technical solutions. It is best practice to:**
  - **Installing appropriate devices in terms of energy performance and functionalities depending on the needs of users;**
  - **Properly configuring equipment to minimise unnecessary functionalities and power consumption;**
  - **Performing regular energy audits to check devices configuration and powered-off devices;**
  - **Developing power management solutions using different types of power management modes (manual, default, through software) or using dedicated devices (smart power strip, etc.).**
- **Adopt organisational solutions:**
  - **Assessing individual user acceptance;**
  - **Raising users' awareness.**

**ICT components**

| Data centre | Telecommunication network | Broadcasting | Software publishing | **Desktop architecture** |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | **Renovation and upgrades** | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and EMF | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental indicators**

- Energy use of offices (kWh) per unit of turnover or number of employees (excluding HVAC and lightning if possible)
- Share of end-user ICT devices having been configured by a power management specialist
- Share of end-user ICT devices audited on power management during the year
- Share of end-user ICT devices audited on power management at least once during their lifetime
- Share of staff trained at least once on energy savings

| Cross references | |
|---|---|
| **Prerequisites** | The implementation of power management depends on:<br>• the leadership commitment to support overall energy savings objectives<br>• the implication of the staff<br>• the size of the company |
| **Related BEMPS** | • 2.2 Making the best use of an environmental management system<br>• 2.3 Procurement of sustainable ICT products and services<br>• 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)<br>• 3.2.3 Define and implement a data management and storage policy<br>• 4.2 Improving the energy management of existing network |

### 2.4.1 Description

There are substantial opportunities to achieve energy and cost reductions from existing equipment by managing their energy performance and adjusting their settings and optimising their use.

All types of ICT devices must be taken into account. For specific energy efficiency measures in data centres refer to BEMPs related to existing data centres (see section 3.2 on 3.2 BEMPs related to existing data centres) and for specific measures for telecommunication networks equipment refer to BEMP on improving the energy management of existing telecommunication networks (section 4.2).

This part focuses on the use of end-users ICT equipment covering:

- Personal computers (desktop and laptop);
- Mobile devices (smartphones, mobile, tablets, etc.);
- Other peripherals (monitors, scanners, copiers, fax machines, set-top box, etc.).

Servers, photocopiers, computers and screens are the largest energy consumers in ICT field regarding office equipment. Studies show that in the scope of office equipment, printers and copiers consume as much electricity as computers (Aebischer and Hilty, 2014).

This BEMP develop different solutions to optimise energy consumption of end-users ICT equipment.

It is best practice to:

**Adopt technical solutions.**

- **Installing appropriate devices in terms of energy performance and functionalities depending on the needs of users.**
  It implies the assessment of ICT equipment and needs to ultimately optimise energy consumption through adapted functionalities and performance.
- **Properly configuring equipment to minimise unnecessary functionalities and power consumption.**
  It requires specific configuration of the equipment by technicians and power management specialist.
- **Performing regular energy audits to check devices configuration and powered-off devices.**

- **Developing power management solutions** using different types of power management modes (manual, default, through software) or using dedicated devices (smart power strip, etc.).

**Adopt organisational solutions:**

- **Assessing individual user acceptance** to ensure full implementation of the different technical solutions.
- **Raising users' awareness** to ensure the implementation of power management policy.

### 2.4.2 Achieved environmental benefits

The main environmental benefit induced by optimising the energy consumption of IT equipment is the **reduction of the annual energy consumption**. According to Webber et al (2006), power management can diminish the energy consumption of devices by 80%. This energy reduction would ultimately result in the **reduction of GHG emissions.**

The optimisation of an existing fleet by adapting the equipment to the user's needs help reduce energy consumption. Laptop computers consume between 50% and 80% less energy than workstations (Buy Smart +, 2012).

The optimisation of the number of devices used through the use of multifunction devices will also impact energy consumption. Multifunction devices consume 50% less energy than the consumption of four separated devices (Buy Smart +, 2012).

Standby mode and switched off stage constitute the main areas of improvement. In standby mode and even switched off some devices (computers, monitors, copiers) still consume energy. A study by the World Economic Forum, claimed that 18% of office workers never switch off their PC at night or during weekends and a further 13% leave it on some nights each week. These behaviours result in the generation of about 700,000 tonnes of $CO_2$ emissions (World Economic Forum, 2009).

Evening and weekends account for 75% of the week hours. Ensuring computers are turned off at night can dramatically reduce the overall energy consumption. Further savings can be made by ensuring computers are put in low power mode while idle (Bray, 2006).

Other indirect benefits, such as **indirect energy savings,** can be observed when improving energy efficiency of IT equipment. Office equipment increases the load on air conditioning by 0.2-0.5 kW per kilowatt of office equipment power draw (Bray, 2006). The reduction of electricity consumption through energy efficient devices reduces the heat generation and therefore reduces the burden on air conditioning system. This additional reduction in energy consumption also contributes to lowering GHG emissions.

### 2.4.3 Appropriate environmental performance indicators

The main environmental performance indicator regarding the power management of ICT equipment is the measurement of the energy use of offices (excluding HVAC and lightning if possible) in kWh, compared to the turnover or number of employees.

In a more organisational and managerial point of view, other performance indicator can be put in place regarding:

- Share of end-user ICT devices having been configured by a power management specialist. For instance as a best practice, Orange (Orange, 2015) is finalizing for all European countries the deployment of consumption measurement tools

for office and IT equipment to ensure proper power management for all of their office IT equipment.

- Share of end-user ICT devices audited on power management during the year;
- Share of end-user ICT devices audited on power management at least once during their lifetime;
- Share of staff trained at least once on energy savings.

### 2.4.4 Cross-media effects

Energy efficiency management techniques shall be designed to be integrated with overall environmental objectives and consider global environmental impacts (European Commission, Reference Document on Best Available Techniques for Energy Efficiency, 2009). If not designed properly a policy aiming at optimising the energy consumption of end-user devices can lead to:

- Increased raw material and embodied energy consumptions, related to a more frequent renewal of ICT devices;
- Hazardous pollutions, related to an inappropriate end-of-life management of replaced ICT devices.

More specific cross-media effect related to power management techniques is the generation of harmonic pollution. Harmonic pollution is defined as periodic steady state distortions of voltage and/or current waveforms in power systems. The switching-mode power supplies generate harmonic pollution that can causes problems within power distribution systems such as malfunction of protective devices and physical damage of power system components and load. Harmonic pollution leads to an increase in total current in use and to a decrease in the quality of the overall electric current (Aebischer and Hilty, 2014). The quality of the current can be evaluated through the power factor.

### 2.4.5 Operational data

**Technical solutions**

*Installation of appropriate devices*

Energy consumption optimisation begins with the use of appropriate devices with the right functionalities and performance. The assessment of ICT equipment and determination of needs is detailed in the BEMP 2.3 Procurement of sustainable ICT products and services. Based on the assessment of end-users' needs, appropriate devices in terms of energy performance and functionalities are used. It ultimately results in energy consumption optimisation (IT2Green, 2014):

- Modern energy-effective devices (based on ecolabel criteria);
- Devices using energy-efficient technologies (e.g. LCD screens);
- Mutualised and multifunctional devices (e.g. printer/scanner/copier);
- Thin client terminals providing energy effective alternative to hardware (e.g. for a multi-room set-top box configuration).

*Proper configuration of equipment*

The correct set-up of the equipment on first install is critical to optimise energy consumption. The configuration of equipment shall be set to the lowest energy factor possible. Appropriate peripherals shall be set such as energy-effective Ethernet.

To ensure proper configuration, installations can be done by technicians either for devices used in companies or for devices used by end-users at home (e.g. set-top boxes).

Global configuration measures can be implemented in companies such as:

- Configure and centrally control the Operating System Power Management settings of the desktop environment (SEAI, 2013).
- Configure and standardise the power management settings in the operating system on all hardware (SEAI, 2013).
- Perform software updates/patch deployments during business hours or use Wake-on-LAN technology to perform this task out of business hours (SEAI, 2013).

The equipment configuration will also aim at minimising unnecessary functionalities and power consumption of the equipment (mainly for computers and smartphones) by limiting the installation of new applications, and by configure them in energy-efficient modes:

- Synchronize updates of always-on applications (such as emails), since a parallel network access consume less energy than multiple separate accesses;
- Automatically turn off positioning information when unnecessary (for smartphone, tablets, etc.);
- Detect and delete energy-greedy bugs and malware.

The best practice is to ensure that all end-users equipment are configured by power management specialist.

### *Perform regular energy audit*

- Check powered off devices after working hours. Software can be used to log which desktops are powered on (SEAI, 2013);
- Run desktop power management audit and produce detailed reports on potential energy and cost savings (SEAI, 2013).

More information is given on the implementation of energy audits within the BEMP 2.2 Implement an environmental management system.

### *Power management solutions*

The energy consumption of an ICT device depends on its operating mode:

- In active mode, a device is on and performing its intended function;
- In idle mode, a device is on and ready to work, but is not actively doing anything;
- In sleep or standby mode, a device has been powered down, but is ready to return to active mode after a short delay;
- In off mode, a device is not powered at all (unplugged or plugged to a strip that has been turned off).

The power efficiency during non-active mode is topical issue:

- Energy requirements for computers or other peripherals are sometimes ten times greater when turned on compared to standby mode (Buy Smart +, 2012)

- Printers, fax machines, copiers and multifunctional devices do consume a significant amount of energy while being on standby mode, while no energy is necessary when turned off. The total amount of energy consumed overnight by such a peripheral not switched off is equal or above the energy consumed on a typical day. Other devices consume electricity even after being turned off.

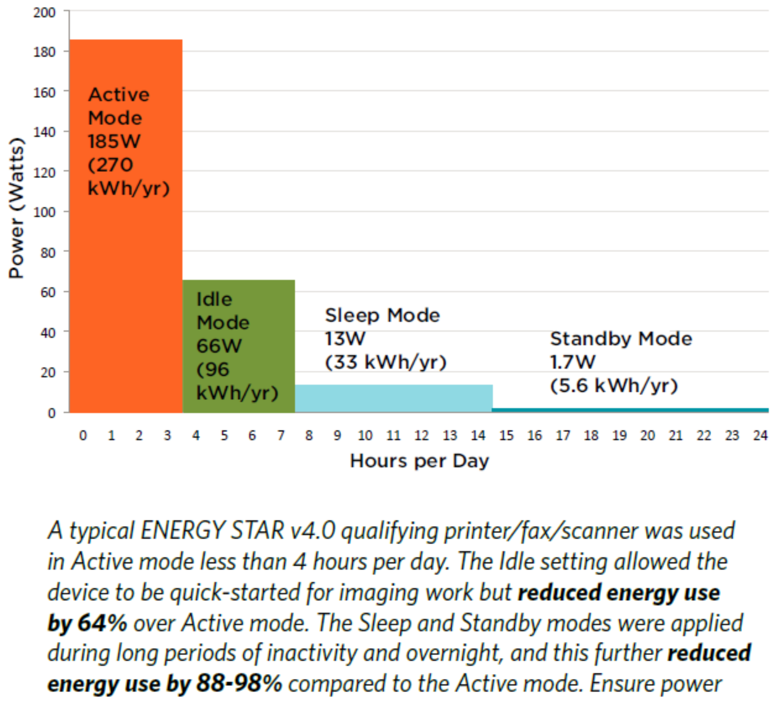


**Figure 18: Power use in a typical multifunctional peripheral in different power modes - Source: (New buildings institute, 2012)**

To manage energy consumption of ICT devices, different power management solutions can be implemented:

- Manually set up power management: it can be set up to reduce energy consumption during non-active mode. The manual set up requires to physically turn to low power mode or switch off equipment (screen, laptop, smartphone, etc.). The manual power management relies more on education program of staff. Ongoing education program and reinforcement can help achieving great energy savings through power management (Bray, 2006).
- Use of default modes: default modes for switching to saving modes on computers and servers or for default printing can be easily set up. It must be integrated as the company policy to use these default modes. Energy saving modes are classified according to Standard Advanced Configuration and Power Interface (ACPI). ACPI system level S3 is the common standby mode used (IT2Green, 2014).
- Use of dedicated power management software: hardware power management can be done through the use of dedicated management software (SEC, 2009). Software can influence the operating states of hardware by using power-saving modes. It can also influence the extent and the timing of power consumption through the distribution of the computing or memory load in network (Aebischer and Hilty, 2014). Theoretically, automatic power management reach

100% of devices by switching to low power mode when idle or by turning off devices.

- Use of usage management software: Beyond the management of hardware power features, software solutions can be installed and used to reduce the utilisation of computing load and memory.
- Use of dedicated devices: solutions such as devices to plug to computers into the USB port can help reducing energy consumption by optimising power modes. This type of device can be used to put a computer in the lowest power mode when not in use. The computer is suspended with a push of a button and reactivates with a click on the keyboard. The device can display a message showing the amount of energy saved during the time the computer was off (IREC, 2012).

  Smart power strip is another type of device used to cut off power to peripherals when a computer is turned off to limit the electricity consumption during this mode. Computer shall be plugged into a socket and the peripherals into another socket. The device smart power strip will detect when the computer is turned off to turn off all the peripherals (IREC, 2012). There are different types of power strips that can be used on office IT equipment (NREL, 2013), (Energy Star, 2015):
    - Remote switch power strip which can be turned off by the user via a remote switch. For the device to be efficient, the user must remember to turn off the power strip each time.
    - Master-controlled power strip which when a primary device is turned off by the user, the power strip automatically turns off the controlled outlets where the peripheral devices are plugged in.
    - Timer-equipped smart power strips: outlets that are controlled by programmable timers. Devices plugged to this type of smart power strip can be scheduled to automatically turn off at a designated time.
    - Occupancy sensing smart power strips: outlets are controlled by a motion detector. Devices plugged can automatically turn off or on in response to physical presence. The user can define a period of time elapses.
    - Current sensing power strips: can turn outlets off or on when a monitor plugged into the master outlet enters a low powered sleep mode or is turn off or on. It can be used in combination with monitor power management features.

**Organisational solutions**

### *Assess the individual user acceptance*

An effective power management priority is to find the "user acceptance" to ensure the full implementation of the different solutions (IT2Green, 2014). The management shall find the right balance between user convenience and energy saving.

Switching from standby mode to operating mode generally takes a short time. The user acceptance to use the standby mode is not an issue in that case. For instance, security settings can require a longer reactivation time. In that case, the delays created in the workflow can create a barrier for the acceptance of power management.

The user acceptance passes through the communication of the power management. Organisational solutions can be considered to help the integration of power management in an organisation.

### *Raise users' awareness*

To implement power management policy, a key step is to raise employees' awareness (IT2Green, 2014).

The objective is to encourage them to question their habits on the use of electronic devices at work:

- Switch off computers when the computer is unused;
- Print documents only when necessary.

The level of energy savings from office equipment is down to everyday management by employees. The staff must be implicated in the management power policy. Employees must be made aware of wastage areas. Communication can focus on monitoring indicators such as the amount of paper used each month or the energy consumed by the workstation each month over time.

To reinforce the power management, educational program can be run. Motivating the staff can also be done through questionnaires to ask employees their opinions, through self-assessment on energy use.

Power management also focuses on the use of the right device for the executed task, therefore rightly assessing the need for each task is key.. How to assess the needs is tackled in the previous section in the development of the BEMP on the procurement of energy efficient IT equipment (refer to section 2.3). Energy efficiency improvement is related to space planning and understanding of common space and device utilization. Through the understanding of the use of the different types of devices, their number can be optimised. For instance, some workstations sometimes have their own single-user machines, printers, copiers, fax machines and scanners, whereas these types of equipment can be commonly used by over 60 people (NREL, Reducing plug and process loads for a large scale, low anergy office building: NREL's research support facility , 2011). Better space planning and need evaluation can help optimising the overall number of devices needed and therefore the electricity consumption related to those devices especially while idle.

Centralisation of shared multifunction devices can be hindered by the will of employees to keep these devices private. Some people can be reluctant to do so because they do not want to send sensitive print documents to a shared device. To counteract these problems, the management can set up password protection and focuses on educating staff.

For end-users devices used by customers, technicians can raise users' awareness on energy saving measures during the equipment installation to raise awareness.

### 2.4.6 Applicability

Implementing power management depends on the leadership commitment to support overall energy savings objectives and environmental performance. It is also dependant on the implication of the staff to contribute to the power management measures. The implementation of a successful power management policy also requires the involvement of different services and functions within a company. The IT department, the procurement department must exchange information.

The applicability of the different techniques detailed in section 2.4.5 depends on the company size:

- Small to medium-sized companies rely more on employees to set their own computers. Manuel power management requires each user to physically turn off their computer or put it into low power mode. It relies on educational programs and communication. It is harder to reach a consistent high level of

power management in a large organisation whereas smaller companies can more easily track "bad users" (Carbon Trust, 2006).

- Larger companies are more likely to succeed in achieving energy savings through power management by using automatic techniques such as software controls to centralise the power management (Carbon Trust, 2006). This type of techniques will be less likely set up in SMEs. However, controlling devices to set up directly on devices like a smart power strip apply to all types of companies.

### 2.4.7 Economics

The implementation of power management on IT equipment leads to energy savings which consequently creates cost savings. According to Energy Star, putting computers to sleep can help save from 8 to 45€ per computer each year (Energy Star, Put your computer to sleep, 2015b).

Regarding technical devices that can be used for power management, devices to plug to computers into the USB port cost around 17€ whereas a smart power strip costs between 25 and 30€ (IREC, 2012).

To calculate accurate cost savings, the payback time shall be calculated for the energy savings devices installed.

### 2.4.8 Driving force for implementation

The main driver in a company to implement power management is the potential cost savings. In relation to the economic data reviewed in the previous section, cost savings can be significant when there is a large amount of ICT equipment.

According to the European Commission's Reference Document on Best Available Techniques for Energy Efficiency (2009), there are other drivers for implementing energy efficiency policy:

- the improvement of the energy efficiency performance and compliance;
- the improvement of the competitiveness, in particular against a trend of increasing energy prices;
- the improvement of the personal motivation;
- the improvement of the company's image and reputation.

### 2.4.9 Reference organisations

The review of sustainability frontrunners in the ICT and telecommunication sector allowed identifying reference organisations on energy efficiency and power management:

  - Orange (Orange, 2015) is finalizing for all European country the deployment of consumption measurement tools for office and IT equipment. While 40% of equipment were left switched on in the evenings and on weekends on average, this rate has been reduced to 25% in 2015.

### 2.4.10 Reference literature


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## 2.5 Use of renewable and low-carbon energy

**SUMMARY OVERVIEW:**

**ICT facilities have high carbon footprint due to intensive energy use. Electricity generation from renewable sources such as biomass, solar, wind and geothermal cooling systems, significantly reduces their carbon footprint. It is considered best practice to:**

- **Purchase third-party green electricity.**
- **Produce one's own electricity, either on or off-site.**
- **Store electricity on-site in an efficient way.**

**ICT components**

| **Data centre** | **Telecommunication network** | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicator**

- Share of renewable electricity purchased (with Guarantees of Origin) out of the total electricity use (%)
- Share of renewable electricity produced on site out of the total electricity use (%)
- Green Energy Coefficient (GEC) = renewable energy use / total energy use (%)
- Carbon Usage Effectiveness (CUE) = CO2-eq. emissions from the energy consumption of the facility (kgCO2eq) / total ICT energy consumption (kWh)

**Cross references**

| | |
|---|---|
| **Prerequisites** | • Depends on the geographical location of the facility and its size |
| **Related BEMPS** | • 3.5.4 Design of the data centre building and physical layout<br>• 3.5.5 Selecting the geographical location of the new data centre<br>• 3.5.6 Use of alternative sources of water |

### 2.5.1 Description

Using renewable energy sources (solar, geothermal, off shore wind and biomass co-generation) reduces significantly the carbon footprint of electricity production compared to burning fossil fuels, as shown on the graphs below.

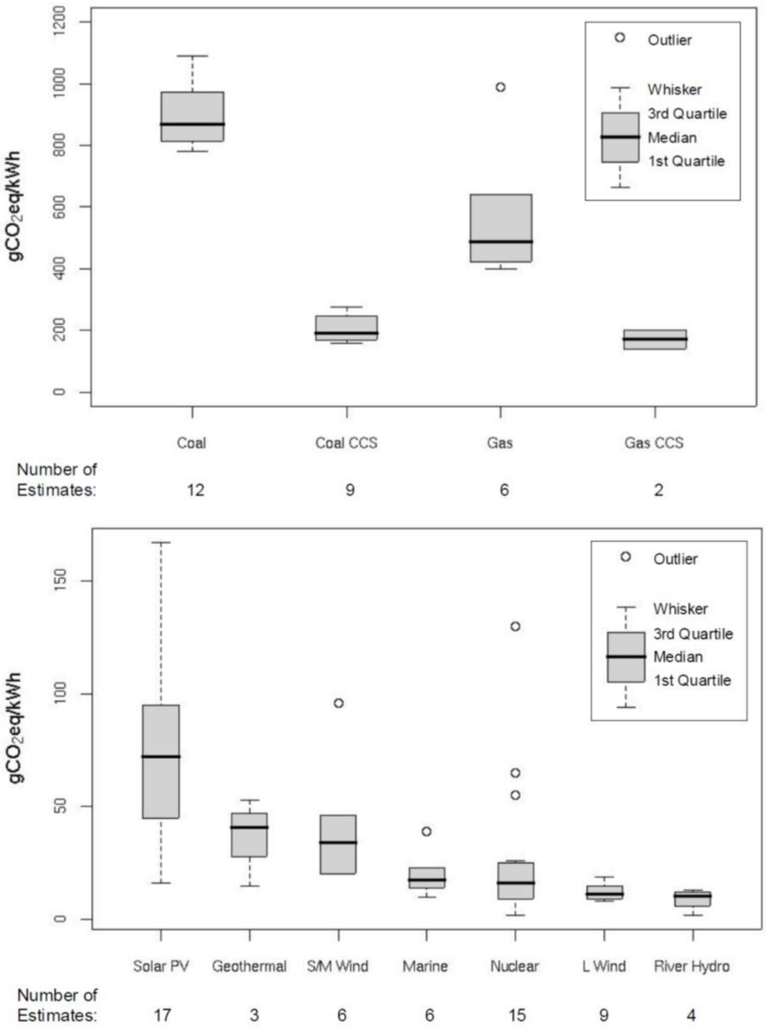



**Figure 19: International carbon footprints for electricity from different energy sources. Source: (UK Parliamentary Office of Science and Technology, 2011)**

It is best practice to:

- **Purchase third-party green electricity from the grid produced from renewable sources.**
- **Produce one's own electricity, either on or off-site.**
  - **On-site generation**: The renewable energy source is produced on site, e.g. by building wind turbines or by setting up solar PVs on the roof (in urban areas) or around the facility (in rural areas).
  - **Off-site generation**: If on-site generation is not possible due to a lack of resources or of space, off-site generation can be established instead in a location where the conditions for renewable electricity production are more favourable. Similarly to on-site production, this requires a

large upfront investment to build the necessary power generation capacities.

Potential renewable energy sources that can be adopted by ICT facilities include:

- Biomass co-generation: Woody biomass can be burnt on-site to produce high-pressure steam that drives a turbine generator to make electricity (with an increased efficiency for Combined Heat and Power systems or CHP) which supplies the site.
- Solar power requires sun exposure surfaces. Large installation of photovoltaic solar panels can be set up on roofs or on adjacent fields in order to produce a part or the entire amount of electricity needed for running ICT equipment in data centres, Telecom centres, base stations, offices, etc. Absorption chillers can also be used to supply cooling in a more energy-efficient way.
- Wind power from on-site turbines can be used to provide electricity for office buildings, data centres, Telecom centres and base stations.
- Geothermal cooling systems include an array of vertical holes drilled into the ground that house a piping system filled with water or refrigerant and serves as a heat exchanger for data centres and Telecom centres.

The use of renewable energy is more developed in data centres and in base stations facilities. Renewable energy from solar panels and small wind turbines offer a viable alternative to diesel although, due to the erratic availability of such energy, they will need adding relevant energy storage (batteries). Renewable energy sources power 4.5% of the world's off-grid base stations in 2014, up from just 0.11% in 2010 (NavigantResearch, 2010). Although the vast majority of off-grid base stations are located in developing countries, some are located in Europe. Nevertheless, if the business case is strong to adopt renewable energies in developing countries (especially solar PVs, which offer a rapid pay-off of the initial CAPEX), it is not yet the case in the European Union, where very few projects have been launched (see Section 2.5.7).

When renewable energy solutions are not technically or economically feasible, the best option is to install:

- Natural gas based CHP plants which combine use of the energy produced, together with its heat, allow a very high efficient use of the resource (more than 80%).

- **Store electricity on-site in an efficient way.**

Sites with local renewable generation can be integrated by local energy storage, as developed within the BEMP 5.4 on System integration (Integration of renewables on grid or off-grid) depending on the grid. Within the framework of smart grids systems, UPSs that power supply ICT facilities can also be used as local storage solution with their batteries.

Another solution for local energy storage is to use fuel cells with $CH_4$ or $H_2$. These cells can for example replace backup diesel generators.

### 2.5.2 Achieved environmental benefits

Electricity from the grid is the main energy source of data centres, telecom centres and base stations sites. Diesel generators are often used either as a backup or a

primary energy source – particularly when located in an area which is not connected – or with an unreliable connection - to the grid. As a consequence, a transition to renewable energy:

- **Decreases $CO_2$ emissions**, both of data centres and of base stations. Data centres in particular are very large energy consumers, and their fast growing consumption should rise up to 93 TWh by 2020 (GENIC, 2014a). A simultaneous rise of the share of electricity coming from renewables would have a massive impact on the $CO_2$ emissions of these infrastructures. Regarding base stations, considering that around 410,000 base stations run on diesel power in 2014 worldwide, the replacement of diesel motors by solar panel or wind turbines would save up to 8.7 billion litres of diesel per year (Hasan, 2011) (Ike, 2014).
- **Decreases the air pollution in the area around the facilities**. This is especially true for the diesel powered base stations, mostly located in developing countries but also in remote areas of developed countries.
- **Decreases the use of water**. The use of free cooling system helps reducing the use of water based chillers.

A potential side-benefit from the use of renewable powered base-stations in Africa is the sharing of additional energy with local villages. GSMA has partnered with the IFC and the World Bank to encourage mobile network operators to provide excess power generated by their base stations to local off-grid communities. This in turn can allow reducing the carbon footprint and local pollution in villages (GSMA, 2010) while contributing to the electrification of such remote areas.

### 2.5.3 Appropriate environmental performance indicators

The most common indicator to track the use of renewable energy is the **purchase of electricity from renewable energy sources**. The share of electricity from renewable sources is calculated based on the share of electricity purchased with guarantees of Origin. Frontrunners sign agreements to purchase 100% of sustainably produced electricity. For instance, Telecom Italia, signed an agreement with A2A to buy "clean" electricity, produced exclusively from renewable sources, to cover the energy requirements of all the Group Companies (Telecom Italia, 2014).

When renewable electricity is directly produced on site, the **share of renewable electricity produced** can also be monitored. A large photovoltaic array or wind farm are needed to power site such as data centre. Frontrunners reach up to 15% of energy needs covered by renewable energy. On-site power production can be combined with an off-site biomass boiler, in order to cover a much larger share of the energy needs and tend toward emission-neutral site.

The Global Task Force in charge of harmonizing global metrics for data centre energy effectiveness (JRC, 2014) identified a few core indicators regarding the use of renewables. The definitions provided by the taskforce for GEC and CUE are given below.

The main indicator assessing the type of energy used to power ICT infrastructures is the Green Energy Coefficient:

- **Green Energy Coefficient (GEC)** (JRC, 2014): is a metric that quantifies the portion of a facility's energy that comes from green sources. GEC has a maximum value of 1.0, indicating that 100% of the total energy used by the data centre is green energy. GEC is computed as the green energy consumed by the data centre (measured in kilowatt-hours or kWh) divided by the total

energy consumed by the data centre (kWh). For the purposes of GEC, "green energy" is defined as any form of renewable energy for which the data centre owns the rights to the green energy certificate or renewable energy certificate, as defined by a local/regional authority.

The consequence of the decision to use renewable energies should be a decrease in the $CO_2$ emissions of the ICT site. The $CO_2$ emissions used to produce a certain amount of service can be monitored from year to year (all other things being equal, e.g. to exclude the variations in energy effectiveness) using the **Carbon Usage Effectiveness (CUE)** (JRC, 2014):

- **CUE** is a metric that enables an assessment of the total GHG emissions of a data centre, relative to its ICT energy consumption. CUE is computed as the total carbon dioxide emission equivalents ($CO_2$-eq.) from the energy consumption of the facility divided by the total ICT energy consumption (kWh). For data centres with electricity as the only energy source, this is mathematically equivalent to multiplying the PUE by the data centre's carbon emission factor (CEF). The scope of CUE includes the emissions from energy consumption and excludes the emissions generated in the manufacturing of the IT equipment, its subsequent shipping to the data centre, the construction of the data centre, etc.

The calculation of the CUE is a good way to measure the results of a policy which intends to increase the use of renewable energy. This indicator will mainly be dependent of the technology of renewable energy production used, and of the country in which the installation is located.

This BEMP does not focus only on renewable energy but also on low-carbon energy, through the installation one-site of CHP plants with a higher efficiency in the use of the resource. An operational indicator aiming at monitoring the results of such practice would be the energy self-generation with up to 90 % energy efficiency (COP, FC).

### 2.5.4 Cross-media effects

If the environmental benefits from renewables are a largely shared consensus, the **social acceptance** of some renewables is yet to be demonstrated. In practice there are often cross-media effects in the implementation of renewable energy but they can be mitigated so that the overall environmental impacts will be positive.

<table>
<tr><th>Energy source</th><th>Potential cross-media effects</th><th>Mitigation options</th></tr>
<tr><td>Solar thermal</td><td>The production of solar thermal collectors requires energy and materials, and emits gases such as $CO_2$. Paid back within two to three years of operation depending on site specific application, so that energy produced over the remaining 20 year operating lifetime creates a large positive balance.</td><td rowspan="2">Maximise output through optimised siting and installation (e.g. south orientation).<br><br>Ensure a long operational lifetime.</td></tr>
<tr><td>Solar photovoltaic</td><td>The production of solar PV cells requires energy and materials and emits gases. It involves toxics in manufacturing and potential concerns with end-of-life waste.<br><br>Payback times are estimated at three to four years against 30- year operating lifetimes.</td></tr>
</table>

| | | |
|---|---|---|
| Wind turbines | Damage to wildlife (e.g. bird strike – although evidence on the severity of this impact suggests that it is relatively small).<br><br>Embodied energy in wind turbines typically represents less than one year's electricity output over typical operating lifetimes of 20 years. | Maximise output through appropriate siting (e.g. in areas of high and consistent wind speeds).<br><br>Ensure the monitoring of the impacts on wildlife. |
| Biomass heating | Air pollution (local). Wood burning emits CO, NOx, hydrocarbons, particles and soot to air and produces bottom ash for disposal. These substances indicate incomplete combustion performance, and occur especially during start-up, shut-down and load variation. Wood chip boilers typically emit slightly more polluting gases than pellet boilers owing to lower fuel homogeneity, but emissions are low compared with other solid fuel boilers. Indirect land use change (ILUC) impacts of biofuels may also be of concern – This relates to the consequence of releasing more carbon emissions due to land-use changes around the world induced by the expansion of croplands for ethanol or biodiesel production in response to the increased global demand for biofuels. | CO, hydrocarbons, soot and black carbon particles can be reduced by using continuously operating wood chip or wood pellet boilers. |
| Geothermal heat | Many systems use an antifreeze solution to keep the loop water from freezing in cold temperature conditions. These solutions have very low toxicity, but many produce CFCs and HCFCs, which add to environmental concerns. | Select antifreeze solutions with low toxicity (refer to section 2.3) |

### 2.5.5 Operational data

**Purchase of third-party green electricity**

This is the easiest way for organisations to add renewable energy to their energy mix. This can be done by acquiring so-called "electricity tracking certificates". Organisations can purchase certificates that guarantee that one MWh of electricity was produced with a certain set of characteristics (e.g. energy source and $CO_2$ emissions). The most common certificate in the EU is the Guarantee of Origin (GO) (RenewIT, 2014). Combined with a Power Purchase Agreement (PPA) of the same amount, ICT organisations can purchase electricity from renewable energies to power their infrastructures. This is the case of Telecom Italia that bought 1,900 GWh of electricity from renewable sources (Telecom Italia, 2014) to power its Italian network.

**Producing own electricity, either on or off-site:**

A more detailed presentation of the different types of renewable energies available to power ICT sites will help understand how on-site renewables can provide additional energy to these infrastructures:

- **Solar**: the maximum current generation capacity of commercial solar cells is 225 W/m², meaning that 4,500 m² are necessary to match 1 MW power demand. In Europe, the average production time frame of a solar PV is 8 to 12 hours. The variability of production levels, depending on weather conditions (night, cloudy periods), requires solar PVs to be complemented by batteries or

a diesel backup system. The investment in solar PV is high, but compensated by lower maintenance costs compared to other energy systems.

- **Wind**: wind is a highly variable resource, often preventing it from being the primary energy source for data centres. In rural areas, where the construction of wind turbines is a less sensitive issue than in urban areas, large scale wind systems can be considered. In order to produce 1 MW of electricity, a 53 meter rotor diameter is necessary, in addition to a reliable backup system. Similarly to solar PVs, wind is a relatively mature technology with a good rate of return on investment. The electricity generation capacity of wind turbines is very broad, ranging from a few kW for micro wind turbines (for example installed on roofs in urban areas) to more than 5 MW for high power wind turbines.
- **Biomass**: there are many ways to produce energy from biomass, depending on the type of biomass used, usually organic waste like wood pellets, straw and other crops. The drawback of biomass is that a large space is required to store the biomass before its use. For data centres, the most common system is the installation of a biomass boiler, functioning in the same way as a conventional gas boiler. Depending on the size of the installation, the power generation can range from a few dozen kW to 100 MW. Operating expenditures include the purchase of the raw material, its transportation and storage. As a consequence, biomass makes more sense in locations where the resource is easily accessible (for instance in woody areas). This can make the use of biomass an attractive alternative to other energy sources, in addition to other advantages like emission reduction and a lower variability of the production levels.

Other, less used, potential sources for providing renewable energy to ICT facilities include:

- **Solar thermal**: since ICT facilities primarily require electrical energy, solar thermal technologies need a conversion of this thermal energy to electrical energy using organic Rankine cycle (ORC) or turbine systems. To reach the temperatures needed for these systems to provide electrical energy, large ground space is needed. For a facility the only use of these technologies would be when a large amount of space is available, so the possibility of this technology will be focused in rural areas.
- **Absorption chillers**: they use heat rather than electricity as their energy source. Natural gas is the most common heat source for absorption cooling but other potential heat sources including solar-heated water can be used. Solar hot water driven absorption chillers allow energy savings compared to gas fired absorption chillers with high gas consumption. They also replace electric chillers. Because absorption chillers can make use of waste heat, they can essentially provide cool air in facilities such as data centres.
- **Geothermal energy production**: geothermal energy generates continuous, clean, safe and reliable power. Geothermal energy is the thermal energy contained in the Earth There are different ways of exploiting geothermal energy, from areas with the highest enthalpy that can use the steam to produce electricity in large power plants to areas with the lowest enthalpy to simply produce hot water. EU expects that geothermal represents the 0.3% of the electricity consumption in 2020 and 1.3% of heating and cooling consumption (GENiC, 2014).

After installing renewables, the second best option is to install:

- **Combined heat and power** (CHP), or tri-generation: CHP and Tri-generation installations generate the most of these thermal energy productions since they produce heat, electricity, and, in the case of tri-generation, cold. The CHP systems used in ICT sites are typically fed by gas to run endothermic engines. They mainly produce electricity, while the waste heath is collected and used to heath or, through absorbers, is used to produce cold.

The ETSI Standard proposes an overview of solutions for using of alternative energy in ICT sector and guidelines on application of alternative solutions (ETSI TR 102 532 V1.2.1, 2012). It presents a three step approach:

- Assessment of the Renewable Energy Solutions (RES)
- Theoretical planning of solution also on the basis of practical inputs from the specific application site
- implementation of the renewable energy solution

The use of these technologies can be combined to add-up the amount of energy needs covered by renewables in ICT sites. The table below presents a few examples of data centres which could resort to renewable energies to cover part of their energy needs (GENIC, 2014a).

**Table 17: Examples of existing data centres renewable energy use (GENiC, 2014)**

| Location | Size | Power Installation | Alternative Energy Type | Energy needs covered by renewables |
|---|---|---|---|---|
| Valencia (Spain) | 600 m², 294 racks | 4,5 MW | Solar PV on roof | 130 kW (3%) |
| | | | Biomass boiler | 100 kW (2%) |
| Pamplona (Spain) | 100 m², 50 racks | 1,5 MW | Solar PV on roof | 22 kW (3%) |
| Cork (Ireland) | 80 m² | 50 kW | Wind turbines on roof | 4 kW (8%) |
| | | | Biomass boiler | 50 kW (100%) |
| Helsinki (Finland) | 270 m² | 600 kW | Wind turbines on roof | 13.5 kW (2%) |
| | | | Biomass boiler | 100 kW (17%) |
| Luxemburg | 410 m² | 275 kW | Wind turbines on roof | 20 kW (7.5%) |
| | | | Biomass boiler | 100 kW (36%) |
| Brno (Czech Republic) | 100 m² | 150 kW | Biomass boiler | 100 kW (67%) |

The table above reveals that on-site energy production has limited capacities to cover the needs of data centres. The combination of on-site power production through wind or solar can nevertheless be combined with an off-site biomass boiler, in order to cover a much larger share of the energy needs and tend toward emission-neutral data centres.

The inability of on-site renewable energy generation to cover the needs of data centres highlights the fact that a major effort must be made for energy efficiency, in

order to reduce the overall consumption of these infrastructures (RenewIT, 2014). In telecom network sites, CHP systems can cover more than 50% of the electricity needs of sites, and nearly reach all the thermal energy needs.

**Use local storage solutions**

<u>Use fuel cells to replace backup diesel generators</u>

Backup power systems have been incorporating fuel cells, in order to provide consistent power to ICT facilities: DC power for telecom operations in a single cabinet or AC power for data centres. Such solutions can present a peak efficiency greater than 55% based on lower heating value of hydrogen.

### 2.5.6 Applicability

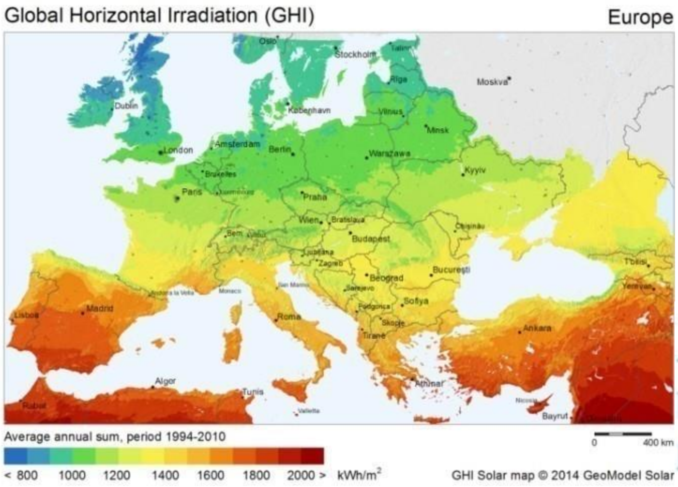
The applicability of the renewable energy sources presented in 2.5.5 depends on several factors, including the **geographical location** of the facility and its **size**.

- **Location/climate zone**

When considering the use of renewable energy to power data centres and base stations, the location, i.e. the climate zone of the facility is a primordial factor. There is no "one size fits all" renewable strategy for data centres across Europe, because of the different climate requirements of each energy source. The maps below show the climate characteristics in Europe:

- Figure 20 shows the global yearly irradiation map, for solar PV installations
- Figure 21 shows the wind average speed, for wind turbines
- Figure 22 shows the biomass availability for cogeneration.

For each resource, GENiC -a EU funded research programme aimed at reducing the energy consumption of data centre across Europe- distinguishes between three levels of abundance, namely above average, on average and below average (GENiC, 2014).

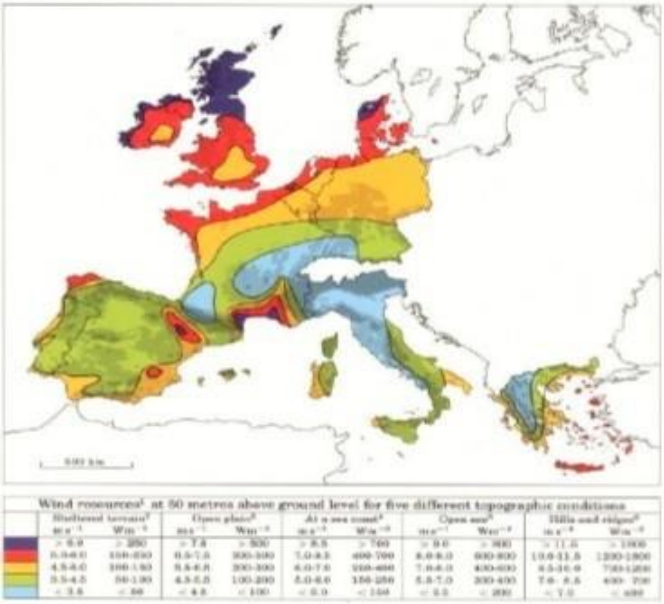



- Average Global horizontal irradiation level Classification:

*Table 3. Solar irradiance level classification*

| LEVEL | AVERAGE GLOBAL HORIZONTAL IRRADIATION(Kwh/m2) |
|---|---|
| 1 | (1500 to 2000) |
| 2 | (1000 to 1500) |
| 3 | < 1000 |

**Figure 20: Irradiation map (GENiC, 2014)**

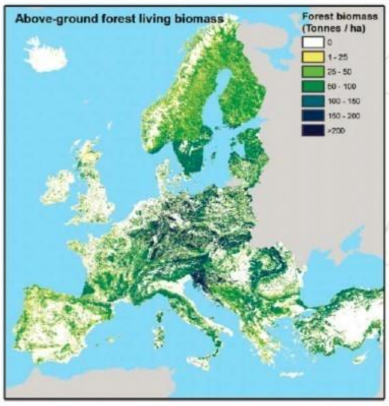


- **Average Global Wind Speed level Classification:**

*Table 4. Wind speed level classification*

| LEVEL | AVERAGE WIND SPEED (m/s) |
|---|---|
| 1 | >= 6 |
| 2 | (4.5 to 5.5) |
| 3 | < 4.5 |

**Figure 21: Wind speed map (GENiC, 2014)**




- **Average above-ground forest living biomass level Classification:**

*Table 5. Biomass resources level classification*

| LEVEL | BIOMASS RESOURCES (Tonnes/ha) |
|---|---|
| 1 | >200 |
| 2 | 100 – 200 |
| 3 | 1 – 50 |

**Figure 22: Biomass availability (GENiC, 2014)**

Based on the above detailed climate characteristics, GENiC established the following merit order or renewable energy sources for each geographical zone (Mediterranean countries, Western Europe, Central and Eastern Europe, northern countries).

**Table 18: Merit order of renewable energy sources for each geographical zone (GENiC, 2014)**

| | **Mediterranean countries** (Spain, Portugal, South of France, Italy, Baltic Countries, Greece) | **Western Europe** (France, Belgium, Holland, Luxemburg, Germany) | **Central and Eastern Europe** (Poland, Austria, Czech Republic, Baltic Countries) | **Northern Countries** (Great Britain, Ireland, Denmark, Sweden, Norway, Finland) |
|---|---|---|---|---|
| Global horizontal irradiation | 1[40] | 2 | 2 | 3 |
| Average global wind speed | 3 | 2 | 2 | 1 |
| Average biomass | 2 | 2 | 1 | 2 |
| Average geothermal heat flow density | 3 | 1 | 1 | 2 |

- **Size/available surface area**

To study renewable energy integration in data centres, a better classification focusing on size and power needs is made by GENiC, using the following typology (GENiC, 2014):

### *Small data centres*

Small data centres such as server rooms and closets are usually located in the office premises of a company. Solar PV is the most popular technology for this size of infrastructures. Similarly, micro turbines can cover a small portion of the energy needs.

Furthermore, cooling of data centres produces low enthalpy flows that usually are dissipated, decreasing the overall efficiency of the data centre. There is increased interest in the recovery of this heat to increase efficiency. In fact there have been some examples using these low enthalpy flows such as use of this flow to heat nearby buildings (such as offices or houses) or nearby swimming pools.

### *Urban data centres*

Urban data centres (localized and mid-tier) are usually located in urban environments, and are connected to the electric grid. Diesel engines can be activated as backups. Renewables and CHP appear to be a good long-term energy source for urban data centres, to reduce the burden of the increase of electricity prices.

### *Large data centres*

Due to their size, large data centres are built in isolated, often colder, locations (see BEMP on data centres). They can benefit from free cooling and from a high availability of natural resources. Large data centres allow a combination of several power sources,

[40] NB: 1 = high recommendation; 2= medium recommendation; 3 = low recommendation

including solar PVs, wind turbines, biomass, geothermal and hydropower. Although these renewables usually account for a small part of the energy needs of large data centres, some best practices centres manage to cover all of their needs.

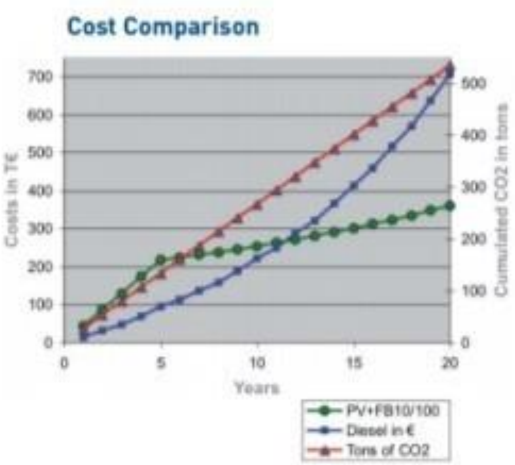
### 2.5.7 Economics

The costs of renewable energy sources are site specific, as many of these components can vary according to location. Costs are very variable, due to the diversity of resources on specific sites and the power output required. Most types of renewable energy also have some economies of scale, so larger installations have a lower per-kW installation cost.

Two elements support the view that renewables will become increasingly financially beneficial over the years:

- **Energy prices from fossil fuel sources are bound to experience a structural increase** in price in the years to come. As a consequence, it will make sense for ICT operators to add renewable energy capacities to their energy mix (GENiC, 2014).
- **Renewable energy sources are still maturing, which means that the price is structurally reducing while the reliability of the technologies is increasing**. Today, the main concern for ICT operators, apart from technical considerations like variability of electricity generation, is the capital expenditures of the installation of solar PVs, wind turbines or biomass boilers. The price of a solar PV module varied between 0.8 and 2.3€/Wp in the year 2011, and has been experiencing a structural downward trend ever since. It is estimated that around 2050, the cost of a solar PV system will be under 1.32€/Wp. In this price range and in countries with a good solar radiation level (over 1,400 Wh/kWp), the levelled energy cost[41] would be significantly lower (9.52c€/kWh) than the current cost of conventional electricity sources. Biomass boilers have a broad price range, depending both on the technology and on the size of the project. Prices seem to range from 500 to 1,200€/kW for projects from 50 kW to 2 MW. The cost is per electricity produced and does not consider the heat and cold produced by CHP. Prices from wind turbines depend on the type of windfarm (onshore or offshore). It appears that onshore farms have a cost of 1,100€/kW to 1,390€/kW, which is expected to remain stable but with an increased capacity factor (40% today). Offshore turbines have higher prices (around 2,415€kW and experiencing a downward trend) along with higher capacity factors (50%) (RenewIT, 2014).

[41] The levelled energy costs is the net present value of the unit-cost of electricity over the lifetime of a generating asset.




Solar powered Telecom Base Station

| 20 Years | Diesel in € | PV + FB10/100 in € |
|---|---|---|
| Cap. Invest. 60 month Lease | 9,368 | 188,690 |
| Replacements | 12 | 0 |
| Repl. Costs val. 5% | 78,861 | 99,198 |
| O+M val. 5% | 34,719 | 66,132 |
| Fuel val. 10% | 582,200 | 0 |
| Insurance val. 5% | 1,984 | 6,613 |
| TOTAL | 707,133 | 360,633 |

**Figure 23: Cost comparison of a solar powered vs. diesel powered telecom base station (in South Africa) (Cellstrom, 2015)**

The following table provides indicative economic costs, exclusive of subsidies or policy incentives. Subsidies may be available for the installation of many technologies, reducing net installation costs and payback periods. Although these are highly significant in determining the overall costs of a project, such schemes vary across countries and are subject to changes or certain conditions. Therefore, they are not explicitly included in the indication of costs below.

| Technology | Plant size | Conversion efficiency | Capacity factor | Capital costs (€/kW) |
|---|---|---|---|---|
| Solar thermal industrial process heat | 100 kWth–20 MWth | - | ~100% | 300 - 700 |
| Solar thermal: Concentrating solar thermal power (CSP) | 50–250 MW | - | 20 – 75% | 2,900 – 7,200 |
| Solar PV | 2.5–250 MW (peak) | 10–30% | 10–25% | 1,100 – 1,900 |
| Wind | 1.5–3.5 MW | - | 25–40% | 1,300 |
| Bioenergy CHP | 0.5–100 kWth | 60–80% | 70–80% | 400 – 4,400 |
| Geothermal power | 1-100 MW | - | 60-90% | 1,500 – 4,500 |

**Figure 24: Indicative costs comparisons for renewable energy, (REN-21, 2013)**

### 2.5.8 Driving force for implementation

A combination of incentives can drive the uptake of renewable energy to power ICT infrastructures:

- **Costs:** while the adoption of renewable energy technologies to power ICT sites involves an immediate major capital expenditure (CAPEX) investment to purchase and install, these are gradually decreasing. The operating expenditure (OPEX) for renewable energy sources such as wind, PV, hydro and geothermal energy can actually be lower than traditional energy sources once the CAPEX has been paid off. Government subsidies for renewable energy installation and guaranteed feed-in tariffs help reduce energy costs for ICT organisations. Some countries have implemented a Green or White Certificate tradable scheme (or Energy savings certificate) to encourage energy savings.
- **Reputation:** corporate social responsibility and the desire to improve the image of the company can be driver for installing renewable energy technologies. Many ICT organisations have carbon targets and renewable energy is one of the main approaches to reducing $CO_2$ emissions.
- **Regulatory pressure:** The Telecommunications and ICT sector is not covered by the EU emissions trading scheme (EU ETS), but some countries have emission trading schemes that apply to ICT organisations. For example, the UK's Carbon Reduction Commitment applies to public and private organisations with annual electricity consumption over 6000 MWh.

### 2.5.9 Reference organisations

**Purchasing renewable energy**

- Telecom Italia purchases 100% renewable energy, which represented 2.5 TWh/year in 2014/2015 (Telecom Italia, 2014).
- SAP SE has purchased 100% renewable energy worldwide since 2015 and controls it through inspection of the certifications of our energy supplier (SAP, 2015).
- Avalon Networks is a German web hosting provider. 100% of its electricity is produced by renewable energy, with the following distribution (AvalonNetworks, 2015):
  - 80% is purchased from the electricity provider Naturstrom, which provides Avalon networks with Guarantee of Origin certifications for the purchased amounts.
  - 20% is locally generated electricity from a 4 kW solar PV system. The amount of electricity produced is documented daily and made available publicly online.

**Powering data centres with renewable energy**

- Resilience Centre Luxembourg South (Kayl) received the Code of Conduct Data centres award for its key design criteria integrating 100% of renewable energies. It uses 100% of electricity certified from renewable sources (hydroelectric power plants) and solar panels with photovoltaic cells (European Commission, 2016).
- All SAP data centres are powered by renewable energy. However, with some exceptions (new power station in Walldorf, Germany) the highest amount of energy is purchased externally (SAP, 2015).
- Google is making large investments in its European data centre in Hamina, Finland. Google aims at powering its data centre 100% with wind electricity,

based on several power purchase agreements. After having purchased the entire 10 year electricity output of a wind farm in Finland, four additional wind farms have been built in Sweden exclusively to support the operations of the data centre. The operator, Eolus Vind AB, will build 29 turbines with a total capacity of 59 MW, and sell the whole capacity to Google with Guarantee of Origin certifications. The wind farms were expected to start powering the Hamina data centre in September 2015 (DataCenterKnowledge, 2014).

- In Norway, Green Mountain Data Centre and Fjord IT both power their data centres using hydropower (Green Mountain, 2015).

**Powering base stations with renewable energy**

- Regarding base stations, very few pilot projects have been launched, like Orange Labs' hybrid base station in Lannion (France) (Orange, 2013).
- Only one project seems to have been brought to the market yet, called KONČAR Hybrid Power Supply, developed by KONČAR (Croatian Electrical Engineering Institute) and Telekom Austria's Croatian subsidiary Vipnet. Vipnet has already installed 13 base stations using type of power supply in the Slavonija region of Croatia. This system is made of three components: fuel cells, along with solar PVs and wind turbines. Vipnet has announced that this combination allows for 99.9% energy effectivness, which would otherwise be difficult to achieve using only renewable energy sources such as solar and wind power. Each component can be modularly set up according to the consumption requirements and depending on the location of the base station (TelekomAustria, 2012).
- In developing countries, companies like Alcatel Lucent (AlcatelLucent, 2010), T-Mobile (Tweed, 2013) Huawei and Vodafone (CellularNews, 2009) have equipped base stations with solar and wind power systems at a large scale.

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## 2.6 Waste management of ICT equipment through waste prevention, reuse and recycling

| SUMMARY OVERVIEW: |
|---|
| **Waste management in the ICT sector is important because of the use of specific materials that need to be properly treated at end-of-life to avoid damage to human health and the environment. It also offers a large potential for limiting resource depletion through recycling. Specific waste management techniques can be implemented in order to improve waste management at each stage of the waste hierarchy in ICT companies. It is considered best practice to:**<br>• **Develop a waste prevention plan.**<br>• **Promote LCA-based eco-design through procurement.**<br>• **Increase the service life and limit the obsolescence of ICT equipment the reduction of the obsolescence.**<br>• **Implement systems to enable re-use of ICT equipment.**<br>• **Ensure traceable collection and proper sorting of end-of-life ICT equipment.** |

| ICT components | | | | |
|---|---|---|---|---|
| **Data centre** | **Telecommunication network** | Broadcasting | Software publishing | **End-user devices** |

| Relevant lifecycle stages | | | | |
|---|---|---|---|---|
| Design and installation | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | **End-of-life management** |

| Main environmental benefits | | | | | |
|---|---|---|---|---|---|
| Energy consumption | **Resources consumption** | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

| Environmental indicators |
|---|
| • Share of facilities or sites with a certified zero waste management system or with a certified asset management system (% of facilities/sites)<br>• Average service life of ICT equipment to be calculated for different product groups (e.g. servers, routes, end-user devices)<br>• Share of ICT waste generated from own operations recovered for reuse or refurbishment or sent for recycling<br>• Share of WEEE or ICT waste generated from clients recovered for reuse or refurbishment, or sent for recycling |

| Cross references | |
|---|---|
| **Prerequisites** | • N/A |
| **Related BEMPS** | • 2.2 Making the best use of an environmental management system<br>• 2.3 Procurement of sustainable ICT products and services |

### 2.6.1 Description

The Telecommunications and ICT services sector has a significant role to play in both reducing the use of raw materials and limiting the environmental impact of waste electrical and electronic equipment (WEEE) through improved waste management[42].

The following table shows the important amount of rare metals used in different ICT components.

| Metal | Use in ICT goods | Share of total going into ICT production, United States |
|---|---|---|
| *Aluminium* | Wiring on circuit boards; housings | 8% in electronic components |
| *Beryllium* | Heat dissipation of conductors in electronics | 50% in ICT components |
| *Cadmium* | Nickel-Cadmium batteries | 83% in batteries |
| *Cobalt* | Rechargeable batteries for mobile devices; coatings for hard disk drives | 25% in batteries (global) |
| *Copper* | Conductors in electronics | 21% in electric and electronic components |
| *Gallium* | Integrated circuits, optical electronics, LEDs | 94% in ICT components |
| *Germanium* | Optical fibres, optical electronics, infrared systems | 30% in optical fibres (global) |
| *Gold* | Solders, conductors and connectors | 8% in electric and electronic components |
| *Indium* | LCDs, photovoltaic components | n.a. |
| *Lithium* | Rechargeable batteries for mobile devices | 25% in batteries (global) |
| *Nickel* | Rechargeable batteries for mobile devices | 10% in batteries |
| *Palladium* | Conductors in electronics | 15% (global) |
| *Platinum* | Hard disk drives, TFT LCDs, etc. | 6% (global) |
| *Silver* | Wiring on circuit boards; miniature antennas in RFID chips | n.a. |
| *Tantalum* | Capacitators and conductors in embedded systems, PCs and mobile phones | 60% in ICT components |
| *Tin* | Lead-free solders | 24% in electric and electronic components |

**Figure 25: Overview of metals found in ICT equipment. Source: (OECD, 2010).**

ICT equipment can contain up to 60 elements, many of them are very valuable. Metals represent on average 23% of weight of the phone, in majority copper. A single mobile phone can contain up to 9 g Cu, 250 mg Ag, 24mg Au and 0.5 mg Tb.

[42] The present BEMP deals with waste management for waste that is specific for the sector, i.e. WEEE from ICT equipment. For general waste management in offices (e.g. dealing with paper, packaging, food waste), see the relevant BEMP in the best practice report for the public administration sector available at: http://susproc.jrc.ec.europa.eu/activities/emas/documents/PublicAdminBEMP.pdf.

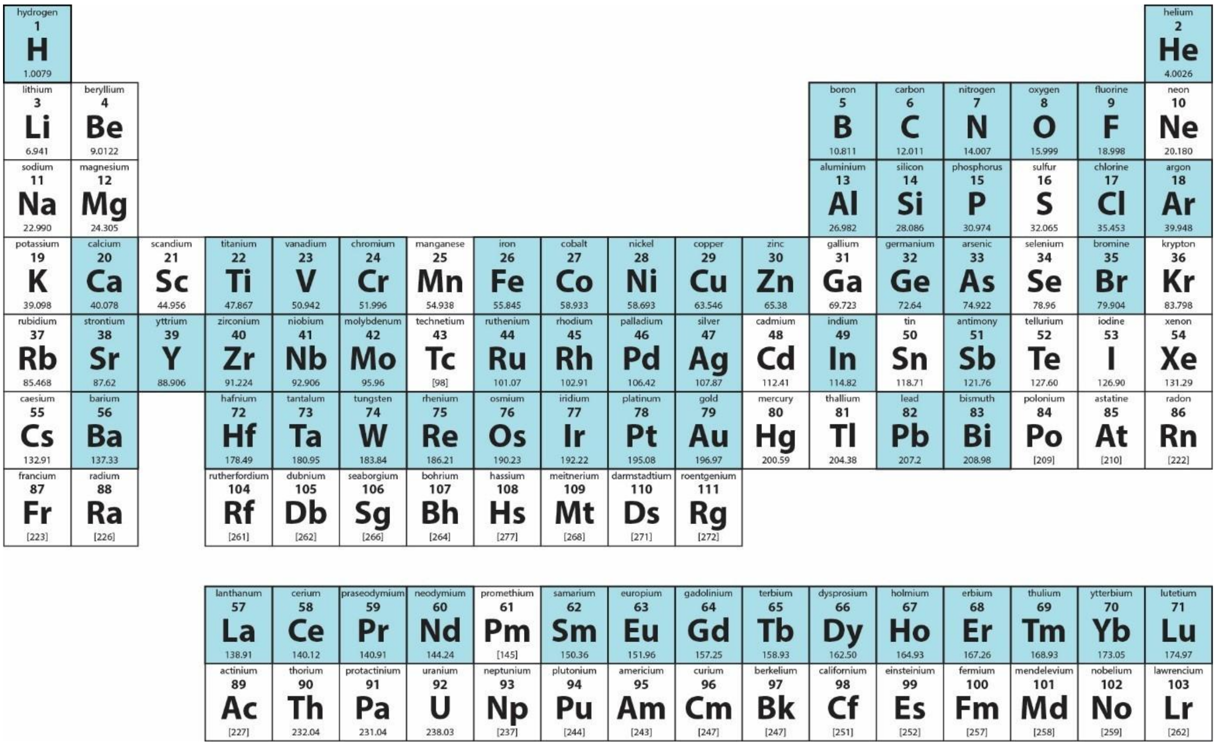



**Figure 26: Material content of a mobile phone (IGEM, 2014)**

The Waste Framework Directive (2008/98/EC) defines the hierarchy of waste management to be applied in order to achieve the best overall environmental performance. Priority is given, sequentially, to prevention, preparing for re-use, recycling, other recovery (e.g. energy recovery) and, finally, disposal.


**Figure 27: The waste hierarchy (European Commission, 2008)**

Each stage of the waste management hierarchy can be defined as follows:

- **Prevention:** measures taken before a product becomes waste. Prevention can be done through the increase of the service life of ICT equipment and by reducing the obsolescence: for instance, by implementing checking, cleaning and maintenance by which product life is extended. Prevention measures also apply to the procurement of ICT services and products. A specific type of prevention is **product re-use**. This is when a product that is no longer needed does not become waste because it is given to another user for the same

purpose for which it was conceived (e.g. re-use of computers, set-top boxes and Wi-Fi routers). The product may undergo **refurbishment, reconditioning or remanufacturing** before it can be ready for re-use.

- **Preparing for re-use:** any operation by which products or components that became waste are processed in order to be used again for the same purpose for which they were conceived. The difference with product re-use is that, in this case, the owner disposes of the product, which is then considered waste and is handled by a waste management organisation.
- **Recycling:** waste is reprocessed into products or materials, whose purpose is the same or other than the original product.
- **Recovery:** any operation which results into replacing materials by waste serving for a useful purpose, or using waste to recover its energy content.
- **Disposal:** any operation which is not recovery.

Specifically for WEEE, its waste management in the EU relies on two main legislative pillars: the "WEEE" Directive (2012/19/EC) and the "RoHS" Directive (2011/65/EC). They set up the European regulatory framework for the separate collection and treatment of electrical and electronic equipment waste. The WEEE Directive enacts the Extended Producer Responsibility principle. This is to give responsibility to the manufacturer for its product impacts on the environment including at end-of-life. Producers are therefore responsible for organising and financing the collection and treatment of WEEE (ETSI, 2016). There are five types of producers listed in the following table:

| Type of EEE Producer | Description |
|---|---|
| Manufacturer | Sells under its own brand products manufactured in member state |
| Importer | Imports from a country outside the EU |
| Introducer | Imports from an EU Member State |
| Reseller under its own brand | Resells products under its own brand |
| Distant seller of household equipment | Direct seller of household EEE from abroad by post or Internet communication |

**Figure 28: Type of EEE Producer (ETSI, 2016)**

Telecommunication and ICT services companies may be considered producers for some equipment depending on how the equipment has been put on the market and what has been specified with the devices suppliers.

In any case, Telecommunication and ICT services companies can develop a waste management plan to minimise their generation of WEEE and reduce the related environmental impacts, while also promoting recycling, while also address the waste generated by their customers.

It is best practice to:

- **Develop a waste prevention plan.**

  Such a waste prevention plan would aim at reducing the amount of waste generated. It can be linked to a policy for the procurement of sustainable ICT services and products, which includes the assessment of the situation and the setting of environmental criteria (see section 2.3).

- **Promote LCA-based eco-design through procurement.**

  Life Cycle Assessment captures the environmental impacts of each phase in a product life cycle. An eco-design process based on LCA helps reducing both the initial amount of resources used and the final waste generated while also minimising environmental impact through the use phase. Its use in

procurement can help selecting products with more potential for reuse, refurbishment or recycling (e.g. easy to dismantle).

- **Increase the service life and the reduction of the obsolescence**.

  This can be achieved by carrying out maintenance and checks on the equipment or through facility management services.

- **Implement systems to enable re-use of ICT equipment.**
  - Promoting reuse: for instance, raising employees' awareness about the possibility to request used ICT equipment, or donating used computers that are still functioning to charities, with associated social benefits.
  - Developing take-back programme and collecting mobile phones, set top boxes and routers for re-use.
- **Ensure traceable collection and proper sorting of end-of-life ICT equipment.** It consists in using waste treatment professionals to separate the different components and dispose of the final waste. It implies the verification of the contractor' skills and its accreditation.

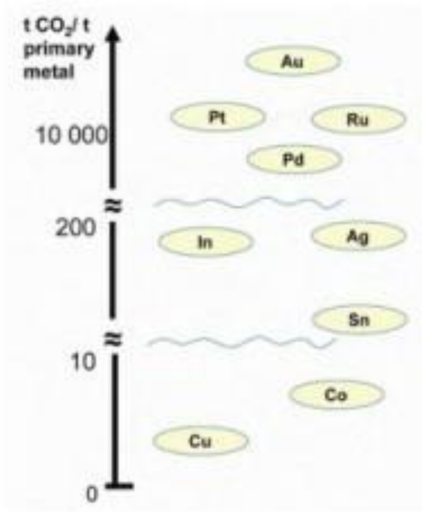
### 2.6.2 Achieved environmental benefits

Minimising the amount of waste generated and maximising re-use and recycling rates have the following environmental benefits:

- Saving virgin resources for the production of ICT equipment;
- Reducing energy consumption and GHG emissions for the raw material extraction and for the production of the ICT equipment – recycling materials uses less energy than extracting and processing virgin materials;
- Reducing the emissions to air, water and soil from waste disposal.

A TNS SOFRES and GIFAM study in 2011 (ADEME, 2012) showed that 40 to 50% of EEE were replaced while still being able to function. If the service life of products is extended, they would not be replaced as often and less WEEE would be generated.

The environmental impact of the primary metal production is significant, especially for precious and special metals. Large amounts of land are used for mining and energy is generated for the extraction of the metals. For example, to produce 1 tonne of gold, palladium or platinum, $CO_2$ emissions of about 10,000 tonnes are emitted. The figure below shows the $CO_2$ emissions related to the extraction of main EEE metals.




| Important EEE metals | demand for EEE t/a (2006) | data for primary production [t $CO_2$/t metal] | $CO_2$ emis-sions [Mt] |
|---|---|---|---|
| Copper | 4 500 000 | 3.4 | 15.30 |
| Cobalt | 11 000 | 7.6 | 0.08 |
| Tin | 90 000 | 16.1 | 1.45 |
| Indium | 380 | 142 | 0.05 |
| Silver | 6 000 | 144 | 0.86 |
| Gold | 300 | 16 991 | 5.10 |
| Palladium | 32 | 9 380 | 0.30 |
| Platinum | 13 | 13 954 | 0.18 |
| Ruthenium | 6 | 13 954 | 0.08 |
| $CO_2$ total [t] | | | 23.4 |

**Figure 29: $CO_2$ emissions of primary metal production calculated, (UNEP, 2009)**

An ITU study (ITU, 2012) shows the estimated GHG emissions avoided by using recycled content and materials:

| Material | Estimated GHG emissions[10, 11] ($kg\ CO_2e$) extraction/mfg stages (to produce 1 kg of material) | | Material finished product form – typical recycled content |
|---|---|---|---|
| | 0% recycled content | 100% recycled content[12] | |
| Metal – aluminium<br>(Bayer refining, Halle-Heroult smelting) | 22.4 | 1.07 | • Typical (world) – 40%<br>• Extruded forms – up to 85%<br>• Sheet products – up to 50%-63%<br>• Electronic components – < 5% |
| Metal – zinc<br>(electrolytic process) | 4.6 | 1.84 | • Typical (world) – 36%<br>• Die castings – 10% |
| Metal – lead<br>(lead blast furnace) | 2.1 | 0.74 | • Typical (world) – 47%<br>• Battery plates – ~50%<br>• Sheathing/foil – ~50%<br>• Solder – <5% |
| Metal – steel<br>(integrated route – BF and BOF) | 2.33 | 0.53 | • Typical (world) – 47%<br>• Structural forms – ~80%<br>• Rolled sheet goods – 25% to 35% |
| Metal – stainless steel<br>(electric furnace and argon-oxygen decarburization) | 6.8 | 1.8 | • Rolled sheet goods |
| Metal – copper<br>(smelting/converting and electro-refining) | 3.33 | 0.55 | • Typical (world) – 38%<br>• Structural – 75%<br>• Electrical/electronic – < 5% |
| Metal – nickel<br>(flash furnace smelting and Sherritt-Gordon refining) | 11.4 | NDA | • Typical (world) – 34% |
| Metal – titanium<br>(Becher and Kroll processes) | 35.7 | NDA | |
| Plastic – polycarbonate (PC) | 8.57[13] | 6.1[14] | |
| Plastic – acrylonitrile butadiene styrene (ABS) | 5.45[7] | 3.9[8] | |
| Plastic – polystyrene (PS)/styrene acrylonitrile (SAN) | 5.09[7] | 3.9[8] | |
| Plastic – polyethylene terephthalate (PET) | 4.93[7] | * | |
| Plastic – polyethylene, low density (PE-LD) | 3.71[7] | * | |
| Plastic – polypropylene (PP) | 3.51[7] | * | |
| Plastic – polyhydroxy- alkanoates (PHA) ("bio plastic") | 0.49[15] | * | |

*NDA – no data available*

**Under study/evaluation within plastics recycling industry*

**Figure 30: GHG emissions from materials used in ICT equipment, (ITU, 2012)**

The following table shows the potential dangerous substances concentration found in ICT waste. It also shows the annual global emissions related to each substance.

| Contaminant | Relationship with E-waste | Typical E-waste concentration (mg/kg)[a] | Annual global emission in E-waste (tons)[b] |
|---|---|---|---|
| Polybrominated diphenyl ethers (PBDEs) polybrominated biphenyls (PBBs) tetrabromobisphenol-A (TBBPA) | Flame retardants | | |
| Polychlorinated biphenyls (PCB) | Condensers, transformers | 14 | 280 |
| Chlorofluorocarbon (CFC) | Cooling units, insulation foam | | |
| Polycyclic aromatic hydrocarbons (PAHs) | Product of combustion | | |
| Polyhalogenated aromatic hydrocarbons (PHAHs) | Product of low-temperature combustion | | |
| Polychlronated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) | Product of low-temperature combustion of PVCs and other plastics | | |
| Americium (Am) | Smoke detectors | | |
| Antimony | Flame retardants, plastics (Ernst et al., (2003)) | 1700 | 34,000 |
| Arsenic (As) | Doping material for Si | | |
| Barium (Ba) | Getters in cathode ray tubes (CRTs) | | |
| Beryllium (Be) | Silicon-controlled rectifiers | | |
| Cadmium (Cd) | Batteries, toners, plastics | 180 | 3600 |
| Chromium (Cr) | Data tapes and floppy disks | 9900 | 198,000 |
| Copper (Cu) | Wiring | 41,000 | 820,000 |
| Gallium (Ga) | Semiconductors | | |
| Indium (In) | LCD displays | | |
| Lead (Pb) | Solder (Kang and Schoenung, (2005)), CRTs, batteries | 2900 | 58,000 |
| Lithium (Li) | Batteries | | |
| Mercury (Hg) | Fluorescent lamps, batteries, switches | 0.68 | 13.6 |
| Nickel (Ni) | Batteries | 10,300 | 206,000 |
| Selenium (Se) | Rectifiers | | |
| Silver (Ag) | Wiring, switches | | |
| Tin (Sn) | Solder (Kang and Schoenung, (2005)), LCD screens | 2400 | 48,000 |
| Zinc (Zn) | | 5100 | 102,000 |
| Rare earth elements | CRT screens | | |

Adapted from (e-waste, 2009).
[a] (Morf et al., 2007).
[b] Assuming a global e-waste production of 20 million tonnes per year.

**Figure 31: Potential environmental contaminants arising from ICT waste, (Robinson B. H., 2009)**

If sent to landfill, ICT waste contaminants can enter aquatic systems via leaching from dumpsites (Robinson B. H., 2009). The recycling and reuse of equipment will reduce the amount of waste sent to landfill and **reduce the impact on aquatic systems.**

When waste is sent to landfills, it also generates air contaminants that spread into the air via dust and wind. Air pollution exposes humans to ingestion, inhalation and skin absorption. Therefore, the reduction of the amount of waste sent to landfill also **reduces the impact on air pollution and human health** (Robinson B. H., 2009).

### 2.6.3 Appropriate environmental performance indicators

Different environmental performance indicators can be relevant to implement and track a waste management policy.

To assess the implementation of the waste management system, the **share of facilities or sites with a certified zero waste management system or asset management system** is a good indicator**.**

Through the review of the life cycle assessment of the products, the different life stage of the product can be reviewed and the **average service life of ICT equipment** monitored for different product groups (e.g. servers, routes, end-user devices).

Different indicators can be followed to monitor the environmental performance of recycling, recovery and reuse processes, e.g. the amount of ICT equipment (e.g. servers, computers, mobile phones, set-top boxes, routers, etc.) collected for reuse and recycling, as for example:

- **Share of WEEE generated from own operations recovered for reuse, reconditioning, recycling.** The best practice is to reach 90% of own ICT equipment recovered for reuse or refurbishment or sent for recycling. For instance, BT reaches 97% of its own waste recovered or recycled (BT, 2016).

- **Share of WEEE generated from clients recovered for reuse, refurbishment, recycling.** The best practice is to reach 30% of ICT equipment from clients took back and recovered for reuse or refurbishment or sent for recycling (for ICT companies providing equipment to customers).

### 2.6.4 Cross-media effects

In some cases, waste prevention and a better management of waste can lead to an increase in energy use and fuel consumption in the waste collection/ reverse logistics chain. These environmental impacts could be reduced through the optimisation of logistics chains and waste management operations.

The extension of the service life of ICT equipment can lead to adverse effects by keeping running old equipment that is less energy-efficient or environmentally performant compared to the new product and technologies available on the market. Reuse of old ICT equipment may have trade-offs in terms of the energy efficiency that can be achieved.

When products are refurbished to be reused, if the refurbishment modifies the quality or functionalities of a product, the company needs to communicate it in full transparency to users within the company or to external customers.

Some re-use/refurbishment channels aims at sending equipment to other countries. However, by doing so, there is a risk that a reused product will not be properly disposed at its end-of-life in its country of destination (GSMA, 2006). Another potential risk is that such programmes are used as a way to export ICT waste (i.e. the ICT equipment that is 'donated' is actually WEEE to be disposed) and avoid European waste legislation. For this reason the development of take-back programmes and the establishment of partnerships and channels for refurbishment, recycling and disposal should be monitored closely to keep track of information and reported on openly to the public. In particular, Telecommunications and ICT services companies should ensure that the overall process is properly managed until the proper disposal of non-recyclable components.

ICT equipment often contains sensitive data. Therefore, when ICT equipment are disassembled and reused the telecom and ICT companies must ensure that data are safely removed.

### 2.6.5 Operational data

An effective ICT waste management program needs to cover each stage of the waste hierarchy with different measures. All require staff involvement and training as well as communication to end-users.

#### Develop a waste prevention plan

The "pre waste" European project[43] identified five different steps in the implementation of a waste prevention plan.

1. The first step is the assessment of the situation to ensure an informed decision making process. The evaluation shall cover several topics such as: previous

[43] For more information, see: http://www.prewaste.eu/index.php?option=com_k2&view=item&id=481&Itemid=74

prevention actions, legal and policy context, good practices, waste generation and management in place.

2. The second step aims at setting priorities and objectives. The waste prevention manager will set priorities and objectives according to political and strategic agendas, waste issues and legal and financial constraints. SMART[44] specific objectives on waste flow and actions can be set.

3. The waste prevention plan needs to be a participative process to ensure its success. Therefore, it needs to involve relevant stakeholders. Stakeholders may be internal actors such as technical staff in charge of waste and resource issues as well as external actors, such as national/local public support, other businesses and NGOs.

4. The waste prevention plan can also be based on a SWOT[45] analysis and implemented within a timeframe. Communication channels and partnerships need to be identified and developed to ensure the implementation of the waste prevention project.

5. The last step of a successful waste prevention plan relies on the monitoring of the plan through the measurement of the strategy's progress and success. Relevant indicators must be identified and measured.


**Figure 32: Pre-waste methodology for waste prevention plans and actions**

A waste prevention plan aims at reducing the amount of waste generated. It can be linked to a policy for the procurement of sustainable ICT services and products. For example, asset management aims at ensuring the identification of all areas of optimisation, consolidation and aggregation to avoid unnecessary investments and additional waste creation. For more details on the implementation of a policy for the procurement of sustainable ICT services and products, refer to the BEMP 2.3.

Instead of purchasing ICT equipment, lease services can also be considered to reduce the potential amount of waste generated. Indeed, providers of lease services have

[44] Specific, Measurable, Achievable, Relevant, Time-bound objectives

[45] Strengths, Weaknesses, Opportunities, Threats matrix analysis

more incentives at providing use of products that are durable and easy to repair, and can better tackle the product at end-of-life (e.g. for re-use) than final users.

The waste management prevention plan can adopt a Zero Waste approach. It is a waste management system that emphasizes waste prevention through planning, design and restructuring production and distribution systems rather than simply managing waste. The Zero Waste International Alliance (ZWIA) has defined Zero Waste as achieving diversion of 90% or more of all discarded resources from landfills or incinerators (ZWIA, 2015). The Zero Waste approach can be certified by an independent third party.

**Promote LCA-based eco-design through procurement.**

A waste prevention plan aims at reducing the amount of waste generated. Assessing the situation helps understanding the composition of the products and their impact on the environment. This stage can be based on a life cycle assessment of the product (LCA). The LCA captures the environmental impacts of each phase in a product life cycle (OECD, 2010). It covers the overall value chain from "cradle to grave". The LCA step can help identify the amount of resources used and where to cut waste. A product life cycle can be represented as showed in the following scheme:

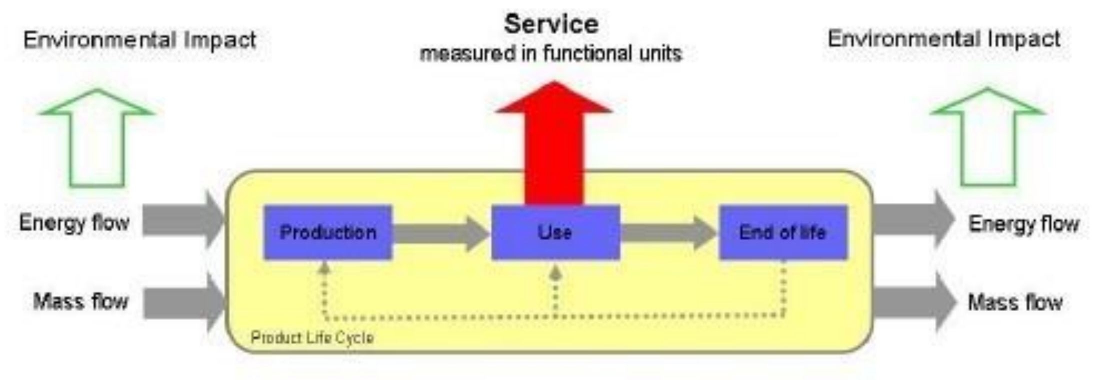



**Figure 33: ICT product life cycle, (OECD, 2010) based on Hilty 2008**

An eco-design process aims at reducing the initial amount of resources used and to reduce final waste generated and consider the environment at the design stage ("Design For Reliability" and Design For the Environment). Eco-design can also help reduce the amount of hazardous materials used which is a topical issue in the ICT sector. Another topic is the reduction of the material used for the packaging.

Different strategies can be applied to eco-design electronic products (NTUA, 2007), (GeSI, 2008):

- Develop a new concept: by integrating innovative strategies like immaterialization which is the replacement of a physical product with nonphysical product or service or dematerialization using fewer new raw materials;
- Make physical optimisation:
    - by increasing the reliability and enhance product functions;
    - by using fewer units to satisfy the same consumer needs;

  - by prolonging the useful life of a product and by making the product more adaptable by allowing continuous updating;
  - by optimising and integrating functions through multipurpose machines combining functions;
- Select the right material: the choice of the right material depends on the life cycle assessment. The materials chosen can be: recycled, recyclable, renewable, using less material, low energy content;
- Optimise the distribution process: optimisation of the packaging and elimination of unnecessary materials.

If eco-design is more relevant for manufacturers at the conception of a product, telecommunication companies and ICT service providers can review in partnerships with manufacturers the composition of the products to ensure that they use or that they will sell products with reduced environmental impact. For example, telecom operators and broadcasting companies can have a great influence on manufacturers through product specifications: they can encourage the greater use of universal equipment (e.g. chargers, modems, etc.), in order to reduce the need for new products and parts. This review must be integrated into the procurement policy.

**Increase the service life and limit the obsolescence of ICT equipment the reduction of the obsolescence.**

After reducing the amount of materials used waste generation through waste prevention and a policy for the procurement of sustainable ICT services and products, the environmental performance can be improved by increasing the service life of the product. Companies have low impact on the way consumers use their products but they can reduce the obsolescence.

There are different types of obsolescence (ADEME, 2012):

- Indirect: impossible to repair because of the lack of availability of components;
- Incompatibility: the software no longer matches the new operating system;
- Aesthetic: new products available on the market with a new design which makes old products obsolete;
- Operating: product programed to function for a determined number of cycles;
- Customer service: too long repair period making customers more willing to buy a new product than repair an old one.

Some ICT equipment are designed and built in a way that can make the product obsolete (GeSI, 2008). For instance, some mobile phones are designed with moving components that last until innovations appear on the market. Other products are built with some components that cannot be replaced because they are glued or welded. Companies should ensure to limit the obsolescence of their products.

From a service provider point of view, a data centre or network operator, these solutions can be integrated at the procurement level. The process for the integration of a green procurement policy taking into account environmental performance criteria is developed in the section 2.3. The procurement policy can integrate a review of the LCA analysis and the eco-design process of the manufacturers. Criteria based on LCA and eco-design and the reduction of resources and materials can be integrated in the contract with a manufacturer.

ICT services providers can also contract with external contractors to extend the service life of products (Appelman, Osseyran, & Warnier, 2014):

- Extend the useful life of products, peripherals and accessories:
  - Creating compatible complements and substitutes within and between systems.
  - Facilitating the replacement and the re use of products;
- Promote repair: by manufacturer, suppliers, specialised social companies, independent repairers;
- Promote services of maintenance;
- Limit replacement: by raising consumers' awareness on usage conditions, developing functionalities to improve existing products, making easier the replacement of components.

ICT companies can contract these kinds of services to extend shelf life of their ICT equipment and reduce the final total amount of WEEE they generate (Ellen Macarthur Foundation, 2016).

**Implement systems to enable re-use of ICT equipment**

### *Optimisation of the re-use of the company's own ICT equipment*

A company can prevent its ICT equipment from becoming waste by encouraging the reuse of the equipment. The first step to reuse ICT equipment is to sell or donate it to employees or to other beneficiaries (charities for example).

It requires the establishment of partnerships with charities or specific channels to manage the distribution and it involves the regular inventory of ICT equipment no longer in use. The inventory can be developed online to facilitate the regular update.

The development of partnerships for reuse can also be extended to enable the reuse of employees' ICT equipment that they can bring from home such as: batteries, IT equipment. ICT equipment from staff shall be reported separately from the company's equipment.

### *A take-back program to better recover end-user devices*

The WEEE Directive 2012/19/EU poses tack-back obligations to the producers of equipment (Article 5.2). As explained in the 'Description' section, Telecommunication and ICT services companies may be considered producers for some equipment depending on how the equipment has been put on the market and what has been specified with the devices suppliers. In any case, it is best practice for them to put in place collection for the equipment they sold or rented to the final-users, such as mobile phones and set-top boxes.

Customers tend to replace their mobile phone along with trends and evolution of technology. This replacement cycle drives the need to put in place collect, decommissioning, reuse and recycle solutions for used mobile phones.

Mobile phones contain potentially dangerous and rare materials which could harm the environment if not responsibly recycled. For instance, old batteries contain cadmium, a toxic substance which, if leaking into landfill site, could cause contamination. Other materials such as plastic do not degrade easily and should be recycled.

Telecommunication companies can help customers to properly dispose of their mobile by offering collecting and recycling solutions. During the first stage of reverse logistic, handling and transportation of the equipment should be managed with care to avoid

damaging that could reduce the potential for reuse and refurbishment. Waste will be transported from different locations to the warehouses where they will be stored. This first step also involves the inspection and cleaning of waste to prepare them for the next step.


**Figure 34: Mobile phone supply chain integrating recycling and reuse (Vodafone)**

The success of take-back program relies on the communication and the incentives provided to customers. Depending on cultural and customers' preferences, telecommunication companies can propose donation to charities programs or create offers such as extra call minutes or discount on a new phone to customers who return their old mobile.

Once the customer returned his/her old mobile phone, different solutions can be considered:

- Refurbishment[46] to extend life: the refurbishment depends on the quality of the product. First the product is evaluated to determine if it is suitable for reuse or for further repair. Faulty part will then be replaced and the device will be reconditioned.
- Reuse phone in developing countries: when a device is suitable for reuse but there is no more market for it in the country where it is located, it can be sent to developing countries where it would still be used, displacing the production of a new phone.
- Recycling products: when a product can no longer be used, it must be properly recycled. Components must be properly separated and sorted in various types to be reprocessed by specialist recyclers. Some materials can be recycled into

[46] The stage of refurbishment depends on the type of components or product. The refurbishment consists in checking the functionality of the equipment through testing. Hardware is verified and then old data and software are removed. If hardware components are needed to complete the equipment they will be assembled. After old digital data destruction, new software and required instructions sets may be installed. The goal is to ensure that the product fully meet the required functions. The components or ICT products entering the refurbishment process and destined to be reused must be handled in suitable manner to preserve their value. Some components or products may still be altered but may be repairable. After refurbishment and repair, products shall be suitable to be reused. Different selling channels can be considered whether on specialised second hand shops or on the Internet. This process will extend products useful life and overall life cycle.

new products such as nickel cadmium and lithium ion/ polymer batteries which can be recovered and reuse for power tools, saucepans and new batteries.

- Disposal: the remaining parts of a mobile phone which cannot be recycled must be sent for environmentally sound disposal.

Efficient and eco-friendly treatment of mobile phone requires sophisticated facilities and expertise and the transparency of the company recycling the devices. The telecommunication company must ensure that all the steps and the final disposal are properly done.

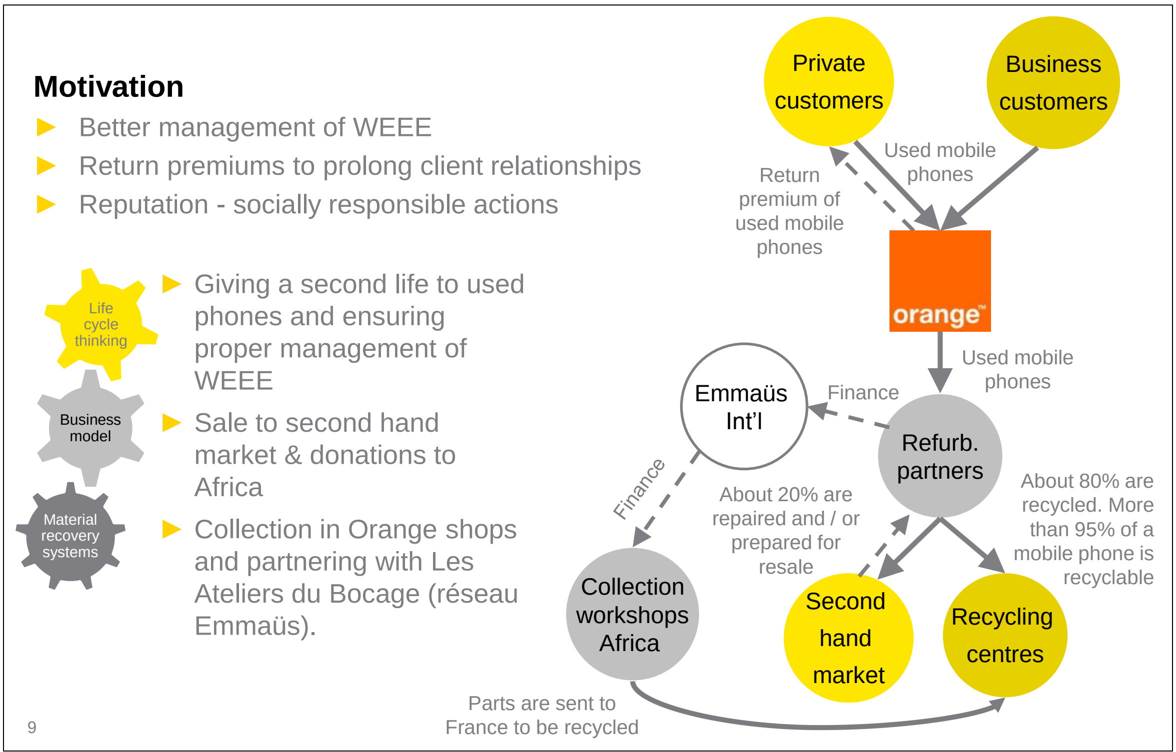



**Figure 35: An example of take-back program and donations (Orange, 2016)**

Telecom operators have an influence on the eco-design characteristics of end-user devices and can play a role at their end-of-life. For example, modems and set-top boxes can be designed in a way that facilitates the recovery of components and materials by easier disassembly or avoiding hazardous substances (e.g. brominated flame retardants).

**Ensure traceable collection and proper sorting of end-of-life ICT equipment**

Once the ICT equipment has become waste, Telecommunications and ICT Services companies contract with waste treatment professionals with the technical skills required and the expertise to dismantle, segregate, recycle and dispose of their own waste (servers, professional computers, etc.). The objective is to find the relevant and traceable collection, transport and treatment scheme.

The responsibility of the telecommunication and ICT companies is to check that the contractor follows the rule to properly dispose of the waste and optimise the possibility of recycling. The waste treatment professional will carry out different steps to manage waste. It will lead to the recycling or the disposal of the components or to donation channels. Under the WEEE Directive there are specific recycling and recovery targets per category of equipment (See annex V to the Directive).

This monitoring can be based on different information. The first step to make sure that the facility will properly manage the end-of-life of the equipment is to verify its compliance with all appropriate regulations. The recovery and recycling facility should also possess an environmental management system. It can be based on a standard and internationally recognised scheme such as EMAS or the ISO 14001 standard. If there is no recognised environmental management standard, the company should still be recording process and audit equipment information.

The company can deepen its analysis on the quality of the facility's operations by asking about the process in place and the monitoring plan. The contract with the facility can also require that the facility operates with the best available technologies available.

ITU in its report End of life management for ICT equipment (ITU, 2012) establishes guidelines on best practices on material recovery and recycling. The steps that a company can follow to ensure the proper treatment of its equipment can be summarised as followed:

- Check information security: check the secure policy in place to protect your information;
- Check risk management:
    - Verify that asset management minimise the risk for the company through inventory controls;
    - Ask about occupational health and safety monitoring: ergonomic work areas, avoidance of heavy lifting, periodic air monitoring, personal protection equipment, etc.;
    - Ask about an emergency planning and monitoring;
    - Ask about employee training and tracking of the data;
    - Check the company has subscribed to insurances needed to protect assets, employees and equipment handled including during transportation
- Monitor environmental performances:
    - ICT life cycle improvement, assets losses, etc.;
- Check operations :
    - Process and optimization of transportation and storage;
    - Check the solution the facility provides to cover all types of equipment;
    - Require that facilities operate according to best available technologies;
    - Monitor the effectiveness of operations: time spent VS value of equipment recovered, monitor the percentage of equipment recovered;
- Check the facility's compliance with regulations and local authorities:
    - Check the license of the facility by all appropriate governmental authorities;
    - Check the consistency between the license, permits and local regulation;
    - Verify specific permits such as : storage permit, air emission permit, water permit, hazardous waste permit, etc.;
    - Ensure proper handling of trans-boundary movements;

### 2.6.6 Applicability

The companies' responsibility in support of its product impacts on the environment including at end of life depends on how the equipment has been put on the market and what has been specified with devices suppliers. It also depends on local applications of the EPR principle. The ETSI standard on Operational energy Efficiency for Users (OEU), Waste management of ICT equipment (ETSI GS OEU 018 V1.1.1 (2016-01)) reminds the regulatory frame in European Union regarding e-waste. In any case, ICT companies have to develop a waste management plan to minimise their generation of WEEE and reduce their environmental impacts.

The ownership of equipment also determined the applicability of certain techniques. In a data centre, the servers can be owned by the operator, leased or own by clients. In the first two cases, the operator can decide the optimum solution.

Waste management is applicable to any company from SMEs to bigger companies. Smaller companies may contract with waste treatment professional facility because of the lack of internal skills for processing equipment and waste. Limited local recycling infrastructure and waste disposal regulations in certain regions can be a barrier to diverting waste from landfill – in these cases, working with local stakeholders is an important aspect of the waste management plan.

The implementation of the techniques described above depends on the type of equipment. For some products, particularly end-user devices, the reuse market in Europe is limited. Servers on the other hand are high-value equipment. Other major differences can be identified between end-user devices (the majority of impacts occur during the production phase) and servers (the majority of impacts occur during the use phase). That explains why replacing servers every two years can be interesting in terms of energy consumption, but requires continuous improvement of recycling techniques.

When waste recycling and recovery are outsourced, the process also depends on the relationship between the waste producer and the recycling facility. If different actors are needed for different steps, the waste producer must ensure that all actors properly interact and that responsibilities are clearly defined. All the stakeholders must be involved and concerned with the environmental objectives.

The ownership of equipment also determined the applicability of certain techniques. In a data centre, the servers can be owned by the operator, leased or own by clients. In the first two cases, the operator can decide the optimum solution.

### 2.6.7 Economics

Using LCA assessment for ICT product can have economic benefits (OECD, 2010) by increasing control over internal efficiencies and over suppliers. The close monitoring of environmental performance allows better risk control over the supply chain.

Waste prevention solutions can foster innovation at the product level or at services level. For instance, eco-design and life cycle assessment will help developing new products and new technologies such as multifunction products. The waste prevention plan can establish services to extend product useful life. The development of new services can encourage customers' loyalty to the company. Waste prevention solutions allow a company to differentiate itself and gain market share.

European countries have implemented taxes on waste sent to landfill. The reduction of the amount of waste a company sent to landfill by recycling and reusing products will

lower this tax. However, the collect of end-users devices such as mobile phone increase the amount of waste can turn out as additional costs for their disposal.

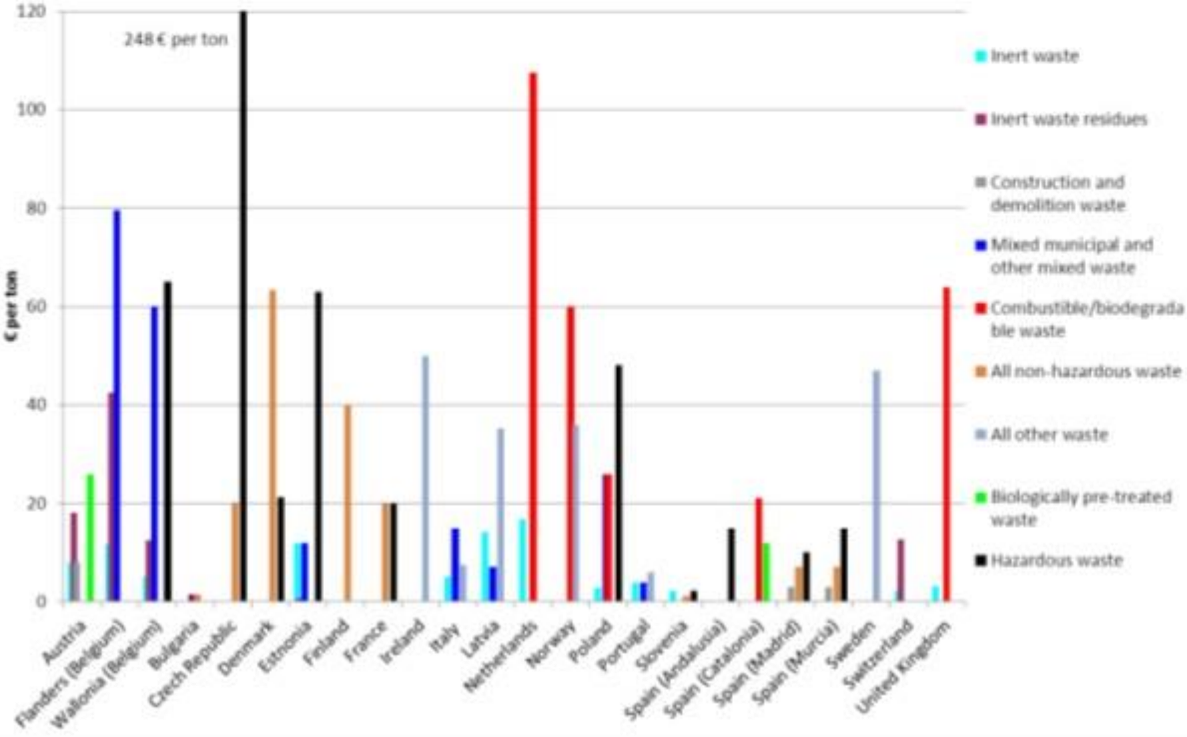



**Figure 36: Comparison of landfill tax levels in European countries EUR per tonne in 2011, excluding VAT, (European Topic Centre on Sustainable Consumption, 2012)**

The cost effectiveness of WEEE collection depends on the operating country. Total fees have been estimated around €132 per tonne of EEE put on the market and €384 per tonne of EEE collected in France and €68 per tonne put on the market and €160 per tonne for EEE collected in Ireland (Bio by Deloitte, 2014).

### 2.6.8 Driving force for implementation

Waste prevention and improved waste management can lead to cost savings. Avoiding purchases lower procurement costs for supplies required by offices, and recycling often costs less than landfilling residual waste.

The main driving force for implementation of recycling, recovery and refurbishment process is the potential to extend the life cycle of the ICT equipment used. The extension of the lifecycle of assets will also create economic benefits for the company. It will allow the company to invest in other strategic area than equipment such as research and development.

In the framework of an environmental strategy and of $CO_2$ emissions and waste reduction objectives, waste prevention is a good way to achieve these objectives.

The establishment and monitoring of disposal process also ensure the compliance with regulation.

The implementation of waste management is a way of protecting the company's image and reputation. Take-back programmes are a good way to communicate on sustainability actions to the final customers.

The implementation of take-back schemes faces difficulties related to customers' behaviour. Most customers keep their mobile phones and the take-back recovery is only 10%.

### 2.6.9 Reference organisations

A benchmarking of major companies in the ICT sector put into relief frontrunners in terms of waste prevention management:

- Nokia has developed a simplified LCA framework that evaluates eco-impact information for ICT products (Nokia, 2016).
- IBM has high rates of reuse of their servers through their asset management and recovery services. Only 0.7% of recovered equipment is sent to disposal (IBM, 2015).
- Orange (Orange, 2016) has developed mobile collect programs in Europe, which has reached for example 31% of mobile collected in Romania (buy-back program) or 17% in Slovakia (eco-friendly collection).
- SAP: Asset life cycle management: Despite the significant growth of the company, SAP was able to reduce the ratio of laptops or PCs per user to a ratio of 1.09 (approximately 90,000 devices in use) in 2015 compared to a ratio of 1.18 in 2011 (SAP, 2015). An internal waterfall model has been established where high-performance machines bought for SAP events are reused by developers afterwards. Returned devices (e.g., from developers) are reused by departments that do not need full computing power. In addition, many departments rent used devices temporarily (e.g., for interns, students, or external workers) from IT via self-services instead of buying new equipment. Also, SAP employees can buy used SAP equipment from our remarketing partner. Regarding end of life: SAP has signed a global contract with a global recycler company that owns all needed certificates. A global remarketing and recycling process has been established that allows all SAP Group companies to participate.
- Proximus: improved packaging of mobile phone SIM cards, namely the replacement of the ABS carrier and information booklet in paper, by an information card packed in polypropylene, which has led to waste savings of 9 tonnes (Proximus, 2015).
- Telefonica (Telefonica, 2013):
  - develops equipment purchase policies for our operations that facilitate reuse and recycling at the end of its useful life;
  - supports standards that reduce the generation of e-waste and improve the eco-design of this kind of equipment for telecoms services.

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# 3 Data centres

## 3.1 Introduction / scope

### 3.1.1 Definition

According to the European Standards EN50600 series, a data centre is *"a structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability"* (CENELEC, 2016). A data centre is typically made of:

- A **physical building** or **server room**;
- **Power equipment** such as uninterruptible power supplies (UPS), transformers, power distribution units and cabling, backup generators and other power related equipment;
- **Air management** and **cooling systems** that control the air quality and temperature in the data centre;
- **IT equipment** such as servers and storage devices, which are often installed in racks;
- **Network and communication equipment** such as routers, switches and cabling;
- **Software** including an operating system and various applications that run the IT equipment.

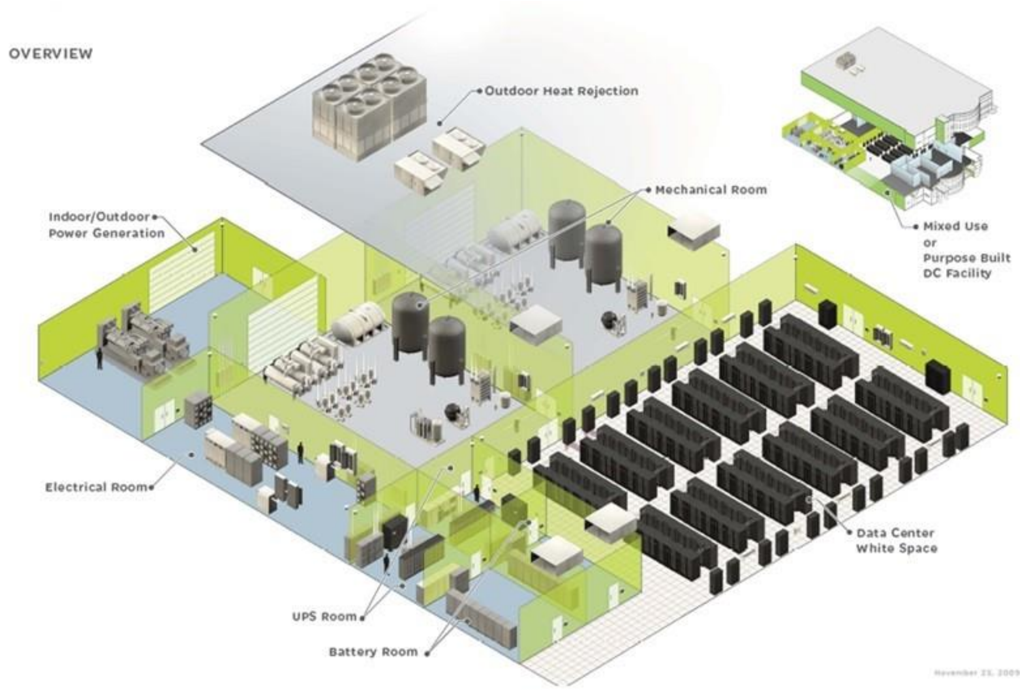


**Figure 37: Example of data centre architecture. Source: Schneider Electric – Reference Design 23 – Performance-Optimized 1MW E-Class data centre.**

### 3.1.2 Categorisation

There is a large variety of data centres and many different ways to categorise them. Many of the techniques identified within this chapter can also be implemented in telecommunication central offices.

The following characteristics can be used to differentiate between data centres and the applicability of BEMPs:

- **The size of the data centre** determined by the physical area, number of servers and / or workload capacity. These factors influence the type of HVAC equipment used, the energy consumption and operation costs. The density of a data centre, i.e. power load (kW) per rack or per compute space (floor area), is one of the factors that influence the dimensioning of the cooling and air management systems.

| Type of data centre | Description | Size ($m^2$) | Number of servers | IT workload |
|---|---|---|---|---|
| Server closet | No external storage; typically use a common HVAC[47] system; room within an office building | <18.6 | 1-2 | Up to 10 kW |
| Server room | No external storage; typically common HVAC with additional cooling capacity | <46.4 | 10-100 | Up to 10 kW |
| Localized data centre | Moderate external storage; typically dedicated HVAC system; a few CRAC[48] units with fixed speed fans | <92.9 | 100-1 000 | Up to 30 kW |
| Mid-tier data centre | Extensive external storage; typically under floor air distribution and CRAC units with variable speed fans | <464.5 | 1 000-10 000 | Typically between 30 and 500 kW |
| Enterprise class data centre | Extensive external storage; most efficient cooling along with energy and airflow management systems | >464.5 | >10 000 | >500 kW |

Table 19: Typical characteristics of different sizes of data centre (GENiC, 2014)

- **The geographic location**: The ambient outdoor climate and surrounding environment (e.g. urban setting compared to a rural setting) determine which opportunities and constraints there might be for energy supply, space, air management and cooling.

[47] HVAC = heating, ventilation and air conditioning

[48] CRAC = Computer Room Air Conditioner

- **The purpose or type of operator**: We can differentiate between enterprise data centres, co-location, co-hosting, and network operator facilities.

| Purpose of the data centre | Description |
|---|---|
| Enterprise data centre | Data centre that is operated by an enterprise which has the sole purpose of the delivery and management of services to its employees and customers |
| Co-location data centre | Data centre in which multiple customers locate their own network(s), servers and storage equipment. The support infrastructure of the building (such as power distribution and environmental control) is provided as a service by the data centre operator. |
| Co-hosting data centre | Data centre operated by a service provider (e.g. a network operator) in which multiple customers share space and resources on a single or multiple servers, which has been designed to host multiple accounts simultaneously. |

**Table 20: Different types of data centre operators depending on who owns and manages the data centre and its equipment (CENELEC, 2016)**

- **The security level**: The level of security can vary, depending on the requirements of the end user. We can distinguish between Tier I, II, III and IV data centres. This classification depends on factors such as the active capacity components to support the IT load, distribution, paths, ability to be maintained concurrently, fault tolerance compartmentalisation and continuous cooling (see below for the complete Tier classification of the UpTime Institute).

| | Tier I | Tier II | Tier III | Tier IV |
|---|---|---|---|---|
| **Description** | Basic site infrastructure with non-redundant capacity components | Redundant site infrastructure capacity components | All IT equipment must be dual-powered and fully compatible with the topology of a site's architecture | All cooling equipment is independently dual-powered, including HVAC systems. Fault-tolerant site infrastructure with electrical power storage and distribution facilities |
| **Active** | N | N+1 | N+1 | N<br>After any failure |
| **Expected availability** | 99.671% | 99.741% | 99.982% | 99.995% |
| **Distribution paths** | 1 | 1 | 1 active and 1 alternate | 2 simultaneously active |
| **Concurrently maintainable** | No | No | Yes | Yes |
| **Fault tolerance** | No | No | No | Yes |
| **Compartment-alization** | No | No | No | Yes |
| **Continuous cooling** | No | No | No | Yes |

**Figure 38: UpTime Institute Tier Requirements Summary (Seader, Brill, & Turner, 2006)**

Data centres have traditionally been designed with large tolerances for operational and capacity changes with possible future expansion in mind (JRC, 2012b). The over-dimensioning of data centres leads to inefficiencies: redundant power and cooling systems, IT equipment with a low average utilization, etc.

### 3.1.3 Environmental aspects of data centres

The Joint Research Centre (JRC, 2012b) has estimated total annual energy consumption of data centres in Western Europe as 56 TWh (or 2%) of the total electricity consumption per year. In 2012, this was projected to increase to 104 TWh (or 4%) per year by 2020. The large consumption of energy is due to the need for permanent storage of data (24 hour availability, back-up generators, etc.) and the need for cooling of the servers to maintain optimal operating temperatures.

While the majority of energy in a data centres is used to power the IT and network equipment, the supporting equipment represents a significant share of the total energy consumption: a cooling system in a typical data centre consumes about 25-50% of the total power supply: with about 23-28% of the energy consumed by chiller, 7-15% by Computer Room Air Conditioners (CRAC) or Computer Room Air Handlers (CRAH) and 3% by humidifiers (Rasmussen, 2011).

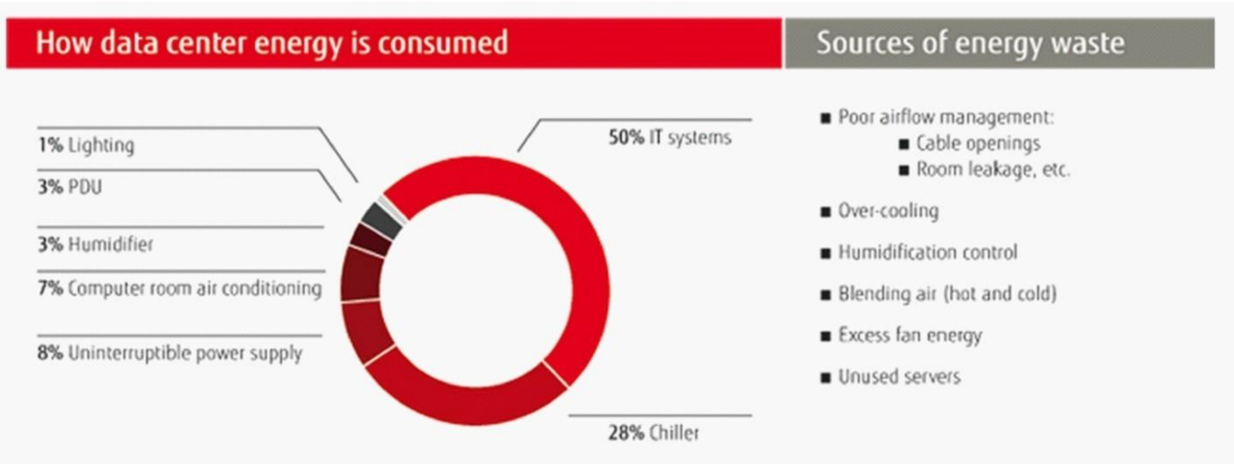


**Figure 39: The breakdown of energy consumption in a typical data centre (Fujitsu, 2016)**

Besides a significant share of energy consumption cooling systems may require large volumes of freshwater and refrigerants.

The indicators suggested within the BEMPs aim at monitoring such impacts. Nevertheless, it should be mainly used to monitoring the progress of a data centre, rather than comparing different data centres because their large diversity (e.g. depending on their geographical location, the level of resilience, data centre requirement tier level, etc.).

### 3.1.4 Identification of Best Environmental Management Practices

Several initiatives have defined best environmental management practices for data centres – typically focusing on energy efficiency; among them, the European Code of Conduct for Energy Efficiency in Data Centre (JRC, 2015)[49]. The Code of Conduct was created in response to increasing energy consumption in data centres and the need to

[49] For more information, see: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

reduce the related environmental, economic and energy supply security impacts. The aim is to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner without hampering the mission critical function of data centres. The Code of Conduct is a voluntary initiative that brings interested industry stakeholders together.

The best practices for data centre operations from the Code of Conduct have been developed in to a CENELEC Technical Report *CLC/FprTR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices*. In agreement with the Technical Working Group, the BEMPs specific to data centres in this document are organised in the same manner as the CENELEC Technical Report:

1. Existing data centres (Section 3.2)
2. ICT equipment (new or replacement) (Section 3.3)
3. Software install or upgrade (Section 3.4)
4. New build or refurbishment of data centres (Section 3.5)

**Table 21: Structure of BEMPs related to data centres and relationship to the CLC/FprTR 50600-99-1**

| **Best practices according to CENELEC CLC/FprTR 50600-99-1** | **Applicability** | | | |
|---|---|---|---|---|
| | **Existing data centres** | **ICT equipment (new or replacement)** | **Software install or upgrade** | **New build or refurbishment of data centres** |
| **Data centre utilisation, management and planning** | **X** | | | **X** |
| a) Involvement of organisational groups | X | | | X |
| b) General policies | X | | | X |
| c) Resilience level and provisioning | X | | | X |
| **Data centre ICT equipment and services** | | **X** | **X** | |
| a) Selection and deployment of new ICT equipment | | X | | |
| b) Deployment of new ICT services | | X | X | |
| c) Management of existing ICT equipment and services | | X | | |
| d) Data management and storage | X | | | |
| **Data centre cooling** | **X** | **X** | | **X** |
| a) Airflow management and design | X | X | | X |
| b) Cooling management | X | | | |
| c) Temperature and humidity settings | X | | | |
| d) Selection of cooling system | | | | X |
| e) CRAC / CRAH equipment | | | | X |
| f) Reuse of data centre heat | X | | | X |
| **Data centre power equipment** | **X** | | | **X** |
| a) Selection and deployment of new power equipment | | | | X |

| | | | | |
|---|---|---|---|---|
| b) Management of existing power equipment | X | | | |
| **Other data centre equipment** | **X** | | | **X** |
| a) General practices | X | | | X |
| **Data centre building** | | | | **X** |
| a) Building physical layout | | | | X |
| b) Building geographic location | | | | X |
| c) Water sources | | | | X |
| **Data centre monitoring** | **X** | | | **X** |
| a) Energy consumption and environmental measurement | X | | | X |
| b) Energy consumption and environmental data collection and logging | X | | | X |
| c) Energy consumption and environmental reporting | X | | | X |
| d) ICT reporting | X | | | |

For an updated list of best practices, see the latest version of CENELEC Technical Report *CLC/FprTR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices*.

Whilst the Code of Conduct and the CENELEC Technical Report mainly focus on energy aspects, the other environmental aspects, e.g. land use, water, noise, are also described under the above listed BEMP structure:

- Land use and noise issues are dealt with the BEMP 3.5.5 on Selecting the geographical location of the new data centre;
- EMF issues are more specifically linked to telecommunication networks, and are addressed in the BEMP 4.3 on Improving risk management for electromagnetic fields through assessment and transparency of data;
- Waste management issues for all ICT and telecommunication network equipment are developed within the BEMP 2.6 on Waste management of ICT equipment through waste prevention, reuse and recycling.

ETSI European standard have been developed to provide guidelines on data centres best practices. It mainly tackles thermal management, cooling system and airflow management solutions. The relevant standards are the following:

- ETSI Standard (ETSI TR 102 489 V1.4.1, 2015) on Thermal management
- ETSI Standard (ETSI EN 300 019-1-3 Ver. 2.4.1, 2014) on Environmental conditions and environmental tests for telecommunications equipment Classification of environmental conditions; Stationary use at weather protected locations
- ETSI Standard (ETSI TR 102 489 V1.4.1, 2015)Thermal management guidance for equipment and its deployment

### 3.1.5 Reference literature

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## 3.2 BEMPs related to existing data centres

### 3.2.1 Scope and structure of BEMPs related to existing data centres

The main environmental impact of data centres is related to the energy consumption during operation. Whilst the majority of energy used to operate a data centre is electricity to power the IT equipment, cooling and ventilation equipment can represent a significant share of the total energy consumption.

One of the main reasons for low energy efficiency of data centres is that many IT and data centre managers are not aware or do not systematically track the energy consumption, environmental conditions (e.g. air humidity and temperature) and data load. When a server consumes electricity, it also generates heat, which then leads to a greater cooling demand, which in turn results in greater energy demand for cooling. Optimising the data load and improving the energy efficiency of a server has the potential of significantly reducing the total energy consumption.

The following best environmental management practices (BEMPs) could be considered to improve the energy efficiency of existing data centres:

**Table 22: Structure of BEMPs related to data centres and relationship to the CLC/FprTR 50600-99-1**

| **BEMPs related to existing data centres**<br>Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/FprTR 50600-99-1 | |
|---|---|
| **Techniques from EU CoC / CLC/FprTR 50600-99-1**[50] | **BEMP** |
| **Utilisation, management and planning of existing data centres** | |
| • Involve representatives from all the relevant stakeholders of the organisation (e.g. software, ICT equipment, mechanical, electrical and procurement) to approve significant decisions *(5.16.01)*<br>• Consider the embodied energy in devices *(5.16.02)*<br>• Implement a plan for life cycle assessment (LCA) *(6.16.86)*<br>• Implement a plan for environmental management (e.g. ISO 14001) *(6.16.87)*<br>• Implement a plan for energy management (e.g. ISO 50001) *(6.16.88)*<br>• Implement asset management for all ICT, mechanical and electrical equipment (e.g. ISO 55000) *(6.16.89)*<br>• Monitor and report on usage / energy consumption by devices powered by ICT cabling *(6.16.91)* | **Implement an energy management system for data centres** (including measuring, monitoring and management) (Section 3.2.2)<br><br>For general environmental management refer to:<br>▪ Environmental management systems (Section 3.2.2) |
| • Use renewable / sustainable energy sources (6.16.90)<br>• Use alternative power generation technologies (6.16.93) | Refer to:<br>▪ **Use of renewable and low carbon energy** (Section 2.5) |
| **Management of existing ICT equipment and services** | |
| • Audit existing physical estate and services *(5.16.03)* | **Implement an energy management system** |

[50] The EU Code of Conduct distinguishes between 'Expected Practices' (identified by the codes starting with 5.1); 'Optional or Alternative Practices' (identified by the codes starting with 6.1); and, 'Practices under consideration' (identified by the codes starting with 7.1).

| | |
|---|---|
| • Decommission and remove unused equipment *(5.16.04)*<br>• Audit existing ICT equipment requirements for allowable intake temperature and humidity ranges *(5.16.05)* | **for data centres** (Section 3.2.2) |
| **Data management and storage** | |
| • Implement a data management policy *(5.16.06)*<br>• Implement a policy defining storage areas by retention policy and level of data protection *(6.16.95)*<br>• Separate physical data storage areas by protection and performance requirements *(6.16.96)*<br>• Select low power storage devices *(6.16.97)*<br>• Reduce total data volume *(6.16.98)*<br>• Reduce total storage volume *(6.16.99)*<br>• Employ service charging models and tariffs in co-location and managed service environments *(6.16.85)*<br>• Consider the impact of mobile / shifting workloads *(6.19.92)*<br>• Define and apply appropriate levels of resilience at the data centre, ICT equipment, software and network levels to achieve the required level of service expected to meet business demands *(6.16.94)* | **Define and implement a data management and storage policy** (Section 0) |
| **Airflow management and design** | |
| • Install blanking plates to manage cabinet/track airflow *(5.16.07)*<br>• Ensure appropriate airflow volume to ICT equipment *(5.16.08)* and reduce obstructions *(5.16.09)* to better manage the raised floor airflow<br>• Segregate equipment *(5.16.10)* and separate environmental zones *(5.16.11)* (including co-location or Managed Service Provider *(5.16.12)*)<br>• Implement containment techniques to separate hot and cold air *(6.16.100)*<br>• Consider the use of a return plenum to return heated air from the ICT equipment directly to the air conditioning units *(6.16.101)*<br>• Minimise fan losses associated with moving air by adjusting the raised floor or suspended ceiling height *(6.16.102)*<br>• Minimise air re-circulation and air oversupply *(6.16.103)* | **Improve airflow management and design** (Section 3.2.4) |
| **Cooling management** | |
| • Review cooling capacities before ICT equipment changes to optimise the use of cooling resources *(5.16.13)*<br>• Review the cooling strategy *(5.16.14)*<br>• Employ effective regular maintenance of cooling system *(5.16.15)*<br>• Install the cooling system in a scalable or modular arrangement allowing unnecessary equipment to be shut down *(6.16.104)*<br>• Shut down unnecessary cooling equipment *(6.16.105)*<br>• Review CRAC/CRAH settings (optimise the temperature and relative humidity settings of CRAC/CRAH units) *(6.16.106)*<br>• Implement control systems that dynamically optimise the cooling system in real time *(6.16.107)* | **Improve cooling management** (Section 3.2.5) |

| | |
|---|---|
| **Temperature and humidity settings** | |
| • Review and if practical raise ICT equipment intake air temperature to reduce energy consumption by reducing or eliminating unnecessary cooling *(5.16.16)*<br>• Review and if practical widen the working humidity range *(5.16.15)*<br>• Review and if practical raise chiller water temperature set-points to maximise the use of free cooling economisers and reduce compressor energy consumption *(5.16.18)*<br>• Consider technical areas of data centres as industrial space (instead of setting temperature according to human comfort) *(5.16.19)* | **Review and adjust temperature and humidity settings** (Section 3.2.6) |
| • Optimise the cooling system operating temperatures *(5.16.20)* | |
| **Management of existing power equipment** | |
| • Reduce engine-generator heater temperature set-point *(6.16.108)*<br>• Monitor the power factor of power supplied to ICT, mechanical and electrical equipment within the data centre and consider the use of power factor correction *(6.16.109)* | **Implement an energy management system for data centres** (Section 3.2.2) |
| **Other data centre equipment** | |
| • Turn off lights (preferably automatically) whenever areas of the building are unoccupied *(5.16.21)* | **Implement an energy management system for data centres** (Section 3.2.2) |
| **Data centre monitoring** | |
| • Install metering equipment capable of measuring the total incoming energy consumption of the data centre *(5.16.22)*<br>• Install metering equipment capable of measuring the total energy consumed by ICT equipment within the computer room space(s) energy consumption *(5.16.23)*<br>• Measure ICT power consumption at cabinet / rack level *(6.16.110)*<br>• Measure ICT power consumption at or at ICT device level *(6.16.113)*<br>• Install monitoring equipment to monitor supply air temperature and humidity for the ICT equipment at room level *(5.16.24)*<br>• Monitor supply or return air temperature at CRAC/CRAH unit level *(5.16.25)*<br>• Measure and monitor temperature at row or cabinet / rack level *(6.16.111)*<br>• Measure and monitor intake and/or exhaust temperature at ICT equipment level *(6.16.112)*<br>• Provide an automated energy and environmental reporting console and report on PUE or DCIE *(6.16.116)*<br>• Provide an integrated energy and environmental reporting capability in the main ICT reporting console and report on PUE or DCIE *(6.16.117)*<br>• Monitor and report server / processor utilisation *(6.16.118)*<br>• Monitor and report network capacity and utilisation *(6.16.119)*<br>• Monitor and report storage capacity and utilisation *(6.16.120)*<br>• Undertake periodic manual readings of energy consumption, | **Implement an energy management system for data centres** (Section 3.2.2)<br><br>For general environmental management refer to:<br>▪ Environmental management systems (Section 2.2) |

| | |
|---|---|
| temperature and humidity data *(5.16.26)* or implement automated daily *(6.16.114)* / hourly *(6.16.115)* readings<br>• Report periodically on energy consumption, PUE and temperature and humidity ranges *(5.16.27)*<br>• Define a business relevant dashboard and report upon business specific metrics relating to data centre services *(6.16.121)* | |

NB:

– Expected practices are reported in black, and optional practices are presented in grey.
– For an updated list of best practices, see the latest version of CENELEC Technical Report *CLC/FprTR 50600-99-1 Information technology – Facilities and*
– *infrastructures – Data centre – Energy management – Recommended Practices*.

The ensuing sections will describe the following BEMPs:

- Implement an energy management system for data centres (including measuring, monitoring and managing equipment) – Section 3.2.2
- Define and implement a data management and storage – Section 3.2.3
- Improve airflow management and design – Section 3.2.4
- Improve cooling management – Section 3.2.5
- Review and adjust temperature and humidity settings – Section 3.2.6

This chapter on BEMPs related to existing data centres provides practice-oriented information to data centre operators that wish to improve the energy performance of their existing data centres. Only direct aspects of energy, i.e. those controlled by the data centre operator, are covered and the focus is mainly made on the operation of data centres. Colocation providers and customers as well as other suppliers and customers of ICT services may also find the BEMPs described here useful to support the procurement of services that meet their environmental or sustainability standards.

### 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)

**SUMMARY OVERVIEW:**

**The energy consumption of data centres is responsible for a major share of their environmental impacts. It is therefore important for data centre operators to have a clear and detailed view on energy consumption at the appropriate granularity levels, and to systematically exploit all opportunities to minimise it. It is considered best practice to:**

- **Implement an energy management system (e.g. ISO 50001 or through EMAS).**
- **Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified to maximise any unused capability prior to new material investment.**
- **Install metering equipment capable of measuring energy consumption and environmental parameters at different levels (row, cabinet, rack or ICT device level).**
- **Monitor and report key performance indicators on equipment utilisation, energy consumption and environmental conditions.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Energy use of the data centre per floor area (kWh/m² of floor area of the data centre)
- Power Usage Effectiveness (PUE)
- $KPI_{DCEM}$ Global KPI for Data Centre according to ETSI standard
- Share of facilities having an energy management certified according ISO 50001 or integrated in EMAS, or complying with the EU Code of Conduct on Data Centre Energy Efficiency or the "expected practices" of CLC/FprTR 50600-99-1
- Share of ICT, cooling or power equipment with specific metering equipment (for their utilisation, energy consumption, temperature or humidity conditions)
- Share of staff provided with information on energy objectives or training on relevant energy management actions during the year

**Cross references**

| | |
|---|---|
| **Prerequisites** | • Commitment from top management |
| **Related BEMPS** | • 3.2.3 Define and implement a data management and storage policy<br>• 3.2.4 Improve airflow management and design<br>• 3.2.5 Improve cooling management<br>• 3.2.6 Review and adjust temperature and humidity settings |

#### 3.2.2.1 Description

Energy management systems are based on the Plan - Do - Check - Act (PDCA) continual improvement framework. It incorporates energy management into everyday organizational practices, as illustrated in Figure 40: The ISO 50001 energy management system model (ISO 50001, 2011). The PDCA approach can be outlined as follows:

- **Plan**: conduct the energy review and establish the baseline, energy performance indicators, objectives, targets and action plans necessary to deliver results that will improve energy performance in accordance with the organization's energy policy;
- **Do**: implement the energy management action plans;
- **Check**: monitor and measure processes and the key characteristics of operations that determine energy performance against the energy policy and objectives, and report the results;
- **Act:** take actions to continually improve energy performance and the energy management system (EnMS).

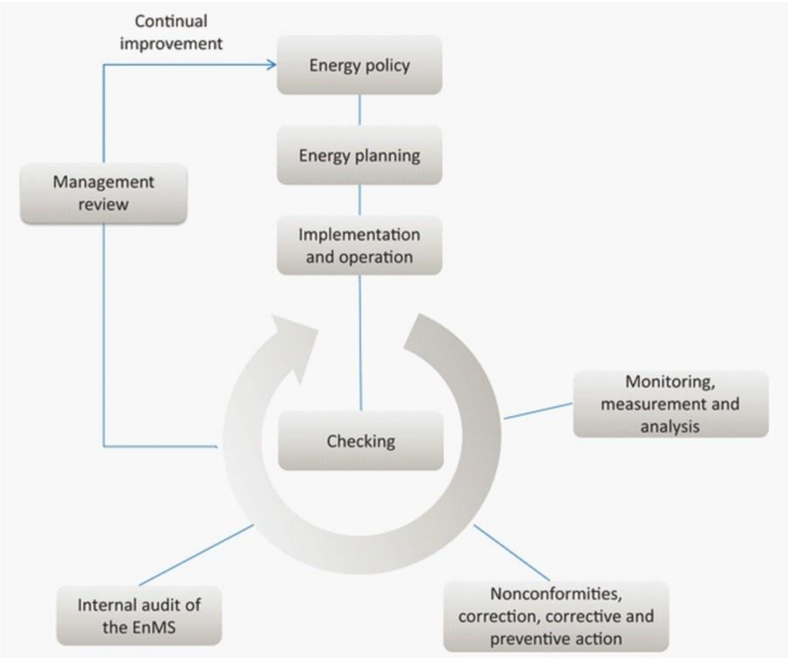


**Figure 40: The ISO 50001 energy management system model (ISO 50001, 2011)**

There are seven major components to ISO 50001:

1. General Requirements:
2. Management Responsibility
3. Energy Policy
4. Energy Action Plan
5. Implementation and Operation
6. Performance Audits

7. Management Review

It is best practice to (CENELEC, 2016):

- **Implement an energy management system (e.g. ISO 50001 or through EMAS).**

  As described before, an advanced energy management system enables continuous monitoring and improvement of energy efficiency. It includes performing an energy audit; measuring and monitoring the energy performance of the data centre and its equipment; and, managing the equipment to reduce their energy consumption. A plan for energy management can be implemented in any data centre, according to a recognised standard such as the ISO 50001 certification or the verified EMAS.

  When creating such a plan, it is important to involve representatives from all the relevant stakeholders of the organisation (e.g. software, ICT equipment, mechanical, electrical and procurement) to approve significant decisions.

- **Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified.**

  Physical estate and services should be audited, as ICT equipment requirements for allowable intake temperature and humidity ranges. Then, an asset management should be implemented for all ICT, mechanical and electrical equipment (e.g. ISO 55000), to maximise any unused capability prior to new material investment. For example, equipment supporting unused services should be removed; and the working intake temperature and humidity should be reviewed and widened when possible.

- **Install metering equipment capable of measuring energy consumption and environmental parameters at different levels.**

  An appropriate number of metering equipment should be installed to improve visibility and granularity of data centre infrastructure energy consumption. Besides measuring the total incoming energy consumption of the data centre, such equipment should allow measuring the ICT power consumption at cabinet, rack or ICT device level when necessary.

  A similar process should be implemented regarding temperature and humidity conditions. Metering equipment should be installed to monitor supply air temperature and humidity for the ICT equipment at room level. Additional meters should be installed at row, cabinet, rack or ICT device level if closer measuring of supply or return air temperature is necessary.

- **Monitor and report equipment utilisation, energy consumption and environmental conditions.**

  On the basis of such specific metering equipment and devices functionalities, different parameters can be monitored according to a process defined within the energy management plan. It should include:

  - the utilisation and capacity of ICT devices (servers, processors, network equipment and storage equipment),
  - the energy consumption of ICT, mechanical and electrical equipment within the data centre,
  - the temperature and humidity environment (at row, cabinet or rack level),

- the utilisation of economisers (full economiser, partial economiser and full refrigerant and compressor based cooling hours).

Depending on the facility and on the organisation, it is possible to undertake periodic manual readings or to implement automated daily or hourly readings.

Besides the collection and logging of utilisation, energy and environmental data throughout the year, analysis should be performed and key performance indicators (e.g. PUE) calculated to support decisions taken within the energy management system. Such indicators should be reported periodically within a reporting console, consolidated within a business dashboard and published in a report on energy or environmental issues.

More general practices on the implementation of plan for an environmental management system (e.g. ISO 14001 or EMAS) are presented in the cross-cutting chapter number 2 (not only related to data centres).

The implementation of a plan for life cycle assessment (LCA) is developed within the BEMP 2.3 on the Procurement of sustainable ICT products and services and within the BEMP 2.6 on Waste management of ICT equipment through waste prevention, reuse and recycling. It can allow better taking into account the embodied energy of ICT devices (including devices used in data centres).

Turning off lights (preferably automatically) whenever areas of the building are unoccupied is considered as a cross-sector best practice when speaking of service providers companies in general. Such technique is described in the best practices report for sustainable offices.

#### 3.2.2.2 Achieved environmental benefits

Implementing an energy management system for data centres can lead to two main types of benefits.

First, this can **reduce the electricity consumption of data centres**. Reducing the numbers of IT equipment powered and optimising the use of servers' sleeping modes directly reduce the electricity consumption of IT equipment. Such energy savings can be explained by a reduction in the power supply of each IT component (memory, drives, processors, chip set, or fans), but also by a more efficient architecture.[51]

Then, this can **reduce the electricity consumption related to cooling or power supply.** As any electrical equipment, IT equipment requires power supply and produces waste heat while running. Need for cooling and energy losses related to the power infrastructure (power distribution unit, UPS, building transformers) increase with the number of active hardware. Consolidating IT equipment will indirectly reduce the electricity consumption related to cooling and the over-consumption due to power supply. Similarly, improving the energy efficiency related to airflow and temperature setting management is expected to primarily reduce the energy consumption of data centres.

Regarding energy savings related to the previous best environmental management practices identified in this section, an order of magnitude is that 1 Wh of energy saved at the server level results in roughly 1.9 Wh of data centre-level energy savings

[51] For example, the communication between two systems in a virtualised environment hosted by a single physical server is less energy consuming than the communication via network between two separate physical servers (E-Server, 2009).

(Energy Star, 2011). Eventually, the decrease in energy consumption leads to a decrease in GHG emissions.

### *3.2.2.3 Appropriate environmental performance indicators*

There are different types of performance indicators that can be used when implementing environmental management systems:

- Outcome-oriented indicators (measures the energy performance of the data centre):
  - **Energy use of the data centre per floor area (kWh/m²)**, which is the ratio between the total energy consumption of the data centre (measured in kWh), and the data centre floor area (measured in m²).
  - **Power Usage Effectiveness (PUE)**, which is defined as the ratio of the total power to run the data centre facility to the total power drawn by all IT equipment. PUE is the most common energy performance indicator for data centres. While it can be used to track performance over time of a specific site given a certain level of service / load, care must be taken to compare PUE of different types of data centres. The PUE is defined by the standard ISO/IEC 30134-2.

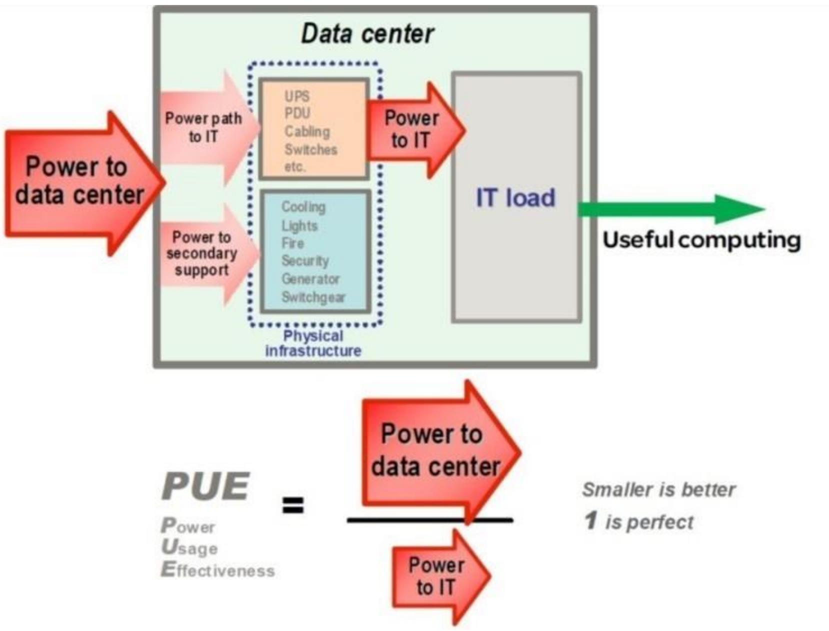


**Figure 41: Definition of the Power Usage Effectiveness (PUE) of a data centre (Source: (Rasmussen, 2011))**

NB: the data centre infrastructure efficiency (DCIE) refers to the PUE's reverse metric (it measures the IT equipment power consumption divided by the total facility power, expressed as a percentage) is currently less used than the PUE.

  - **The Global KPI for data centre energy management**, or $KPI_{DCEM}$, as defined by the following ETSI standard: ETSI GS OEU 001 V2.1.1 on Global KPIs for ICT Sites; (ETSI GS OEU 001 V2.1.1, 2014), developed on the basis of the ETSI standard ETSI ES 205 200-2-1 V1.2.1 on Global KPIs for Data Centres. (ETSI ES 205 200-2-1, 2014). This indicator aims at assessing the level of eco-efficiency in data centres, and at allowing benchmarking of data

centres in a wide range of industrial sectors. This indicator combines two aspects: the data centre size or gauge (S, M, L or XL) and its energy efficiency performance (9 levels, similar to the ones used for home appliances).

| $DC_G$ | $KPI_{EC}$ range |
|---|---|
| S | $KPI_{EC} \leq$ 1 GWh |
| M | 1 GWh < $KPI_{EC} \leq$ 4 GWh |
| L | 4 GWh < $KPI_{EC} \leq$ 20 GWh |
| XL | $KPI_{EC}$ > 20 GWh |

| DC commissioning date | since 2005 (see note) | | before 2005 (see note) | |
|---|---|---|---|---|
| | $DC_P$ | | $DC_P$ | |
| Class | ≥ | < | ≥ | < |
| A | | 0,70 | | 1,00 |
| B | 0,70 | 1,00 | 1,00 | 1,40 |
| C | 1,00 | 1,30 | 1,40 | 1,70 |
| D | 1,30 | 1,50 | 1,70 | 1,90 |
| E | 1,50 | 1,70 | 1,90 | 2,10 |
| F | 1,70 | 1,90 | 2,10 | 2,30 |
| G | 1,90 | 2,10 | 2,30 | 2,50 |
| H | 2,10 | 2,40 | 2,50 | 2,70 |
| I | 2,40 | | 2,70 | |
| NOTE: Year of Kyoto Protocol entering into force. | | | | |

**Figure 42: Data Centre Default Gauges (on the left) and Data Centre Default Class Performance (on the right) (ETSI ES 205 200-2-1, 2014)**

Where:

$KPI_{EC}$ is the Data Centre energy consumption (GWh);

DCP is the Data Centre Performance = $KPI_{TE}$ x (1-($KPI_{REN}$ x $W_{REN}$)) x (1-($KPI_{REUSE}$ x $W_{REUSE}$), with:

**$KPI_{TE}$ is the Data Centre task efficiency**, or the ratio of global electricity consumption to the electricity consumption of components that manage data, for calculation storage or transport purposes.

**$KPI_{REUSE}$ refers to the Data Centre energy reuse**, and is equal to the ratio of reused energy for external uses to total data centre energy use. $W_{REUSE}$ is a mitigation factors that depends on the gauge.

**$KPI_{REN}$ refers to the Data Centre use of renewable energy**, and is equal to the ratio of local renewable energy used by the data centre over its total energy consumption. $W_{REN}$ is a mitigation factors that depends on the gauge.

A $KPI_{DCP}$ of 1.5 or below can be considered as a best practice (ETSI GS OEU 001 V2.1.1, 2014).

- Process-oriented indicators (measures the implementation of environmental management) such as:
  - Share of facilities having an energy management system certified according to ISO 50001 or integrated in EMAS, or complying with the EU Code of Conduct on Data Centre Energy Efficiency or the "expected practices" of CLC/FprTR 50600-99-1.
  - Share of ICT, cooling or power equipment with specific metering equipment (for measuring their use, energy consumption, temperature or humidity conditions).

- Share of staff provided with information on energy objectives or training on relevant energy management actions during the year.

### 3.2.2.4 Cross-media effects

The best practices identified in this chapter are mainly linked to the creation of additional e-waste. For instance, the installation of metering equipment can have adverse environmental consequences due to the use of batteries to power the equipment.

While metering equipment allows to gather accurate data, they imply additional overheads: cost overhead, energy consumption overhead because metering equipment has to be powered, and skill overhead because installing and using equipment requires technical knowledge (Zomaya & Lee, 2012).

### 3.2.2.5 Operational data

**Implement a plan for energy management (e.g. ISO 50001 or through EMAS)**

The following steps are typically part of an energy management system (EMS) (Blackmores, 2015):

1. Planning
    a. Obtain commitment from top management
    b. Identify the scope, including the physical boundaries
    c. Conduct a Gap Analysis (to evaluate the conformity of the organisation's processes with the Energy Management System detailed in ISO 50001)
    d. Review existing data in relation to energy aspects
    e. Create an implementation plan to identify the resources required
    f. Facilitate an 'Energy Working Group' to champion the project
    g. Conduct an energy review
2. Document the Energy Management System Planning
    a. Identify and document the applicable energy legislation
    b. Identify and document the energy management controls
    c. Establish energy targets and programmes
    d. Document the Energy Management System
3. Awareness Training
    a. Create the training materials for operatives and management
    b. Delivery of Energy Management Awareness Training
    c. Keep records of training attendance
4. Compliance
    a. Plan and conduct internal audits to verify the level of compliance to ISO 50001 or through EMAS.
    b. Close out any Corrective and / or Preventive Actions as part of the assessment preparation
    c. Management Review Meeting
    d. Independent verification and validation (optional) to be able to certify or verify the EMS.
    e. External communication (optional) of environmental performance to customers, suppliers, public authorities and the local community.

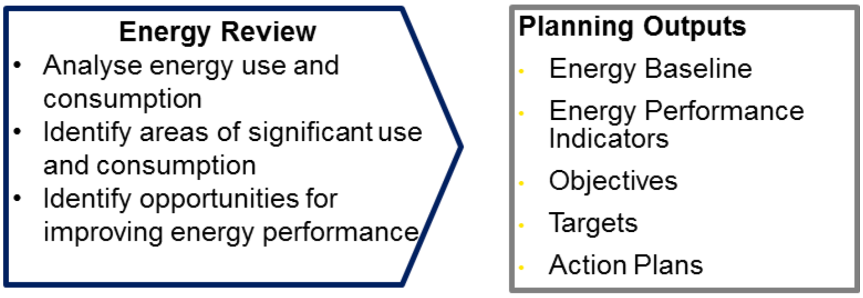


**Figure 43: Components of an energy review**

**Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified**

Performing an audit the IT services and analysing IT reported data (when useful indicators are monitored, as server and network utilisation for example) is an essential preliminary step before implementing a consolidating strategy. The inventory should focus on (Uddin and Rahman, 2010):

- Identifying server resources (type of processors, memory size, network type, local storage, operating system, etc.);
- Categorising server resources (network infrastructure servers, application servers, web servers, database servers, etc.);
- Categorising application resources (custom applications, mission critical applications, support to business applications, etc.);
- Allocating computing resources required by these different workloads.

Such work may allow the identification of:

- IT services which do not achieve high utilisation of their hardware. Such IT services may be consolidated, through the use of resource sharing technologies improving the use of physical resources.
- IT services which are not used on a regular basis, and which can be virtualised or archived, and be brought online or on low power media.
- IT services with a low business value and servers with no use still running - comatose servers typically represent about 10 to 30 % of servers (Energy Star, 2011). They may be decommissioned or removed to locations with a lower reliability or resilience level (and which use less energy).

**Install metering equipment capable of measuring energy consumption and environmental parameters at different levels**

The energy monitoring process starts with the development of measurement capacities. Several items can be measured, starting with the incoming energy consumption. This can be done by installing metering equipment capable of measuring the total energy use of the data centre including all power conditioning, distribution and cooling systems. Similar metering equipment can be installed to measures the IT energy consumption (total energy delivered to the IT system) and the supply air temperature and humidity for the IT equipment. These measurements can be done at various spots, including (CLP Power, 2013):

- Transformer, where the total facility power can be measured. Power Electricity travels through the service entrance and into a transformer, which feeds everything downstream: switchgear, UPS, lighting, CRAC/CRAHs, and, eventually, the IT equipment.
- Uninterruptible Power Supply (UPS), where the total IT load can be measured. Downstream from transformer, transfer switches, switchgear.
- Power Distribution Unit (PDU), where the total IT load can be measured (in a more comprehensive way than at UPS level). Different from a rack-based power units (where the IT equipment is actually powered), these floor mount units distribute power via circuit breakers to the cabinets and racks housing IT equipment (CLP Power, 2013).

Regarding the installation of metering equipment to measure the energy consumption of the equipment, it is important to define the right balance between the number of metering equipment and the targeted level of monitoring. Consequently, the installation of such equipment should be an iterative process, starting with a limited number of meters. Following this first period of control, a more precise monitoring can be implemented if necessary by installing more metering equipment.

**Monitor and report ICT devices utilisation, energy consumption and environmental conditions.**

Measuring and monitoring its energy usage and calculate the losses. This includes measuring the electricity consumption of the IT equipment (i.e. servers, storage and network equipment) in relation to the energy consumption of the supporting infrastructure equipment such as HVAC equipment and lighting as well as the UPS, transformer and cable losses. Figure 44 below shows the different sources of energy consumption in a data centre besides IT equipment.

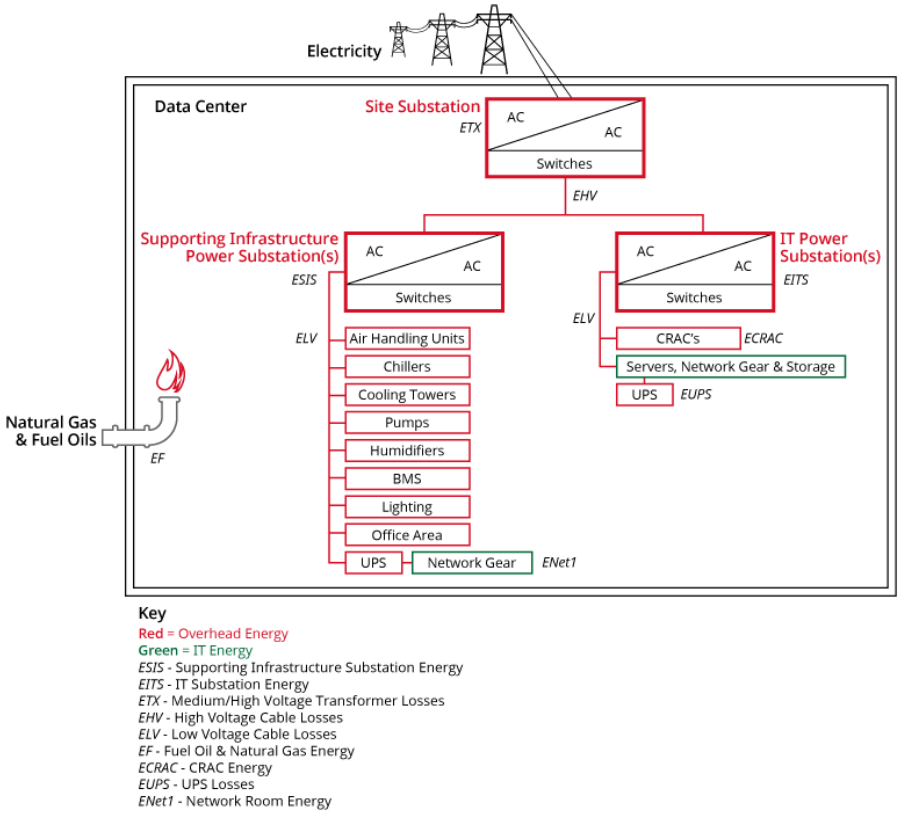


**Figure 44: An overview of the different equipment that consume energy besides the IT equipment (servers, storage and network equipment) (Google, 2016)**

Collecting the data measured can be done either with periodic manual readings of the data provided by the metering equipment, occurring at regular times (ideally at peak load), or with automated daily readings.

Specific types of smart equipment exist to carry out partly automatically the measurement and data collection effort, thereby enhancing the monitoring process. This is especially the case of self-aware data centre equipment (Bigelow, 2014). Some of these emerging self-aware equipment include:

- Enterprise-class lower-power servers to reduce idle processor cores. These new generation servers use thermal controls such as variable-speed cooling fans monitored by tachometers, multiple temperature measurement locations within the system and continuous power monitoring that calculates and reports usage to compatible tools (Bigelow, 2014).
- Smart Power distribution units (PDUs) use intelligence to help organisations map energy draw. Networked PDUs offer real-time power monitoring and temperature or humidity sensing. Smart PDUs pay off in large data centres that require granular monitoring. Complementary management tools process data

provided by PDUs to analyse power use and environmental conditions in the racks (Bigelow, 2014).

- Uninterruptable power supply (UPS). Modern UPS systems report readiness, battery status, load and other operating conditions to monitoring and management software. For large data centres, an emerging trend in UPS is the incremental ramping up of battery capacity as load increases. By matching the battery count to the load allows to reduce the energy wasted on charging extra batteries (Bigelow, 2014).

The main attribute of this type of equipment is that it creates a link between the equipment itself and a more or less centralised energy management system (DEMS, data centre energy management system, in the figure above) (Matsuda, 2012). Two major benefits of such a system can be highlighted.

- First, the real time interactions between the equipment and the DEMS allow a self-awareness of the system, which means that it can adapt its activity to a given context. For example, the most advanced data centres are equipped with tools allowing them to optimise electric power by varying the working servers in response to load fluctuations. That means that if the load requires only half of the servers in a data centre to operate in order to provide its service, the power consumption can be reduced by concentrating the activity in half of the servers while stopping the other, instead of supplying partly idle servers with power. In addition to this self-adjustment, the ICT equipment sends data on its operation to the data centre energy management system, which analyses the data automatically and in turn sends operation orders to the equipment. The data can be overviewed and analysed by management teams, for control purposes and in order to define an energy strategy for the facility.
- Second, this system allows for operators to benefit from an extensive data flow. This data flow in turn allows for a better benchmarking, data analysis, and ultimately decision making, as shown in the "operation know-how" of the figure above.

Data reporting can be done in the form of periodic written reports, or with an automated energy reporting console.

Analysing data allows the infrastructure management team to set energy effectiveness objectives for the facility, to check the variation of its performance over time, and to discover potential unexpected and inefficient consumption sources. To help the target setting process, the management team can estimate its position among industry peers. The average industry PUE is estimated to be somewhere between 1.6 and 1.8 (PASM, 2016) (Geet, 2014), although the performance varies very much from one data centre to another. The EU Code of Conduct participant average was a PUE of 1.8, meaning that 56% of electricity was delivered to the IT equipment (Newcombe L. , 2011). With the implementation of best practices is has been estimated that data centres could reach 1.5 or 1.4 (Ishfaq A. and Sanjay R., 2012).

By implementing some of the best practices presented throughout this report, the energy performance of data centres is expected to increase progressively. For instance, Figure 45 shows how the performance (measured in PUE) of Google's data centres increased.

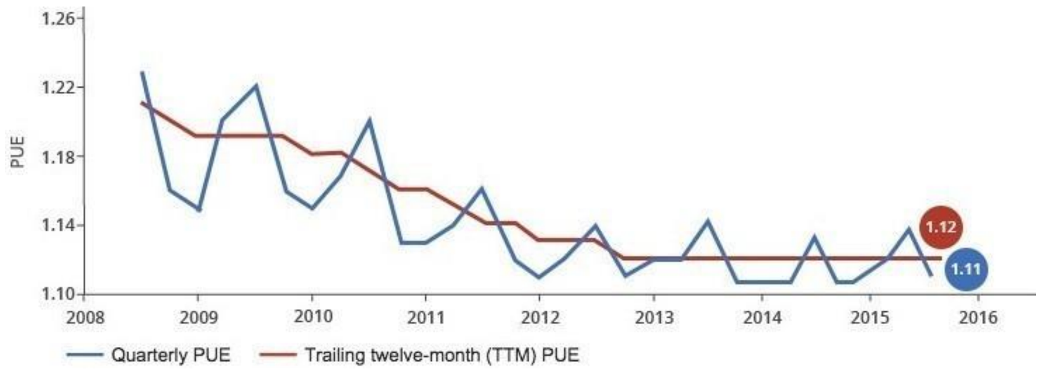


**Figure 45: PUE data for all large-scale Google data centres (Google, 2016)**

Thanks to data analysis that identifies consumption sources and potential sources of progress, it becomes possible to set targets by taking action on specific energy consumption sources, both indirect (like cooling and lighting) and direct (server load, idle servers).

The best practices described in this chapter can take different forms when being implemented. Below is one example of best practices (energy monitoring and cooling) that has been implemented.

| **BEMP implemented: Data centre monitoring** | |
|---|---|
| Within this case study, the following techniques were implemented:<br>- Audit of the IT, cooling and power equipment;<br>- Installation of additional metering equipment;<br>- Collection and analysis of IT workload, energy consumption and temperature conditions. | |
| **Operator of the data centres** | **Technical characteristics and context** |
| CIT Campus - Cork (Ireland)<br><br>2013 (GENIC, 2014) | Surface: One room of 35 m² and one of 55 m²<br><br>Number of physical and virtual servers: around 100 in total<br><br>The first data centre houses largely communications equipment for the CIT campus and the main e-mail and DNS server, serving the whole campus community of ca. 17 000 users.<br><br>The other one houses servers for students completing online courses, among other equipment. |
| **Practice implemented** | **Results** |
| Prior to the project, the metering equipment consisted of a power meter integrated in the supply board that feeds all the IT equipment.<br><br>The project was composed of three parts:<br>- A survey of the systems installed at | Metering allowed for the measurement of IT workload, thermal conditions inside the data centre space as well as the power consumption of the data centre as a whole. Although an energy audit itself does not reduce consumption, measurement is the first step towards |

| | |
|---|---|
| the data centres was conducted with the campus electrical maintenance staff.<br>- Two additional panel mounted measurement units (unit cost of around 500€) were installed for measuring the relevant parameters for describing the baseline operation of the sites.<br>- Data was retrieved after two weeks and was used to produce a full analysis of energy use for IT equipment, air conditioning and services in each of the data centres. | managing usage that can in turn trigger considerable energy savings for minimal costs. Indeed, data can be routinely made available to all users of the server rooms after the audit, together with energy performance targets and an action plan for savings. |

#### *3.2.2.6 Applicability*

The applicability of the above mentioned best practices depend on the characteristics of the data centre. The table below lists which best practices are the most relevant for different types of data centres.

**Table 23: Applicability of energy management best practices in existing data centres**

| Best practice | Size | Security | Purpose |
|---|---|---|---|
| Implement a plan for energy management (e.g. ISO 50001 or through EMAS) | Localised, mid-tier and enterprise-class data centre | Any tier | Any purpose |
| Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified | Localised, mid-tier and enterprise-class data centre | Any tier | Any purpose |
| Install metering equipment capable of measuring energy consumption and environmental parameters at different levels | Localised, mid-tier and enterprise-class data centre | Any tier | Any purpose |
| Monitor and report equipment utilisation, energy consumption and environmental conditions | Any size | Any tier | Any purpose |

Some technology intensive automated data management tools can be very costly, especially for smaller size structures. The tools are mainly for large size data centres because of heavy upfront investments.

Another constraint for the implementation of smart energy monitoring tools is the pay-off time. Data centres with large growth forecasts might plan to relocate in order to extend their activity. As the return on investment (ROI) takes a few years to

materialise due to large upfront investments, these facilities would wait before they invest in monitoring tools.

### 3.2.2.7 Economics

The main economic benefit of energy monitoring is an increased profitability, due to lower energy costs combined with increased business levels. A decrease in energy consumption can deliver substantial cost savings over time. It is estimated that implementing energy practices in data centres, and consolidating applications onto fewer servers, could reduce data centre energy usage by 20% (Universal Electric Corporation, 2010). When taking into account the use of newer servers and best practices that include real time power monitoring, the improvement could reach 45%. If operators fully understand their power usage, they can enter a load shifting strategy, meaning that they alternate between several data centres to follow less expensive electrical rates around the world, take advantage of lower rates at night or decrease air conditioning costs. In addition, better understanding its power usage can help a data centre manager to project growth more accurately, e.g. when to add more UPS, racks, and servers, etc. (Universal Electric Corporation, 2010).

In addition, by adopting energy monitoring practices, data centres can make room for additional business opportunities, thanks to a better understanding of their energy capacities. Without energy monitoring practices, staffs doesn't know which devices and systems are generating the load and it is not clear where spare capacity exists in the data centre. By better monitoring the energy consumption and spare capacity, data centres can provide more service while decreasing the risk of power outage. Upgrading to the new generation of equipment, in addition to saving power and space, is essential for rolling out new revenue-generating services as well (Eltek, 2012).

The table below gives an overview of the costs related to the installation of meters, which represent one of the highest investments when implementing an energy management plan.

**Table 24: Application and cost comparison of different types of electrical meter devices used in data centres (Kidd & Torell, 2013)**

| Type of meter | Applications | installation cost per meter* |
|---|---|---|
| Power quality meters | • power quality monitoring<br>• electric utility bill verification<br>• power circuit loading & balancing<br>• energy management<br>• maintenance activity support | €4500 – €10000*** |
| Power meters | • power circuit loading & balancing<br>• energy management<br>• cost allocation / billing<br>• maintenance activity support<br>• critical incident alarming | €500 - €3000 |
| Digital relay embedded meters** | • protective device for medium voltage equipment | ~€1000 |

| | | |
|---|---|---|
| | • power circuit loading & balancing<br>• maintenance activity support<br>• critical incident alarming | |
| Electronic trip unit embedded meters** | • protective device in low voltage circuit breakers<br>• power quality monitoring<br>• power circuit loading & balancing<br>• energy management<br>• maintenance activity support<br>• critical incident alarming | €500 - €11600 |
| Uninterruptible power supply (UPS) embedded meters | • engineering data support<br>• PUE monitoring<br>• critical incident alarming | Included in UPS price |
| Power distribution unit (PDU) embedded meters | • PUE monitoring<br>• management of power capacity<br>• cost allocation<br>• critical incident alarming | Included in PDU price |
| Rack PDU embedded meters | • most accurate "IT load" measurement per Green Grid<br>• load balancing<br>• rack level power capacity management | €0.04-€0.05 / watt<br>premium over basic rack PDUs |

** Based on typical pricing in US market and assumes that the metering is ordered with, and installed into, the power distribution equipment*
*** Cost to add metering functionality to protective devices*
**** Large price range due to functionality differences in embedded meters; low end trip unit meters are basic power meters whereas high end trip unit meters are power quality meters with breaker diagnostics*

The table below gives an overview of costs and return estimates for each best practice.

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Implement a plan for energy management (e.g. ISO 50001 or through EMAS) | Headcounts for an energy manager<br>Logistics and time related to animating regular meetings | Certification or verification process | Reduction of energy consumption<br>Reduction of maintenance costs |
| Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are | Headcounts of the IT service<br>Logistics and time related to the | NA | Savings from equipment decommissioned:<br>Small data centre: |

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| identified | animation of regular meetings | | from 1 000€ to 2 000€<br>Large data centre: from 200 000€ to 400 000€[52] |
| Install metering equipment capable of measuring energy consumption and environmental parameters at different levels | NA | Selecting and installing metering equipment<br>(approx. 11.000€ (Therkelsen et al., 2013) | Reduction of energy from IT consumption<br>Reduction of energy cost from cooling<br>Reduction of energy cost from humidification [53] |
| Monitor and report equipment utilisation, energy consumption and environmental conditions | Headcount to perform meter readings or data analysis and reporting | Selecting and installing automated monitoring and reporting devices | Reduction of energy from IT consumption<br>Reduction of energy cost from cooling |

### 3.2.2.8 Driving force for implementation

Against the background of the above-mentioned details with regards to economics, **cost savings** are considered to be the main driver for implementing an energy management system. Cost savings can be significant for both small and large data centres. Two types of savings can be identified:

- Savings from direct energy consumption, by reducing the power consumption of ICT equipment (e.g. by removing equipment supporting unused services)
- Savings from indirect energy consumption, by reducing the power consumption of supporting equipment, such as the cooling system (e.g. by increasing the ICT equipment intake air temperature, widening the working humidity range and raising chilled water temperature).

Another benefit from implementing some of the best practices mentioned in this chapter is the involvement of a large number of experts in the management of the data centre. This pool provides a **resource of knowledge and expertise** that can increase the performance of the ICT equipment and reduce risks linked to decision-taking.

[52] Method: yearly savings from the decommissioning of 1% to 2% of total racks

[53] If complemented with an energy management plan.

According to the European Commission's Reference Document on Best Available Techniques for Energy Efficiency (European Commission, *Reference Document on Best Available Techniques for Energy Efficiency*, 2009), other drivers for implementing energy efficiency policy include the improvement of:

- energy efficiency performance and compliance;
- competitiveness, in particular against a trend of increasing energy prices;
- personal motivation;
- company's image and reputation.

#### 3.2.2.9 Reference organisations

- All Equinix's / TelecityGroup's data centres in France, the UK and the Netherlands are certified for ISO 50001 (Equinix, 2011).
- 100 % of EDF data centres are certified ISO 50001 (EDF, 2016).
- EDH becomes the first data centre in Luxembourg to acquire the ISO 50001 Certification for Energy Management.
- Google's main European data centres, in St. Ghislain, Belgium, Hamina, Finland, and Dublin, Ireland are ISO 50001 certification (Google, 2014).
- Getronics (Getronics, 2016).
- TIM (ex-Telecom Italia S.p.A.) data centre in Milano-Rozzano received the ISO 50001 in 2016

#### 3.2.2.10 Reference literature

Reference literature are consolidated in the section 3.2.7 Reference literature.

The content of this BEMP is based on the techniques (detailed in Section 3.2.1 of this document) which are included in the following chapters of the final draft of the technical report CLC/FprTR 50600-99-1:

- Utilisation, management and planning of existing data centres;
- Management of existing ICT equipment and services;
- Management of existing power equipment;
- Other data centre equipment;
- Data centre monitoring.

### 3.2.3 Define and implement a data management and storage policy

**SUMMARY OVERVIEW:**

**Minimising the quantity of data stored onto drives and the computing capacity required to run applications, databases and services is a key measure to reduce the energy consumption of data centres by reducing the number of powered hardware (servers and storage devices). It is considered best practice to:**

- **Implement an effective data management and storage policy to minimise the share of stored data either unnecessary, duplicated or does not require rapid access.**
- **Deploy grid and virtualisation technologies to maximise the use of shared platforms.**
- **Consolidate existing services and decommission unnecessary hardware to reduce the number of highly resilient and reliable hardware powered (servers, networking and storage equipment).**

**When properly implemented, these techniques lead to a reduction of the hardware purchased which also results in significant material resources savings.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Energy use (kWh) per rack
- Server PUE (SPUE) = (Server Input Power) / (Computation Useful Power)
- Average storage disks space utilisation (%)
- Average server utilisation (%)
- Share of servers virtualised (%)
- Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services

**Cross references**

| | |
|---|---|
| **Prerequisites** | • Commitment from top management |
| **Related BEMPS** | • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)<br>• 3.2.4 Improve airflow management and design<br>• 3.2.5 Improve cooling management<br>• 3.2.6 Review and adjust temperature and humidity settings |

#### 3.2.3.1 Description

IT systems traditionally consume about 50% of the data centre energy power. Servers and storage drives are power supplied in order to run drives (about 16% of the electricity consumption), PCI cards (about 9%), processors (about 19%), memory (about 6%) and chip sets (about 7%); another 7% of electricity is consumed by fans and about 35% is lost due to AC/DC and DC/AC conversions (Source: Intel and EXP Critical Facilities, quoted in (The Green Grid, 2007).

The main factors influencing IT equipment energy consumption are:

- The means of network data transmission (wired, wireless, etc.);
- The IT hardware numbers, architecture and efficient rating;
- The server utilisation rate.

The techniques described below aim at reducing the number of servers and storage hardware powered within the data centre and optimising the performance of all hardware regarding to their energy consumption. These practices deal with the operation of applications, databases and services run onto servers, and with the data stored onto drives.

It is best practice to (CENELEC, 2016):

- **Implement an effective data management and storage policy.**

  The data management and storage policy of data centres usually has room for improvement, since a significant part of the data being stored is either unnecessary, duplicated or does not require rapid access. Reducing both the total volume of data stored and the total storage volume reduces the number of storage hardware used. Depending on the demand of end-users and the level of protection required, a data management policy can include practices such as deduplication, data compression and tiering storage.

- **Deploy grid and virtualisation technologies.**

  Grid and virtualisation technologies should be deployed wherever possible to maximise the use of shared platforms. Virtualisation of data storage can be done by implementing techniques such as thin provisioning, snapshots, and RAID.

- **Consolidate existing services and decommissioning unnecessary hardware.**

  Services can be consolidated in order to reduce the number of highly resilient and reliable hardware powered (servers, networking and storage equipment). IT services which do not achieve high utilisation of their hardware, which are not used on a regular basis or with a low business value may be identified through an audit of the IT services, the analysis of IT reported data (server and network utilisation for example) or the use of resource management systems (identify and optimise when and how ICT workloads are executed and their consequent energy use). Consequently, it can be decided to implement a combination of applications or to use N+1 server clustering.

  Decommissioning unnecessary hardware is a direct source of energy savings for data centres. Nevertheless, it is necessary to validate the ability of legacy applications and hardware to survive these state changes without loss of function or reliability. If shutting down equipment represents a risk for the functioning of the data centre, idle servers, networking and storage equipment can be put into a low poser sleep state.

Decommissioning can be part of an effort to shape the service offered to the customers' requirements. In case end-users of data centre services require different levels of protection and retention of their data, the data management policy can define storage areas with different characteristics, and decommission low business value services for each type of user. However, because little information is available on the separation of data management between different types of users, this practice will not be further detailed.

A similar approach was observed regarding techniques that intend to reduce ICT equipment resilience level.

In addition to the CENELEC CLC/TR 50600-99-1:2016 report, it must be noted that three sections of the EU Code of Conduct on Data Centres[54] also refer to practices related to data centres' data management practices.

### 3.2.3.2 Achieved environmental benefits

#### Direct decrease of energy consumption

Reducing the numbers of IT equipment powered and optimising the use of servers' sleeping modes directly reduce the electricity consumption of IT equipment. Such energy savings can be explained by a reduction in the power supply of each IT component (memory, drives, processors, chip set, or fans), but also by a more efficient architecture[55].

#### Indirect decrease of energy consumption

As any electrical equipment, IT equipment requires power supply and produces waste heat while running. The need for cooling and energy losses related to the power infrastructure (power distribution unit, UPS, building transformers) increases with the number of active hardware. Consolidating IT equipment will indirectly reduce the electricity consumption related to cooling and the over-consumption due to power supply. Such indirect effects can also be observed when developing energy efficient software since software systems do not consume energy directly but affect hardware utilisation rate and lead to indirect electricity consumption.

Combined energy savings (that to say both direct and indirect effects) potential are important. Indeed, 1 Wh of energy saved at the server level results in roughly 1.9 Wh of data centre-level energy savings (Energy Star, 2011). Although energy-efficient storage performance depends mainly on the quantity of data to be stored (and on the number of files), energy savings up to 50% can be reached at the storage equipment level (Manzanares A. and Qin Z., 2015) (see Figure 46 below).

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[54] It describes Best Practice Guidelines related to energy efficiency of data centres (JRC, 2015). This document is based on a voluntary approach and on expected minimum practices. Available at:http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/COC_DC/2015_best_practice_guidelines_v6.1.1.pdf

[55] For example, the communication between two systems in a virtualised environment hosted by a single physical server is less energy consuming than the communication via network between two separate physical servers (E-Server, 2009).

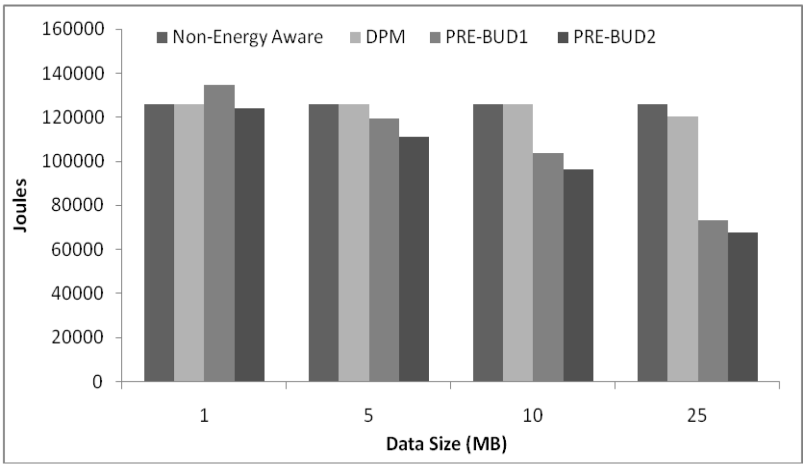


**Figure 46: Evolution of storage practices energy consumption function of the size of data to be stored. Source: (Manzanares A. and Qin Z., 2015).**

According to Energy Star (2011), the following data storage energy savings can be obtained:

- 40 to 50% by deduplication;
- 80 to 95% by using snapshots compared to point-in-time copies;
- 40 to 60% by thin provisioning;
- 15 to 30% by storage compression;
- 45% by going to 11-disc RAID 5 from a 20-disc RAID 1 configuration.

As shown on Figure 47, virtualisation projects allow for major savings in terms of energy consumption (Energy Star, 2011; PrimeEnergyIT, 2013). Virtualisation can lead to savings in the order of 40%-80%, depending on the degree of virtualisation (hardware partitioning, full or para virtualisation container virtualisation, etc.), on the degree to which new applications and features are implemented, and on the specificity of the system.

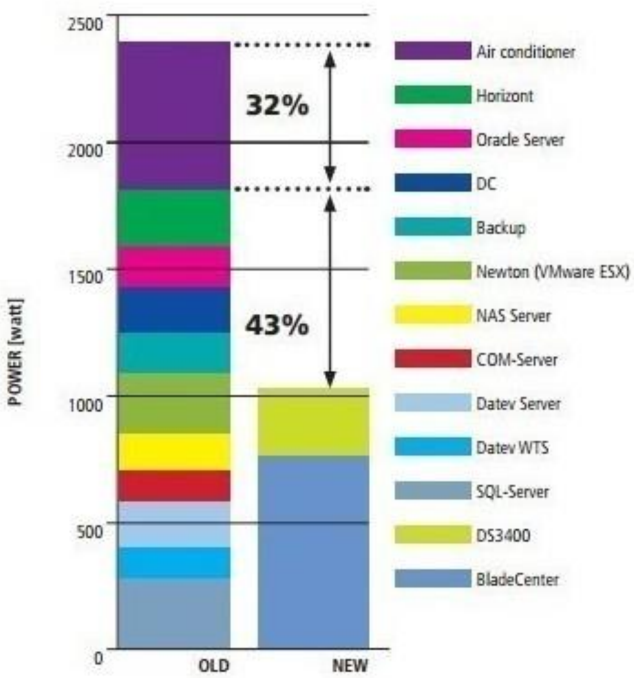


**Figure 47: Reduction in servers' energy demand by virtualisation. Source: Case study from the PrimeEnergyIT project (PrimeEnergyIT, 2011).**

#### *3.2.3.3 Appropriate environmental performance indicators*

A similar metric to the PUE can be defined to monitor the energy effectiveness of servers:

- **Server PUE**: the ratio between the server input power and the computation useful power. A state-of-the-art server SPUE is expected to be less than 1.2 (Ishfaq A. and Sanjay R., 2012).

Besides, **the energy consumption (kWh) per rack** can also be an easier indicator to monitor.

In addition to outcome-oriented indicators, process-oriented indicators can be defined, such as:

- **Average storage disks space utilisation** (%): the ratio between the storage disk space currently used (onto all the storage devices of the data centre) and the overall storage capacity of the data centre. The higher is this utilisation rate, the more energy efficient is the storage equipment.
- **Average server utilisation** (%): the ratio between the average computing capacity used on all the servers of the data centre over a certain period, and the overall computing capacity of the data centre. The higher is this utilisation rate, the more energy efficient are the servers.

  In average, server utilisation is between 12 and 18%, while best performances are assessed to be between 40 and 70% of server utilisation (NRDC, 2014).
- **Share of virtualised servers** (%): the number of virtualized servers over the total number of servers. This reflects the ability of the servers' owner to virtualize servers in order to increase its utilisation rate
- **Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency** or the Expected

Practices of CLC/FprTR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services

#### 3.2.3.4 Cross-media effects

The main cross-media effect results in the use of applications to implement techniques such as virtualisation, automatically management, and so on. These applications occupy system resources for their execution and reduce the effects of these practices on lowering server utilisation rate. At intensive traffic, virtualised servers consume more energy than physical ones (Wen et. al., 2010).

Another side-effect of virtualisation can occur because of the facility and speed of implementing new virtual servers. Then the number of virtual-servers can increase quickly and lead to an increased power demand.

#### 3.2.3.5 Operational data

**Implementing an effective data management and storage policy**

One of the most visible storage inefficiencies is low disk-space utilisation, with utilisation rates of 20% frequently observed in organisations, while a 60 or 70% utilisation rate should be a minimum (Hitatchi et. al., 2013). Several causes can be identified: data duplication, inability to remove obsolete data, limited consolidation of resources, etc.

A data-reduction technology aims at reducing storage consumption by removing data waste and redundancy (Hitatchi et. al., 2013):

- *Deduplication* intends to reduce redundancies that consume disk space unnecessarily and require more storage devices. Deduplication software find and eliminate unnecessary copies by retaining unique files or data blocks and providing pointers to duplicates. Such software should perform automated operations, without impacting the performance of the storage system and in a maximum efficient way[56]. Storage capacity savings from deduplication can be up to 90% (Hitachi et. al., 2013), except for primary and archive storage where a 35% maximum saving can be reached (PrimeEnergyIT, 2011).
- *Data compression* can reduce the amount of data stored. Data compression should be performed on rarely accessed files (since compressing and decompressing the data consume energy), on uncompressed formats (e.g., JPEG, MPEG or MP3 are already compressed) and before encryption (Energy Star, 2011). Between 15 and 40% of storage capacity can be saved by compressing data, depending on initial state (PrimeEnergyIT, 2011).
- *Tiering storage* - also referred to as Information Lifecycle Management or Hierarchical Storage Management - refers to the dynamically storage of data according to the relative demand for that data:
    - Low-priority data (rarely used, such as archival or “cold” data) can be stored on higher latency storage equipment that uses less energy;

[56] E.g.: not wasting a large amount of the capacity in order to perform deduplication.

- High-priority data (to be expected in immediate demand) can be stored on low latency storage equipment that consumes more energy (Energy Star, 2011).

Applications called automated tiering have been developed in order to perform such work automatically (Hitachi et. al., 2013).

A storage capacity planning and monitoring solution may facilitate the identification of inefficiencies and enables the implementation of the techniques described above.

**Deploying grid and virtualisation technologies**

Storage virtualisation refers to different techniques of mapping from physical location to virtual location. It is a method for running multiple independent virtual operating systems on a single device (US Department of Energy, 2011). It allows consolidation of applications from different operating systems and/or servers and reduction of the required number of physical servers by an increase of their utilisation rate. Consolidation factors through virtualisation can be of at least 10 to 20 (PrimeEnergyIT, 2011). Moreover idle power consumption of virtualised server is closed to zero and much lower than physical server idle consumption (Kommeri et. al., 2012) and energy consumption can be minimised at a given traffic load by launching the optimal number of virtual machines (Wen et. al., 2010).

Before implementing virtualisation, servers with specific restrictions (from a privacy, security or regulatory order) or with very high-level service requirements should be put away and servers with similar workloads should be grouped (Energy Star, 2011). Workloads with complementary characteristics should be combined (with applications run during business hours and others during peak off hours for example) up to the targeted utilisation level, as 50% or higher for many areas (PrimeEnergyIT, 2011). At the same time, required storage capacities, processor resources and cooling capacities should be adapted to the new architecture (Energy Star, 2011). Different technologies for server virtualisation may be chosen:

Storage virtualisation does not provide directly energy savings, since it does not allow reductions in dataset size or does not ensure the utilisation of energy efficient servers (SNIA, 2012). However, storage virtualisation is needed for using some energy-efficient technologies, such as:

- *Thin provisioning* enables more efficient disk space utilisation by centrally allocating space only as applications require the space (and not before there is data to store). Such technology avoids over-allocation of storage capacities based on anticipated storage requirements implemented because applications would suffer performance issues if storage capacities were exceeded. Space utilisation savings from thin provisioning have been estimated at between 20 to 50% (PrimeEnergyIT, 2011).
- *Snapshots* refer to a form of deduplication that creates temporary "copies" of data that only include data changes, instead of using additional space for complete copies of live data (Energy Star, 2011).
- *RAID* (or redundant array of independent disks) combines multiple disk drive components into a single logical unit and require less capacity than for mirroring (SNIA, 2012). While mirroring (or RAID 1) doubles storage consumption by creating a duplicate copy of each storage disc for back-up, RAID 5 requires only one extra redundant disc in a RAID set to prevent data loss from a single disc failure (RAID 6 can survive two disks failure). According to the National Renewable Energy Laboratory: "For a 10-disk array, increasing to an 11-disk RAID 5 level (one extra disk) from a 20-disk RAID 1 level

(duplicate copy) configuration would save 45% of data storage energy use." (NREL, 2015).

Other techniques may be used for reducing energy consumption related to storage activities, as spinning down storage discs when not in use, since spun down discs no not use power (SNIA, 2012). This technique is known as Massive Array of Idle Discs (MAID).

**Consolidating existing services and decommissioning unnecessary hardware**

Similarly to other BEMPs, performing an audit of the IT services and analysing IT reported data (when useful indicators are monitored, as server and network utilisation for example) is an essential preliminary step before implementing a consolidating strategy. The inventory should focus on (Uddin and Rahman, 2010):

- Identifying server resources (type of processors, memory size, network type, local storage, operating system, etc.);
- Categorising server resources (network infrastructure servers, application servers, web servers, database servers, etc.);
- Categorising application resources (custom applications, mission critical applications, support to business applications, etc.),
- Allocating computing resources required by these different workloads.

Such work may allow the identification of:

- IT services which do not achieve high utilisation of their hardware. Such IT services may be consolidated, through the use of resource sharing technologies improving the use of physical resources.
- IT services which are not used on a regular basis, and which can be virtualised or archived, and be brought online or on low power media.
- IT services with a low business value and servers with no use still running - comatose servers typically represent about 10 to 30 % of servers (Energy Star, 2011). They may be decommissioned or removed to locations with a lower reliability or resilience level (and which use less energy).

These techniques enable the use of fewer servers or at least fewer highly-performance servers, thus decreasing electricity consumption and waste heat (PrimeEnergyIT, 2013).

Decommissioning of unused servers requires the definition of baseline utilisation, so that unused servers can then be identified; for example, if a server received only network activity from the backup server, domain controller and antivirus server, it can be considered as unused (Energy Star, 2011). Then examining CPU utilisation of each server through a Data Centre Infrastructure Management (DCIM) may allow identifying unused servers. Before removing definitively unused servers, they can be turned off for a limited time to see if any users require the server to be turned on again.

Server consolidation refers to techniques that intend to reduce the total number of used servers by concentrating applications on fewer devices.

- *Combining applications* onto a single server (and onto a single operating system process) can consolidate two or three lightly used servers into a single one (Energy Star, 2011).
- *N+1 server clustering* technology requires only one backup server per cluster of server, while a system usually needs one backup server for each primary

working server (Energy Star, 2011). If an application fails on one server, the application is automatically and instantly activated on another server within the cluster.

- *Downsizing the application portfolio*, by uninstalling redundant applications that are underutilised (Energy Star, 2011).

### 3.2.3.6 Applicability

Practices presented can be implemented by most data centres, irrespectively of their size, security level or purpose.

Even if virtualisation is more frequently used in bigger data centres, this technique can also be implemented in smaller server rooms. PrimeEnergyIT project (PrimeEnergyIT, 2011) identified several side effects of virtualisation, which can lead to difficulties while implementing such technique:

- Creation of hotspots within the server room, by changing load density and location;
- Lower stability of the system, because of changes dynamically operated by several operators without a centralised coordination;
- Creation of complex interdependencies between power, cooling and space capabilities, and difficult provisioning.

Consolidation of both storage devices and servers should avoid datasets or applications with security and privacy requirements or highly variable in terms of storage or workload capacities.

### 3.2.3.7 Economics

The table below gives an overview of costs and return estimates for each best practice.

**Table 25: Economics data related to the definition and the implementation of a data management and storage policy**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Implement an effective data storage policy | Human resources from IT services | Purchase of data management systems | Increase of storage available and decrease in energy consumption |
| Deploy grid and virtualisation technologies | Human resources from IT services | Costs for one virtual server (Siebert, 2009):<br>- 9,000€<br>Costs for two servers, to ensure high availability for organisations running critical activities (Siebert, 2009): | Increase of storage available and decrease in energy consumption |

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| | | - Physical server cost: 13,500€<br>- Shared storage: 8,000€<br>- Software: 3,000€ | |
| Consolidate existing services and decommission unnecessary servers | Human resources from IT services | Purchase of software | Savings from decommissioning a single rack (Energy Star, 2011):<br>- Energy: 440€<br>- Operating system licences: 440€<br>- Hardware maintenance costs: 1,320€ |

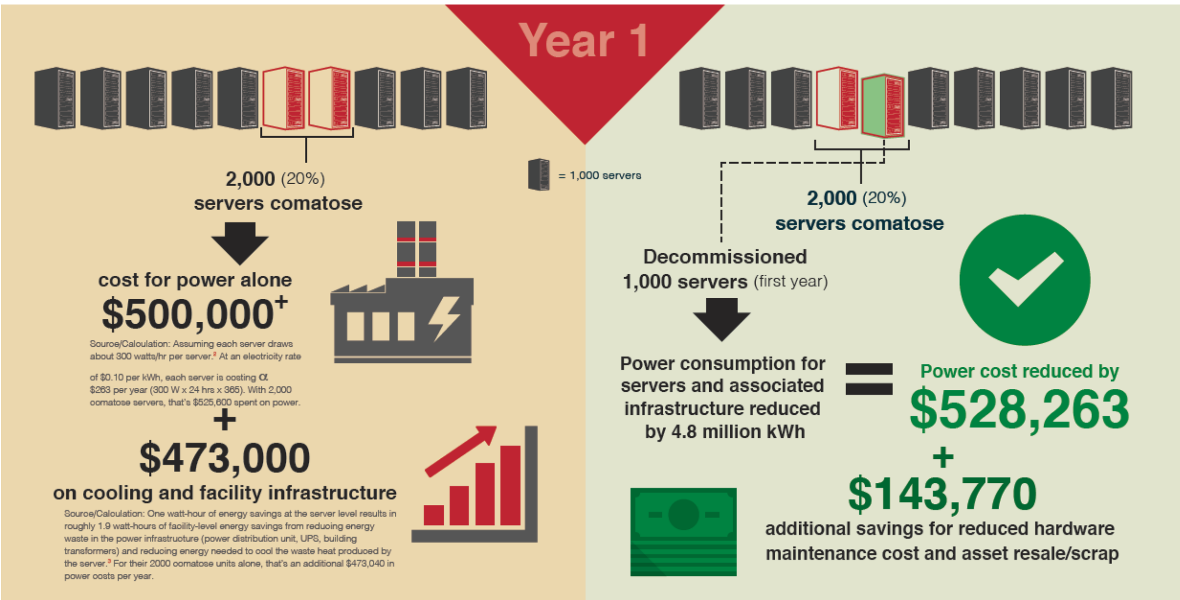


**Figure 48: Cost savings from decommissioning idle servers. Source: (Uptime Institute, 2014).**

The Uptime Institute annually organises a Server Roundup contest where participants have to decommission the higher number of existing servers. The 2013 winners were:

- Barclay's, which decommissioned 9 124 servers, resulting in savings of $4.5M in power costs and €1M in legacy hardware maintenance costs.
- Sun Life Financial, which decommissioned 441 servers, resulting in savings of 88,000€ in power costs.

Specifically, the judicious use of a small amount of solid-state can "take the performance strain" as needed. For example, it can involve the use of fewer high-

performance HDD spindles, which then leads to OPEX and CAPEX savings and less need for active management.

#### *3.2.3.8 Driving force for implementation*

As shown in the paragraph above, consolidation leads to cost savings from lower power consumption, less cooling, less maintenance and fewer operating system licences. Consolidation also leads to reduction of IT equipment numbers and space requirements. Benefits from consolidation largely exceed costs related to software purchasing. Economics represent the major reason for implementing consolidation.

Virtualisation techniques offer a number of advantages for the data centre management (Energy Star, 2011), by:

- improving flexibility;
- reducing downtime, because of a higher availability and disaster recovery solutions (Energy Star, 2011);
- enabling faster deployments (PrimeEnergyIT, 2013) due to an optimisation of the test and development phase (reuse of pre-configured systems, standardised environments, etc.).

#### *3.2.3.9 Reference organisations*

- TIM (ex - Telecom Italia S.p.A.) uses extensive virtualisation in its data centres (TIM, 2011)
- Dassault Systèmes hase virtualised more than 90% of its servers within its principal data centre (Dassault Systèmes, 2016).

#### *3.2.3.10 Reference literature*

Reference literature are consolidated in the section 3.2.7 Reference literature.

The content of this BEMP is based on the techniques which are included in the following chapters of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Data management and storage;
- Selection and deployment of new ICT services;
- Management of existing ICT equipment and services.

### 3.2.4 Improve airflow management and design

**SUMMARY OVERVIEW:**

**The reliability of IT systems depends on environmental conditions (temperature, humidity, dust, etc.) that must be ensured by appropriate control of the indoor air quality. Airflow management for data centres aims at avoiding air recirculation and mixing of cooling air supplied and hot air rejected from equipment. It is considered best practice to:**

- **Implement a hot aisle / cold aisle configuration for ICT equipment to ensure that hardware shares an air flow direction without mixing cold and hot air.**
- **Ensure aisles separation and containment to avoid the recirculation of air around the servers.**
- **Segregate ICT equipment according to their environmental requirement (mainly humidity and temperature) and provide appropriate airflows to separate environmental areas.**
- **Improve the floor and ceiling design to reduce bypass air flow, to prevent re-circulated air, and to reduce obstructions created by cabling or other structures.**
- **Adjust volumes and quality of supplied cooled air to the IT equipment needs (function of heat produced and environmental requirements), and provide a slight oversupply of air to minimise heated air recirculation.**

**Improved airflow management increases both the efficiency and the capacity of the cooling equipment, reduces the utilisation of fans and humidifiers (and their energy consumption) and minimise the production of waste heat.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Air flow efficiency (fan power in kWh / fan airflow in m3/hour)
- Return Temperature Index (identification of air recirculation)
- Flow performance of the air handler (unit less)
- Thermal performance of the air handler (unit less).
- Rack cooling index (difference between allowable intake temperature and the one recommended by ASHRAE)
- Share of racks installed with hot aisle/cold aisle configuration (with containment)
- Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding airflow management and design

| Cross references | |
|---|---|
| **Prerequisites** | • Readiness to engage in retrofitting of the existing building |
| **Related BEMPS** | • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring, and management of ICT and other equipment)<br>• 3.2.3 Define and implement a data management and storage policy<br>• 3.2.5 Improve cooling management<br>• 3.2.6 Review and adjust temperature and humidity settings |

### 3.2.4.1 Description

The reliability of IT systems relies on environment conditions, such as temperature, humidity (to prevent electrostatic discharge and condensation inside servers) or cleanliness (to prevent contamination). The production of heat loads by data centre equipment and the influence of outdoor conditions (sunshine exposure, use of outdoor air for cooling, etc.) affect these parameters. In order to meet the equipment specifications, the inside air quality must be controlled: heated (indoor) air should be removed and cooled (outdoor) air brought in, incoming air should be filtered and inside air humidity should be managed (by humidifying or dehumidifying).

The airflow management intends to maintain the data centre operating environmental envelope and to optimize the functioning of cooling system, humidifiers and filters. It will depend:

- On the data centre architecture, including layout and arrangement;
- On the existing IT equipment performance, and especially on the number and the utilisation rate of devices;
- On the cooling system, and particularly the use of an air-side economiser or not.

Poor airflow management will reduce both the efficiency and capacity of cooling equipment, increase the utilisation of fans and humidifiers (and their energy consumption) and generate excessive waste heat.

Airflow management for data centres includes the design of data centres and the configuration of equipment to minimise or eliminate the mixing of cooling air supplied and the hot air rejected from equipment. Airflow management aims to continuously supply only the necessary amount of cold air for removing the heat created by IT equipment: the entire volume of air has to circulate only one time through IT equipment and has to absorb heat.

It is best practice to (CENELEC, 2016):

- **Implement a hot aisle / cold aisle configuration for ICT equipment.**

  Configuring hot and cold aisles layout ensures that hardware shares an air flow direction without mixing cold and hot air. Specific equipment can be installed to implement a hot aisle / cold aisle configuration, as a return plenum to return heated air from the ICT equipment directly to the air conditioning units.

- **Ensure aisles separation and containment.**

  Containing volumes of air with a different temperature and reducing the circulation of air around the servers allows the separation of cold air from the heated return air. This can be achieved through the deployment of floor layout and equipment deployment as:

  - blanking plates between racks that help minimise waste heat from one device contaminating the intake air of another device;
  - aperture brushes (draught excluders) or cover plates and panels that help minimise all air leakage in each cabinet / rack;
- **Segregate equipment and separate environmental zones.**

  Segregating IT equipment according to their environmental requirement (mainly humidity and temperature) intends to provide appropriate airflows to separate areas. ICT equipment requiring more restrictive temperature or humidity control should be placed in areas with separate cooling systems to enhance the efficiency of the cooling for each zone.

  Separating the data centre's cooling system from the (human) comfort cooling system. This avoids the cooling system set points to be dictated by non IT equipment.
- **Improve the floor and ceiling design to optimize airflow.**

  Raising floor airflow management can contribute to reduce bypass air flow and prevent re-circulated air. Similarly, adjusting suspended ceiling height can minimise fan losses associated with moving air. A good floor and ceiling design reduces obstructions created by cabling and other structures placed in the airflow paths that require additional energy to deliver the required air flow.
- **Adjust volumes and quality of supplied cooled air.**

  When IT equipment is operating, the volumes of supplied cooled air have to be adjusted to the IT equipment needs (function of heat produced and environmental requirements). Supply fans should produce a slight oversupply of air compared to the IT equipment flow demand, in order to minimise heated air recirculation.

#### *3.2.4.2 Achieved environmental benefits*

Improving the energy efficiency related to airflow management is expected to directly **reduce energy consumption** of data centres.

Below are a few estimates of the energy savings related to several of the previous best environmental management practices identified above (42U, NA):

- Aisle containment systems increase the efficiency of the hot/cold aisles arrangement, and can drop energy consumption by 5-10%;
- Blanking panel installation, which aims at improving air flow through the IT equipment and avoiding inefficient airflow around, can reduce energy consumption by 1-2%;
- Floor plenum management intends to avoid air flow obstructions, and can reduce energy consumption by 1-6%;
- Floor layout planning in a hot/cold aisles arrangement can reduce energy consumption by 5-15%.

#### *3.2.4.3 Appropriate environmental performance indicators*

Specific metrics have been developed to monitor airflow management:

- **Air Flow Efficiency** is defined by the Lawrence Berkeley National Laboratory as the total fan power (W) divided by the total fan air flow (m3/hr). This metric measures how efficiently air is moved through the data centre (depending on fan system efficiency, low pressure drop design, etc.).
- **Return Temperature Index** (RTI) has been defined by the Lawrence Berkeley National Laboratory in two ways:
  - The ratio (in percentage) between the air handler temperature drop (C°) and the IT equipment temperature rise (C°), airflow weighted;
  - The ratio (in percentage) between the total airflow rate through the air-handler ($m^3$/h) and the total airflow rate through the IT-equipment (in $m^3$/h).

  An RTI of 100% should be the target goal for an efficient air management system, since a RTI over 100% suggests recirculation of air (creation of "hot spots" which increase the return air temperature) and a RTI less than 100% indicates by-pass of air (the cold air does not contribute to cooling the electronic equipment and returns directly to the air handler). However, calculating such indicator requires numerous temperature sensors or measuring air flow rate which companies usually do not meter.
- **Flow performance** is defined (Tozer et al., 2009; Tozer R. and Flucker S., 2011) as the air handler temperature drop (C°) divided by the difference between the server outlet temperature and the discharge air temperature from the air handler (C°). This metric indicates how much cooled air is really used to cool the IT equipment.
- **Thermal performance** is defined (Tozer et al., 2009; Tozer R. and Flucker S., 2011) as the IT equipment temperature rise (C°) divided by the difference between the server outlet temperature and the discharge air temperature from the air handler (C°). This metric indicates how much of the air used by the IT equipment really comes from the cooling system.
- **Rack Cooling Index** is defined by the ASHRAE as the difference between the allowable and recommended intake temperatures from the ASHRAE guidelines, with the $RCI_{HI}$ as a maximum and the $RCI_{LOW}$ as a minimum. The RCI measures how effectively equipment racks are cooled according to equipment intake temperature guide-lines established by ASHRAE. A RCI over 96% is considered as a good performance (B. Norouzi-Khangah et al., 2016).

Monitoring these indicators requires the installation of specific metering equipment, to measure temperatures, outflows or energy consumption. In case of numerous equipment, specific equipment can be selected for monitoring.

In addition to outcome-oriented indicators, process-oriented indicators can be defined, such as:

- Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding airflow management and design.
- Share of racks installed with hot aisle/cold aisle configuration (with containment). This practice is recommended by the Data Centre Maturity Level from the Green Grid (Level 2 or current best practice) (The Green Grid, 2015).

#### 3.2.4.4 Cross-media effects

Installing new equipment (as blanking panels) requires additional resources and generates additional waste.

#### 3.2.4.5 Operational data

**Implementing a hot aisle / cold aisle configuration**

This technique intends to optimise supply and return air configuration, by ensuring that cold and hot air do not mix. In such an arrangement, the IT equipment is laid out in parallel rows of racks with alternating cold (rack air intake side) and hot (rack air heat exhaust side) aisles between them. Racks are located in a perpendicular way to the aisles and IT equipment with non-standard exhaust directions must be addressed in some way (shrouds, ducts, etc.). An air flow, with the same direction and coming from the cold aisle, is passing through each rack and is exhausted into the hot aisle behind the rack, as shown on the figure below.

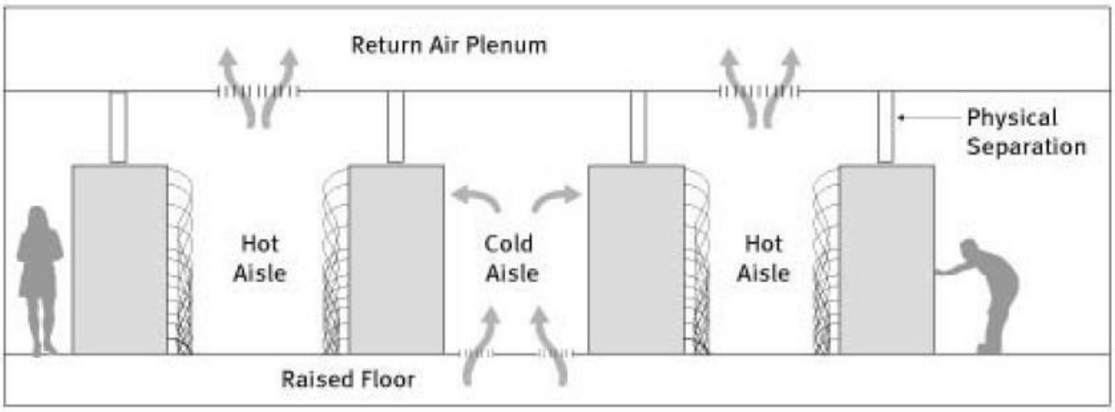


**Figure 49: Hot aisles / Cold aisles approach (source: (Greenberg, 2006))**

Both overhead and under-floor air distribution systems can be used in a hot aisle / cold aisle configuration (U.S. Department of Energy, 2011).

- With an overhead air distribution system, supply outlets should be used (instead of traditional office diffusers) and located in front of racks (above the cold aisle), while return grilles or open ducts can be used for air return.
- With an under-floor air distribution system, because the under-floor plenum is used as a duct, attention should be paid at avoiding obstructions (see the technique of cable management above), at preventing by-pass and negative pressure air flows (see the technique below), and at correctly guiding supply air flows (by installing well vented tiles).

In order to better control the volume of air supplied, the temperature monitoring should be located in front of the computer equipment and variable speed fans should be used (in order to be able to provide optimised air flow at part-load conditions).

**Ensuring aisle separation and containment**

Specific equipment can be installed to improve the_containment of volumes of air with a different temperature and reducing the circulation of air around the servers (U.S. Department of Energy, 2011), and so reinforcing the energy efficiency of a hot aisle / cold aisle arrangement:

- Blanking panel should be installed on the intake side of the rack, where there are vacant equipment slots, in order to block off existing holes through the rack and to reduce air recirculation;
- Cover plates should cover floor or ceiling openings (grommets can be used for sealing cable openings) in order to avoid by-pass and negative pressure flows;
- Enclosing panels should be installed in a way to isolate cold aisles, hot aisles or both from the data centre room (see figure below), and to mitigate "short-circuiting" (the mixing of hot and cold air).

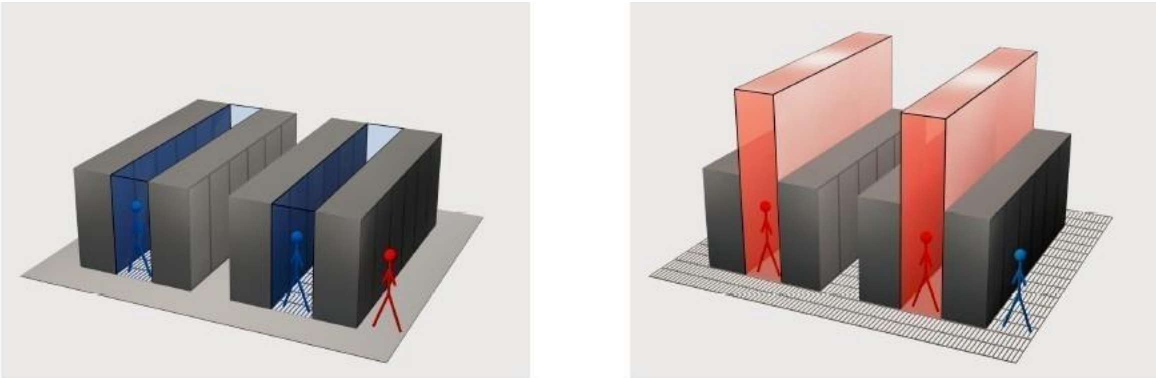

**Figure 50: Cold aisle containment (on the left) and hot aisle containment (on the right)**

Since the supply air volume is dramatically reduced, fan speeds and cold supply can be reduced, and so as the energy consumption related to fans and chiller. Higher return temperatures extend the use of an air-side economiser and facilitate the use of the exhaust air as a heat source. Moreover, higher IT equipment densities are also better supported by this configuration.

**Segregating equipment and separating environmental zones**

Beyond the containment of hot and cold aisles, IT equipment should be segregated according to their environmental requirement. Such a configuration will allow providing appropriate air flows (in terms of humidity and temperature mainly) to separate areas in the data centre room.

The comfort cooling system (providing cooling for offices or technical areas) should be separate from data centre's cooling system: only IT equipment should define the set points of the cooling systems, in order to optimise cooling performances.

**Improving the floor and ceiling design to optimize airflow**

The distribution of cooling air can suffer from interferences under-floor (cable congestion in raised-floor plenums for example) or over-head. This can significantly reduce the airflow and promote the development of hotspots. A cable management strategy aims at minimising air flow obstructions. It should target the entire cooling air flow path and insure a 60 cm clear height within raised floor. The following actions can

be implemented: using overhead cabling, removing abandoned or inoperable cables, etc. (U.S. Department of Energy, 2011).

Ceiling height should be sufficient to enable the use of efficient air cooling technologies such as raised floor, suspended ceiling, aisle containment or ducts.

**Adjusting volumes and quality of supplied cooled air**

Real-time metering should be installed throughout the data centre in order to monitor IT equipment power usage and pressures at different locations of the data centre room: racks (by-pass air flow and recirculation air flow percentage), raised-floors (pressure differentials within plenums) and CRAC/CRAH (air flow supply).

With such measurements fan speed can be adjusted (if multiple speeds fans are used), in order to produce a slight oversupply of air compared to the IT equipment flow demand, in order to minimise heated air recirculation (JRC, 2015).

The air quality inside the data centre and in the surrounding areas should also be monitored to identify particulates or gaseous contaminations (due to industries, forest fires, etc.) which could damage IT equipment. A mitigation strategy may involve filtration, which increases the fan power required.

#### *3.2.4.6 Applicability*

Depending on the characteristics of a data centre, implementing the best practices mentioned in this chapter can be more or less relevant.

For example, segregating equipment and creating separate environmental zones can be particularly interesting in the case of colocation: servers from different companies can require different environmental conditions.

Most of these techniques can only be implemented by the data centre operator, since they require changes in operational conditions, evolutions of the design of the facility or installation of new equipment.

If the best practices identified before can be implemented in data centres of any size, scale effects can be observed in larger data centres with shorter return of investments.

The table below shows that, from an operational point of view, the aforementioned best practices are applicable by any existing data centre, regardless of their size and purpose.

**Table 26: Applicability of air flow management best practices**

| Best practice | Size | Security | Actor |
|---|---|---|---|
| Implement a hot aisle / cold aisle configuration | Any size | Tiers I, II, III[57] | Data centre operator |
| Ensure aisles separation and containment | Any size | Tiers I, II, III | Data centre operator |
| Segregate equipment and separate environmental zones | Any size | Tiers I, II, III | Data centre operator |

[57] The compartmentalisation of Tier IV data centres prevents contamination of waste heat.

| | | | |
|---|---|---|---|
| Improve the floor and ceiling design to optimize airflow | Any size | Tiers I, II, III | Data centre operator |
| Adjust volumes and quality of supplied cooled air | Any size | Tiers I, II, III | Data centre operator |

### 3.2.4.7 Economics

As shown in the table above, designing a hot aisle / cold aisle layout or an efficient floor and ceiling design are energy saving solutions that can be adopted in a majority of data centres (Energy Star, 2014). However, retrofitting an existing data centre layout may have significant costs and designing an appropriate airflow management may require a professional expertise.

**Table 27: Economics data related to the implementation of air flow management best practices**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Implement a hot aisle / cold aisle configuration | NA | Cost of retrofitting the building<br><br>Cost of additional equipment such as return peplum | Energy savings:<br>- Up to 40-45% in annual cooling system energy cos (Niemann, 2011). |
| Ensure aisles separation and containment | NA | Cost of additional equipment such as blanked racks to separate aisles | Energy savings from avoiding spinning up server fans due to the lack of a single blanking panel: 30-250€ (Dell, 2011) |
| Segregate equipment and separate environmental zones | NA | Cost of retrofitting the building | Energy savings |
| Improve the floor and ceiling design to optimize airflow | NA | Cost of retrofitting the building | Energy savings |
| Adjust volumes and quality of supplied cooled air | Monitoring of air pressure | Cost of additional metering equipment | Energy savings |

### 3.2.4.8 Driving force for implementation

The main driving force for implementation of best practices regarding airflow management are the savings obtained from a lesser energy consumption for cooling purposes.

According to the European Commission's Reference Document on Best Available Techniques for Energy Efficiency (European Commission, Reference Document on Best Available Techniques for Energy Efficiency, 2009), other drivers for implementing energy efficiency policy include the improvement of:

- energy efficiency performance and compliance;
- competitiveness, in particular against a trend of increasing energy prices;
- personal motivation;
- company image and reputation.

#### 3.2.4.9 Reference organisations

The data centre of Six Degrees Group Energy Efficient Solutions, located in Birmingham (UK), installed a cold aisle containment system with automatic closing doors. It also provided cost effective Corex (fire resistant) blanking panels to all customers, free of charge. UPS batteries were moved to separate enclosures to increase operating temperature of UPS and electrical switchgear.

The data centre of CSC Sevenoaks (UK) has specific airflow management design. Computer room are divided into low density and high density areas. All data equipment racks are laid out forming hot and cold aisle improving air flow management. To cater for high heat loads produced by blade technology, APC cubes have been deployed where hot air is contained and not allowed to mix with cooled air therefore maximizing cooling ability of the air. The data centre won the Code of Conduct award in 2015.

All data centres of Equinix have a hot aisle and cold aisle configuration with containment (Equinix, 2015).

#### 3.2.4.10 Reference literature

Reference literature are consolidated in the section 3.2.7 Reference literature.

The content of this BEMP is based on the techniques (detailed in Section 3.2.1 and 3.3.1 of this document) which are included in the following chapters of the final version of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Airflow management and design;
- Installation of ICT equipment to optimise airflow management.

### 3.2.5 Improve cooling management

**SUMMARY OVERVIEW:**

**Cooling is needed to remove the heat produced by ICT equipment in a data centre or a network room and to ensure the right operating conditions for ICT equipment to perform reliably. Sizing the necessary cooling system of a data centre depends on the environment where the data centre is located, on the efficiency of the IT equipment used in the data centre and on the airflow management performance. It is considered best practice to:**

- **Maintain the cooling system close to its original condition to preserve its efficiency.**
- **Review and adapt the cooling system capacity by shutting down unused equipment and better taking into account specific equipment operating requirements.**
- **Optimise and automate the cooling system output by connecting CRAC units or suing smart and multifactor units.**

| ICT components | | | | |
|---|---|---|---|---|
| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |

| Relevant lifecycle stages | | | | |
|---|---|---|---|---|
| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |

| Main environmental benefits | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- COP (coefficient of performance): average cooling load (kW) / average cooling system power (kW)
- Share of data centre total energy use dedicated to the cooling system (%)
- Power Usage Effectiveness (PUE)
- Carbon Usage Effectiveness (CUE)
- Water Use Efficiency (WUE)
- Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency (parts 5.2, 5.4 and 5.5) or the Expected Practices of CLC/FprTR 50600-99-1 regarding cooling management

| Cross references | |
|---|---|
| **Prerequisites** | • Commitment from top management |
| **Related BEMPS** | • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)<br>• 3.2.3 Define and implement a data management and storage policy<br>• 3.2.4 Improve airflow management and design<br>• 3.2.6 Review and adjust temperature and humidity settings |

#### 3.2.5.1 Description

Cooling is needed to ensure the right operating conditions for ICT equipment to perform reliably – some IT equipment can only function in a particular range of temperature and humidity. Cooling removes the heat produced by ICT equipment in a data centre or a network room (Rasmussen, 2011). The figure below explains how cooling typically functions for a data centre: a chiller produces chilled water which is provided to a Computer Room Air-Conditioner (CRAC) that refreshes the server room.

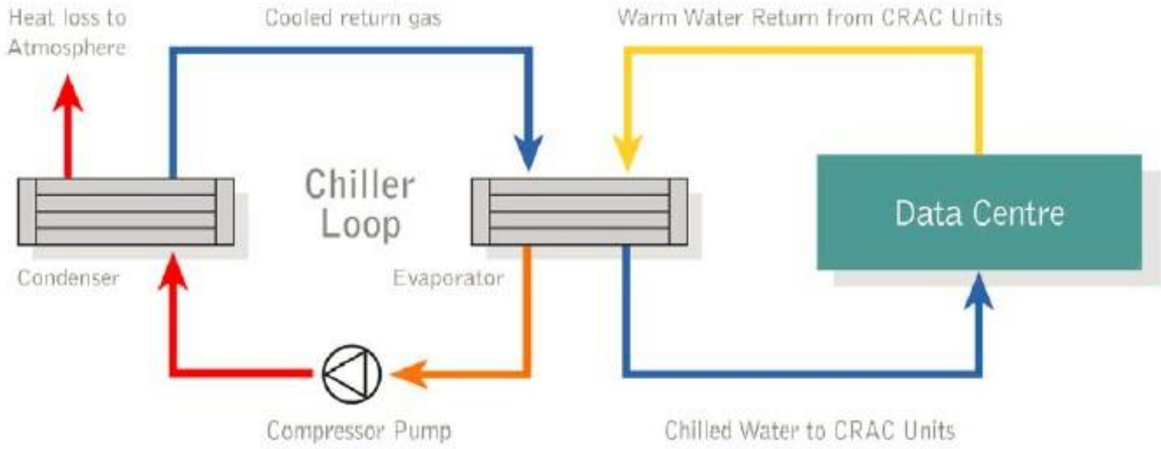


**Figure 51: Simplified chiller schematic - Simplify cooling (Source: (BCS, 2010))**

Sizing the necessary cooling system of a data centre depends on the environment where the data centre is located (see also 3.5.5 Selecting the geographical location of the new data centre), on the effectiveness of IT equipment used in the data centre (see also 3.2.3 Selection and deployment of equipment for data centres) and on the airflow management performance (see also 3.2.4 Improve airflow management and design

In order to improve cooling management of existing data centres, it is best practice to (CENELEC, 2016):

- **Maintain the cooling system close to its original condition.**

  Ensuring an effective regular maintenance of the cooling system allows preserving the system close to its original condition, hence preserving its efficiency.

- **Review and adapt the cooling system capacity.**

  Regular reviews of the cooling system capacity helps monitoring its evolution against its original design. Following a review of capacities, several measures can be decided, such as:

  - shutting down unused equipment (facilitated when the cooling system has been installed in a scalable or modular arrangement),
  - better taking into account specific equipment's operating requirements (temperature and relative humidity settings of CRAC/CRAH units for example).

- **Optimise and automate the cooling system output.**

  Automating the cooling system output allows an optimisation of its performance. Several measures can be taken to optimise and automate the cooling system output, such as connecting CRAC units or using smart, multi-factor units.

Other energy-efficient measures include:

- At a cooling plant level, by:
  - Selecting chillers with high Coefficient Of Performance (COP);
  - Installing the cooling plant in a modular arrangement allowing the shutting down of unused cooling equipment;
  - Creating a thermal storage, where chilled water is used for later use.
  - Design recooler and fans for free cooling conditions up to 18°C (PASM, 2016);
  - Install chillers to reuse ICT-heat in winter in building heating systems (PASM, 2016);
  - Use refrigeration fluid with GWP 1 (e.g. 1234ze).
- At a computer room air conditioner or handler level, by:
  - Selecting cooling units sized to the IT equipment and shutting down unnecessary cooling equipment;
  - Installing fans with variable and automatic speed control in order to facilitate airflow and temperature management;
  - Installing a centralised humidity control (through the humidity of fresh air coming into the building) instead of humidifiers controlled at computer room level.

### 3.2.5.2 Achieved environmental benefits

Improving the energy efficiency of the cooling system is expected to primarily reduce **direct energy consumption** of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply[58].

Mechanical cooling is often considered to be the major part of the overhead energy consumption. It is possible to reduce the mechanical cooling losses to less than 5% of the overall energy consumption, by applying a combined action on chillers and other devices such as water pumps and fans (Newcombe L. , 2011).

### 3.2.5.3 Appropriate environmental performance indicators

The energy efficiency of a cooling technology is measured through indicators that correlate the electricity consumption of the cooling system (kWh) and the cooling energy provided by the cooling system (kWh). The most common metric used to measure the efficiency of cooling systems is the **coefficient of performance or COP** (sometimes CP) which is equal to: **average cooling load (kW) / average cooling system power (kW)** (U.S. Department of Energy, 2011). Higher COPs equate to lower operating costs, with a COP of 1 meaning that the conversion from electricity into heat is 100% efficient. Including heat pumps or free cooling technologies allows for a COP over 1. Best performances can be assessed to be a COP over 7 for water chillers, and over 4 for Direct Expansion (DX) cooling systems (Sustainability Victoria, 2010).

[58] Energy production and transmission generates huge pressure on environment: greenhouse gases emission (related to fossil-fuel burning), water consumption (for running steam-turbine of fossil-fuel and nuclear plant), natural resources consumption (fossil fuels, wood, etc.) or landscape disturbance (plants, electrical lines, etc.).

To assess the energy efficiency of the entire cooling system within the data centre, the following indicators can be monitored:

- **Share of data centre total energy use dedicated to the cooling system (%),** which is the ratio between the energy consumption of the data centre and the energy consumed by the cooling system.
- **Power Usage Effectiveness (PUE),** since the non IT power consumption of data centres is mainly due to the energy consumption of the cooling system (for more information on the PUE, see sub-section 3.2.2.3).

The Green Grid Association developed similar indicators relevant for measuring and comparing environmental performance of data centres:

- The **Carbon Usage Effectiveness (CUE)** is the total $CO_2$ emissions caused by the data centre consumption of energy / IT equipment consumption of energy (The Green Grid, 2010a);[59]
- The **Water Use Efficiency (WUE)** is the annual site water consumption (humidification and water consumption for cooling) / IT equipment consumption of energy (The Green Grid, 2011a).[60]

Besides these outcome-oriented meters, process-oriented indicators can be defined, such as:

- Share of facilities or sites have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency (parts 5.2, 5.4 and 5.5) or the Expected Practices of CLC/FprTR 50600-99-1 regarding cooling management.

#### *3.2.5.4 Cross-media effects*

Energy consumption and second-order environmental pressures (water consumption and GHG emissions) are intimately linked through the different measures described in this section:

- If ambient outdoor air is non-appropriate (e.g. in case of moist climate, forest fire, etc.) when a direct air-side economiser is functioning, that can lead to an indoor air contamination or humidification / drying and affect IT equipment. Humidifiers can be used for maintaining an optimal humidity range but consume energy.

[59] For more information about the CUE: http://www.thegreengrid.org/~/media/WhitePapers/Carbon%20Usage%20Effectiveness%20White%20Paper_v3.pdf?lang=en

[60] For more information about the WUE : http://www.thegreengrid.org/~/media/WhitePapers/WUE

Evaporative cooled chillers allow huge energy savings, but require water. The National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 M litres per MW year (NREL, 2014).

#### *3.2.5.5 Operational data*

An environmentally efficient cooling management can be implemented through different practices. Operational specificities of these practices are presented below.

**Maintaining the cooling system close to its original condition**

The cooling system must be maintained regularly to preserve its original condition, allowing the data centre to match the designed cooling efficiency. A specific attention should be paid to equipment such as belt tension, condenser coil fouling, evaporator fouling and filter changes.

**Reviewing and adapting the cooling system capacity**

Before any change to ICT equipment, a review of the availability of cooling and means of delivery can help optimise cooling resources. On a periodic basis, the consistency of deployment of ICT equipment with respect to the cooling design can be reviewed, which will allow to identify appropriate changes to be made.

Reviewing the cooling system capacity and its evolution against its original design can help identify unused capacities. Idle, non-variable cooling equipment should be shut down or turned off. For instance, non-variable equipment such as fixed speed fan CRAC units may be turned off if the facility is not yet fully populated or space has been cleared through consolidation. Installing the cooling system in a modular arrangement makes shutting down of unused equipment easier.

A review of the cooling system capacity can also help identify how operating requirements of equipment must be taken into account. Some ICT equipment requires more restrictive temperature and humidity controls than other. This is for instance the case for UPS, where battery capacity and lifetime must be maintained; tape, where archival criteria are crucial; or any equipment which require tight environmental monitoring to meet long warranty durations. Separating this sensitive equipment from less demanding equipment allows the optimisation of the cooling efficiency of each zone. Consequently, the whole cooling system does not need to be adjusted to the needs of the most restrictive equipment. A differentiated environmental management (temperature, humidity setting) can also be implemented to answer to clients' demands. Computer rooms can be designed to enable areas with additional control for clients requiring a tight environmental monitoring. Areas with additional control can be priced differentially to cover additional costs. Of course, these practices apply to data centre operators that offer their computing or storage space, not for companies that manage their own data centres.

**Optimising and automating the cooling system output**

Several measures can be taken to optimise and automate the cooling system output, such as connecting CRAC units or using smart, multi-factor units. Many CRAC units now have the ability to connect their controls and run together when installed in the same area to avoid working against each other. Specific attention should be paid to avoid potential new failure modes or single points of failure that may be introduced. A dynamic control of the cooling system can also be implemented. A dynamic cooling system takes into account several factors in real time, such as cooling load, room air temperature and external air temperature.

Finally, the chilled water temperature set-points can be increased to maximise the use of free cooling economisers and reduce compressor energy consumption. Set-points should be raised together with supply air flow set-points to avoid reducing capacity.

#### 3.2.5.6 Applicability

Maintaining the cooling system and carrying out regular reviews of its capacities can be done in most data centres, irrespectively of their size, security level or purpose.

However, automating the cooling system output can imply costs to purchase smart equipment, making it more appropriate for large size data centres.

**Table 28: Applicability of cooling management best practices**

| Best practice | Size | Security | Purpose |
|---|---|---|---|
| Maintaining the cooling system close to its original condition | Any size | Any tier | Any purpose |
| Reviewing and adapting the cooling system capacity | Any size | Any tier | Any purpose |
| Optimising and automating the cooling system output | Localized to enterprise-class data centre | Any tier | Any purpose |

It must be noted that specific regulation and environmental guidance can conflict with the decrease of cooling needs. For instance, BREEAM and LEED give points for increasing insulation of data centres. An increased insulation of data centres will require additional cooling needs since the heat produced by servers cannot dissipate.

#### 3.2.5.7 Economics

The table below gives an overview of costs and return estimates for each best practice.

**Table 29: Economics data related to the implementation of cooling management best practices**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Maintaining the cooling system close to its original condition | Maintenance costs | NA | Energy savings due to the cooling system working at the designed efficiency |
| Reviewing and adapting the cooling system capacity | Review costs | Cost of designing a modular arrangement | Energy savings due to decreased consumption |
| Optimising and automating the cooling system output | NA | Cost of smart | Energy savings due to decreased consumption: |

| | | | |
|---|---|---|---|
| | | equipment | - Automatically adjusting fan speeds can result in energy savings as high as 30% of the total cooling cost (CES Group, 2014)<br>Real-time update on problems in the functioning of equipment |

#### 3.2.5.8 Driving force for implementation

Similarly to the driving forces at work in the previous BEMPs, cost savings are considered to be the main driver for implementing best environmental management practice related to cooling technology and systems.

#### 3.2.5.9 Reference organisations

The PrimeEnergyIT Project supported by the Intelligent Energy Europe Programme (PrimeEnergyIT, 2012) produced case studies about implementing different free cooling solutions. The organisations selected for these case studies were:

- Emerson Network Power Knürr GMbH (Germany)
- ALTRON (Czech Republic)
- Laboratoire de Physique Subatomique et de Cosmologie (France)
- University of Coimbra (Portugal)
- CSC LOEWE Frankfurt (Germany)
- Technical University of Dresden (Germany)
- Esselunga (Italy)
- Electroson (Spain)

#### 3.2.5.10 Reference literature

Reference literature are consolidated in the section 3.2.7 Reference literature.

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Cooling management.

### 3.2.6 Review and adjust temperature and humidity settings

**SUMMARY OVERVIEW:**

**ICT facilities are often overcooled, and the server intake temperature set point can be raised within the recommended or allowable temperature ranges (given in the manufacturer specifications) in order to reduce the cooling capacity and the energy consumption of the cooling system.**

**A similar situation is generally observed regarding humidity, and the energy and water consumption of humidifiers can be reduced by allowing a broader range of humidity levels.**

**It is therefore considered best practice to:**

- **Review and raise temperature set points of cooling systems if practical, to reduce cooling needs and maximise the use of economisers.**
- **Review and change humidity settings of cooling systems if practical, to reduce the needs for humidifiers.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Airflow Efficiency (fan power in kWh / airflow in $m^3$/hour)
- Return Temperature Index (RTI)
- Share of facilities or sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding temperature and humidity settings

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)<br>• 3.2.3 Define and implement a data management and storage policy<br>• 3.2.4 Improve airflow management and design<br>• 3.2.5 Improve cooling management |

### 3.2.6.1 Description

To properly operate, IT equipment has standardized operating environments (temperature, humidity and air quality) that must be maintained. The standardised operating environments for different types of equipment are set forth by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)[61]. These specifications give the optimal temperature and humidity set points for standard equipment, regarding its operational performances (e.g. reliability, energy consumption, etc.). The last set of values published by the ASHRAE in 2011 is given on the figure below (class A1 refers to enterprise servers and some storage products, while class A2 refers to volume servers and workstations in an IT space, etc.). The 2011 specifications confirm the widening of recommended and allowable values given by the ASHRAE (compared to the 2004 and 2008 sets of values).

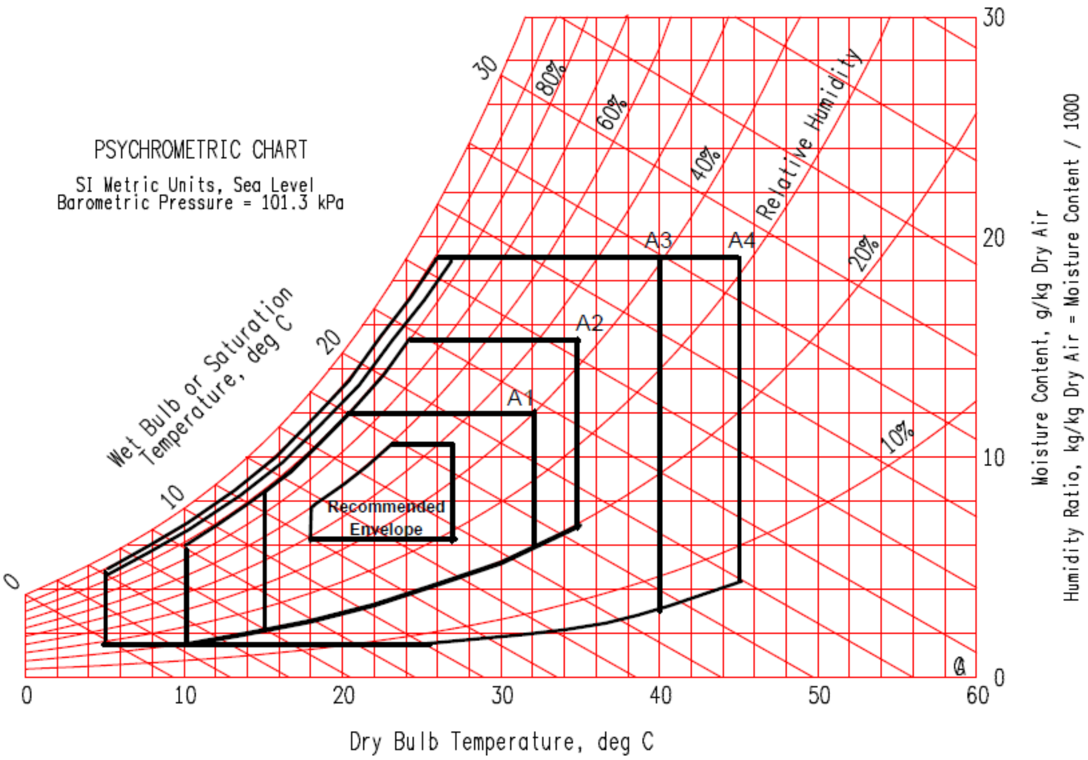


**Figure 52: ASHRAE environmental classes for data centres (ASHRAE, 2011)**

Usually, facilities are overcooled, and the server intake temperature can be raised within the recommended or allowable temperature ranges. Such increase of inlet temperature should be performed gradually (careful metering of potential or existing hot spots) and take into account manufacturer specifications. These changes can reduce the capacity of the cooling system needed (and so the size and / or the number of units) and the energy consumption related to cooling supply and fan speed. The use of an air-side or a water-side economiser can be facilitated by increasing the number of potential hours of free cooling.

[61] The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) signed a memorandum of understanding in order to strive to harmonize international standards with the ASHRAE. We assumed that the operating environment parameters were similar.

Regarding temperature and humidity settings, it is best practice to (CENELEC, 2016):

- **Review and raise temperature set points if practical.**

  Because many data centres are overcooled, several measures can be taken to increase efficiency. Thermal sensors can be installed to evaluate the performance of the cooling system. Temperature set points should aim at meeting IT equipment's requirements (and not unnecessarily meet human comfort standards), without overcooling the building:

  - ICT equipment intake air temperature should be raised if possible, to reduce cooling needs;
  - Chiller water temperature set-points should be raised if possible, to maximise the use of free cooling economisers and reduce compressor use.

- **Review and change humidity settings.**

  High humidity is a concern for IT equipment reliability as moisture can damage components within the server. Humidity settings should be reviewed to widen the working humidity range, hence decreasing energy consumption. Humidity should be monitored at racks and CRAC/CRAH level to optimise humidification and dehumidification. In addition, thanks to specific equipment, humidity control can be better coordinated, or optimised by the adoption of an adiabatic humidifier.

Adjusting volumes and quality of supplied cooled air is another good practice regarding temperature and humidity settings in a data centre. This practice is presented in section 3.2.4 on airflow management and design.

#### *3.2.6.2 Achieved environmental benefits*

Up to a certain point, raising server inlet temperature reduces energy consumption, due to a reduction of cooling need (similarly to humidity). Energy savings related to changes in inlet temperature will depend on the initial inlet temperature (how far from the optimal temperature) and on the equipment's own characteristics (Moss & Bean, 2013; 42U, NC).

Although this is mostly valid, a paper published by the Chartered Institute for IT found that there is no significant reduction in overall energy consumption from "increasing the IT equipment environmental range from the existing ASHRAE Class 2 (up to 35°C and 80% relative humidity or 21°C dew point) to the ETSI environmental range (up to 45°C and 80% relative humidity, no dew point limit)" (Newcombe L. , 2011).

#### *3.2.6.3 Appropriate environmental performance indicators*

Performance indicators used in the management of temperature and humidity settings include:

- **Airflow Efficiency** (see BEMP 3.2.4 on airflow management and design);
- **Return Temperature Index** (RTI) (see BEMP 3.2.4 on airflow management and design).

A process-oriented indicator that can be monitored is:

- Share of facilities or sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the/ Expected Practices of CLC/FprTR 50600-99-1 regarding temperature and humidity settings

### 3.2.6.4 Cross-media effects

Raising operational temperature settings in a data centre for an energy efficiency purpose can only be done up to a certain point (The Green Grid, 2013) since:

- The server power utilisation increases above a certain temperature (roughly 25C°), due to higher server fan power consumption (required to cool IT components) and to an increased silicon electrical leakage current;
- The server fan noise increases as the fan rotation speed increases to move the more important amount of air need at higher operating temperatures;
- The exhaust air temperature can be inadequate for operational working practices within hot aisles (the temperature can reach 50°C);
- The relative server failure rate slightly increases with temperature, and so the lifetime of the IT equipment reduces. At higher operating temperatures the IT equipment should be replaced more often, and the consumption related to manufacturing (raw materials, embodied energy, water, etc.) and the WEEE production would be more important.

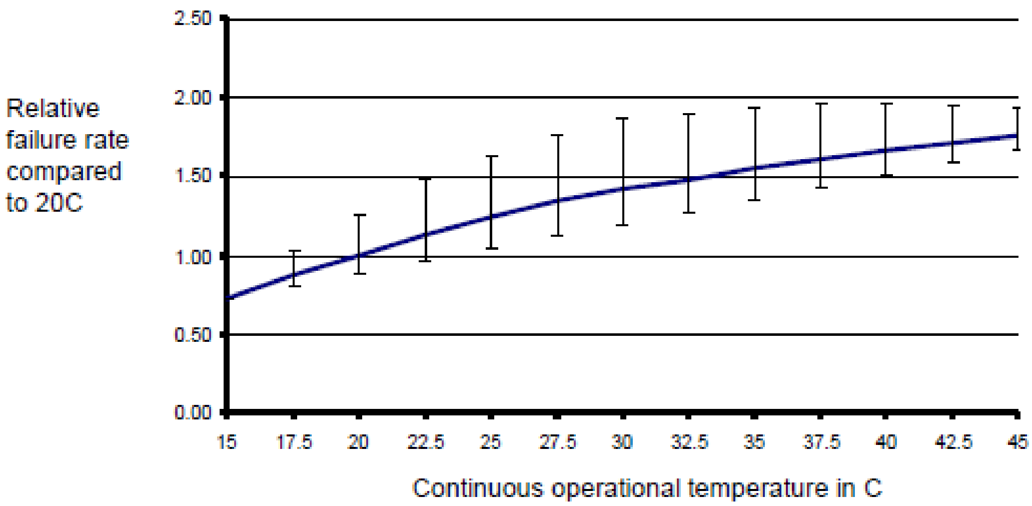


**Figure 53: Relative server failure rate with temperature (ASHRAE, 2011)**

### 3.2.6.5 Operational data

An environmentally efficient cooling management can be implemented through different practices. Operational specificities of these practices are presented below.

**Reviewing and raising temperature set points if practical**

The whole Heating, Ventilation and Air-Conditioning unit should use the server intake temperature as the set point temperature (and not the return air temperature entering the CRAC/CRAH for cooling). However thermal sensors should also be installed in other locations (supply and return temperature at CRAC/CRAH level, chilled water temperature, etc.) in order to evaluate the thermal performance of the cooling system. Wireless sensor network solutions have the advantage to be quickly deployed and easily adapted to IT equipment changes in the data centre. A centralised control system can avoid competition between the different units forming the cooling system.

The temperature set points should meet IT equipment needs, depending on heat produced and environmental requirements. The standardised operating environments for different types of equipment are set forth by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)[62]. These specifications give the optimal temperature and humidity set points for standard equipment, regarding its operational performances (reliability, energy consumption…).

Usually, facilities are overcooled, and the server intake IT equipment can be raised within the recommended or allowable temperature ranges. Such increase of inlet temperature should be performed gradually (careful metering of potential or existing hot spots) and take into account manufacturer specifications. These changes can reduce the capacity of the cooling system needed (and so the size and / or the number of units) and the energy consumption related to cooling supply and fan speed. The use of an air-side or a water-side economiser can be facilitated by increasing the number of potential hours of free cooling.

In order to further increase temperature set points, technical areas of data centres should be considered as industrial space (instead of setting temperature according to human comfort). This means that these rooms must be designed and operated with the primary objective of delivering high availability ICT services reliably and efficiently rather than for seated human comfort. As such these spaces may only require the control of make-up air volumes and environmental conditions to pressurise the spaces in order to avoid ingress of particles and contaminants. These areas should not contain desks or workstations.

However, it must be noted that raising set point temperature or widening humidity range of servers can only be done within the operational specification given by the server manufacturer and within acceptable working conditions (depending on containments and separations implemented). Also, increasing the intake air temperature of servers will have more impact on the energy consumption of data centres using air-side economisers (more hours of free-cooling are available) or variable speed fans (a reduced speed fan for CRACs can be used) (Energy Star).

| **Case study**<br>**Implementation of best practices regarding temperature set points** | |
|---|---|
| **Operator of the data centres** | **Technical characteristics and context** |
| The Green Grid and a Green Grid member company in 2010 (The Green Grid, 2011b) | Surface: 3 100 m²<br>Number or racks: 900<br>This data centre comprises approximately 900 ICT racks, comprised of approximately 85% ICT server racks and 15% other floor mounted devices (such as non-standard pre-packaged racks or storage devices) within the data centre. The data centre contains a total of 44 CRAH. |

[62] The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) signed a memorandum of understanding in order to strive to harmonize international standards with the ASHRAE. We assumed that the operating environment parameters were similar.

| Practice implemented | Results |
|---|---|
| One of the upgrades of the data centre consisted in an adjustment of the temperature set-points of the CRAH sensors and the chiller units.<br><br>The chiller plant leaving water temperature was increased by 16.7°C, and then the supply air temperature was ultimately increased by 16.1°C. 180 man-hours were required to make the necessary adjustments. | By increasing the inlet air temperature to ICT equipment, the data centre saved energy because the chilled water temperature into the data centre increased. This in turn allowed the chiller plant to run more efficiently because the temperature of the water does not have to be lowered as much.<br><br>Eventually, this triggered savings of over 893,000 kWh per year, i.e. a PUE improvement from 1.71 to 1.69. |

**Adjusting volumes and quality of supplied cooled air**

Real-time metering should be installed throughout the data centre in order to monitor IT equipment power usage and intake temperature, and pressures at different locations of the data centre room: racks (by-pass air flow and recirculation air flow percentage), raised-floors (pressure differentials within plenums) and CRAC/CRAH (air flow supply). With such measurements fan speed can be adjusted (if multiple speeds fans are used), in order to produce a slight oversupply of air compared to the IT equipment flow demand, in order to minimise heated air recirculation (JRC, 2015).

The air quality inside the data centre and in the surrounding areas should also be monitored to identify particulates or gaseous contaminations (due to industries, forest fires, etc.) which could damage IT equipment. A mitigation strategy may involve filtration, which increases the fan power required.

**Reviewing humidity settings**

Humidity should be monitored at racks and CRAC/CRAH level, in order to optimise the operation of humidification and dehumidification. Equipment specifications related to humidity range should be met: most of the modern IT equipment is usually designed to operate in an environment with a humidity comprised between 20 and 80%. The wider humidity range (as the one given by the ASHRAE on the figure above) should be used in order to reduce the demand for humidification and the humidifiers load (in accordance with recommended environmental conditions).

Centralising the humidity control by using a centralised signal which will coordinate all the units in a same room to be in the same mode (humidification or dehumidification) and avoid competitions (one unit is dehumidifying and one other is humidifying).

Further energy savings can be reached (PG&E, 2012) by switching from a standard humidifying system (most often integrated into a CRAC/CRAH unit) to an adiabatic humidifier or to an evaporative cooling system, which will be able to humidify and cool at the same time.

#### *3.2.6.6 Applicability*

Raising temperature set points, adjusting volumes and quality of supplied cool air, and reviewing humidity settings can be done in most data centres, irrespectively of their size, security level or purpose.

Raising set point temperature or widening humidity range of servers can only be done within the operational specification given by the server manufacturer and within

acceptable working conditions (depending on containments and separations implemented). Increasing the intake air temperature of servers will have more impact on the energy consumption of data centres using air-side economisers (more hours of free-cooling are available) or variable speed fans (a reduced speed fan for CRACs can be used) (Energy Star).

### *3.2.6.7 Economics*

The table below gives an overview of costs and return estimates for each best practice.

**Table 30: Economics data related to the implementation of temperature and humidity settings best practices**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Raising temperature set points | NA | No additional cost if the equipment is already capable of working in a broader temperature range<br><br>Selection of ICT equipment with a broader working range | Savings from decreased energy consumption from cooling |
| Adjusting volumes and quality of supplied cooled air | NA | Cost of monitoring equipment | Savings from decreased energy consumption from cooling |
| Review humidity settings | NA | Cost of monitoring equipment : because humidity sensors are often integrated in temperature sensors, this cost is typically very low | Savings from decreased energy consumption from humidification |

### *3.2.6.8 Driving force for implementation*

Similarly to the driving forces at work in part 4.2, the main driving forces for implementation are:

- Savings from direct energy consumption, by reducing the power consumption of ICT equipment (e.g. by removing equipment supporting unused services);
- Savings from indirect energy consumption, by reducing the power consumption of supporting equipment, such as the cooling system (e.g. by increasing the ICT equipment intake air temperature, widening the working humidity range and raising chilled water temperature).

According to the European Commission's Reference Document on Best Available Techniques for Energy Efficiency (European Commission, Reference Document on Best

Available Techniques for Energy Efficiency, 2009), other drivers for implementing energy efficiency policy include the improvement of:

- energy efficiency performance and compliance;
- competitiveness, in particular against a trend of increasing energy prices;
- personal motivation;
- company image and reputation.

### 3.2.6.9 Reference organisations

Among other practices, the Institute of Research and Technology in Rennes (France) raised cold aisle temperature set point to 25°C. This data centre received an EU Code of Conduct award in 2016 (JRC, 2016).

### 3.2.6.10 Reference literature

Reference literature are consolidated in the section 3.2.7 Reference literature.

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Temperature and humidity settings.

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## 3.3 BEMPs related to selecting and deploying new equipment for data centres

### 3.3.1 Scope and structure of BEMPs related selecting and deploying new equipment and services for data centres

In order to have an energy-efficient data centre, the individual equipment and ICT services need to be energy efficient.

The following best environmental management practices (BEMPs) could be considered to improve the energy efficiency of individual equipment and ICT services used in data centres:

**Table 31: Structure of BEMPs related to data centres and relationship to the CLC/FprTR 50600-99-1**

| **BEMPs related to selecting and deploying new equipment and services in data centres**<br>• Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/FprTR 50600-99-1 | |
|---|---|
| **Techniques from EU CoC / CLC/FprTR 50600-99-1**[63] | **BEMP** |
| **Selection and deployment of new ICT equipment** | |
| • Include energy efficiency performance when choosing new ICT equipment *(5.16.28)*<br>• Purchase ICT equipment which operates within higher temperature and humidity ranges *(5.16.29) (5.16.30) (6.16.122)*<br>• Select ICT equipment suitable for the data centre power density and cooling delivery capabilities *(5.16.31)*<br>• Select ICT equipment which performs the required task within the lowest power consumption in the expected environmental conditions (temperature and humidity) *(5.16.32)*<br>• Select ICT equipment suitable for the airflow direction in the area in which it is to operate *(5.16.33)*<br>• Enable power management features on ICT equipment *(5.16.34)*<br>• Provision power and cooling to meet the as-configured power consumption requirement of the ICT equipment based on the components installed rather than the power supply unit or nameplate rating *(5.16.35)*<br>• Use the EnergyStar labelling programmes as a guide to selecting the most efficient ICT equipment *(5.16.36)*<br>• Select ICT equipment that is capable of reporting energy consumption and inlet temperature *(5.16.37)*<br>• Restrict the use of free standing ICT equipment or ICT equipment supplied in custom enclosures to areas where the airflow direction of the enclosure matches the airflow design in the area (e.g. front to rear or front to top) *(5.16.38)*<br>• Select ICT equipment containing high efficiency AC/DC power | **Selection and deployment of equipment for data centres (Section 3.3.2)**<br><br>For general BEMPs related to procurement of ICT equipment and services refer to:<br>▪ Procurement of sustainable ICT products and services (Section 2.3) |

[63] The EU Code of Conduct distinguishes between 'Expected Practices' (identified by the codes starting with 5.1); 'Optional or Alternative Practices' (identified by the codes starting with 6.1); and, 'Practices under consideration' (identified by the codes starting with 7.1).

| | |
|---|---|
| converters *(5.16.39)*<br>• Select ICT equipment which provides mechanisms to allow the external control of its energy use *(6.16.123)*<br>• Operate direct liquid cooled devices with supply coolant liquid temperatures sufficient to meet manufacturers' minimum cooling requirements *(6.16.124)* | |
| **Management of existing ICT equipment and services** | |
| • Virtualise and archive legacy services *(6.16.125)*<br>• Consolidation of existing services *(6.16.126)*<br>• Identify and decommission low business value services *(6.16.127)*<br>• Shut down and remove or put into a low poser 'sleep' state servers, networking and storage equipment that are idle *(6.16.128)*<br>• Use resource management systems capable of analysing and optimising where, when and how ICT workloads are executed and their consequent energy use *(6.16.129)* | Refer to:<br>Define and implement a data management and storage policy (Section 3.2.3) |
| **Selection and deployment of new ICT services** | |
| • Deploy grid and virtualisation technologies wherever possible to maximise the use of shared platforms *(5.16.40)*<br>• Reduce ICT equipment resilience level *(5.16.41)*<br>• Restrict the deployment of standby ICT equipment to the situations where the business need demands additional resilience (reduce hot/cold standby equipment) *(5.16.42)* | Refer to:<br>Define and implement a data management and storage policy (Section 3.2.3) |
| **Installation of ICT equipment to optimise airflow management** | |
| • Align ICT equipment in the computer room space(s) in a hot/cold aisle configuration *(5.16.43)*<br>• Install cabinets with either no doors or doors with at least 66% perforated area where a hot/cold aisle configuration is implemented *(5.16.44)*<br>• Deploy groups of ICT equipment with substantially different environmental (temperature and humidity operating ranges) requirements and / or equipment airflow direction in separate areas *(5.16.45)* | **Improve airflow management and design (Section 3.2.4)** |

NB:

- Expected practices are reported in black, and optional practices are presented in grey.
- For an updated list of best practices, see the latest version of CENELEC Technical Report *CENELEC technical report CLC/TR 50600-99-1:2016*.

The ensuing sections will describe the following BEMPs:

- Implement a green procurement policy;
- Select energy-efficient server and storage equipment;
- Select energy-efficient cooling equipment;
- Select energy-efficient power equipment.

This chapter on BEMPs related to the selection and deployment of equipment and services in data centres provides practice-oriented information to data centre

operators that wish to improve the energy performance of their existing data centres. Only direct aspects of energy, i.e. those controlled by the data centre operator, are covered and the focus is mainly made on the operation of data centres. Colocation providers and customers as well as other suppliers and customers of ICT services may also find the BEMPs described here useful to support the procurement of services that meet their environmental or sustainability standards.

### 3.3.2 Selection and deployment of green equipment for data centres

**SUMMARY OVERVIEW:**

**The selection and deployment of ICT devices as well as cooling and power supply equipment needs to be based on an integrated strategy to minimise their overall environmental performance (energy use, water use, embodied energy, resource efficiency). It is considered best practice to:**

- **Implement a green procurement policy specific to data centres equipment, from process preparation to bid evaluation.**
- **Select and install environmental-performant servers and storage equipment; i.e. equipment with enable power management features, equipment suitable for the data centre power density and cooling delivery capabilities, equipment meeting the expected environmental conditions (temperature and humidity), etc.**
- **Select environmental-performant cooling equipment; i.e. equipment with high CoP or variable speed controls, appropriately sized cooling units, centralised cooling systems, economisers, etc..**
- **Select environmental-performant power equipment; i.e. highly efficient UPS, modular UPS, etc.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | **Selection and procurement of the equipment** | Operation and management | **Renovation and upgrades** | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Share of ICT products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, EnergyStar, sourced renewable energy, etc.)
- Share of suppliers with an environmental management system or energy management system in place (e.g. EMAS verified, ISO 14001 or ISO 50001 certified)
- Share of facilities that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding the selection and deployment of new IT equipment / power equipment / cooling equipment
- Average energy efficiency of UPS (given by manufacturers)
- Average COP of cooling equipment (given by manufacturers)

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 2.3 Procurement of sustainable ICT products and services |

### 3.3.2.1 Description

ICT and other energy-using equipment in data centres should be selected on the basis of their energy and environmental performance. When purchasing new equipment, specific energy efficiency or environmental criteria can be defined.

Regarding the selection and deployment of equipment for a data centre, it is best practice to (CENELEC, 2016):

- **Implement a green procurement policy.**

  A green procurement policy can be implemented in order to cover all steps of the procurement phase, from process preparation to bid evaluation. Such a process can be applied to all types of equipment, namely ICT equipment, cooling equipment and power equipment.

**Table 32: An overview of the main priority equipment, software and services relevant for the procurement of sustainable data centres equipment**

| ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|
| Servers and storage equipment | • Benchmark performance of the environmental performance of equipment<br>• Select more energy efficient equipment, e.g. purchasing ecolabelled equipment such as EnergyStar<br>• Select equipment that have extended operating temperature and humidity ranges that allow free cooling<br>• Select equipment with power management features and allows external control of energy use<br>• Select equipment suitable for the data centre airflow direction<br>• Select with power and inlet temperature reporting capabilities<br>• Purchase of products easily reparable or recyclable with less hazardous materials | • Energy consumption (and $CO_2$ emissions)<br>• Material consumption and waste management<br>• Toxicity |
| Cooling system equipment and air handling equipment | • Select appropriately sized cooling units<br>• Select more energy efficient equipment such as:<br>- chillers with high Coefficient of Performance<br>- equipment with variable speed (or frequency) controls for compressors, pumps and fans<br>- direct liquid cooled devices<br>• Select equipment that use natural refrigerants or with low ozone depleting potential<br>• Select appropriately sized air handling units<br>• Select more energy efficient equipment such as equipment with variable speed (or frequency) controls for fans | • Energy consumption (and $CO_2$ emissions)<br>• Ozone depleting substances and GHG emissions (from refrigerants) |

| ICT equipment | Procurement options | Environmental hotspots |
|---|---|---|
| Power supply equipment | • Select more energy efficient equipment, e.g. .g. purchasing ecolabelled equipment such as EnergyStar, SERT or SPECPower; or following the EU Code of Conduct for external power supplies and Uninterruptible Power Systems (UPS)<br>• Select equipment containing high efficiency AC/DC power converters (rated at 90% power efficiency) | • Energy consumption (and $CO_2$ emissions) |

- **Select and install environmental-performant servers and storage equipment.**

  Direct energy efficiency performance criteria should be included when selecting new ICT equipment, as ICT equipment with enable power management features (including external controls), ICT equipment containing high efficiency AC/DC power converters or ICT equipment labelled EnergyStar.

  When selecting new ICT equipment, characteristics of the data centre should also be taken into account, to perform the required tasks within the lowest power consumption. ICT equipment should be suitable for the data centre power density and cooling delivery capabilities, and should meet the expected environmental conditions (temperature and humidity) and airflow direction in the area in which it is to operate.

  Purchasing ICT equipment which operates within higher temperature and humidity ranges can reduce cooling needs and allow for a higher utilisation of free cooling. Then it can reduce indirectly energy consumption.

- **Select and install environmental performant cooling equipment.**

  Selecting and installing energy-efficient cooling equipment covers several types of practices:

  - Selecting cooling equipment with high Coefficient of Performance (for chillers), and with variable speed (or frequency) controls for compressors, pumps and fans to maximise its efficiency under partial load conditions;
  - Selecting appropriately sized cooling units and define its set-points on the basis of ICT equipment requirements;
  - Installing a specifically-designed central air handler system, which is a more efficient alternative than a multiple distributed unit system;
  - Implementing free cooling, by installing air or water side economisers that use cool ambient conditions to remove heat from the compressor;
  - Implementing direct liquid cooling.

- **Select and install environmental-performant power equipment.**

  The deployment of energy efficient power equipment is based on:

  - The selection of electrical equipment which is highly efficient (including static UPS systems that are compliant with the EU Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems) and which does not itself require cooling in normal operation;

- The specification and installation of modular (scalable) UPS systems, to better adapt the power provision to the evolution of power consumption requirement (function of ICT and cooling equipment installed);
- The deployment of UPS units in their most efficient operating modes.

In addition to ICT, cooling and power equipment, best practices can be implement for other components of a data centre. For instance, low energy lighting systems can be deployed, and pale colours can be used on walls, floors and cabinets to reduce the amount of lighting required.

### 3.3.2.2 Achieved environmental benefits

Selecting energy-efficient technologies (cooling, power supply, IT, etc.) is expected to primarily reduce **direct energy consumption** of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply[64].

- Installing an air-side economiser system can reduce data centre cooling energy consumption by over 60% (PG&E, 2012).
- Chilled water plant energy consumption can be reduced by up to 70% when using an indirect fluid-economiser (PG&E, 2012) which can minimise the load on the primary cooling system or entirely stop the need for the chiller or compressor.

Besides energy savings, efficient cooling technologies and systems can also reduce other environmental pressures:

- **Direct water consumption**, related to the use of evaporative cooled chillers which use the evaporation of water as a heat rejection mechanism. Freshwater usage is a concern (particularly in dry areas) and the amount of sediment in a given volume increases as vapour is removed, requiring separation and disposal of this "blowdown." Some data centres have implemented techniques for using non-utility water sources cooling or other non-potable purposes: rainwater, wastewater or seawater have already been used.
- **Direct greenhouse gases emissions**, via refrigerant gases leakages from condensers. The use of synthetic chlorofluorocarbon (CFC) refrigerant gases in cooling plants resulted in significant impacts to the ozone layer. These gases were substituted by hydrofluorocarbons (HFC) which are now being targeted for replacement due to their high contribution to global warming. Free cooling concepts lead to the non-utilisation of refrigerants with a large Global Warming-Potential (e.g. R410A has a GWP of 1.725).

### 3.3.2.3 Appropriate environmental performance indicators

Indicators to monitor the implementation of green procurement policy include:

- **Share of ICT products or services purchased by the company complying with specific environmental criteria** (e.g. EU Ecolabel, Energy Star, Blue Angel, etc.)

[64] Energy production and transmission generates huge pressure on environment: greenhouse gases emission (related to fossil-fuel burning), water consumption (for running steam-turbine of fossil-fuel and nuclear plant), natural resources consumption (fossil fuels, wood, etc.) or landscape disturbance (plants, electrical lines, etc.).

- **Share of suppliers with an environmental management system** (e.g. EMAS, ISO 14001, ISO 50001, etc.)
- **Share of suppliers that have an environmental management system or energy management system in place** (e.g. EMAS verified, ISO 14001 or ISO 50001 certified)
- **Share of facilities that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency** or the Expected Practices of CLC/FprTR 50600-99-1 regarding the selection and deployment of new IT equipment / power equipment / cooling equipment

Specific indicators can also be defined to assess and monitor the performance of specific equipment, such as:

- **Average energy efficiency of UPS** (given by manufacturers);
- **Average COP of cooling equipment** (see BEMP 3.2.5 Improve cooling management).

### 3.3.2.4 Cross-media effects

Energy consumption and second-order environmental pressures (water consumption and GHG emissions) are intimately linked through the different measures described into this section

- If ambient outdoor air is non-appropriate (e.g. in case of moist climate, forest fire, etc.) when a direct air-side economiser is functioning, that can lead to an indoor air contamination or humidification / drying and affect IT equipment. Humidifiers can be used for maintaining an optimal humidity range but consume energy.
- Evaporative cooled chillers allow huge energy savings (see section 3.2.5 on cooling management) but require water. The National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 M litres per MW year (NREL, 2014).

If the renovation of an existing data centre reduces direct energy consumption, replacing equipment (cooling, IT, power supply, etc.) could lead to:

- Acquiring new electrical and electronic equipment, which means increasing the consumption of raw materials (rare earths, plastics, glass, metals, etc.), and embodied energy;
- Generation of more waste of electronic and electrical equipment, including hazardous waste which can lead to water and soil pollution, if not treated properly.

For each technique, all the environmental benefits and pressures must be identified and quantified, in order to allow a global view on environmental performance.

### 3.3.2.5 Operational data

An environmentally efficient cooling management can be implemented through different practices. Operational specificities of these practices are presented below.

**Implementing a green procurement policy**

The energy efficiency criteria can be considered at each level of the procurement policy:

- Process preparation: it covers the assessment of the existing fleet of ICT equipment and of the needs compared to the different equipment and new technologies available on the market. There are several opportunities for reducing energy consumption from an existing fleet of equipment. An audit of existing IT equipment can help identify:
    - unused equipment which can be completely decommissioned or removed;
    - idle equipment which can be powered down / put on standby or removed;
    - IT equipment with restrictive intake temperature which may be replaced with newer equipment or placed in an appropriate area (segregated from other equipment).
- Call for tender: it can include required environmental criteria to meet.
- Bid evaluation: environmental criteria shall be checked, and the Total Cost of Ownership (TCO) shall be used to assess the offers (including energy savings related to the installation of more energy-efficient equipment that might be more expensive).

More specific criteria for each type of equipment are detailed hereafter[65].

**Selecting environmental-performant servers and storage equipment**

Energy efficient ICT equipment can include one or several of the following features:

- ICT equipment which operates within higher temperature and humidity ranges;
- ICT equipment suitable for the data centre power density and cooling delivery capabilities;
- ICT equipment which performs the required task within the lowest power consumption in the expected environmental conditions (temperature and humidity);
- ICT equipment suitable for the airflow direction in the area in which it is to operate;
- ICT equipment is complying with specific environmental criteria (e.g. EU Ecolabel, Energy Star, Blue Angel, etc.);
- ICT equipment that is capable of reporting energy consumption and inlet temperature, and which provides mechanisms to allow the external control of its energy use;
- ICT equipment containing high efficiency AC/DC power converters.

In addition, the use of free standing ICT equipment or ICT equipment supplied in custom enclosures should be restricted to areas where the airflow direction of the enclosure matches the airflow design in the area (e.g. front to rear or front to top).

In addition to the aforementioned equipment, another possibility for reducing energy consumption is to take into account the energy use performance of software when

[65] Parts 4.5.3.6 and 4.5.3.7 will focus solely on the deployment of cooling equipment. For other type of equipment, see BEMP 4.4 "Selecting and deploying more energy-efficient telecommunication network equipment" for power equipment; 4.2.4 for air handling equipment; 4.2.4 for server equipment.

purchasing new software. Poorly behaved software inhibits the energy saving features of the servers' Core Process Unit (CPU) (Sabharwal, Agrawal, & Metri, 2013).

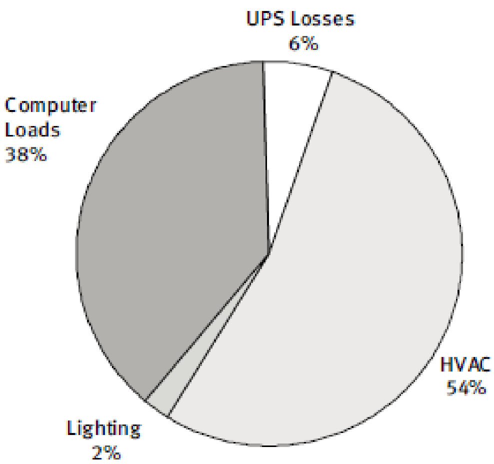
**Selecting environmental-performant cooling equipment**

Selecting energy-efficient air handling

In a centralised air handling system, cooling is made by blowing air over a cooling coil filled with chilled water typically supplied by a chilled water plant (i.e. chiller).

A specifically-designed central air handler system is much more efficient than a multiple distributed unit system (Computer Room Air Conditioners) since:

- It uses larger motors and fans, more energy-efficient than smaller ones;
- It is more suitable for the use of Variable Speed Drives (or VSDs) on fans, improving the fans efficiency when under loaded;
- It allows redundancy to be implemented in a manner that increases normal operating system efficiency;
- It prevents simultaneous humidifying and dehumidifying by using centralised controls;
- It facilitates air management and free cooling (installation of an air-side economiser).



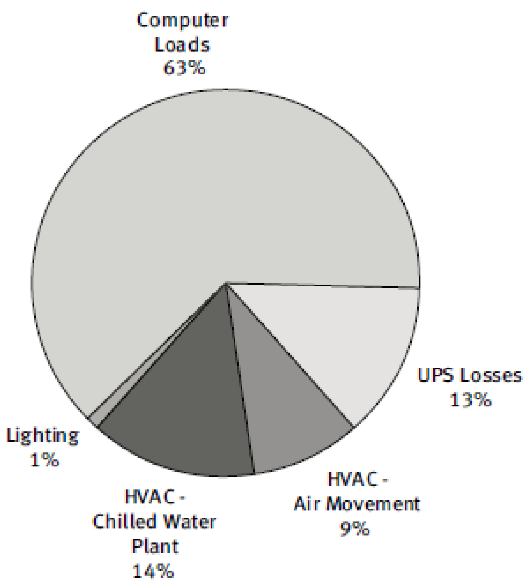
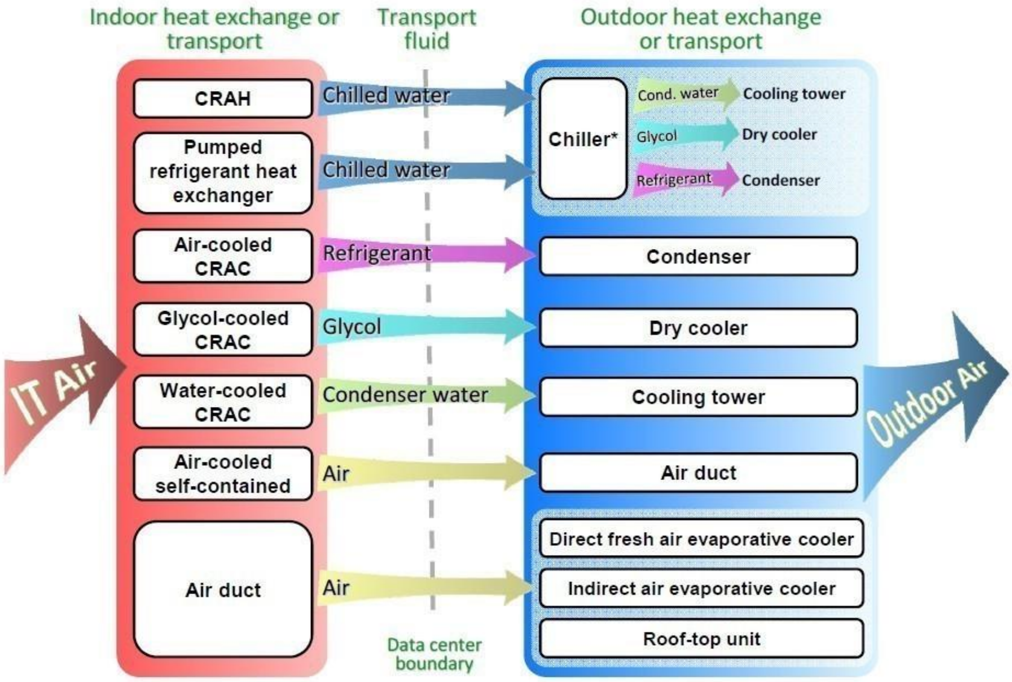




**Figure 54: Distribution of electricity consumption of two data centres, one using multiple CRAC units (on the left), and one functioning with a centralised air handling (on the right) (source: (PG&E, 2012))**

Selecting energy-efficient cooling equipment

The different solutions which can be implemented (and described below) rely on transforming or improving indoor or outdoor heat exchange, or changing of transport fluid (e.g. refrigerant, chilled water, air, etc.).




* Note that in some cases the chiller is physically located indoors.

**Figure 55: The different technologies for cooling data centres (Source: (Evans, 2012))**

The first step when designing an energy efficient cooling system relies on the selection of the most appropriate technology. Several technologies will be presented in this section:

- Direct liquid cooling;
- Using water source cooling;
- Free cooling;
- Centralised air handling.

<u>Free cooling</u>

Data centres operate 24 hours a day and present an almost constant internal cooling load that is independent of the outdoor air temperature. Free cooling operates on the principle that during cool weather conditions (at night or during cold months) data centre cooling loads can be provided by using outside-air lower temperature.

Free cooling designs use cool ambient conditions in order to remove heat from the compressor (Tschudi, 2013):

- Direct air free cooling uses external fresh air to cool the facility (after being filtered) if the indoor air quality must meet specific humidity and temperature requirements;
- Indirect air free cooling uses an air-to-air heat exchanger in order to remove heat produced by IT equipment to the atmosphere;
- Indirect water free cooling uses cooling coils (cooling towers, dry coolers, etc.) to cool chilled water by using external ambient conditions.

If ambient conditions do not allow the use of free cooling concepts all the time (depending on the difference between the outdoor and indoor temperature), and backup mechanical cooling or compressor should be used otherwise. These are called

'economised cooling systems', which use 'free cooling' a part of the year. Cooling designs should allow the use of 'free cooling' as much as possible.

Air economizers can provide "free" cooling by introducing the outside air for complete or partial cooling of the data room. When outside conditions are suitable for the use of air-economizers, the need for an air conditioning system is reduced or eliminated and energy used by compressors or cooling towers is saved. Such direct outside-air cooling may be supplemented by compressor-based cooling when free cooling cannot be provided (due to temperature or environmental conditions). In very cold conditions the incoming air may be mixed with some of the heated air extracted from the data centre.

Data centres require clean air with a specific relative humidity (the optimal relative humidity range is between 40 and 55 percent (Emerson, 2007)). Thus, outside air must be filtered before entering the data centre, and humidified if necessary:

- "Dry air" economisers can only be used in few geographic locations due to contamination and humidity issues: using humidifiers for correcting the humidity of the server room consumes important amount of energy and mitigates the energy savings from not chilling or compressing.
- "Evaporatively conditioned" air systems are effective for transforming the incoming air into the desired conditions before entering the data centre but present reliability issues (mildew concerns and high maintenance requirements).

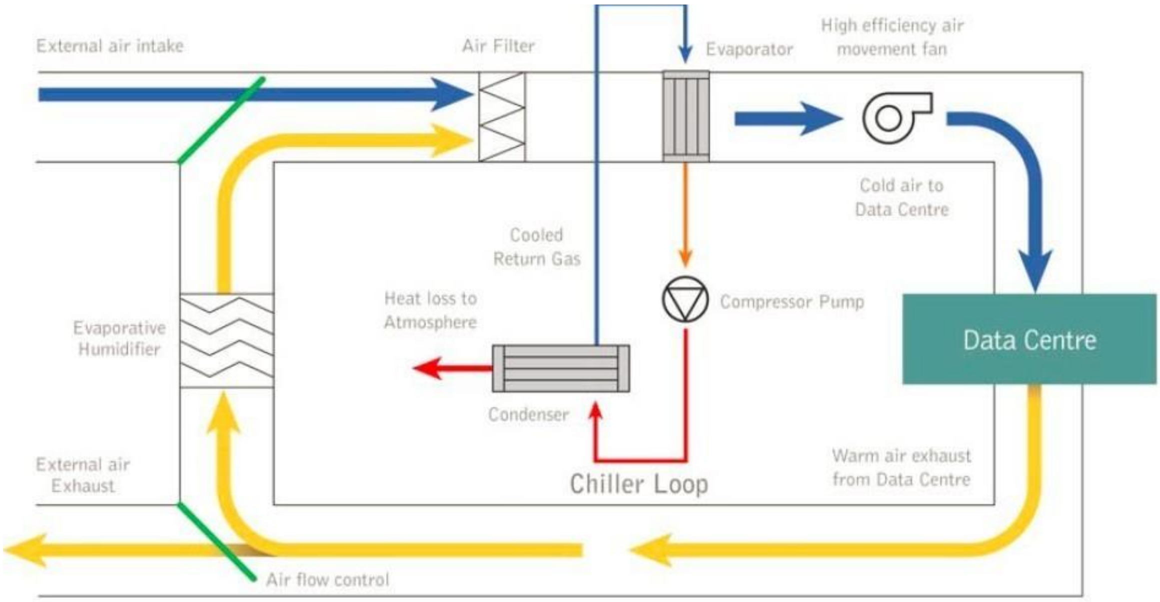



**Figure 56: Simplified layout of an air-side economiser (Source: (BCS, 2010))**

The use of air-side economizers should be preceded with an engineering evaluation of the local climate and contamination conditions. They can be installed into rooftop air handlers or mixing boxes mounted on each CRAH unit.

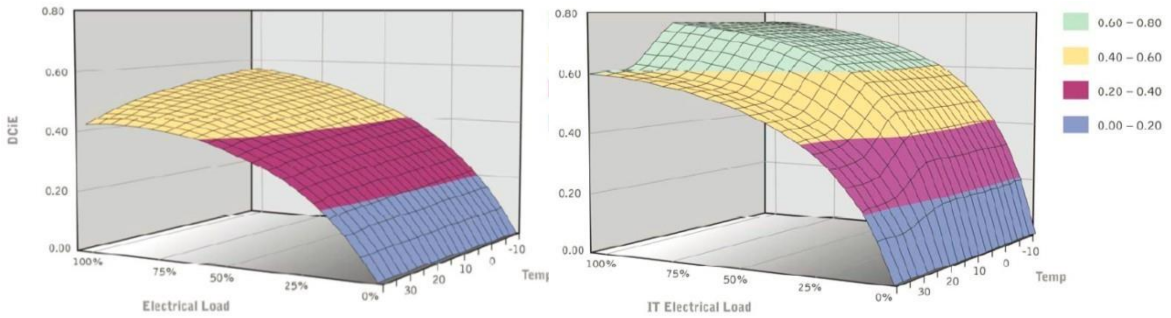



**Figure 57: DCIE by IT Electrical Load and External Temperature for traditional cooling (on the left) and while using direct-air free cooling (on the right) (Source: (BCS, 2010))**

Fluid economisers can be used in a wider range of climates since they allow a better control of humidity and contaminants and require less maintenance. In fact, outside air does not enter the data centre, and so does not require humidification and does not bring contaminants (gases, dust, pollen, etc.).

A fluid economiser system can be incorporated into a chilled water or glycol-based cooling system. Outside air is used to cool the fluid (water or glycol) in an open cooling tower or dry coolers, minimising or eliminating the need for chiller or compressor work:

- With a direct fluid economiser, the cooled water can directly flow through the main cooling loop. This technique remains rarely used for data centres due to contaminant issues.
- With an indirect fluid economiser, the fluid from the cooling tower or dry coolers is isolated from the other cooling loop. A heat exchanger is used to produce chilled water that is then used for cooling the data centre.

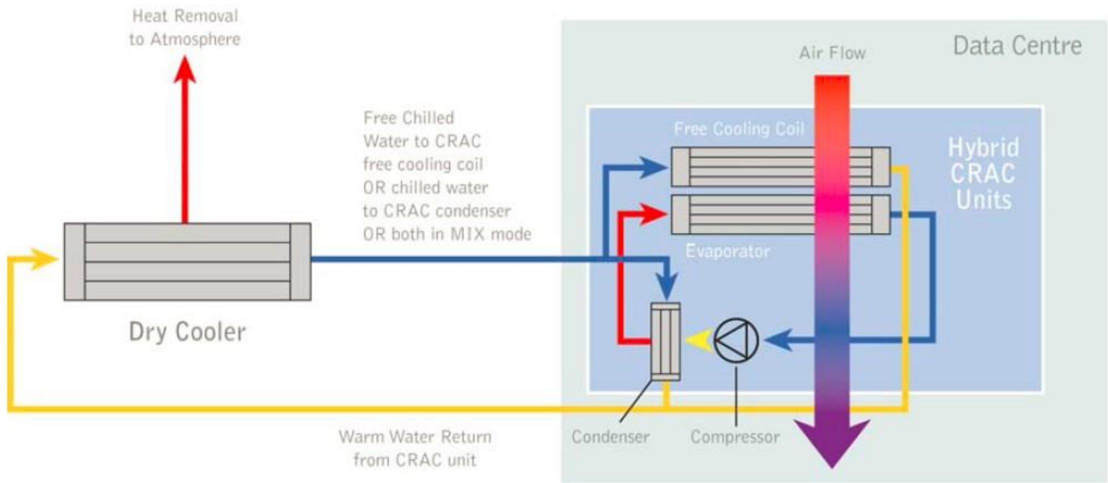



**Figure 58: Simplified layout of a water-side economiser (Source: (BCS, 2010))**

Indirect fluid economisers can be installed in two main configurations:

- While using a parallel configuration, the cooling loop is isolated from the chiller and provides the entire cooling load when outside conditions are suitable or is shut down (and the chiller takes over).
- With a series configuration, fluid economisers are able to share the load with the chiller or compressor. Then, they can be used at warmer conditions than parallel economisers and can provide free cooling during a longer time during the year.

*Using water source cooling*

This technique, which can be implemented by data centres located in proximity to a lake or a river, is very similar with a fluid side economiser. This water is used for dissipating the thermal load of the data centre, but without a cooling tower as shown on the figure below.

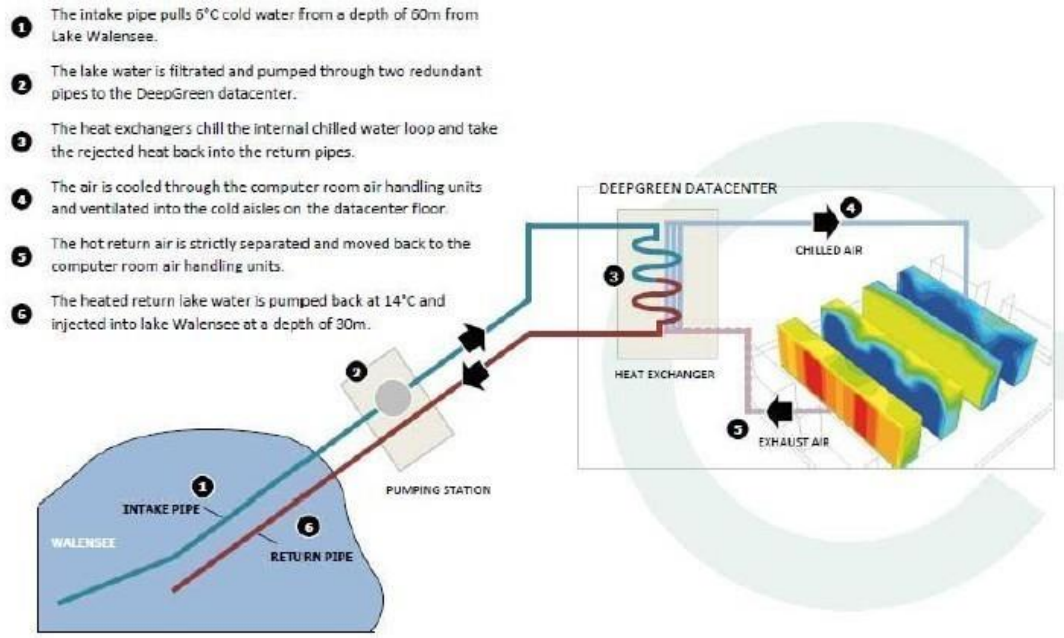



**Figure 59: Water source cooling process (Source: (GENIC, 2014))**

*Direct liquid cooling*

Another cooling technology may be chosen in order to reduce energy consumption, with a liquid immersion cooling system where servers are directly submerged in a liquid.

Direct liquid cooling is far more efficient than air cooling: water has a significantly higher heat capacity than air; water pumps are much more energy-efficient than air fans; and, the separation of cool and warm flows is easier.

There are many variations of direct liquid cooling solutions. They all deliver liquid at or very near the point heat is generated (directly into IT equipment or at the row or rack level), rather than conditioning the server room. Two main approaches can be identified:

- Water cooled racks use chilled water coils integrated into the racks and coolant lines than can be installed underfloor.
- Liquid immersion cooling where IT components are immersed in sinks filled with a dielectric fluid cooled via a heat exchanger.

Such technologies are much more efficient than air-cooling systems: they can serve higher heat densities and use warmer chilled water (13°-15°C compared to 6°-7°C (PG&E, 2012)). Implementing a direct liquid cooling solution can eliminate or significantly reduce the need for compressor-based equipment (especially if combined with a water-side economiser).

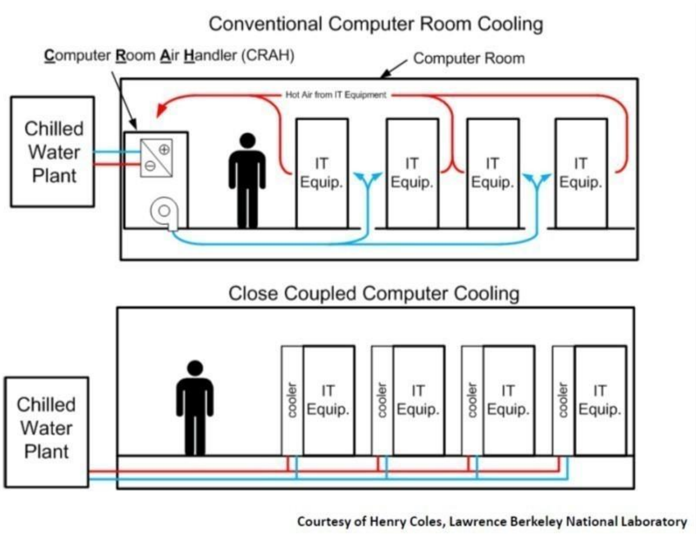



**Figure 60: Schematic view of traditional computer room cooling (top) and water cooled rack (down) systems. Source: (Henry Coles, Lawrence Berkeley National Laboratory)**

### Selecting energy-efficient power equipment

Selecting energy efficient UPS is an important part of the deployment of energy efficient power equipment.

The following solutions (also mentioned in the JRC *EU code of conduct for data centre energy efficiency* (JRC, 2015)) can be implemented in order to increase the energy efficiency of power systems providing the energy used by data centres:

- Selecting high efficient Uninterruptible Power Systems (or UPS), using rectifiers which can allow a reduction of energy losses due to electricity conversion. UPS efficiency over 97 can be considered as best performances (Emerson, 2010; UPS Ltd, 2015).

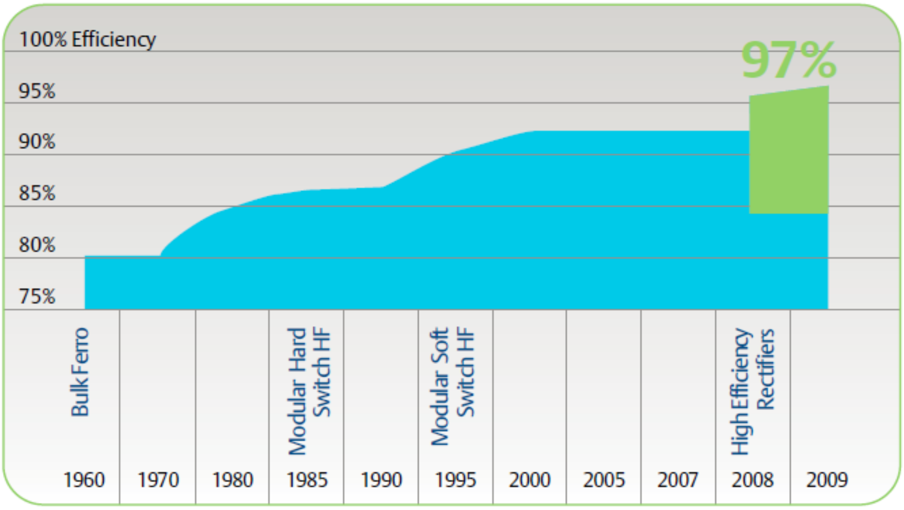



**Figure 61: Telecom Rectifier efficiency Trend. Source: (Emerson, 2010).**

- Installing modular UPS, where equipment sources of inefficiency (mainly switching units and batteries) can be easily changed if the electrical load of the facility evolve.
- Choosing an appropriate UPS solution design depending on the load requirements of an infrastructure.

### *3.3.2.6 Applicability*

**Cooling equipment**

Free cooling can only be used when the temperature level of the return flow of the cooling system must be above the outside temperature. Then, the location of the data centre is a fundamental factor concerning the feasibility and the performance of the free cooling system, so is the temperature and humidity range of IT equipment. A few years ago free cooling was said best suited for climates with wet bulb temperatures lower than 13°C for 3,000 or more hours per year. Following the update of temperature and humidity ranges for data centres defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), free air-cooling is expected to be applicable all year in 99 percent of Europe (too hot areas in North-western Spain and in Sicily, and one too humid area in South-Western Ireland are excluded) (The Green Grid, 2011c).  Free cooling can be used in the Mediterranean area for partial loads, but not at full load.

Alternative cooling systems such as liquid cooling or free-air cooling are most easily implemented in new data centres. Implementing such solutions in existing data centres requires investigations related to the geographical location and design of the data centre and to the existing data centre (type of cooling system). For example, an air-side economiser can only be installed if the data centre has access to an exterior wall or roof and moving from computer room air conditioners (CRACs) to a centralised air handling system may spare space in the server room since air handlers can be installed outside the data centre (on the roof for example). A year-round cooling load must be available – at least, it would improve the economic feasibility of the measures.

The choice of the cooling system solution depends on the size of the data centre, which is intimately linked to the activity and the size of the company. For example, chilled water system are suitable for data centre 200 kW and larger, and air evaporative cooling systems are used in 1,000 kW and larger data centres with high power density (Evans, 2012).

**Power equipment**

The elements to take into consideration for the adoption of new, more efficient UPS systems vary depending on when a new infrastructure is being built or when upgrading an existing infrastructure. For new installations, the management team must (PrimeEnergyIT, 2011):

- Assess its needs and size the UPS systems correctly (evaluate multiple or modular UPS, scalable and expandable solutions): battery back-up time, cost, size, number of outlets, etc.
- Analyse the UPS technology and efficiency. Take into account the partial load efficiency of UPS.
- Select correct topology of the power supply systems.
- Select UPS systems compliant with the EU Code of Conduct for UPS or Energy Star (minimum efficiency requirements for UPS are specified in the EU Code of Conduct for UPS and in the Energy Star programme requirements).

For the optimisation of existing infrastructures, the decision process includes the following steps (PrimeEnergyIT, 2011):

- Analyse the UPS technology and efficiency.
- Evaluate options and benefits of replacement of old equipment.
- Evaluate costs and benefits of redundancy.

**Table 33: Applicability of best practices regarding the selection and deployment of equipment**

| Best practice | Size | Security | Purpose |
|---|---|---|---|
| Implementing a green procurement policy | Any size | Any tier | Any purpose |
| Selecting environmental-performant servers and storage equipment | Any size | Any tier | Any purpose |
| Selecting environmental-performant cooling equipment | Localized to enterprise class data centres (depending on the technology implemented) | Any tier | Any purpose |
| Selecting environmental-performant power equipment | Server room to enterprise-class data centre Localized to enterprise class data centres (depending on the technology implemented) | Any tier | Any purpose |

### *3.3.2.7 Economics*

The Table 34 below gives an overview of costs and return estimates for each best practice.

**Table 34: Economics data related to the implementation of practices related to the selection and deployment of green equipment for data centres**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Implementing a green procurement policy | Costs of applying the policy to procurement processes | NA | Savings from decreased energy consumption |
| Selecting environmental-performant servers and storage equipment | Costs of applying the policy to procurement processes | Additional costs from purchasing higher quality equipment | Savings from decreased energy consumption |
| Selecting environmental-performant cooling | Costs of applying the policy to procurement | Additional costs from purchasing higher quality | Savings from decreased energy consumption (PG&E, 2012): |

| | | | |
|---|---|---|---|
| equipment | processes | equipment | - Up to 60% cooling costs reduction, depending on the climate<br>- Up to 50% reduction in electricity costs with a centralised air handling system |
| Selecting environmental-performant power equipment | Costs of applying the policy to procurement processes | Additional costs from purchasing higher quality equipment;<br>- Modular UPS is 10-15% more expensive than a traditional UPS system (UPS Ltd, 2016) | Savings from decreased energy consumption:<br>- Up to 50% reduction in energy costs with a modular UPS (UPS Ltd, 2016) |

**Cooling equipment**

The costs of installing the cooling technologies described before depend on the size of the data centre (and thereby the cooling requirements), e.g. if the operation is a construction of a new data centre or the renovation of an older one, etc.

Technology providers have created models to evaluate the economic feasibility of implementing such solutions.

- Adding a fluid economiser (series configuration) and optimising parameter settings (variable fans, warmer water) increases the capital cost of the installation by 10%, but reduces the floor space occupation and the energy consumption (by 39%). Thus the total cost of ownership (TCO) is reduced by an average of 18% (Emerson, 2007).
- Adding an air-side economiser increases the capital cost of the installation by 13%, but reduces the floor space occupation and the energy consumption (by 42%). Thus the total cost of ownership (TCO) is reduced by an average of 22% (Emerson, 2007).

The PrimeEnergyIT Project supported by the Intelligent Energy Europe Programme (PrimeEnergyIT, 2012) produced case studies about implementing different free cooling solutions. This project concluded in most of the cases to amortisation period of 1 year when upgrading existing data centres with such technology.

**Power equipment**

Using higher efficiency power supplies will directly lower a data centre's power bills and indirectly reduce cooling system cost and rack overheating issues.

It is estimated that, in most cases, a high efficiency power supply can pay-off within one year, even if the manufacturing costs for the newer equipment are doubled (PG&E, 2012). PG&E estimates that improving the energy efficiency by 10% through the purchase of newer equipment can trigger savings of €1,800 (for a 10kW rack) to €6,200 (for a 25kW rack), on the basis of a cost of electricity at €0.12/kWh. Similarly, selecting a 5% higher efficiency model of UPS can save over €34,000 per year in a

1,400 m² data centre, with no visible impact on the data centre's operation beyond the energy savings (PG&E, 2012).

### 3.3.2.8 Driving force for implementation

As already mentioned, the main driving force for the implementation of the aforementioned best practices is the saving resulting from the use of a more energy-efficient technology.

Another important driver when selecting cooling equipment can be the legislation, since some national and local authorities prohibit the removal of water for cooling purposes from surface and underground waters.

Besides, maintenance remains an important issue when selecting a new cooling technology, since some solutions may require specific conditions (high pressure, protection against fire, etc.) and additional equipment (filters, humidifiers, etc.).

### 3.3.2.9 Reference organisations

Google has long been a frontrunner in terms of data centre energy efficiency. A large part of these data centre's very high PUE (slightly above 1.1) is due to the integration of a high efficiency UPS. This specific design shifts the UPS and battery backup functions from the data centre into the server cabinet, providing the data centre with UPS efficiency of 99.9% (DataCenterKnowledge, 2009).

Among other good practices included in the EU Code of Conduct on Data Centre Energy Efficiency, b<>com Institute of Research and Technology in Rennes (France) installed modular UPS. This data centre received an EU Code of Conduct award in 2016 (JRC, 2016).

### 3.3.2.10 Reference literature

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Utilisation, management and planning of existing data centres (technique related to the selection and deployment of mechanical and electrical equipment);
- Selection and deployment of new ICT equipment;
- Selection of cooling system;
- Selection and deployment of new power equipment;
- Other data centre equipment.

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UPS Ltd. (2016). *The cost benefits of advanced modular UPS technology*. Retrieved 7 12, 2016, from UPS Power: http://www.upspower.co.uk/the-cost-benefits-of-advanced-modular-ups-technology/

## 3.4 BEMPs related to the deployment of new ICT services and software

### 3.4.1 Scope and structure of BEMPs related to deployment of new ICT services and software

Software systems do not consume energy directly but affect hardware utilisation rate and lead to indirect electricity consumption. The following best environmental management practices could be considered to improve the energy efficiency of software used in data centres:

**Table 35: Structure of BEMPs related to data centres and relationship to the CLC/FprTR 50600-99-1**

| **BEMPs related to the deployment of new ICT services and software** | |
|---|---|
| • Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/FprTR 50600-99-1 | |
| **Techniques from EU CoC / CLC/FprTR 50600-99-1**[66] | **BEMP** |
| **Deployment of new IT services** | |
| • Select software which uses the least energy to perform the required task *(5.16.46)*<br>• Develop efficient software *(5.16.47)*<br>• Include incentives to develop efficient software when outsourcing software development *(6.16.130)*<br>• Eliminate traditional 2N hardware clusters *(6.16.131)* | **Developing new ICT services and software minimising servers utilisation (Section 3.4.2)**<br><br>For general BEMPs related to procurement of ICT equipment and services refer to:<br>▪ Procurement of sustainable ICT products and services (Section 2.3) |

NB:

- Expected practices are reported in black, and optional practices are presented in grey.
- For an updated list of best practices, see the latest version of CENELEC Technical Report *CLC/FprTR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices*.

The ensuing section will describe the following BEMP for energy efficient software – Section 3.4.2.

For general BEMPs related to procurement of ICT equipment and services refer to the BEMP on the procurement of sustainable ICT equipment and services (2.3).

[66] The EU Code of Conduct distinguishes between 'Expected Practices' (identified by the codes starting with 5.1); 'Optional or Alternative Practices' (identified by the codes starting with 6.1); and, 'Practices under consideration' (identified by the codes starting with 7.1).

### 3.4.2 Developing new ICT services and software minimising servers utilisation

**SUMMARY OVERVIEW:**

**While software does not directly consume energy, it greatly influences the energy efficiency of the ICT hardware on which it runs. However, a large share of software code does not take into account energy consumption, and opportunities exist to optimise software and reduce the energy consumption of servers. It is considered best practice to:**

- **Select energy efficient software that minimises power consumption of ICT equipment while running.**
- **Develop internally or outsourced energy-efficient software that uses the least energy to perform the required task.**
- **Monitor the energy consumption of software to assess the real performance of the acquired software, or to assess the opportunity of improving the energy efficiency of existing software.**
- **Refactor existing software to improve its energy efficiency.**

**ICT components**

| | | | | |
|---|---|---|---|---|
| **Data centre** | Telecommunication network | Broadcasting | **Software publishing** | End-user devices |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| **Design and installation** | Selection and procurement of the equipment | Operation and management | **Renovation and upgrades** | End-of-life management |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- Share of new acquired software for which the energy performance has been used as a selection criteria within procurement (%)
- Share of new developed software for which the energy performance has been used as a development criteria (%)
- Share of existing software which has been refactored (%)
- Share of software for which the energy use has been assessed (%)
- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding the development and deployment of new IT services

**Cross references**

| | |
|---|---|
| **Prerequisites** | • The internal development of software is mostly applicable for large sized companies. |
| **Related BEMPS** | • 2.3 Procurement of sustainable ICT products and services<br>• 4.2 Improving the energy management of existing network<br>• 4.7 Minimising data traffic demand through green software |

#### 3.4.2.1 Description

The service architecture, software and deployment of ICT services have an impact at least as great as that of the ICT equipment. Indeed, the root cause of ICT energy consumption lies in the software that commands the hardware to start processing (Musthaler, 2014). A large share of software code does not take into account energy consumption. Consequently, it is possible to optimise software to make it accomplish more in an efficient manner, while better using underlying hardware capacities (CERN, 2008). Case studies of energy-aware software have shown the potential to reduce consumption between 30% and 90% (Musthaler, 2014).

Regarding the deployment of new ICT services and software for a data centre, it is best practice to (CENELEC, 2016):

- **Select energy efficient software.**

  Although metrics are still in development, software should be chosen based on the power consumption of ICT equipment whilst software is running.

- **Develop energy efficient software.**

  Attention should be paid to the fact that software developed internally and outsourced should use the least energy to perform the required tasks.

- **Monitor the energy consumption of software.**

  In order to assess the real performance of the acquired software, or to assess the opportunity of improving the energy-efficiency of existing software, the energy consumption of software shall be monitored.

- **Refactor existing software.**

  Based on energy monitoring and green IT audit, existing software can be modified in order to improve its energy efficiency.

This BEMP is more applicable for data centres operators or clients that intend to minimise the utilisation of their servers. It is linked to the following techniques:

The BEMP 4.7 that focuses on reducing the energy consumption of end-user devices and data traffic on telecommunication networks. This BEMP is more applicable for companies developing software on end-user devices, both for an internal or an external use (section 4.7 on Minimising data traffic demand through green software).

The BEMP 4.2 on Improving the energy management of existing network deals with techniques that telecommunication networks operators can implement to minimise data traffic at peak loads.

#### 3.4.2.2 Achieved environmental benefits

Using more energy efficient software leads to a decrease of the utilisation rate of servers, and opens opportunities for consolidating some servers. Fewer servers are required for operating IT process, and **indirectly data centre energy consumption is decreased**. Case studies carried out by Software Energy Footprint Lab (SEFLab) indicate that 30% to 90% of the power entering a data centre is wasted due to inefficient software, while only a small part of the power is used by the processor. 100 watt saved at software level saves approximatively 1,000 watt at data centre level (SEFLab, 2014).

Reducing hardware utilisation is an opportunity for extending hardware lifespan (because hardware replacement caused by software demand is avoided or postponed) and for minimising needs for new hardware (through the consolidation of servers for example). Then less hardware manufacturing is required, as well as less ICT equipment end-of-life management. **Environmental impacts associated to these phases are indirectly reduced** (resource consumption, embodied energy, etc.).

#### 3.4.2.3 Appropriate environmental performance indicators

At company level, process-oriented indicators that can be monitored include:

- Share of sites that have implemented the best practices of the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding the development and deployment of new IT services;
- Share of new acquired software for which the energy performance has been used as a selection criteria within procurement (%);
- Share of new developed software for which the energy performance has been used as a development criteria (%);
- Share of existing software which has been refactored (%);
- Share of software for which the energy use has been assessed (%).

#### 3.4.2.4 Cross-media effects

The techniques described above primarily intend to minimise the energy consumption of servers by reducing their utilization. However, the approach must be global, and also include the energy consumption related to the telecommunication networks and end-user devices. Otherwise, the workload processed by the servers could be transferred on front ends, leading to a decreased utilisation and energy consumption of servers on the one hand, but to an increased energy consumption of telecommunication networks and end-user devices.

#### 3.4.2.5 Operational data

**Selecting energy efficient software**

Software should be chosen based on the power consumption of ICT equipment whilst software is running. Although the selection of software must aim for software using the least energy to perform the required tasks, it must also meet organisational needs.

Smarter software must take into consideration both its own parameters and parameters of the whole equipment of the data centre:

- the energy consumption of individual components and systems;
- the energy consumption of the whole data centre.

This means that smart software must connect with different equipment to give a global answer. With this feature, only necessary software components can run at a given time, while doing so on the most energy-efficient system available (CERN, 2008).

For example, poorly behaved software inhibits the energy saving features of the servers' Core Process Unit (CPU)[67].

**Developing efficient new software**

Energy performance optimization should be made a high priority in the development process. Consequently, software developed should use the least energy to perform the required tasks whilst ensuring it meets the organisation needs.

The main goal when developing energy efficient software is to get the workload achieved as fast as possible in order to get back the server back to idle and to reduce energy consumption (Intel, 2011).

Techniques of computational efficiency consist in delivering better performance and as well as better energy-efficiency (Intel, 2011). Programmers should develop new software[68] according to the following principles:

- Design efficient algorithms by writing a compact design of codes and data structures and by sticking to the only functions presented in the requirement stage (Mahmoud S. and Ahmad I., 2013);
- Develop multi-threading software where different parts of a sequential code can be run simultaneously on multiple processors (or multiple cores).
- Vectorise the code, by using advanced instructions such as Single-Instruction Multiple Data.

Data efficiency reduces data movement (Intel, 2011). It can be achieved by:

- Designing algorithms minimising data movement;
- Memory hierarchies that keep data close to processing elements;
- Application software that efficiently use cache memories.

When the development of software is outsourced, a bonus and penalty clause can be included in the contract, in order to encourage software providers to take into account the energy consumption of their products.

**Monitoring software energy-consumption**

Energy monitoring aims at "providing feedback on the energy consumption of software applications, to identify opportunities for energy optimisation and / or to assess the energy savings gained by applying other strategies" (Procaccianti, 2015).

Figure 62 shows that the information flow coming from hardware (memory access, I/O usage, CPU usage) is collected and used as input for software energy models. These models analyse applications during execution and provide consumption estimations[69]. By verifying the energy efficiency improvements through profiling tools, software strategies can then be applied iteratively and adapted. Energy monitoring also takes into account other parameters, such as the software mission and main functionalities, the required quality of service and the interests of the stakeholders : "for example, reducing the network usage might improve energy efficiency, but it might also violate service level agreements on response time or availability" (Procaccianti, 2015).

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[67] C-states refer to the different core power states defining the degree to which the processor is "sleeping". In state C0 the processor is active and executing instructions.

[68] An existing program can be transformed into a similar output program that uses less energy by taking better advantage of the underlying processor architecture. For that purpose, an optimising compiler can be purchased and used for minimising the time taken to execute a code.

[69] Examples of existing profiling tools based on energy models include Joulemeter, ARO, Power TOP and PowerTutor (Procaccianti, 2015).

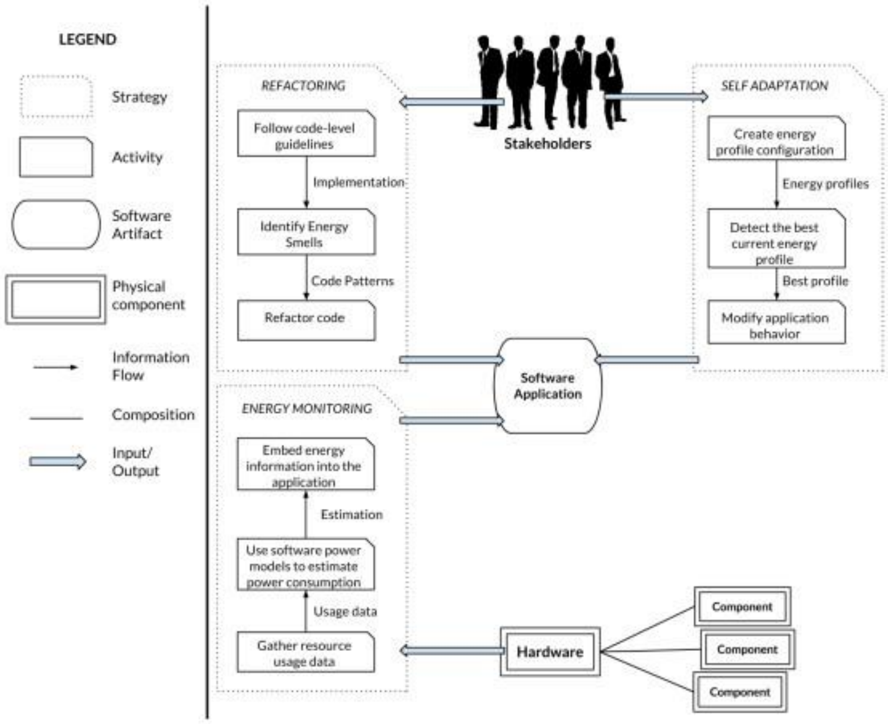



**Figure 62 : Framework for energy efficient software strategies (Procaccianti, 2015)**

The main objective of optimizing software is to minimise CPU (Central Processing Unit), RAM (Random Access Memory) and energy consumption of hardware. Different outcome oriented indicators can be monitored at software level, such as:

- **CPU utilisation** related to the use of the software (and relative savings due to optimisation projects at servers' level);
- **RAM usage** related to the use of the software (and relative savings due to optimisation projects at servers' level);
- **Power consumption** related to the use of the software (and relative savings due to optimisation projects at servers' level).

### Refactoring existing software tower greater efficiency

Refactoring means identifying code patterns responsible for high energy usage. However, because software execution depends not only on its internal structure and environmental but also on the input it receives, refactoring's results might differ depending on the situations. To prevent unsuccessful research, the most frequent usage scenarios must first be identified. Guidelines for refactoring include (Procaccianti, 2015):

- Cleaning up useless code and data: Because parts of software can become obsolete as it evolves, cleaning up useless instructions can improve energy efficiency.
- Looking for immortals: Some services restart after the user killed them, thereby continuing to use energy. Preventing the unnecessary restart of a service can decrease energy consumption.
- Focusing on higher-level structures and complex routines: Refactoring from high level constructs allows for higher impact on CPU and memory than

refactoring at lower level. This is especially true when lower levels are hidden by higher level inefficiencies, due to a large number of software layers or when software run in a complex environment (e.g. virtualisation).

- Checking loops: Loop inefficiencies can happen when an application repeats the same activity without achieving the intended results (e.g. polling an unreachable server). Refactoring loops can save energy, especially on battery powered devices.
- Reducing the amount of data transferred: Data transfer might be a significant source of power consumption. Data exchanged between software applications and / or databases can be reduced using data compression or aggregation. Communication Energy Cost can be used as metric to estimate the energy consumption induced by data transfers for each software component.

#### 3.4.2.6 Applicability

Depending on the characteristics of data centres, implementing the best practices mentioned in this chapter can be more or less relevant.

From an operational point of view, the aforementioned best practices are applicable any type of data centres, irrespectively of their size, security level or purpose. This is especially true for the development of software, which can be too costly for small size data centres.

Regarding the development of energy efficient software, many researchers have worked on software power models able to predict the energy consumption of software applications. However, research has not yet transformed into directly reusable information for practitioners and developers to develop energy efficient software applications (Procaccianti, 2015). Some guidelines have been suggested by experts from Intel Corp., but were never validated by implementation, and did not lead to precise quantification of benefits in terms of energy consumption (Larsson, 2011).

#### 3.4.2.7 Economics

The table below gives an overview of costs and return estimates for each best practice.

**Table 36: Economics data related to the deployment of new ITC services and software**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Selecting energy efficient software | NA | Cost of purchasing software | Savings from decreased energy consumption |
| Developing energy efficient software | NA | Cost of developing software | Savings from decreased energy consumption, lower server requirements and lower maintenance operation |
| Monitoring the energy consumption of software | NA | Cost of meters | Savings from decreased energy consumption |

| | | | |
|---|---|---|---|
| Refactoring existing software towards greater energy efficiency | NA | Cost of audit and software refactoring | Savings from decreased energy consumption |

#### 3.4.2.8 Driving force for implementation

Similarly to previous BEMPs, decreased energy costs are the main incentive for data centres to adopt energy efficient software.

Reducing the energy consumption of servers is associated with an improved performance, since servers are able to process data for more users.

In addition, developing energy efficient software can increase the innovation capacity of the organization running the data centre, and help identify opportunities to optimise the activity of the data centre. Optimized software will be more performant and deliver an efficient service, even in less energy-consuming data centres.

Providing more energy efficient software is also a way for data centres to enhance the quality of service provided to clients, who can be in demand of less energy-consuming data storage services, while maintaining a high quality of data management.

#### 3.4.2.9 Reference organisations

- Intel (Green Software)
- Oracle (Green Software)
- GREENSPECTOR (tools including "green rules" for optimizing software, and energy and resources metering)

#### 3.4.2.10 Reference literature

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Deployment of new IT services.

CENELEC. (2016). CENELEC Technical Report *CLC/FprTR 50600-99-1. Information technology - Data centre facilities and infrastructures – Part 99-1: Recommended practices for energy management*

CERN. (2008). *Reducing data center energy consumption.* CERN.

Intel. (2011). *Developing Green Software*.

Larsson, P. (2011). *Energy-efficient software guidelines.* Intel Software Solutions Group.

Mahmoud S. and Ahmad I. (2013). *A green model for sustainable software engineering, in International Journal of Software Engineering and Its Applications Vol. 7, No. 4, July, 2013*

Musthaler, L. (2014, 12 18). *Energy-aware software design can reduce energy consumption by 30% to 90%*. Retrieved 7 5, 2016, from Network World: http://www.networkworld.com/article/2861005/green-it/energy-aware-software-design-can-reduce-energy-consumption-by-30-to-90.html

Procaccianti, G. (2015). *Energyefficient software.* SIKS.

SEFLab. (2014). *Software Energy Footprint Lab uitgelegd*. Retrieved 2016, from Greening the Cloud: http://www.greeningthecloud.nl/en/video-software-energy-footprint-lab-uitgelegd/

## 3.5 BEMPs related to new build or refurbishment of data centres

### 3.5.1 Scope and structure of BEMPs related to new build or refurbishment of data centres

The design and sitting of a data centre has a major influence over its performance in terms of energy efficiency. Data centres have traditionally been designed with large tolerances for operational and capacity changes with possible future expansion in mind (JRC, 2012). The over-dimensioning of data centres leads to inefficiencies: redundant power and cooling systems, IT equipment with a low average utilization, etc. Nowadays, data centres owners and operators have incentives (energy costs for example) and tools (including energy-efficient equipment) for designing new high energy performance data centres, and improving the energy efficiency of existing ones.

**Table 37: Structure of BEMPs related to data centres and relationship to the CLC/FprTR 50600-99-1**

| **BEMPs related to new build or refurbishment of data centres**<br>• Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/FprTR 50600-99-1 | |
|---|---|
| **Techniques from EU CoC / CLC/FprTR 50600-99-1**[70] | **BEMP** |
| **Utilisation, management and planning of existing data centres** | |
| • Select and deploy mechanical and electrical equipment which does not itself require cooling in normal operation *(5.16.48)* | **Selection and deployment of equipment for data centres (Section 3.3.2)**<br><br>For general BEMPs related to procurement of ICT equipment and services refer to:<br>▪ Procurement of sustainable ICT products and services (Section 2.3) |
| • Limit the level of physical infrastructure resilience and service availability according to business requirements *(5.16.49)*<br>• Consider building a data centre to provide multiple levels of power and cooling resilience *(5.19.50)*<br>• Limit provisioning of power and cooling to a maximum of 18 months of computer room growth capacity *(5.16.51)*<br>• Design the data centre infrastructure to maximise their efficiency under partial and / or variable load conditions *(5.16.52)* | **Planning of new data centres (Section 3.5.2)** |
| **Airflow management and design** | |
| • Implement hot/cold aisle alignment of ICT equipment *(5.16.53)*<br>• Utilise floor layout and equipment deployment design concepts that contain and separate the cold air from the heated return air in the computer room *(5.16.54)* | **Improve airflow management and design (Section 3.2.4)** |

[70] The EU Code of Conduct distinguishes between 'Expected Practices' (identified by the codes starting with 5.1); 'Optional or Alternative Practices' (identified by the codes starting with 6.1); and, 'Practices under consideration' (identified by the codes starting with 7.1).

| | |
|---|---|
| • Install aperture brushes (draught excluders) or cover plates and panels to minimise all air leakage in each cabinet / rack *(5.16.55)*<br>• Replace solid doors with perforated doors to ensure adequate cooling airflow to ICT equipment *(5.16.56)* | |
| **Selection of cooling system** | |
| • Select chillers with high Coefficient of Performance *(5.16.57)*<br>• Design the cooling system infrastructure to maximise its efficiency under partial load conditions *(5.16.58)*<br>• Utilise variable speed (or frequency) controls for compressors, pumps and fans to optimise energy consumption during changing load conditions *(5.16.59)*<br>• Select cooling designs and solutions which facilitate the use of economisers *(5.16.60)*<br>• Segregate chilled water systems from those designed to provide human comfort *(5.16.61)*<br>• Ensure that cooling system set-points are defined by ICT equipment requirements / Segregate non-ICT equipment requiring more restrictive temperature and humidity control ranges from ICT equipment *(5.16.62)*<br>• Review chilled water systems configured with dual pumps (one active, one standby) for options to improve energy efficiency during operations *(5.16.63)*<br>• Install free cooling in all new builds and retrofits or upgrades of cooling systems *(6.16.133)*<br>• Implement air free cooling / cooling of the data centre by using external air *(6.16.134)*<br>• Implement indirect air free cooling / cooling using an air-to-air heat exchanger *(6.16.135)*<br>• Implement indirect water free cooling with CRAH and dry cooler or cooling tower / cooling using a water circuit and removal of heat by a free heating cooling coil *(6.16.136)*<br>• Implement indirect water free cooling with CRAH with integrated free cooling coil / cooling using chilled water cooled by cooling towers or dry coolers *(6.16.137)*<br>• Implement indirect water free cooling with CRAH and free cooling chiller / cooling using chilled water produced by the free cooling chiller *(6.16.138)*<br>• Implement indirect water free cooling with condenser water cooling chilled water / cooling using chilled water cooled via a plate heat exchanger to the condenser water circuit passing through dry/adiabatic coolers/cooling towers *(6.16.139)*<br>• Use alternative cooling sources *(6.16.106)*<br>• Install variable speed fans *(5.16.64)*<br>• Control CRAC/CRAH units based on cold air supply temperature only *(5.16.65)*<br>• Centralise humidity control at the supply air handling unit / Do not control humidity at CRAC/CRAH unit *(5.16.66)*<br>• Select appropriately sized cooling units *(5.16.67)* | **Selection and deployment of equipment for data centres (Section 3.3.2)**<br><br>For general BEMPs related to procurement of ICT equipment and services refer to:<br>▪ Procurement of sustainable ICT products and services (Section 2.3) |

| | |
|---|---|
| • Implement direct liquid cooling of ICT equipment *(6.16.141)*<br>• Operate CRAC/CRAH units with variable speed fans in parallel *(6.16.142)*<br>• Turn entire CRAC/CRAH units on and off where variable speed fans are not included to manage overall airflow volumes *(6.16.143)* | |
| **Selection and deployment of new power equipment** | |
| • Specify and deploy modular (scalable) UPS systems *(5.16.68)*<br>• Select high efficiency UPS systems *(5.16.69)*<br>• Deploy UPS units in their most efficient operating modes *(5.16.70)*<br>• Install static UPS systems that are compliant with the EU Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems *(5.16.71)*<br>• Eliminate isolation transformers from distribution to ICT equipment *(5.16.72)*<br>• Ensure that all electrical infrastructure remains energy efficient under variable ICT electrical loads *(5.16.71)* | **Selection and deployment of equipment for data centres (Section 3.3.2)**<br><br>For general BEMPs related to procurement of ICT equipment and services refer to:<br>▪ Procurement of sustainable ICT products and services (Section 2.3) |
| **Other data centre equipment** | |
| • Deploy low energy lighting systems in the data centre spaces *(5.16.74)*<br>• Use pale/light colours on walls, floor fixtures and fittings including cabinets, etc. to reduce the amount of lighting required *(5.16.75)*<br>• Select mechanical and electrical equipment with local metering / monitoring of energy use and/or temperature that allow for reporting of cumulative periodic energy consumption and instantaneous power usage *(5.16.76)* | **Selection and deployment of equipment for data centres (Section 3.3.2)** |
| **Reuse of data centre waste heat** | |
| • Re-use the waste heat to provide low grade heating to industrial or office space *(6.16.144)*<br>• Use additional heat pumps to raise the temperature of waste heat to a useful point *(6.16.145)*<br>• Use computer room waste heat to warm office, generator and fuel storage areas *(6.16.146)*<br>• Measure and report on energy reuse *(6.16.147)* | **Reuse of data centre waste heat (Section 3.5.3)** |
| **Data centre building physical layout** | |
| • Locate mechanical and electrical equipment which generate heat outside the cooled data centre spaces *(5.16.77)*<br>• Ensure sufficient ceiling height to enable use of efficient air cooling technologies such as raised floor, suspended ceiling, aisle containment or ducts when air movement is used to cool the ICT equipment *(5.16.78)*<br>• Ensure that the physical layout of the building does not obstruct or restrict the use of cooling economisers or other equipment with an economisation mode *(5.16.79)*<br>• Locate cooling equipment in an area with free air movement *(5.16.77)*<br>• Minimise direct solar heating (insolation) of the cooled areas of | **Design of the data centre building and physical layout (Section 3.5.4)** |

| | |
|---|---|
| the data centre *(5.16.77)* | |
| **Data centre geographical location** | |
| • Locate the data centre where there are available opportunities for the reuse of waste heat *(6.16.148)*<br>• Locate the data centre in areas of low ambient external temperature in order to maximise the potential for free and economised cooling technologies *(6.16.149)*<br>• Locate the data centre in areas of low external humidity in order to maximise the potential for free and economised cooling technologies *(6.16.150)*<br>• Locate the data centre near a source of free ground source cooling such as a river or lake *(6.16.151)*<br>• Locate the data centre close to the power generating equipment as this can reduce transmission losses *(6.16.152)* | **Selecting the geographical location of the new data centre (Section 3.5.5)** |
| **Water sources** | |
| • Capture and store rain water for evaporative cooling *(6.16.153)*<br>• Use local non-utility water sources for evaporative cooling *(6.16.154)* | **Use alternative water sources (Section 3.5.6)** |
| • Meter, monitor and manage water consumption from all sources in all data centre spaces *(6.16.155)* | Environmental management system (Section 2.2) |
| **Data centre monitoring** | |
| • Improve visibility and granularity of data centre infrastructure energy consumption / distribution board level of mechanical and electrical energy consumption *(5.16.82)*<br>• Implement collection and logging of full economiser, partial economiser and full refrigerant and compressor based cooling hours throughout the year *(5.16.83)*<br>• Implement reporting of full economiser, partial economiser and full refrigerant and compressor based cooling hours throughout the year (5.16.84) | **Implement an energy management system for data centres (Section 3.2.2)** |

NB:

- Expected practices are reported in black, and optional practices are presented in grey.
- For an updated list of best practices, see the latest version of CENELEC Technical Report *CLC/FprTR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices*.

The ensuing sections will describe the following BEMPs:

- Planning of new data centres (Section 3.5.2);
- Reuse of data centre waste heat (Section 3.5.3)
- Design of the data centre building and physical layout (Section 3.5.4)
- Selecting the geographical location of the new data centre (Section 3.5.5)
- Use alternative water sources (Section 3.5.6)

Further best practices related to new build and refurbishment of data centres can be found in other chapters of the report:

- Airflow management and design: see the BEMP for improving airflow management and design (Section 3.2.4).
- Selection of cooling system: see the BEMP for selection and deployment of equipment for data centres (Section 3.3.2).
- Selection of power equipment: see the BEMP for selection and deployment of equipment for data centres (Section 3.3.2)
- Selection of other equipment for data centres: see the BEMP for selection and deployment of equipment for data centres (Section 3.3.2)

### 3.5.2 Planning of new data centres

**SUMMARY OVERVIEW:**

**When building or upgrading a data centre, the planning phase offers the most significant opportunities to ensure its environmental performance. Data centres are often oversized to allow future extensions, which generates energy inefficiencies. In many cases, the building can prevent the data centre from upgrading to new and more energy efficient equipment. It is considered best practice to:**

- **Limit the level of physical infrastructure resilience and service availability according to business requirements.**
- **Build a modular data centre to avoid oversizing and maximise infrastructure efficiency under partial and variable load conditions.**

**ICT components**

| | | | | |
|---|---|---|---|---|
| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- Energy use of the data centre per floor area (kWh/m²)
- Power Usage Effectiveness (PUE)
- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 3.5.3 Reuse of data centre waste heat<br>• 3.5.4 Design of the data centre building and physical layout<br>• 3.5.5 Selecting the geographical location of the new data centre<br>• 3.5.6 Use of alternative sources of water |

### 3.5.2.1 Description

The planning sequence should establish the location site and design requirements of the data centre's equipment and physical infrastructure (e.g. power, cooling, building, security, etc.). It can be divided into 4 main steps:

- Establishing key project parameters (capacity, costs, etc.);
- Developing system concept (location, technologies, etc.);
- Incorporating user preferences and constraints (in terms of design);
- Determining implementation requirements (regulations to follow, procurement rules, installation guidelines, etc.).

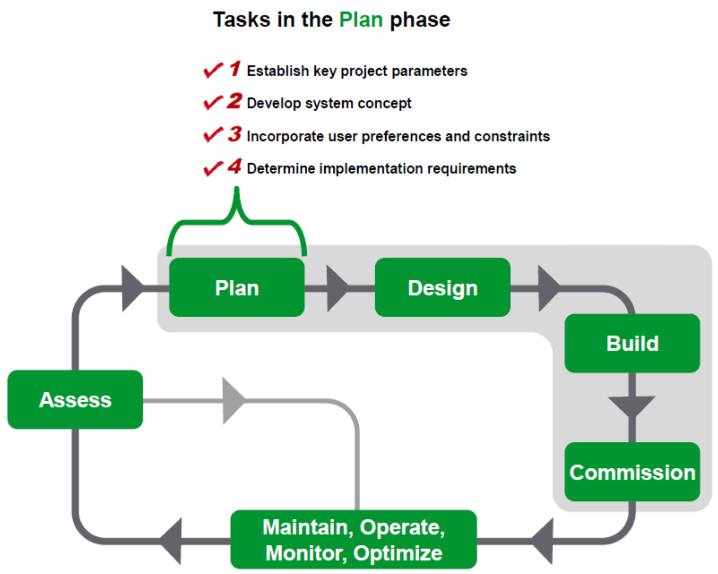



**Figure 63: System planning of data centre projects. Source: (Rasmussen, 2013).**

The planning of projects to build or upgrade data centres remains a major challenge for many IT departments (lack of communication, non-adequacy to needs, extra costs, delays, etc.), especially in terms of building an environmental-friendly data centre.

The energy and environmental goals for the data centre infrastructure system should be one of the key parameters defined initially (with criticality, capacity, growth plan, density and budget) by consulting key stakeholders: finance executive, CEO, key IT executive, IT operations manager, etc. (Rasmussen, 2013). Two main issues rely on avoiding oversizing the data centre and building a data centre on a practical modular architecture (i.e. able to accommodate variations in room size and shape), in order to facilitate future upgrades toward more efficient systems (Rasmussen N. , 2014).

When planning data centres, it is best practice to (CENELEC, 2016):

- **Limit the level of physical infrastructure resilience and service availability according to business requirements.**

  The level of physical infrastructure resilience and service availability should be adapted to business requirements. These requirements should be supported by a business impact analysis. Multi-path infrastructures can be unnecessary and inappropriate. If only a single level of resilience is available in the data centre, an increased resilience or availability for critical services can be obtained by

splitting the ICT platform across multiple sites and making applications resilient to the loss of an individual site.

- **Build a modular data centre to avoid oversizing.**

  When building a new data centre, it must be designed to provide different levels of power and cooling resilience to different spaces to accommodate differing business needs. Many co-location providers deliver this, for instance single power supplies or optional grey power feeds without UPS or generator back-up. A new data centre should be designed to maximize infrastructure's efficiency under partial and variable load conditions.

### 3.5.2.2 Achieved environmental benefits

By avoid oversizing the data centre and building a data centre on a practical modular architecture, this will:

- Reduce energy and material consumption as less space is needed;
- Lower the land footprint of the facility (soil sealing).

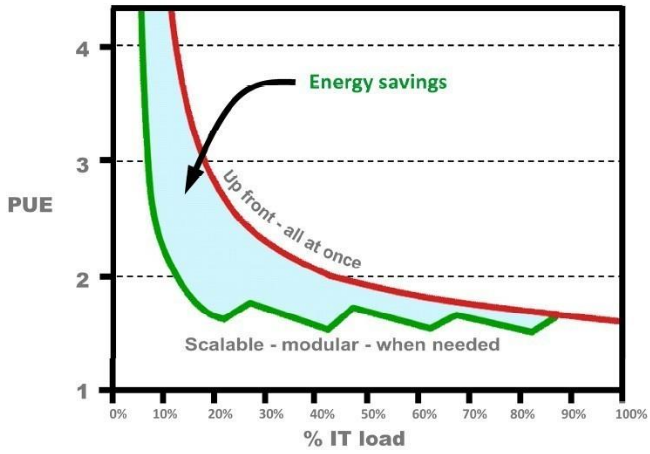



**Figure 64: PUE improvements due to data centre modularity (Source: (Rasmussen, 2011))**

### 3.5.2.3 Appropriate environmental performance indicators

The major metrics for defining energy-efficiency goals, and then to monitor results are:

- **Energy use of the data centre per floor area (kWh/m²),** which is the ratio between the total energy consumption of the data centre (measured in kWh), and the data centre floor area (measured in m²).
- **Power Usage Effectiveness (PUE)**, which is defined as the ratio of the total power to run the data centre facility to the total power drawn by all IT equipment.

In order to monitor the progress of actions related to the planning of data centres, process-oriented indicators can be defined, such as:

- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of

CLC/FprTR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres

### 3.5.2.4 Cross-media effects

While avoiding oversizing, a data centre can be built too small from the start. If this is the case, it will be more expensive and less efficient than if it was designed to be the right size from the start. (SURF, 2013) (Newcombe, 2011)

### 3.5.2.5 Operational data

**Limit the level of physical infrastructure resilience and service availability according to business requirements**

Data centre over-sizing is one of the largest drivers of electrical waste and occurred when the design value of the power and cooling equipment exceeds the IT load (Rasmussen, 2011). This situation can be observed when:

- IT systems are initially oversized due to overestimates of current and future loads and necessary computing capacity, and to redundancies added by multiple stakeholders (owners, process engineers, electrical engineers, HVAC engineers, etc.) whose intention is to secure their own activities (E-Server, 2009). Power and cooling systems can then be sized for too large for the IT load.
- The power and cooling systems are sized for a future larger load. Not only the expected IT load is usually about 90% of total capacity, but the IT load is being deployed over time, and initial loads are often below 20% of total capacity (E-Server, 2009). Then, power and cooling equipment, which remains the same, is initially largely oversized, and slightly gains use over time.
- The airflow management design is poor, requiring over-sizing of the cooling plant and conditioners in order to successfully cool the IT equipment.

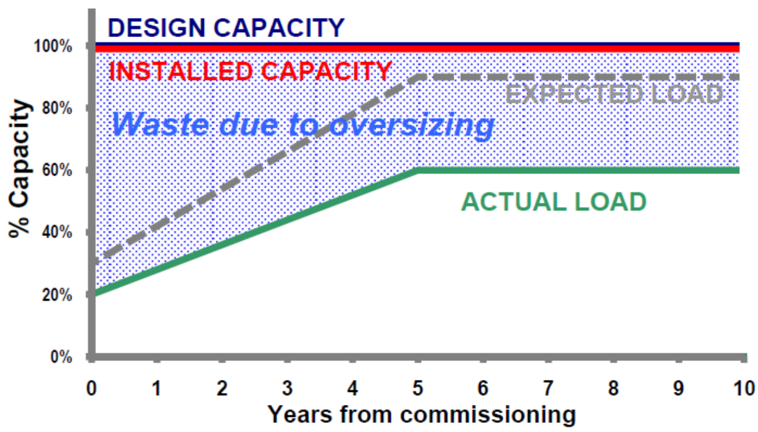



**Figure 65: Evolution of the IT load of a typical data centre (Source: ((Rasmussen, 2011))**

Consequently, the power supply required is often over-estimated. While data centres are commonly estimated to need an electrical grid connection to support a 2.7 kW/m² (or more) IT equipment density, benchmarks have demonstrated that average values in practice were around a tenth: 0.27 kW/m² (E-Server, 2009).

**Consider building a data centre to provide multiple levels of power and cooling resilience**

The first solution is to optimise computer equipment redundancy, in accordance with resilience and reliability, and energy consumption. An overall assessment of power and IT failure risks for the business should be performed, so as the consolidation of such equipment.

Another solution to avoid extra energy consumption related to oversizing is to continuously adapt power and cooling equipment to IT load. In many actual data centres the extra cost associated with installing such equipment later is significant. Consequently, powering and cooling equipment are often completely installed up-front. Designing a data centre with a modular architecture can facilitate continuous changes in equipment. It can be deployed according to the following principles (Rasmussen, 2011):

- The data centre should be provided in pre-engineered modular building blocks;
- The main input switchgear, main power distribution panels, and the standby generator(s) should be deployed up-front (and then meet ultimate design capacity);
- The installation of UPS, battery system, power distribution units, bypass switchgear and rack power distribution wiring can be phased, and should be able to use the cable distribution primarily installed (in order to reduce wiring, drilling and cutting);
- The cooling system can be upgraded and extended according to specific needs, by using blade systems in cooled racks for example and using the existing airflow design. Another upgrade would be to use a system (software) that can dynamically optimize switch on and switch off of cooling system (or adjust fan speed if possible) in line with the required temperature[71].
- Special site preparation such as raised floors would be reduced.

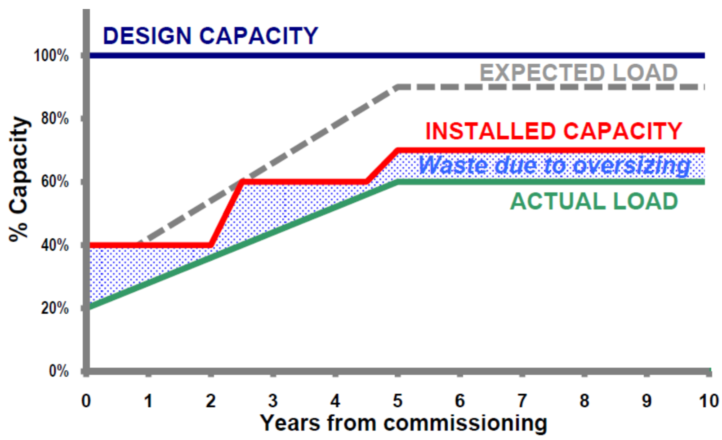



**Figure 66: Mitigation of the oversized power capacity over the lifetime of a data centre through modularity (Source: (Rasmussen, 2011))**

[71] Wireless sensors (i.e. temperature sensors distributed on rack and control unit on cooling unit) implement adaptive algorithms in order to maintain the set point defined for each sensor, and switch on and off the cooling unit or adapt fan speed.

#### 3.5.2.6 Applicability

Building a data centre according to a modular architecture is particularly relevant for big data centres (since costs savings can overcome the constraints resulting in building a data centre remotely) and for activities whose future needs in terms of IT loads are expected to be much higher than the actual needs, or that are currently uncertain.

It must be noted that the adoption of TIER certifications can require higher redundancies, which can then increase energy consumptions.

**Table 38: Applicability of best practices regarding the planning of new data centres**

| Best practice | Size | Security | Purpose |
|---|---|---|---|
| Limiting the level of physical infrastructure resilience and service availability according to business requirements. | Localised, mid-tier and enterprise-class data centre | Any tier[72] | Any purpose |
| Considering building a data centre to provide multiple levels of power and cooling resilience | Localised, mid-tier and enterprise-class data centre | Any tier | Any purpose |

#### 3.5.2.7 Economics

Integrating modular power and cooling technologies can result in total cost of ownership (TCO) savings of 30% compared to a typical oversized data centre (Torell, 2014). Using a standardised and scalable architecture can reduce:

- CAPEX, with a reduction of overbuilt capacity (reduced costs for power and cooling equipment, reduced installation costs related to wiring and ductwork);
- OPEX, with a reduction of maintenance costs (annual costs typically represent 10% of capital costs) and electricity consumption by 10% (Rasmussen, 2011).

[72] This practice must be implemented within the frame of the Uptime Tier Certification.

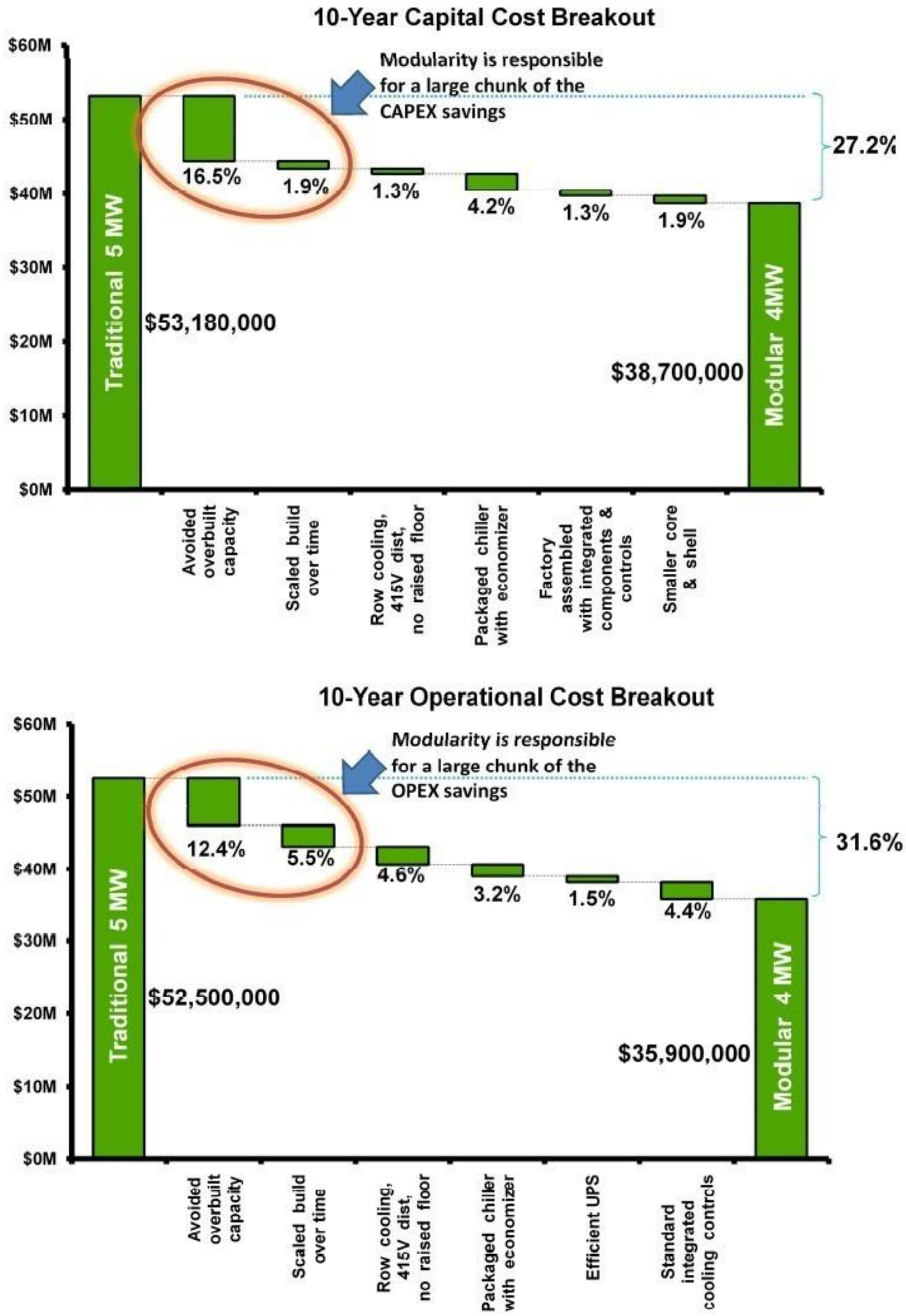



**Figure 67: Major CAPEX (top) and OPEX (down) cost savings related to the implementation of a modular architecture (Torell, 2014))**

The Table 39 below gives an overview of costs and return estimates for each best practice.

**Table 39: Economics data related to the implementation of practices related to the planning of data centres**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Limiting the level of physical infrastructure resilience and service availability according to business requirements. | NA | Selecting modular equipment and design | Savings from decreased energy consumption:<br>- Up to 30% decrease of TCO in a modular data centre compared to a traditional oversized data centre (Torell, 2014) |
| Considering building a data centre to provide multiple levels of power and cooling resilience | NA | Selecting modular equipment and design | Savings from decreased energy consumption |

### 3.5.2.8 Driving force for implementation

As demonstrated previously, the main driver when designing a modular architecture relies on the important cost reductions allowed during the lifetime of the data centre. But other parameters can benefit from such practices since the reliability of the data centre will be improved by a facilitated maintenance and replacement of power and cooling equipment.

On the contrary, reducing computer equipment redundancy can slightly reduce the resilience and reliability of such equipment, and by consequence of the whole data centre. An accurate assessment of the minimum redundancy necessary should avoid facing oversized risks.

### 3.5.2.9 Reference organisations

The Citigroup Frankfurt (Miller, 2009) data centre obtained a Platinium Leadership in Energy and Environmental Design (LEED) rating from the U.S. Green Building Council (USGBC) for its optimized design, while the Lamda Hellix Athens 1 (USGBC, 2016) obtained a Gold rating. Among other things, both data centres optimized their cooling system, water treatment and waste management design.

The data centre of Six Degrees Group Energy Efficient Solutions, located in Birmingham (UK), implemented a comprehensive control strategy for cooling system. It uses sensor average temperatures and supply and return temperatures on cooling system to alter fan and pump speeds on indoor and outdoor equipment to optimize free cooling (JRC, 2016).

The FCO Services Milton Keynes DC data centre (UK) installed a modular, scalable power and cooling architecture that allows deployment as needed (JRC, 2016).

#### 3.5.2.10 Reference Literature

Reference literature are consolidated in the section 3.5.7 Reference literature.

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Utilisation, management and planning of new build and refurbishment of data centres

### 3.5.3 Reuse of data centre waste heat

| SUMMARY OVERVIEW: | | | | | |
|---|---|---|---|---|---|
| **As any electrical equipment, IT equipment requires power supply and produces waste heat while running. Data centres produce large quantities of waste heat, which is an opportunity for heat reuse. It is considered best practice to:**<br>• **Re-use the waste heat produced in some rooms of the data centre to provide low grade heating to industrial or office space (including other areas of the data centre).** | | | | | |
| **ICT components** | | | | | |
| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices | |
| **Relevant lifecycle stages** | | | | | |
| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management | |
| **Main environmental benefits** | | | | | |
| Energy consumption | Resources consumption | Air emissions | **Water use & consumption** | Noise and electromagnetic radiations | Landscape and biodiversity |
| **Environmental performance indicators** | | | | | |
| • Energy Reuse Factor (ERF)<br>• Energy Reuse Effectiveness (ERE)<br>• Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding reuse of data centre waste heat | | | | | |
| **Cross references** | | | | | |
| **Prerequisites** | NA | | | | |
| **Related BEMPS** | • 3.5.2 Planning of new data centres<br>• 3.5.4 Design of the data centre building and physical layout<br>• 3.5.5 Selecting the geographical location of the new data centre<br>• 3.5.6 Use of alternative sources of water | | | | |

#### 3.5.3.1 Description

As any electrical equipment, IT equipment requires power supply and produces waste heat while running. As explained in EU Code of Conduct for data centres (JRC, 2015), data centres produce large quantities of waste heat. Heat produced by IT equipment can be reused, by installing a heat recovery system. Heat pumps may be used for circulating heat from the data centre to buildings which need to be warmed (offices, industrial buildings, swimming pools, etc.).

Best practices regarding the reuse of data centre waste heat include (CENELEC, 2016):

- Re-using the waste heat to provide low grade heating to industrial or office space.

  When planning a new data centre, an analysis must be made of the opportunity to locate the data centre where there are available opportunities for the reuse of waste heat. It may be possible to provide low grade heating to industrial space or to other targets such as adjacent office space fresh air directly from heat rejected from the data centre. This does not reduce the energy consumed by the data centre itself but does offset the total energy overhead by potentially reducing energy use elsewhere.

  The heat produced in some rooms of the data centre can also be used to warm other areas of the data centres, such as offices, generator and fuel storage areas. Indeed, the electrical preheat loads for generators and fuel storage can be reduced or eliminated by using warm exhaust air from the data floor to maintain temperature in the areas housing generators and fuel storage tanks.

  The use of additional heat pumps can help raise the temperature to a useful point, for situations where waste heat produced by the data centre cannot be directly re-used due to an insufficient temperature.

#### 3.5.3.2 Achieved environmental benefits

Reusing waste heat leads to an indirect decrease in energy consumption, both of the data centre itself, and of adjacent buildings if connections between the two heating systems are made.

#### 3.5.3.3 Appropriate environmental performance indicators

The opportunity for the reuse of waste heat from data centres is referenced by the **Energy Reuse Factor** (ERF) and **Energy Reuse Effectiveness** (ERE) from The Green Grid (The Green Grid, 2010b), and should be used currently for reporting the use of waste heat. The formulas are the following:

- ERE = (Total energy – Reused Energy ) / IT energy
- ERF = Reuse energy / Total energy.

However, as mentioned in the EU Code of Conduct for Data Centres (JRC, 2015), standardised metrics continually develop (particularly in relation to the work being done within the ISO/IEC 30134 series of standards).

One process-oriented indicator can be:

- Share of sites that have implemented the EU Code of Conduct on Data Centre Energy Efficiency / Expected Practices of CLC/FprTR 50600-99-1 regarding reuse of data centre waste heat

### 3.5.3.4 Cross-media effects

As long as BEMP is implemented correctly, no significant cross-media effect seems to exist.

### 3.5.3.5 Operational data

**Re-using the waste heat to provide low grade heating to industrial or office space**

The use made of waste heat will depend on several criteria:

- The proximity to other buildings which could use waste heat for heating purposes;
- The temperature in data centre's hot aisles (typically between 27 and 46°C).

Heat produced by IT equipment can also be reused, by installing a heat recovery system. A heat exchanger may be used for removing heat from the data centre and for heating water which can be then sent to buildings which need to be warmed (offices, industrial buildings, swimming pools, animal and fish breeding, hydroponic cultivations, etc.).

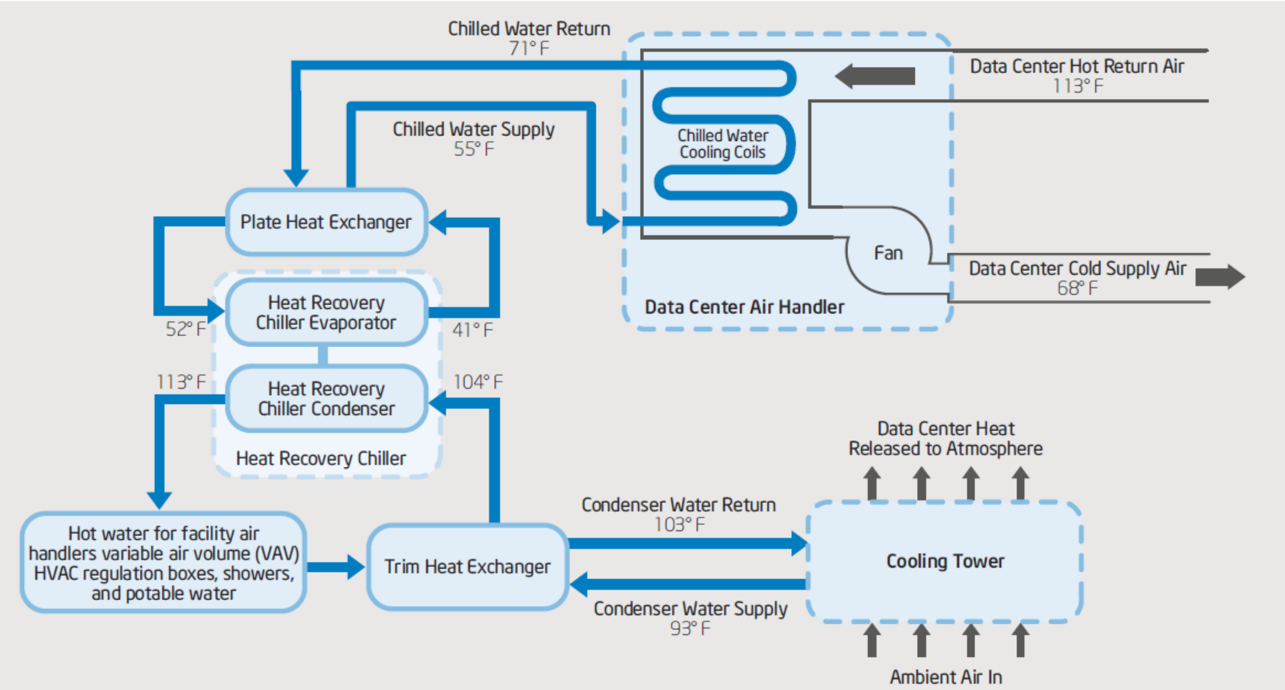



**Figure 68: Heat recovery system implemented into an Intel data centre (source: Intel, 2007)**

Where it is not possible to directly reuse the waste heat from the data centre due to the temperature being too low it can still be economic to use additional heat pumps to raise the temperature to a useful point. This can supply office, district and other heating.

### 3.5.3.6 Applicability

The BEMPs presented in this section can be implemented by any data centre regardless of its size, tier or purpose. Applicability will mostly depend on other factors, as mentioned in 3.5.3.5.

While this heat is typically at a relatively low temperature, there are some applications for reuse of this energy. This is especially true as consolidation and virtualisation increase the utilisation of IT equipment, thereby likely increasing exhaust temperature. Consequently, opportunities for reuse of waste heat will be growing.

### 3.5.3.7 Economics

**The**

Table 40 below gives an overview of costs and return estimates for each best practice.

**Table 40: Economics data related to the implementation of practices related to the reuse of the data centre waste heat**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Re-using the waste heat to provide low grade heating to industrial or office space | NA | Selection and installation of equipment to connect data centre to adjacent buildings:<br>- Up to 1,500€ per meter for trenching and installation to run a hot water pipe to a heat user (Monroe, 2016)<br><br>Additional capex to reuse ICT-heat via 2 chillers of 400kWth : 174,000€ (PASM, 2016) | - Some heat and power systems sell waste heat to district heating for 0.1€-0.3€ per kWh<br>(i.e. 300,000€ per year for a 1.2 MW data centre) (Monroe, 2016) |

Intel developed a heat recovery system into a data centre (the heat is used inside the same building), with an estimated ROI of 1.7 months (Intel, 2007). Projects aiming at reusing the heat produced by the data centre in another location may show a much longer ROI.

### 3.5.3.8 Driving force for implementation

Data centres can transform waste heat into financial incomes if they sell this heat as energy to third parties.

In addition, because heat is an important (and growing) issue for data centres, implementing BEMPs in this area can benefit data centres in terms of image.

### 3.5.3.9 Reference organisations

Telecity, based in Paris, uses waste heat from its Condorcet data centre to heat an on-site Climate Change Arboretum.

Telehouse West data centre in London is used to heat nearby houses and offices.

An IBM data centre in Switzerland is used to heat a nearby swimming pool. Alternatively, the same level of waste heat is sufficient to heat 80 homes.

Resilience Centre Luxembourg South (KAYL) data centre was awarded a EU Code of Conduct in 2016. It reuses energy with heat pumps for offices (2,000m²) within the data centre, and for offices in another adjacent building (3,000m²).

### 3.5.3.10 Reference literature

Reference literature will be consolidated in the final version of the report.

Please refer to the section reference of the conclusion displaying all the report's references.

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Reuse of data centre waste heat.

### 3.5.4 Design of the data centre building and physical layout

**SUMMARY OVERVIEW:**

**The physical layout of the data centre influences significantly its cooling system performance, since cooled areas (where racks are located) may be unnecessarily located close to internal heat sources (such as mechanical or electrical equipment) or in areas heated by external sources (e.g. solar radiation). It is considered best practice to:**

- **Minimise direct solar heating of the cooled areas of the data centre, in order to minimise cooling requirements.**
- **Locate cooling equipment in appropriate areas of the data centre, such as areas with free air movement, areas with sufficient space to optimize cooling performance, areas free of obstructions and free of equipment generating heat.**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre building physical layout

**Cross references**

| **Prerequisites** | NA |
|---|---|

| | |
|---|---|
| **Related BEMPS** | • 3.3.2 Selection and deployment of green equipment for data centres<br>• 3.5.2 Planning of new data centres<br>• Reuse of data centre waste heat3.5.3 Reuse of data centre waste heat<br>• 3.5.5 Selecting the geographical location of the new data centre |

**SUMMARY OVERVIEW:**

**As any electrical equipment, IT equipment requires power supply and produces waste heat while running. Data centres produce large quantities of waste heat, which is an opportunity for heat reuse. It is considered best practice to:**

- **Re-use the waste heat produced in some rooms of the data centre to provide low grade heating to industrial or office space (including other areas of the data centre).**

**ICT components**

| | | | | |
|---|---|---|---|---|
| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| Energy consumption | Resources consumption | Air emissions | **Water use & consumption** | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- Energy Reuse Factor (ERF)
- Energy Reuse Effectiveness (ERE)
- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding reuse of data centre waste heat

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 3.5.2 Planning of new data centres<br>• 3.5.4 Design of the data centre building and physical layout<br>• 3.5.5 Selecting the geographical location of the new data centre<br>• 3.5.6 Use of alternative sources of water |

#### 3.5.4.1 Description

After the planning sequence, key parameters, including energy efficiency can be used for developing the physical infrastructure system concepts for the data centre, including:

- Environmental criteria for site selection (see chapter 3.5.5);
- Equipment technologies of the data centre, and especially powering, cooling and air-managing systems, since this equipment consumes important amount of energy in a data centre[73]. Moreover, such equipment must be carefully adapted to the expected powering and cooling needs of IT equipment that will be installed (see chapter 3.3.2).

The design of the data centre can be completed, in order to lead to project engineering specifications able to be used for building the data centre (Rasmussen, 2013):

- Detailed component lists;
- Exact floor plan of racks (including power and cooling equipment);
- Detailed installation instructions;
- Detailed project schedule.

The physical layout of the data centre mainly influences its cooling system performance, since cooled areas (where racks are located) may be warmed by inside (mechanical and electrical equipment) or outside (insolation) sources of heat.

Regarding data centre building and physical layout, it is best practice to (CENELEC, 2016):

- **Minimise direct solar heating of the cooled areas of the data centre.**

  Direct solar heating on cooled areas of the data centre should be minimised, so as not to increase cooling requirements.

- **Locate cooling equipment in appropriate areas of the data centre.**

  Cooling equipment should be installed in appropriate areas of the data centre, such as areas with free air movement, areas with sufficient space to optimize cooling performance, areas free of obstructions and free of equipment generating heat.

After the design sequence, implementation requirements should be set up. It corresponds to a set of rules that can be divided between standard requirements (special regulatory compliance, compatibility of subsystems, safety, etc.) and project requirements, where user specific details are defined: human and equipment resources, special procurement, deadlines, etc. (Rasmussen, 2013). Best environmental management practices can be implemented within this step:

- Procurement related to the purchasing of energy-efficient equipment, as for IT equipment, cooling plants and air conditioners, fans and humidifiers or power plants can be implemented to selected more-efficient models within equipment technologies already chosen (see chapter 3.3.2).

[73] Chapter 3.3.2 demonstrates that important energy-savings can be made when choosing more energy-efficient technologies

- Equipment installation guidelines, in order to ensure the efficiency of the equipment that will be purchased, and which has to be installed properly in order to show optimised energy consumption performances (see chapter 3.3.2).

#### 3.5.4.2 Achieved environmental benefits

Energy needed for cooling can be decreased by implementing the practices presented in this section. For instance:

- Locating equipment which generate heat (such as UPS) outside the cooled data centre spaces reduces the loading on the data centre cooling plant.
- Reducing obstructions of air flows increases the efficiency of cooling (better air movement and increased efficiency of economisers).
- Minimising solar heating of the cooler areas will decrease the need for additional cooling requirements.

#### 3.5.4.3 Appropriate environmental performance indicators

An overall process-oriented indicator that can be monitored is:

- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre building physical layout.

#### 3.5.4.4 Cross-media effects

In order to have separated rooms for different types for equipment, and to ensure sufficient ceiling height, the size of the data centre will tend to be increased. This will increase building material, and potentially necessitate additional resources (energy to power new rooms, additional metering equipment and sensors to monitor the activity of different rooms etc.).

#### 3.5.4.5 Operational data

**Minimising direct solar heating of the cooled areas of the data centre**

Minimising direct solar heating of the cooled areas of a data centre can be done in several ways. Effective insulation can be provided by using suitable wall and roof coverings. For instance, shade can be installed using natural features, such as green roofs systems. Alternatively, the use of light coloured roofs and walls increases the reflectivity of the building and decreases additional cooling needs. Finally, minimising solar heating can be done by avoiding the use of external windows in data centre spaces.

An integrated solution can be to shadow roofs using photovoltaic panels producing local renewable energy that can directly aliments UPS batteries with the DC current produced.

**Locating cooling equipment in appropriate areas of the data centre**

Regarding the location of cooling equipment, it should be located in an area of free air movement, in order to avoid trapping it in a local hot spot. In addition, cooling

equipment should also be located in a position on the site where the waste does not affect other buildings and create further demand for cooling.

The data centre design should also include sufficient ceiling height to enable use of efficient air cooling technologies such as raised floor, suspended ceiling, aisle containment or ducts when air movement is used to cool the ICT equipment.

Finally, attention should be paid to the location of mechanical and electrical equipment which generate heat, such as UPS. These should not be installed in the cooled data centre spaces, in order to reduce the loading on the data centre cooling system.

#### *3.5.4.6 Applicability*

The BEMPs presented are most relevant for building new, enterprise-class data centres, as these practices aim to shape the aspect and structure of the new built data centre and can be costly to implement.

#### *3.5.4.7 Economics*

The table below gives an overview of costs and return estimates for each best practice.

**Table 41: Economics data related to the implementation of practices regarding data centre building and physical layout**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Minimise direct solar heating of the cooled areas of the data centre | NA | Cost of additional analysis during design and construction phases | Decrease cost of energy for cooling purposes |
| Locate cooling equipment in appropriate areas of the data centre | NA | Cost of additional analysis during design and construction phases | Decrease cost of energy for cooling purposes |

#### *3.5.4.8 Driving force for implementation*

Similarly to other practices related to new build data centres, integrating energy-efficiency parameter within the design of the data centre location should be positive in terms of operating cost savings since the performance of the cooling system should be increased.

#### *3.5.4.9 Reference organisations*

NA

#### *3.5.4.10 Reference literature*

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Data centre building physical layout.

### 3.5.5 Selecting the geographical location of the new data centre

**SUMMARY OVERVIEW:**

**The geographical location of the data centre has great influence on its future carbon and environmental impacts. It is considered best practice to:**

- **Select a geographical location with environmental conditions improving the performance of side-economisers, offering opportunities for installing equipment for the production of renewable energy or limiting threats and natural disasters (such as flooding).**
- **Locate the data centre close to energy, cooling and heating sources, to minimise energy losses due to energy transport and to offer opportunities for the of carbon emissions (consumption of renewable energy, waste heat or free cooling).**
- **Minimise impacts of the building on the environment (noise, aesthetic impacts, needs for telecommunication networks and other infrastructures, etc.).**

**ICT components**

| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Share of new facilities with free cooling solutions (air-side economisers, geothermal cooling, etc.)
- Share of new facilities with renewable energy production on site (photovoltaic panels, wind turbine, etc.)
- Share of new facilities with heat reuse system
- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre geographical location

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 3.5.2 Planning of new data centres<br>• 3.5.3 Reuse of data centre waste heat<br>• 3.5.4 Design of the data centre building and physical layout |

#### 3.5.5.1 Description

After establishing key project parameters (capacity, costs, etc.), the system concept shall be developed and the site selection for the new data centre selected. The location of the data centre will have great influence on the carbon and environmental impacts of the future facility.

Regarding the geographical location of new data centres, it is best practice to (CENELEC, 2016):

- **Select a geographical location with favourable environmental conditions.**

  When planning the construction of a data centre, locating the data centre in a place with favourable environmental conditions can help reduces energy needs. Climate and ambient temperature will have an influence on:

  - inside temperatures,
  - the performance of side-economiser cooling systems (facilitated by low temperature and humidity conditions),
  - the opportunities for installing equipment for the production of renewable energy.

  Unfavourable locations should also be avoided, to limit threats and natural disasters as flooding.

- **Locate the data centre close to energy, cooling and heating sources.**

  The first step is to minimise energy losses due to the transportation of energy by locating the data centre close to power generating equipment. The second step is to select the location considering the types of resources available:

  - proximity to renewable sources of energy;
  - proximity to opportunities for waste heat reuse (offices, swimming-pool, etc.);
  - proximity to free ground cooling resources.

- **Minimise impacts of the building on the environment.**

  When designing a new data centre, its direct environmental impacts (noise, nature etc.) should be taken into account, as well as its indirect ones (needs for telecommunication networks and other public infrastructures for example).

#### 3.5.5.2 Achieved environmental benefits

Better site-selection and planning of data centres leads to:

- Significant energy savings and reduction of cooling refrigerants (emissions of potential GHG and ozone depletion substances) due to a reduced need for cooling;
- Reduced GHG emissions from reduced energy consumption and the use of available renewable energy resources;
- Less impact of natural habitats and wildlife (avoids land take and soil sealing);
- Less energy consumption due to low temperature of chosen location (depending on the geographical location).

#### 3.5.5.3 Appropriate environmental performance indicators

One indicator related to the implementation of the techniques recommended by the CENELEC technical document CLC/FprTR 50600-99-1 can be monitored:

- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding data centre geographical location

Selecting the appropriate geographical location of the data centre aims at facilitating the use and production of more sustainable sources of energy, cooling or heating through the production of renewable on site, the installation of free cooling equipment, the development of heat reuse systems, etc. The deployment of such solutions is intended to be carried out when building a new data centre after the site selection. One possibility to monitor the effectiveness of the site selection upon environmental criteria is to assess whether targeted solutions have been installed on site or not. Environment performance indicators can be:

- **Share of new facilities with free cooling solutions** (air-side economisers, geothermal cooling, etc.)
- **Share of new facilities with renewable energy production on site** (photovoltaic panels, wind turbine, etc.)
- **Share of new facilities with heat reuse system**

#### 3.5.5.4 Cross-media effects

Some of these indicators are suited for setting energy performance goals / objectives during planning (PUE), while others are more useful for selecting data centre designs and sites (e.g. solar insolation, share of renewable energy in the local energy mix).

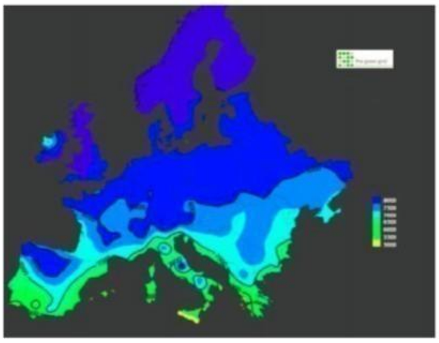
While locating a data centre in order to reduce its direct impact, this can lead to significant indirect impacts, caused by the transportation of data on a longer distance (requiring additional energy consumptions from telecommunication networks).

#### 3.5.5.5 Operational data

**Selecting a geographical location with favourable environmental conditions**

When deciding where to build a new data centre, the following parameters may reduce its environmental footprint, especially in terms of energy consumption (Sustainability Victoria, 2010):

- The ambient outdoor temperature: an area with a low ambient external temperature (Western, Central and Northern Europe, for example) may allow the deployment of free or economised cooling concepts.
- The ambient outdoor humidity: an area with a low ambient humidity rate does not require the use of dehumidifiers when using free cooling and may improve the efficiency of evaporative cooling.



Average free Cooling or Economizer average external air usage level Classification:

*Table 6. Free cooling level classification*

| LEVEL | HOURS/YEAR |
|---|---|
| 1 | >7500 |
| 2 | >6500 & <7500 |
| 3 | <6500 |

**Figure 69: Average yearly number of free-cooling usage hours (GENiC, 2014)**

Free-cooling usage hours above apply to data centres. Telecom centres aim at higher free-cooling usage rate due to the much wider temperature ranges accepted by the Telecom equipment. Telecom centres can reach 100% usage rate.

**Locating the data centre close to energy, cooling and heating sources**

Locating a data centre close to the power generating equipment can reduce transmission losses. Consequently, new data centres should be –when possible- located close to a power generating plant. In order to benefit from renewable energy sources, environmental conditions (solar exposure, wind potential, etc.) and the possibility to connect locally produced electricity to the network should be analysed in the design phase.

The availability of other resources, such as cooling sources (e.g. a river or a lake without nature conservation restrictions) can also be taken into account when deciding where to locate a data centre.

The impact of a data centre on the environment can also be minimised by locating the data centre where there are available opportunities for the reuse of waste heat.

**Minimising impacts of the building on the environment**

The planning phase should take into account noise pollution, aesthetic pollution and the existence of nature conservation constraints that can be written in local planning documents.

New data centres should also be located close to telecommunications network and other public infrastructure (e.g. roads).

### *3.5.5.6 Applicability*

Locating a data centre according to its energy-efficiency potential is particularly relevant for big data centres (since costs savings can overcome the constraints resulting in building a data centre remotely) and for activities whose future needs in terms of IT loads are expected to be much higher than the actual needs, or that are currently uncertain.

**Table 42: Applicability of best practices regarding the choice of the geographical location of new data centres**

| Best practice | Size | Security | Purpose |
|---|---|---|---|
| Selecting favourable environmental conditions (temperature, humidity) | Mid-tier and enterprise-class data centre | Any tier | Any purpose |
| Locating the data centre close to an energy source | Mid-tier and enterprise-class data centre | Any tier | Any purpose |
| Minimising impacts on the environment | Mid-tier and enterprise-class data centre | Any tier | Any purpose |

#### *3.5.5.7 Economics*

The table below gives an overview of costs and return estimates for each best practice.

**Table 43: Economics data related to the choice of the geographical location of new data centres**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Selecting favourable environmental conditions (temperature, humidity) | NA | Additional costs for analysis | Savings from decreased energy consumption for cooling and humidification |
| Locating the data centre close to an energy source | NA | Additional costs for analysis | Less transmission losses |
| Minimising impacts on the environment | NA | Additional costs for analysis | Avoidance of potential legal fees |

#### *3.5.5.8 Driving force for implementation*

Integrating energy-efficiency parameter within the selection of the data centre location should be positive in terms of operating cost savings since the performance of the cooling system should be increased. Then a greater focus on the Total Cost of Ownership when building a data centre can give arguments in favour of better integration of environmental criteria.

Nevertheless, this decision takes into account capital costs (land price, labour costs, etc.) and other operating costs (labour costs, costs of network access, etc.) that might not be the lowest on the site selected for its highest energy-efficiency potential. (Grid, 2013)

Moreover regulations vary according territories and do not allow the same possibilities in terms of building a data centre (town planning constraints, incentives for renewable sources, etc.). It can also not be authorized to use ground water for cooling purposes.

Other parameters can benefit from such practices since the reliability of the data centre will be improved by a facilitated maintenance and replacement of power and cooling equipment.

Finally, energy security can be increased when selecting the location of the data centre, e.g. by locating the data centre away from frequent natural disaster zones (flooding etc.).

### 3.5.5.9 Reference organisations

Major ICT companies and organisations have recently decided to build large data centres in territories with a colder climate, such as Ireland (Google), Finland (Microsoft), Sweden (Facebook) or Iceland (Verne Global).

ENI has decided to develop a data centre close to an energy plant in order to be provided with all of its energy needs with biogas (CH4).

### 3.5.5.10 Reference literature

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Data centre geographical location.

## 3.5.6 Use of alternative sources of water

**SUMMARY OVERVIEW:**

**Water is used in data centres for two purposes: cooling and humidification, which are intimately linked. In particular, evaporative chillers require significant amount of water. It is considered best practice to:**

- **Monitor water consumption from all sources in all data centre spaces.**
- **Limit impact on potable water resources by using non-potable water sources (rainwater, wastewater, etc.).**

| ICT components | | | | |
|---|---|---|---|---|
| **Data centre** | Telecommunication network | Broadcasting | Software publishing | End-user devices |

| Relevant lifecycle stages | | | | |
|---|---|---|---|---|
| **Design and installation** | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |

| Main environmental benefits | | | | | |
|---|---|---|---|---|---|
| Energy consumption | Resources consumption | Air emissions | **Water use & consumption** | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental performance indicators**

- Share of water consumed in data centres by source, such as mains water, rainwater or non-utility water sources
- Water consumption of the data centre per floor area ($m^3$ consumed /$m^2$ of data centre)
- Water Use Efficiency (WUE)
- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding water sources

| Cross references | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 2.5 Use of renewable and low-carbon energy<br>• 3.2.5 Improve cooling management<br>• 3.3.2 Selection and deployment of green equipment for data centres<br>• 3.5.5 Selecting the geographical location of the new data centre |

### *3.5.6.1 Description*

Water is specifically used in data centres for two purpose: cooling and humidification, which are intimately linked. The consumption of water depends on the type of cooling system installed in the facility (see BEMP 3.2.5 Improve cooling management and BEMP). In particular, evaporative chillers require significant amount of water: the National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 M litres per MW year (NREL, 2014). Other cooling technologies use water in closed circuits that does not consume significant amount of water.

As in any building hosting human activities, water consumption also occurs consequently to sanitary usage. Besides, when consuming energy on site, there is also an indirect consumption of water. However these two sources of water consumption are not specifically addressed within this BEMP. The BEMP report for the public administration sector deal with the consumption of water in buildings, while the BEMP on the use of renewable and low carbon energy addressed the topic of energy production (see BEMP 2.5 Use of renewable and low-carbon energy).

The following figure gives example of total water consumptions (including energy production – related water consumption) for different cooling technologies:

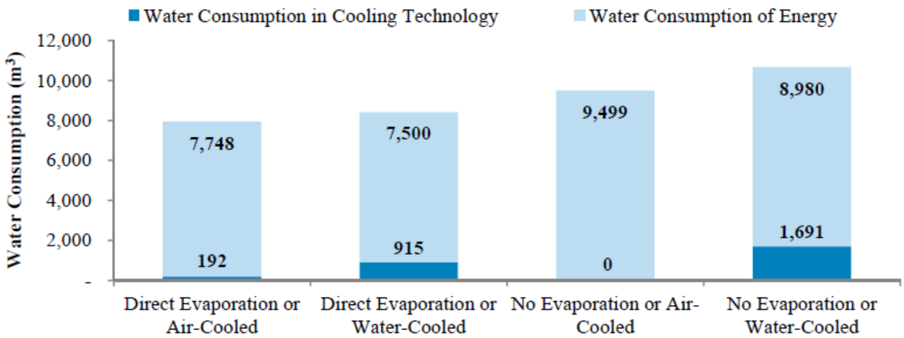



**Figure 6.** Annual water consumption of different cooling technologies in a DC cooling technology with a capacity of 61,164 m$^3$/min, based on inlet supply temperature to servers of 27 °C in Phoenix, Arizona. (After Vokoun [74] who reports United Metals Products values. Vokoun uses National Renewable Energy Laboratory (NREL) figures for the water consumption for electricity production (8254 m$^3$/TJ) [75]. Note that NREL is using only evaporative water consumption not WF).

**Figure 70: Annual water consumption of different cooling technologies in data centres - Source: (B. Ristic, K. Madani and Z. Makuch, 2015)**

In order to reduce both the amount of water purchased externally and the environmental impact of water consumption, several techniques can be implemented. It is best practice to (CENELEC, 2016):

- **Monitoring water consumption.**

  Water consumption from all sources in all data centre spaces should be metered and monitored.

- **Limiting impact on potable water resources.**

  Data centres should be designed to be able to use non-potable water sources, thereby limiting their ecological impact.

#### *3.5.6.2 Achieved environmental benefits*

Using alternative sources of water can decrease the environmental impact of water consumption by data centres. Indeed, freshwater usage is a concern (particularly in dry areas) and the amount of sediment in a given volume increases as vapour are removed, requiring separation and disposal of this "blowdown." Some data centres have implemented techniques for using non-utility water sources cooling or other non-potable purposes: rainwater, wastewater or seawater have already been used.

#### *3.5.6.3 Appropriate environmental performance indicators*

Standardized metrics in terms of water consumption are evolving rapidly, and here are two examples of outcome indicators that can be monitored:

- **Water consumption of the data centre per floor area** ($m^3$ consumed /$m^2$ of data centre);
- **Water Usage Effectiveness** (L/kWh) (The Green Grid, 2011a), which is the ratio between the annual water consumption of the data centre (L) and the annual energy consumption of IT equipment (kWh).

Other sources for information on the measurement of water consumption include the works on ISO/IEC 30134 and EN50600-4.

Regarding the use of alternative water sources for cooling, an appropriate metric can be:

- **Share of water consumed in data centres by source**, such as mains water, rainwater or non-utility water sources.

Another process oriented indicator that can be monitor is:

- Share of sites that have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/FprTR 50600-99-1 regarding water sources

#### *3.5.6.4 Cross-media effects*

As stated in 4.2.5.2, evaporative chillers allow huge energy savings, but require large amounts of water. The National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 M litres per MW year (NREL, 2014). This means that rainwater collection might only be used as a complementary source of water for data centres located in dry areas.

#### *3.5.6.5 Operational data*

**Monitoring water consumption**

Water consumption from all sources in all data centre spaces should be metered and monitored, by following a KPI such as water consumption in $m^3/m^2$. It must be noted that water consumption cannot be directly compared with energy efficiency unless the energy intensity of the water source is understood. Comparing water consumption between buildings is therefore not useful.

**Limiting impact on potable water resources**

New build data centres should be designed to capture and store rain water for non-potable purposes, such as evaporative cooling[74]. Alternatively, other local non-utility water sources should be used (waste water for example), in order to reduce overall energy consumption.

### 3.5.6.6 Applicability

The choice of the cooling system solution depends on the size of the data centre, which is intimately linked to the activity and the size of the company. For example, chilled water system are suitable for data centre 200 kW and larger, and air evaporative cooling systems are used in 1,000 kW and larger data centres with high power density (Evans, 2012).

Consequently, the best practices presented in this section are relevant for large, enterprise-class data centres.

### 3.5.6.7 Economics

The table below gives an overview of costs and return estimates for each best practice.

**Table 44: Economics data related to the implementation of best practices related to the use of alternative sources of water**

| Best practice | Operating costs | Investment costs | Return on investment |
|---|---|---|---|
| Monitoring water consumption | Maintenance of equipment | Selection and installation of water collection equipment and connection to cooling system | Savings from decreased water quantities to be purchased |
| Limiting impact on potable water resources | Maintenance of equipment | Selection of more complex water supply | NA |

### 3.5.6.8 Driving force for implementation

Two main drivers are at work regarding the source of water used by data centres:

- First, data centres can achieve savings, as rainwater collection can be a substitute to some of the water needs (mostly for cooling);

[74] "Evaporatively conditioned" air systems are effective for transforming the incoming air into the desired conditions before entering the data centre but present reliability issues (mildew concerns and high maintenance requirements) (see also 4.3.7.6).

- Second, data centres can benefit in terms of image, especially in areas were water scarcity is an issue.

#### *3.5.6.9 Reference organisations*

Resilience Centre Luxembourg South (KAYL) data centre was awarded EU Code of Conduct in 2016. It has installed a rainwater recycling system (300m$^3$ rainwater tanks) for hybrid cooling towers (JRC, 2016).

#### *3.5.6.10 Reference literature*

The content of this BEMP is based on the techniques which are included in the following chapter of the CENELEC technical report CLC/TR 50600-99-1:2016:

- Water sources.

### 3.5.7 Reference literature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# 4 Telecommunication networks

## 4.1 Introduction / scope

### 4.1.1 Definition

Telecommunication networks are defined as *"transmission systems which permit the conveyance of signals by wire, by radio, by optical or by other electromagnetic means, including satellite networks, fixed and mobile terrestrial networks, electricity cable systems, networks used for radio and television broadcasting and cable television networks, irrespective of the type of information conveyed. It also covers electronic communications services, which consist of the transmission of signals over these networks, and associated facilities and services of the networks or of the electronic communications services, which enable or support the provision of services via that network or service"* (EU Directive 2002/21/C).

This chapter focuses on the network configuration of the different elements that form telecommunication infrastructure and networks:

- **Terminals or input/output devices** that send or receive signals, voice and data such as telephones (landline and mobile), computers and faxes. The devices allow users to access the network.
- **Telecommunication channels** that transmit between sending and receiving devices in a network. Examples of media used for transmission include fibre optics, coaxial cable and twisted wire for fixed networks; and radio transmission, terrestrial microwaves and satellite transmission for wireless networks using antennas.
- **Telecommunication processors** that process information and provide support functions for data transmission and reception. These are equipment such as base stations, modems, multiplexers, switches and routers.
- **Telecommunication control software** that manage the network and transmissions. Telecommunications and network management software may reside in PCs, servers, mainframes and communications processors like multiplexers and routers.
- **Other telecommunication equipment** such as host computers (mainframes), front-end processors (minicomputers) and network servers (microcomputers)

The different devices in a network are able to communicate together through standard protocols (e.g. from GSM to 5G for mobile phones and TCP and IP for the Internet) as well as standard software and hardware interfaces.

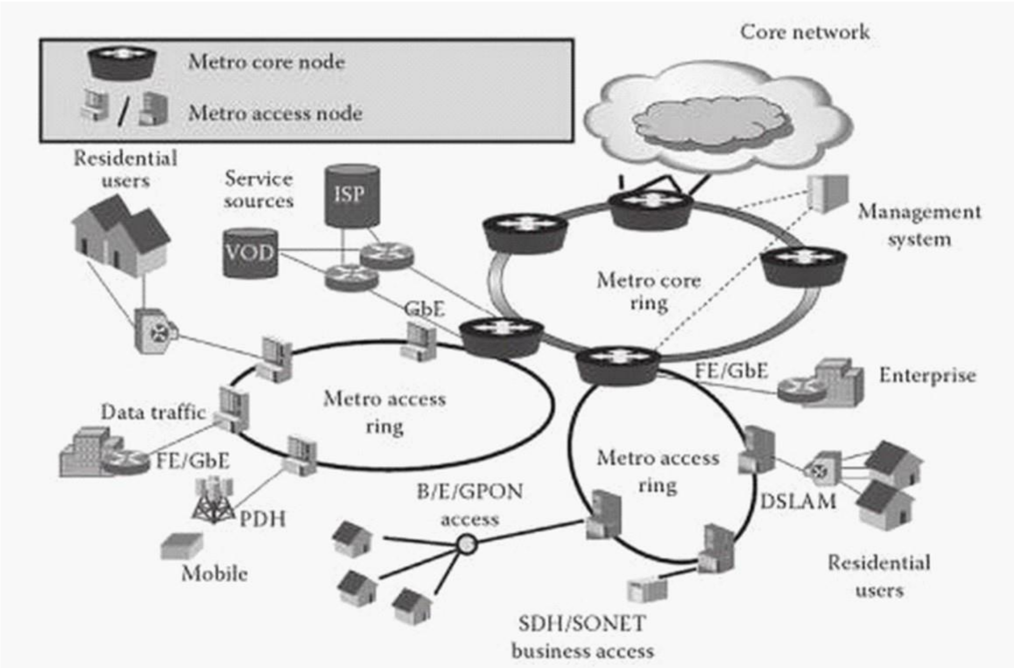


**Figure 71: An overview of telecommunication networks (Iannone, 2012)**

A mobile communications radio base station is a transmission and reception station in a fixed location, consisting of one or more receive/transmit antenna, microwave dish, and electronic circuitry, used to handle mobile traffic. It serves as a bridge between all mobile users in a cell and connects mobile calls to the mobile switching centre.[75] This assembly of different components varies, depending on:

- the location of the base station, since a rural site consists often of three symmetrical sectors with high RF power and only 1-2 carriers per sector, while urban and sub-urban sites vary typically from single sector to six sector installations with various multi-carrier configurations and additional capacity layers at multiple frequency bands;
- the combination of technology generations provided by the base station (GSM, HSPA, LTE and soon 5G), achieved with generations specific equipment (operators naturally use their existing sites to install also the next generation network equipment) or alternatively with a multi-standard base station;
- the telecom manufacturers of the elements.

### 4.1.2 Operating conditions

In order to function telecommunication networks consume significant amounts of electricity. Globally, it was estimated that telecommunication networks consumed 354 TWh of electricity or about 1.8% of all electricity use (for more information see section 1.3 on Environmental aspects of the telecommunication and ICT services sector) (Lambert, Van Heddeghem, Vereecken, Lannoo, Colle, & Pickavet, 2012). It has been reported that the annual energy consumption of mobile networks, excluding diesel generators and efficiency losses, was about 80 TWh in 2010 (GSMA, 2012a).

[75] http://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields/glossary/abc/base-station.htm

Due to the growth of the telecommunications and ICT services sector, the electricity consumption of networks has been increasing rapidly. However, trends of reduced energy consumption have been recently observed in certain areas such as Sweden (Malmodin, 2010) or by certain telecommunication operators (such as BT or Proximus).

The relative share of mobile and fixed infrastructure in telecom operator networks' overall energy consumption is not known, but the contribution of the mobile network is estimated to be between 60% and 75% according to a benchmark of telecommunication operators annual or CSR reports (Proximus, 2015; Vodafone, 2015; KPN, 2015).

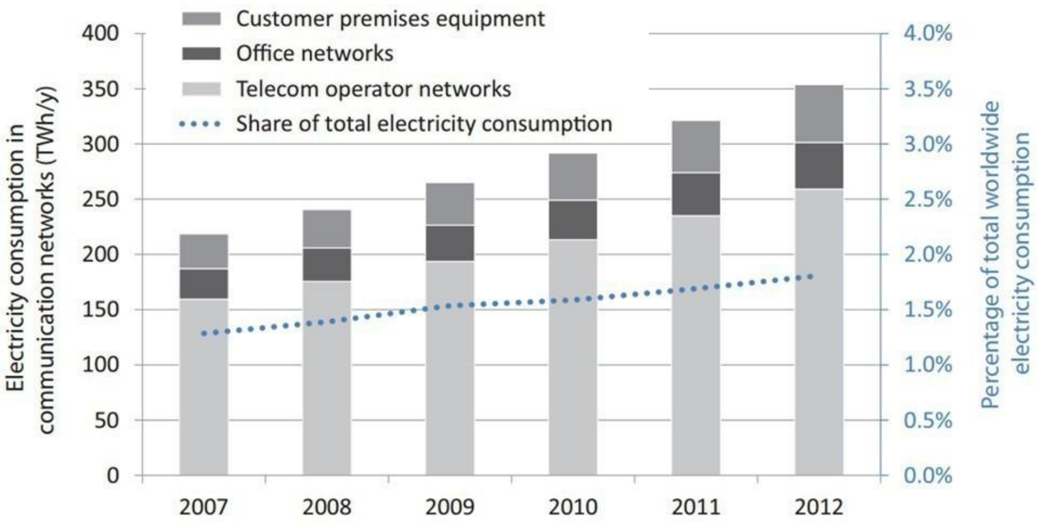


**Figure 72: Worldwide electricity consumption of telecommunication networks (Lambert, Van Heddeghem, Vereecken, Lannoo, Colle, & Pickavet, 2012)**

The code of conduct on Energy Consumption of Broadband Communication Equipment set up energy consumption targets for base stations, based on data reported by major manufacturers and telecommunication operators in Europe. For the period 2015-2016, the targets are as follow (JRC, 2013):

- Between 340 and 480 W of power load (at low-load-state and busy-hour-load state respectively) for a WiMAX radio base station (three sectors, 3.5GHz GHz, 10 MHz bandwidth channel, 4x4 MIMO, 29:18 DL/UL subframe ratio);
- Between 540 and 760 W of power load (at low-load-state and busy-hour-load state respectively) for a GSM/EDGE radio base station (three sectors, four carriers per sector, 0.9/1.8/1.9 GHz);
- Between 540 and 760 W of power load (at low-load-state and busy-hour-load state respectively) for a WCDMA/HSDPA radio base station (three sectors, two carriers per sector, 2.1 GHz);
- Between 600 and 840 W of power load (at low-load-state and busy-hour-load state respectively) for a LTE radio base station (three sectors, 2.6 GHz, 20 MHz bandwidth channel 2×2 MIMO).

A diversity of base station sites exists because a site might host several base stations: for different technologies (2G sites are usually reused to host also 3G and 4G equipment), for different frequency bands or for different operators. A "typical" BS has three sectors but there are lots of possibilities, and the energy usage breakdown can significantly vary from one site to another.

- Different DC power consumption breakdown were developed on the basis of the energy consumption model developed by the EARTH project (EARTH, 2012a). Power Amplifiers were shown as the main energy consuming equipment of macro LTE base stations at maximum load, due to high antenna interface losses. Such losses may be avoided through the use of feederless systems (Remote Radio Head system for example), which are not available in any location for a various number of reasons. In micro base stations, the power amplifier and the base band interface consume about the same amount of energy.
- Some base station sites does not require any cooling supply or just an active ventilation consuming 2-5% of the total power. Others may require air-conditioning consuming about 20% of the site power, especially if the base station is located in heated area (e.g. under the roof in poorly isolated attics) and if backup batteries are installed at the same place. When all equipment is installed in one single room, cooling will be set to match the requirements of the most sensitive equipment, thereby leading to a loss of energy efficiency.

### 4.1.3 Categorisation

The implementation of the different techniques presented in this chapter can vary depending on the characteristics of a network. A few main criteria can be used to differentiate between several types of networks:

- **Network segment**, namely core, metro or access network. This work mainly focuses on access and metro networks.
    - The core network, which refers to the backbone infrastructure that interconnects large network nodes (cities for example) and spans nationwide. In order to ensure high speed, high capacity and scalability of the core network, optical technologies are widely used to support the basic physical infrastructure (Zhang, 2010). Energy consumption of the core network occurs both from switching between the optical layer and the electronic layer (consumption due to IP routers, Digital and Optical Cross Connects, etc.) and from transporting data (consumption due to transmitters, pre-amplifiers, transponders, etc.).
    - The metro network, which typically covers metropolitan areas and provides interfaces between the core network and dispersed access networks. It provides direct Internet connectivity to residential subscribers. Different networking technologies have been deployed in different metropolitan areas across the world (Zhang, 2010), such as Metro Ethernet (based on the use of edge routers, broadband network gateways and Ethernet switches), Metro WDM ring (where Optical Add-Drop Multiplexers add and drop optical signals) or SONET ring architectures (an add-drop multiplexer is used to aggregate low-bite-rate traffic to high-bandwidth pipes of core networks).
    - The access network, which connects the telecom Central Office or Exchange with end-users. It comprises the larger part of the telecom network and can be deployed through diversified techniques (Baliga J. e., 2011), which are listed below.

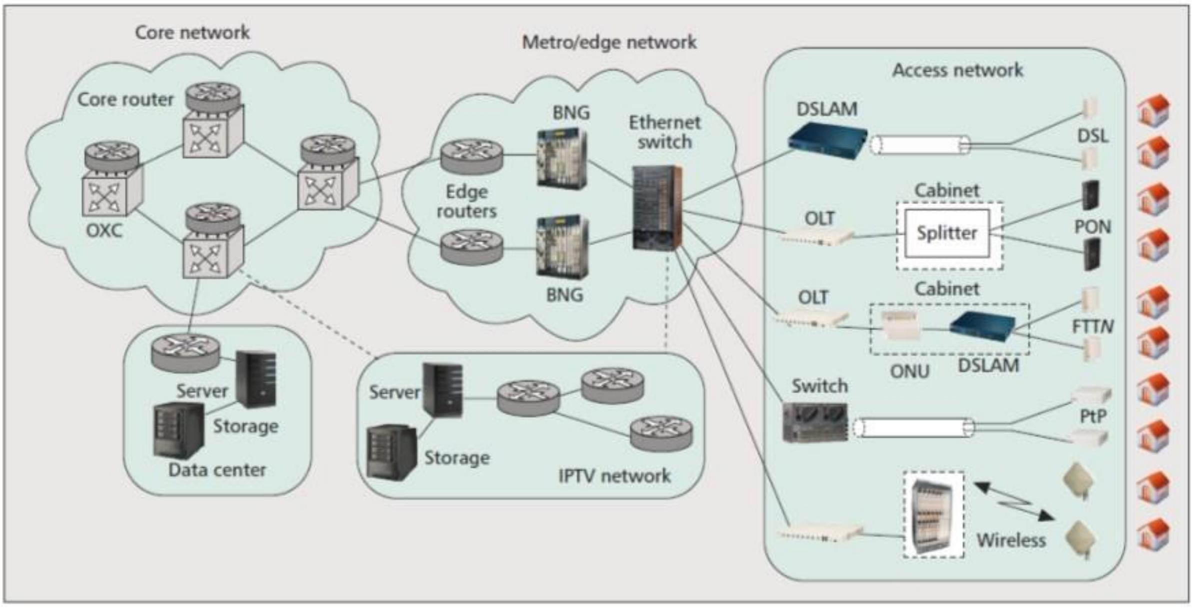


**Figure 73: A high-level network structure with various options for the access network (Hinton, 2011)**

- **Technology** used by the wireless or wireline network.
    - Technologies used in wireless networks can primarily be divided between:
        - Cellular mobile systems, such as GSM (Global System for Mobile communications), EDGE (Enhanced Data rates for GSM Evolution), GPRS (General Packet Radio Service), WAP (Wireless Application Protocol), UMTS (Universal Mobile Telecommunications System), International Mobile Telecommunications-2000 (IMT-2000), LTE (Long-Term Evolution), where cell phones use radio waves for accessing a base station connected to the core network (through fibre or point-to-point wireless backhaul);
        - Internet wireless access systems, such as WiFi (Wireless Local Area Network (WLAN)), where each home uses a modem to connect to a base station remotely located and connected to the metropolitan and edge network through fibre or point-to-point wireless backhaul.

          Nevertheless, the separation between these two networks is less and less significant, since modern smartphones can easily switch between mobile and WLAN, even without being noticed by the user.
    - Technologies used in access wireline networks include:
        - Digital Subscriber Line (DSL) is provided through copper cables used for fixed-line telephone service and needs a modem at each customer home;
        - Hybrid Fibre Coaxial (HFC) networks, where radio frequency material is transmitted through optical fibre before being converted into an electrical signal distributed to customers through coaxial cables (coupled to electrical amplifiers);

- Passive Optical Network (PON) is made of optical fibres, each one feeding one or more clusters of customers through a passive splitter, and optical network units at customers' home for receiving the signal;
- Fibre To The Node (FTTN) uses an optical fibre from a network to a Digital Subscriber Line Access Multiplexer (DSLAM) located in a street cabinet, and then high-speed copper cables for feeding the customer premise;
- Point-to-Point optical (PtP) uses a dedicated fibre between each customer and the terminal unit and optical media converters at customers' home to convert the optical signal into an electrical signal.

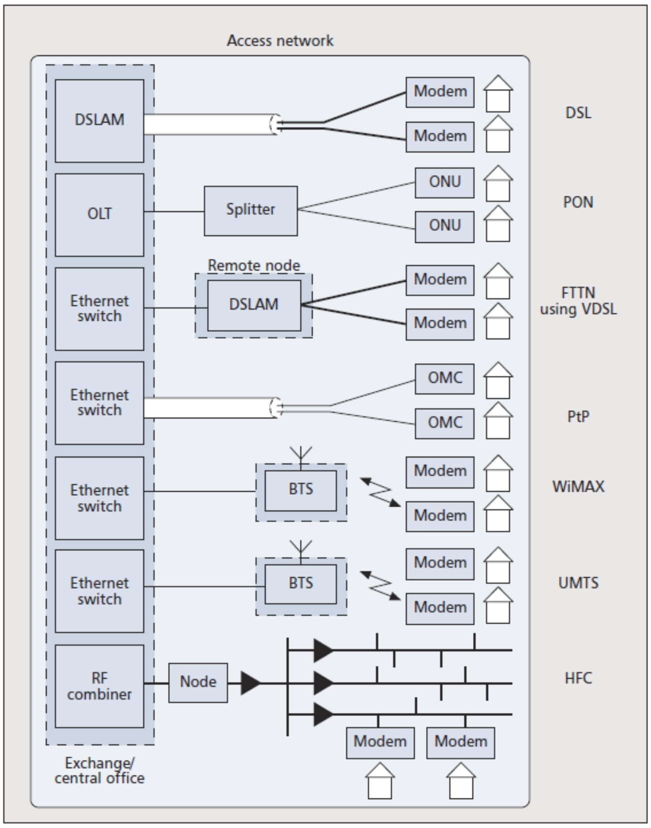


**Figure 74: Overview of the main access network technologies (Baliga J. e., 2011))**

- Depending on the **end-user**, the requirements of the network can also vary. Some users may require a very high quality of service, especially businesses, for which a stable connexion with a fast transmission rate, a high workload capacity and a very low resuming time are necessary. The implementation of the practices presented in this chapter depends on which actor has the ability to implement it (network operator or ICT service provider).

### 4.1.4 Environmental aspects of telecommunication networks

As telecommunication networks are expanding in size and capacity to provide services to a larger number of beneficiaries, the environmental impact (which includes - but is

not limited to - energy consumption) of these networks is becoming increasingly material for many actors.

Wireless communication, used for providing both telecommunications and broadcasting services, uses radio wave transmissions (with a spectrum from 3 kHz to 300 GHz) as signals, which are captured by receivers (phones, satellites, modems, etc.). All radio transmitters create electromagnetic fields (EMF); for more information on potential health issues of EMF see section 4.3 on

- Environmental pressures. Moreover, telecommunications and broadcasting infrastructure can have a visual impact on the character and amenity of the local environment depending on the perception of the local community as well as the aesthetic value assigned to the landscape, both in urban and in rural contexts.
- Wireline communication networks, on which this report focuses, rely on the use of thousands of kilometres of electric cables and optical fibres. These infrastructures have visual and physical impacts on the landscape (with aerial landlines), besides being a source of electrical losses. Contrary to wireless access networks, little attention is paid to energy consumption since there is no problem of interference (which can be caused by excessive base station transmission power), nor is the issue about IT equipment energy autonomy (which is the case for mobile phones, for example). However, as a consequence of increased traffic rates, attention has recently been paid to core and wireline access networks' capacity and energy consumption.

Apart from the wireline/wireless distinction, the environmental impact of the various network segments can also be distinguished. According to Bolla et al. (2010), access network devices account for about 70% of the total energy requirements of the network. The access network can be a major consumer of energy due to the presence of a large number of active elements.

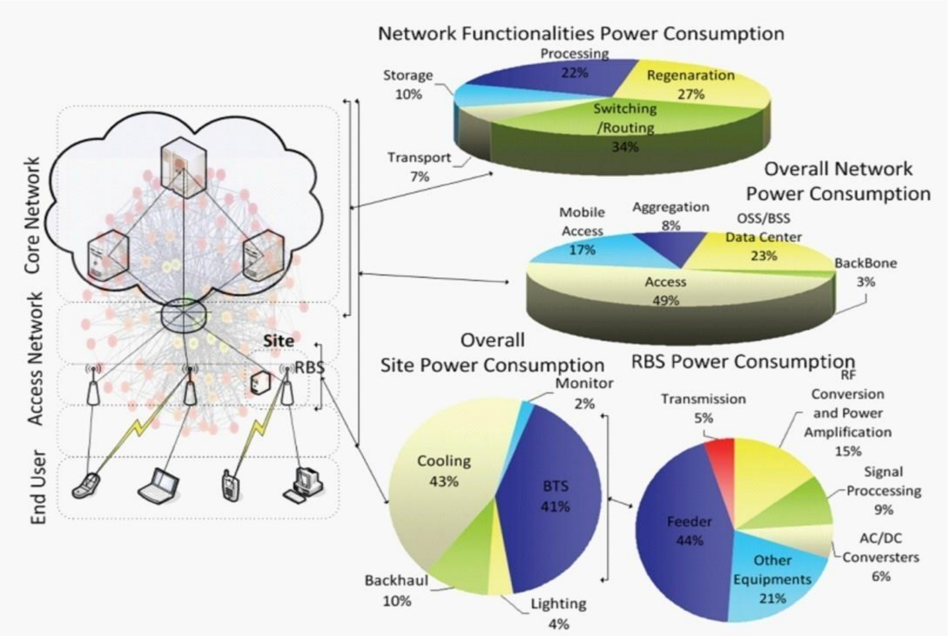


**Figure 75: Power consumption in different layers of the network (Koutitas & Demestichas, 2010)**

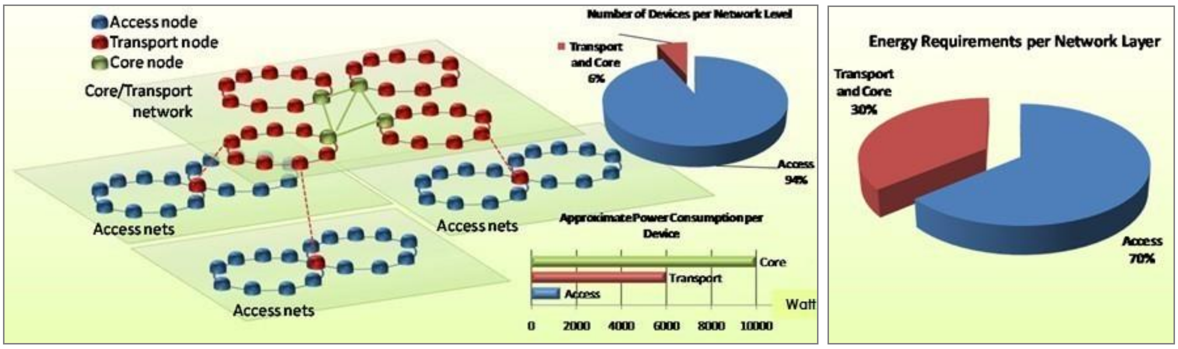


**Figure 76: Typical core, metro and access device density and energy requirements (Bolla, 2010)**

It is important to understand the dependencies of energy consumption in a telecommunications network. As network equipment is connected, an energy saving in one component can result in significant overall savings. For example, if it is possible to reduce the energy consumption of a radio frequency (RF) feeder by 1 Wh, this can yield 16.7 Wh in the radio frequency (RF) amplifier, which in turn can result in savings at the DC power system. Reduced energy consumption of each of these three components may in addition lead to reduced demand for cooling and further reduce the energy consumption for cooling.

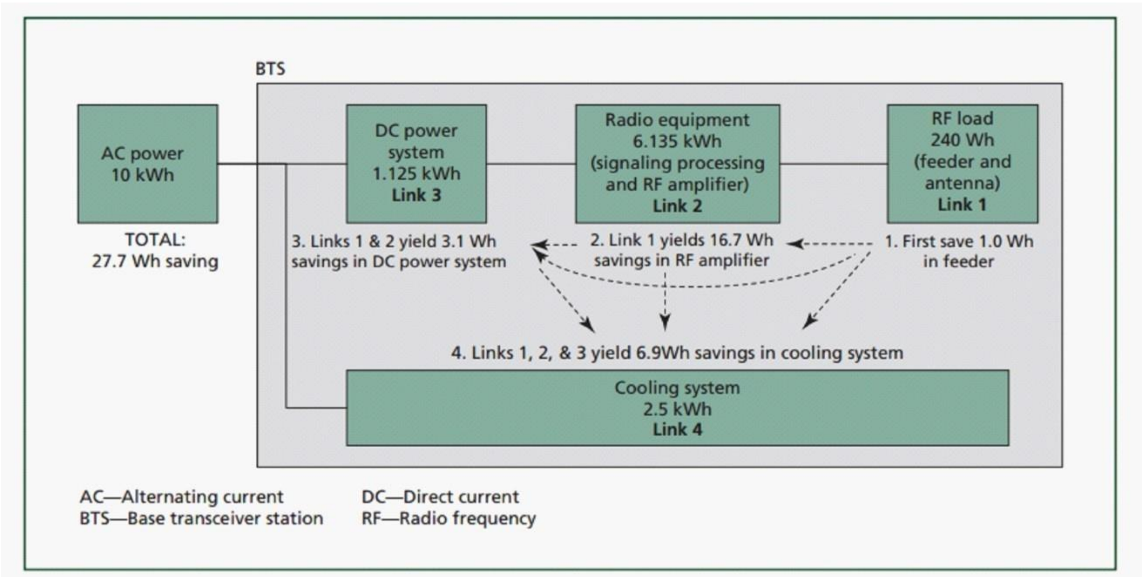


**Figure 77: Example of energy dependencies of a base transceiver station (BTS) (Matthews, et al., 2010)**

### 4.1.5 Identification of Best Environmental Management Practices

Networks are organised in hierarchies and designed with relatively few core nodes that host servers, switches and routing equipment. When energy efficiency opportunities are identified beyond the network core, these can often be replicated to multiple sites.

This report also focuses more on access networks than on core network, because telecommunication companies can have a greater influence on access networks in terms of environmental management.

This section was developed on the basis of a similar structure as used in the section on data centres. The following sub-sections intend to describe the BEMPs that reduce the environmental impacts of telecommunication networks by focusing on:

1. Improving the energy management of existing network (BEMP 4.2)
2. Improving risk management for electromagnetic fields through assessment and transparency of data (BEMP 4.3)
3. Selecting and deploying more energy-efficient telecommunication network equipment (BEMP 4.4)
4. Installing and upgrading telecommunication networks (BEMP 4.5).
5. Reducing the environmental impacts when building or renovating telecommunication networks (BEMP 4.6).
6. Minimising data traffic demand through green software (BEMP 4.7).

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## 4.2 Improving the energy management of existing network

**SUMMARY OVERVIEW:**

**Due to end-user demand variability, traffic loads on telecommunication networks vary significantly over time and space. The energy consumption of modern telecommunications equipment is the highest when the equipment is operating at maximum traffic load, but it does not decrease much when the equipment is underutilised. A large part of the daily network energy consumption is thus spent for providing full system capacity, even when the actual traffic demand is much lower. It is best practice to:**

- **Measure the energy consumption of network elements by using smart energy meters and automated analysis.**
- **Use smart stand-by functions to implement network energy management, and switch as many devices as possible to low consumption mode when the traffic load is low to adapt the overall capacity of the network to the demand.**
- **Use dynamic power scaling opportunities to adapt the operation mode of network equipment to low or moderate traffic period times.**
- **Take advantage of dynamic scheduling transmission to better manage data traffic, and to control the amount and the timing of data packet transmission.**
- **Provide energy-aware services to reduce the traffic demand at peak load, as well as the overall capacity of the network.**

**ICT components**

| Data centre | **Telecommunication network** | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic fields | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Share of network nodes for which energy consumption is measured (in %)
- Share of network nodes for which dynamic power management solutions (such as dynamic power scaling or dynamic scheduling transmission) are implemented (in %)
- Power consumption per customer or subscriber in kWh / subscriber or customer
- Mobile Network coverage Energy Efficiency (the area covered by the mobile network / the energy consumption) in $m^2/J$
- Mobile Network data Energy Efficiency (the data volume delivered / the energy consumption) in bit/J
- Network minimum power consumption divided by network maximum power consumption in %

**Cross references**

| | |
|---|---|
| **Prerequisites** | The implementation of such techniques will depend on the characteristics of the existing network equipment (e.g. energy consumption level, presence of a sleeping mode, transmission technology, end-users' requirements, etc.). |

| | |
|---|---|
| **Related BEMPS** | • 2.2 Making the best use of an environmental management system<br>• 4.4 Selecting and deploying more energy-efficient telecommunication network equipment<br>• 4.5 Installing and upgrading telecommunication networks<br>• 4.6 Reducing the environmental impacts when building or renovating telecommunication networks<br>• 4.7 Minimising data traffic demand through green software |

### 4.2.1 Description

Communications networks are very distributed, and a large telecommunications network has many thousands of separate sites connected to the electricity grid. Parameters such as population density, climate, traffic load, or equipment configuration will have a great influence on the equipment energy consumption.

The energy consumption of modern telecommunications equipment is at its highest when the equipment is operating at maximum traffic load, but it does not decrease much when the equipment is underutilised due to:

- fixed energy consumption (e.g. energy losses, air conditioning systems in base stations, etc.);
- low energy efficiency of some components at lower loads (e.g. rectifiers).

Due to end-user demand variability, traffic loads on telecommunication networks vary significantly over time and space, as shown in the figure below. There are long periods each day in which the average load of the network can be 5 or 10 times smaller than the peak values during the busy peak hours (EARTH, 2012d). A large part of the daily network energy consumption is thus spent for providing full system capacity, even when the actual traffic demand is much lower. Therefore, a majority of broadband equipment is typically idle most of the time and exchanges data only to maintain its network status.

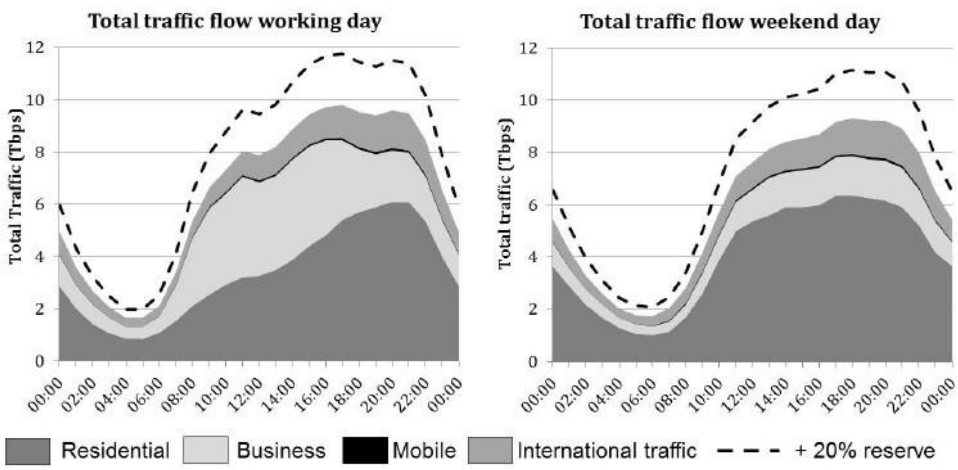


**Figure 78: Example of traffic flow composition in a backbone network (ZIB report, 2014)**

Not only can peak load traffic be several times greater than low load traffic, but the network maximum capacity is generally overprovisioned in order to be capable of absorbing an extra end-user demand (20% reserve in the case of Figure 78). Existing

network equipment can be optimised in terms of energy consumption and activity, by being adapted to the workload.

It is best practice to:

- **Measure the energy consumption of network elements.**

  To face the challenge of measuring the energy consumption of manifold and distributed sites, and to provide relevant information for improving the energy management of the entire network, smart energy meters are a solution. They provide frequent readings that can be brought together in real time and in single point. Using automated analysis systems can facilitate the analysis of numerous data, by spotting anomalous behaviour (through benchmarking between sites or trends analysis).

- **Use smart stand-by functions to implement network energy management.**

  Network energy management intends to switch as many devices as possible to low consumption mode (i.e. into sleep or idle state) when the traffic load is low to adapt the overall capacity of the network to the demand. With smart stand-by, devices can be powered down without the cooperation of the network (e.g. through the proxying function, which can respond to the network's solicitation instead of the device) or with its cooperation when the network adapts to the presence of sleeping or idle devices (e.g. with network traffic reduction or filtering, or with leading device adjustment). (ITU, 2012)

- **Use dynamic power scaling opportunities to adapt the operation mode of network equipment to low or moderate traffic period times.**

  Dynamic network adaptation aims at dynamically reaching the maximum energy-efficient potential of the network (while ensuring a sufficient Quality of Service). One solution is to adapt the energy consumption of each device to its current workload with dynamic power scaling techniques (e.g. through light sleep, selectively operating sub-systems, dynamic power savings, power islands and Energy Efficiency Ethernet).

- **Take advantage of dynamic scheduling transmission to better manage data traffic.**

  Another solution in terms of network adaptation is to dynamically adjust the characteristics of the data traffic with packet forwarding or aggregation. Dynamic scheduling transmission aims at controlling the amount and the timing of packet transmission through core network routers in an energy-efficient way (by avoiding output waits at each node).

- **Provide energy-aware services to reduce the traffic demand at peak loads.**

  Besides dynamic adaptation of the data traffic path to end-users' demand, the demand itself can also be reduced. From the ICT operators' perspective, demand management where permitted through Quality of Service (QoS) protocols (e.g. filters, sorry servers, cache server, etc.) can reduce workload at peak loads, as well as the overall capacity of the network. Telecommunication operators and internet service providers can also conceive and provide energy-aware services (e.g. contents with reduced data size) to limit overall workload demand.

### 4.2.2 Achieved environmental benefits

All the following techniques intend to provide significant **energy savings** within any type of network: sorry servers and filtering blocs, efficient broadcast distribution (CDN, catch servers, shared services, scheduled distribution, etc.) or network connectivity proxying which can results in 60 to 70% energy savings (Khan, Bolla, Repetto, Bruschi, & Giribaldi, 2012).

The EU FP7 EARTH project (EARTH, 2012a) measured energy savings related to the implementation of different energy-efficient techniques within wireless networks:

- Applying sleeping modes for small-size cells can lead to 80% power reduction in pico-cell power amplifiers and 94% in macro-cell power amplifiers;
- Power scaling can improve radio frequency transceiver energy efficiency by 35%;
- Turning off the appropriate base stations in a heterogeneous network at low loads traffic is able to provide from 25 to 40% of energy savings at network level (EARTH, 2012d);
- Dynamic scheduling allows short sleep periods that can be utilised by Multicast Broadcast Single Frequency Network (MBSFN) which provides from 20 to 30% of energy savings per bit or by Cell Discontinuous Transmission (DTX) which can save up to 45% energy when combined with power control;
- Delay constraints allow to reduce the transmit power by adaptively scheduling the data packets at the "best" time within the delay of the QoS requirements and provide up to 20% of energy savings per bit of data transferred;
- Dynamic allocation of users to the best available Radio Access Technology (through vertical handovers) can lead to 10% in energy savings.

### 4.2.3 Appropriate environmental performance indicators

The overall energy consumption (kWh) can be monitored. Then, specific indicators can be determined for energy-efficiency analysis.

- The energy efficiency of an access network can be defined as **the power consumption per customer** or subscriber (in kWh / subscriber or customer). This metric, called $P_a$, can be split into three parts (Baliga J. e., 2011):
    1. The power consumed by the customer premises equipment (e.g.: the modem, the Optical Network Unit, the optical Media Converter, etc.) is referred to as $P_{CPE}$;
    2. The power consumed by the remote node or base station (if there is one), which is shared by $N_{RN}$ customers or subscribers, is called $P_{RN}$;
    3. The power consumed by the terminal unit (located in the local exchange or the central office), which is shared by $N_{TU}$ [76]customers or subscribers, is named $P_{TU}$.

[76] Number of terminal unit customers

Since, $P_a$ can be expressed in the form[77]:

$$P_a = P_{CPE} + P_{RN} / N_{RN} + 1.5 * P_{TU} / N_{TU}$$

This metric, which is suitable to compare network solutions, can be easily monitored by network operators since they know the power consumption and the number of subscribers. However, the number of installed customer premises equipment is not always monitored. Based on such results, it can be demonstrated that PON and point-to-point optical networks are the most energy-efficient access alternatives at typical access rates. However, such a metric has to be handled with care as operators have different service and customer strategies (for example, a network in a rural area has a much lower efficiency compared to an urban network).

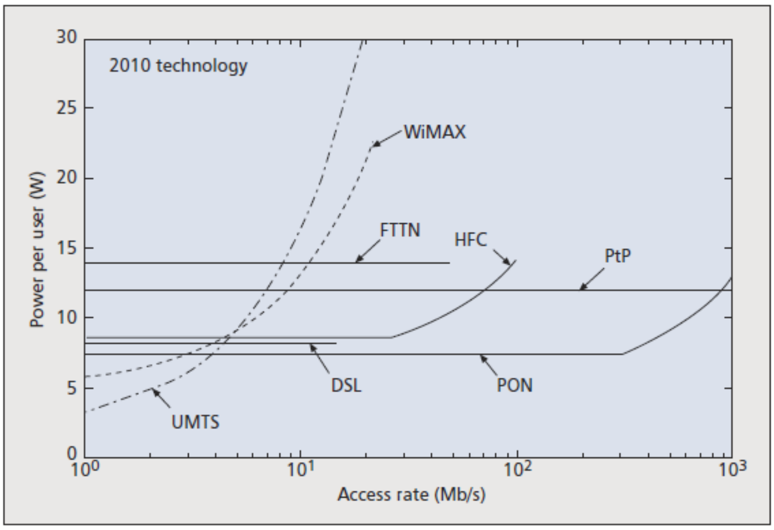


**Figure 79: Power consumption of different access network technologies (Baliga J. e., 2011)**

- **Mobile Network data Energy Efficiency** ($EE_{MN,DV}$) is the ratio between the data volume delivered by the equipment of the mobile network ($DV_{MN}$) and the energy consumption ($EC_{MN}$) when assessed during the same time frame. $EE_{MN,DV}$ is expressed in bit/J, and defined by the ETSI standard ES 203 228.
- **Mobile Network coverage Energy Efficiency** ($EE_{MN,CoA}$) is the ratio between the area covered by the mobile network under investigation and the energy consumption when assessed during one year. $EE_{MN,CoA}$ is mainly used to complement the previous performance indicator for mobile networks handling low data volumes, in particular in rural or deep rural areas. $EE_{MN,CoA}$ is expressed in m²/J, and defined by the ETSI standard ES 203 228.
- Another indicator could be ratio between **the minimum power consumption of the network and the maximum power consumption of the network** in %. This indicator illustrates the performance of the network in terms of reduction of energy consumption at low traffic load, compared to high traffic load.

[77] Baliga et al. (2011) considered that the equipment at the customer premise or in the remote node is cooled naturally by the surrounding environment, while the equipment at the terminal unit requires an external power supply and a cooling system (counting for 50% of the power consumed by the equipment only).

Beyond outcome-oriented indicators, process-oriented indicators can be monitored in order to assess to effectivity of the energy management action plan implementation, such as:

- **Share of network nodes for which energy consumption is measured (in %)**, which reflects the achievements in terms of better measuring the consumption of network elements by using smart energy meters and automated analysis.
- **Share of network nodes for which dynamic power management solutions are implemented (in %),** which refers to the implementation of best practices such as dynamic power scaling or dynamic scheduling transmission.

### 4.2.4 Cross-media effects

Developing the techniques described before requires processing applications, transmitting protocols or monitoring performance (e.g. energy consumption, data traffic loads, etc.) which can add to network power consumption.

Moreover, if certain types of technology are implemented without an efficient control, this can degrade the network performance and require extra network resources, and thereby consume more energy.

### 4.2.5 Operational data

**Measuring the energy consumption of network elements.**

ETSI Standards give guidelines on measurement methods and gives the conditions under which these measurements shall be performed:

- assessment method;
- reference configurations: room temperature, room relative humidity, operating voltage, minimum measurement duration;
- test equipment requirements.

Relevant standards for telecommunication network equipment are the following:

- ETSI Standard (ETSI EN 303 215 V1.3.1 (2015-04), 2015) Measurement methods and limits for power consumption in broadband telecommunication networks equipment;
- ETSI Standard (ETSI ES 202 706 V1.4.1 (2014-12), 2014) Measurement method for power consumption and energy efficiency of wireless access network equipment;
- ETSI Standard (ETSI ES 203 136 V1.1.1, 2013) Measurement methods for energy efficiency of router and switch equipment;
- ETSI Standard (ETSI ES 201 554 V1.2.1, 2014) Measurement method for Energy efficiency of Mobile Core network and Radio Access Control equipment;
- ETSI Standard (ETSI ES 203 184 V1.1.1, 2013) Measurement Methods for Power Consumption in Transport Telecommunication Networks Equipment.

**Using smart stand-by functions**

An effective energy-aware network management consists in switching off as many devices and links as possible, while respecting the connectivity and Quality of Service (QoS) constraints. Idle network elements can be selectively switched off at low traffic loads, such as at night. As shutting down network elements can affect the overall performance of the network (e.g. congestion, extra-delay, etc.), it has to be carefully evaluated under connectivity and QoS constraints.

Due to a redundancy in core networks, some of the network nodes can be put in standby mode when they are not used as a source or destination of traffic, and they are also not essential as transfer nodes (Zhang, 2010). As nodes can only be put to sleep when totally unused, energy-aware traffic engineering and routing should be used. When the traffic falls below a given threshold, residual traffic can be rerouted through few "active" nodes, so that the others can be put in standby mode[78]. With the hypothesis that low traffic demand (at off-peak hours) is 60% lower than peak traffic demand, 83% of network nodes can be shut down (Zhang, 2010). Similarly, links can be switched off when no traffic is passing or when traffic flowing along them can be rerouted (Zhang, 2010). At low traffic load, up to 45% of network links can be shut down (Zhang, 2010).

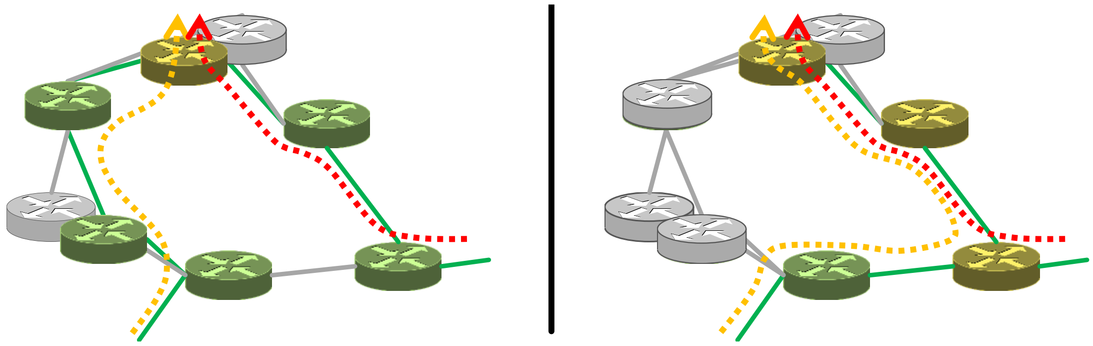

**Figure 80: Energy-aware routing to reduce the number of active nodes at low traffic loads (ECONET Project, 2010)**

Most wireline networks are designed to be continuously and always available: only some devices can be turned off when it is not communicating, since when the entire device is shut down, it loses contact with the network (and cannot be awaken when required). Standby modes then have to be explicitly supported with special techniques able to maintain the "network presence" when nodes or components are at sleep. A "proxy" (i.e. a computer that maintains full network connectivity) can maintain a continuous network presence while a network node is in a sleeping mode operation and consumes less energy (ITU, 2010). The proxy responds to small control traffic (e.g. responding to requests, sending periodic network presence messages, etc.) instead of the network node which is woken up when further processing is required. Support for the Network Proxy function for various types of broadband equipment were defined by the ECMA task group under the work programme of TC38-TG4 - Proxying Support for Sleep Modes[79].

[78] Such technology should be compliant with the latest version of the European Commission's Code of Conduct on Energy Consumption of Broadband Equipment.

[79] For more information, see: http://www.ecma-international.org/memento/TC38-TG4-M.htm

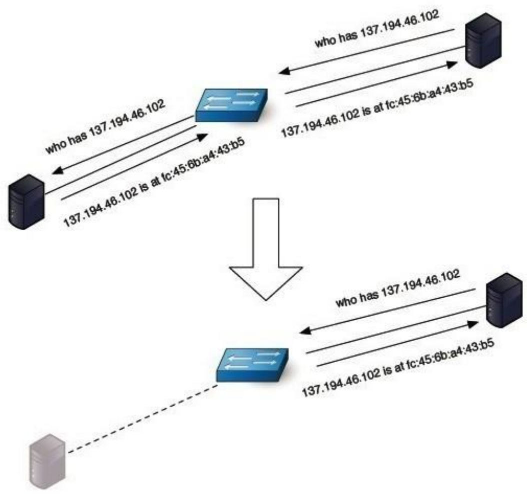


**Figure 81: External proxying (Rossi et al, 2010)**

In wireless networks, idle cells can be switched off by using sleep control software that shuts off/down the whole radio base station or one of its bands at low traffic patterns. Coverage-aware switch-offs can detect existing spatial coverage, while traffic-aware sleep modes which detect User Equipment (UE) activity via protocol analysers.

### Using dynamic power scaling opportunities

Power scaling can dynamically reduce the working rate of processing engines or link interfaces:

- Adaptive Link Rate and Dynamic Voltage Scaling can respectively control link speeds and the driving voltage of devices (e.g. CPU, hard disk, NIC, etc.) according to the amount of the traffic to be processed. Traffic routes can be distributed so that each node treats minimum traffic, and sets link rates or voltage at the adequate level.
- With Low Power Idle (LPI), links or processing engines enter low power states when not sending or processing packets, but can quickly switch to a high power state when needed.

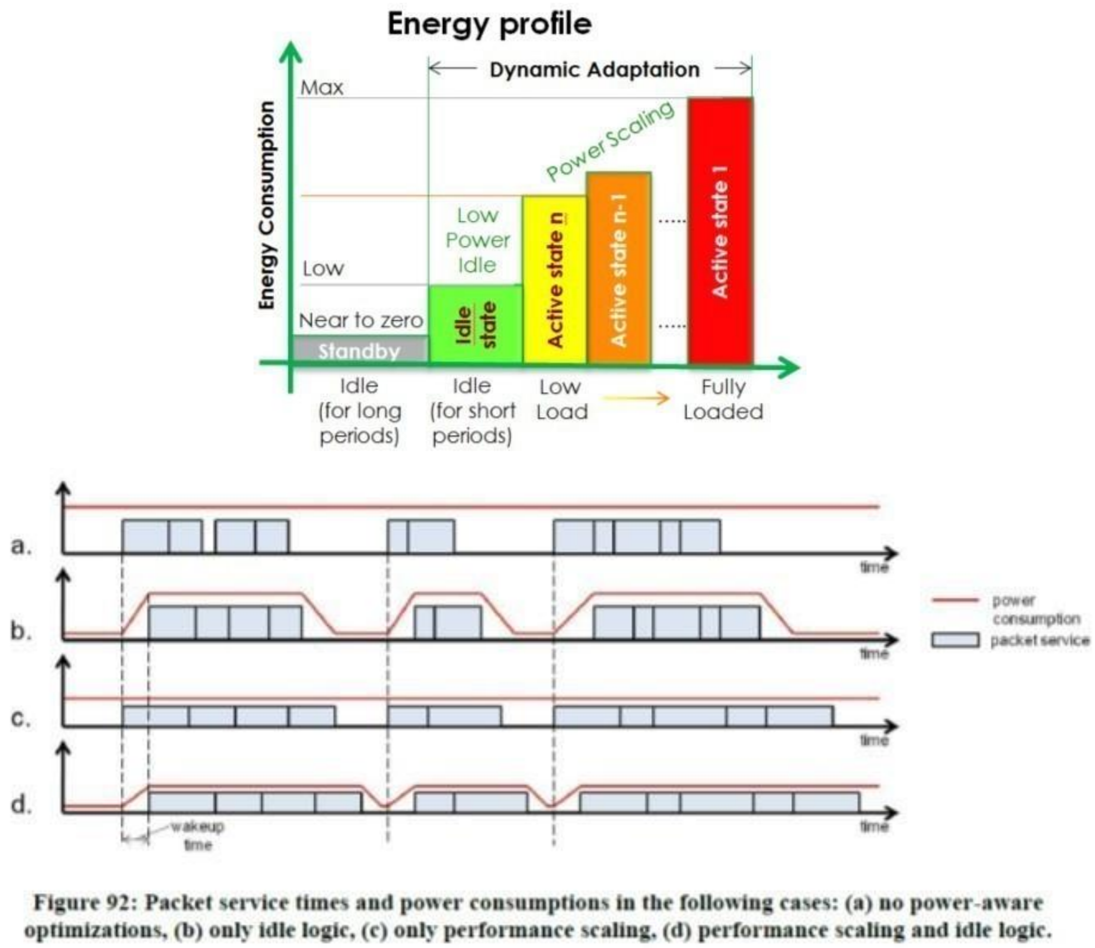


**Figure 82: Dynamic adaptation approaches to reduce energy consumption of network devices. Source: Davoli, 2013 (top) and (ECONET Project, 2010).**

Transmit and operation power consumption of wireless networks can be significantly reduced during low or moderate traffic period times, where base stations can be put into a discontinuous transmission mode (DTX) to reduce energy consumption (EARTH, 2012a). Different levels of discontinuous transmission mode can be implemented, depending on the duration: micro DTX (duration less than one millisecond), short DTX (between 1 ms and 10 ms duration) and long DTX (more than 10 ms duration).

**Taking advantage of dynamic scheduling transmission**

Dynamic scheduling transmission can control the amount and the timing of packet transmission through core network routers in an energy-efficient way (by avoiding output waits at each node):

- The size of IP packets impacts the energy consumption of routers in core networks. Energy-aware packet forwarding can lower energy consumption by increasing the size of IP packets the routers transfer (Zhang, 2010).
- The energy-efficiency of IP packet forwarding depends also on the frequency that packets are forwarded from node to node. Pipeline forwarding uses predefined schedules for IP packets to be switched and forwarded periodically (every time cycle). This results in the creation of a synchronous virtual pipe where periodic switching prevents delays due to resource contention and loss resulting in congestion, by insuring transmission availability of each node for forwarding the packets of each flow (Zhang, 2010). This pipeline forwarding

parallel network can be used for carrying traffic requiring a deterministic service (e.g. phone calls, video on demand, video conferencing, distributed gaming, etc.) which require large bandwidth.

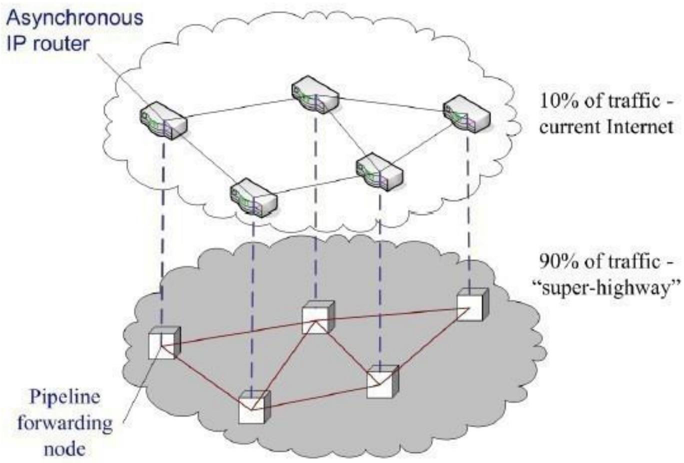


**Figure 83: Pipeline forwarding architecture (Zhang, 2010).**

- Shaping controls the output rate of packets according to the link speed, in order to avoid congestion in the following nodes and can then save energy (ITU, 2010).
- In wireless networks, dynamic bandwidth management is based on the adaptation of the bandwidth usage to the required traffic load. The total transmitted maximum output power can be decreased when fewer resources are allocated to user data transmission. The supply voltage of the adaptive power amplifier can be reduced, while the power amplifier is operating close to its most efficient operation point. Further energy savings in base stations can be observed at off-peak traffic hours by implementing bandwidth adaptation at system level. Neighbouring cells can coordinate their bandwidth configuration through a reuse scheme that allow significant reduction of inter-cell interference (EARTH, 2012a).

### Providing energy-aware services to limit data traffic at peak loads

A diversity of Quality of Services (QoS) requirements for different applications may be used to achieve energy savings:

- Delay-tolerant traffic should be identified (e.g. email, file downloading, offline processing, etc.) since such data traffic loads can be more easily served by a dynamic scheduling transmission scheme and provide energy savings (see above). This technique can be implemented through Store-Carry-and-Forward (SCF) transmission: the data flow related to the delay-tolerant application is transmitted to a mobile relay which carries the data close to the base station, before transmitting the data to the base station (Feng, 2013).
- Sorry server returns the alternative response to inform that services cannot be provided for some reason (such as traffic congestion), which allows to shift peak traffic demand (ITU, 2010).
- Filtering blocks unnecessary data to be transmitted, and can save energy associated with this data transmission (ITU, 2010).

Server networks can be designed and managed in an energy-aware way (ITU, 2010):

- Using an optimised Contents Delivery Network (CDN) for delivering web contents via the Internet can save energy since optimised CDN can access a closer server than the original one (if the same content is available, which is more likely when the content is more popular);

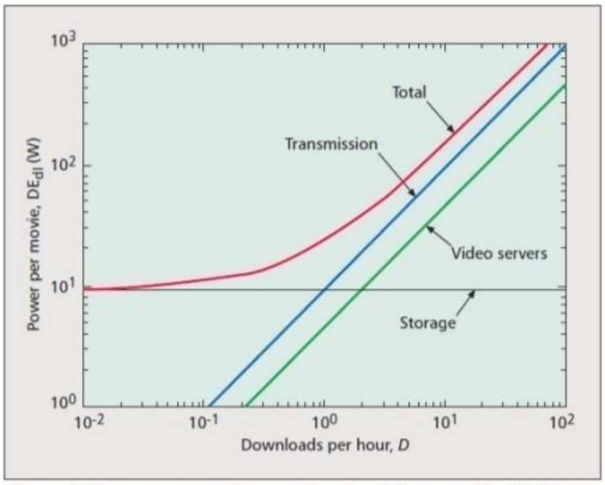


Figure 6. *Power consumption per download for a standard definition 2 hour video that has 20 copies replicated in data centers [10].*

**Figure 84: The effect of content downloading frequency on overall energy consumption (Hinton, 2011)**

- Using cache servers can reduce bandwidth usage, so it can achieve energy saving corresponding to the reduction if the copy of the contents exists in this server;

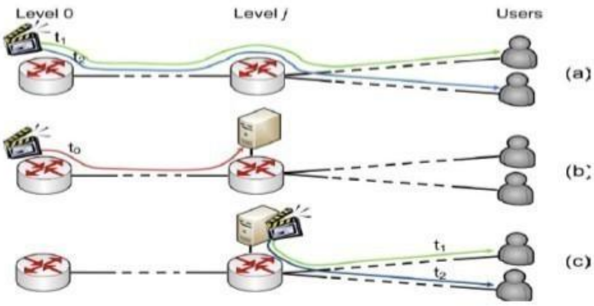


*Figure 5 – Traditional content distribution (a) and content caching approach (b) (c).*

**Figure 85: Cache servers approach for content distribution (TREND Project, 2013).**

- Using shared services for delay-tolerant applications (e.g. emailing, web browsing, video or audio downloading, etc.) allows for many users to share the bandwidth provided without noticing any degradation in speed;

Distributing broadcast content in advance can peak-shift the traffic and reduce the maximal transmission capacity needed, so it reduces the number of active devices and saves energy.

### 4.2.6 Applicability

This subchapter presented the main practices which should be followed when managing networks, but techniques should be adapted to the characteristics of the network:

- Depending on the segment of the network concerned by the upgrade (core, metro or access network);
- In relation to the technology currently used in the network (e.g. DSL, PON, WiMAX, GSM, etc.);
- In function of end-users' requirements (e.g. video demand, connexion stability, workload capacity, etc.);
- Depending on who can implement the practice (e.g. telecommunication operator, IT service provider, consumer, etc.).

**Table 45: Applicability of best practices aiming at improving the energy management of existing telecommunication networks**

| Technique | Network segment | Network technology | End-users' requirements | Actor |
|---|---|---|---|---|
| **Measure the energy consumption** | From core to access network | All type of technology | All type of end-users | Network operators |
| **Using smart stand-by functions** | From core to access network | All type of technology | Inappropriate for users requiring connexion stability or a very short resuming time | Network operators |
| **Using dynamic power scaling opportunities** | From core to access network | All type of technology | All type of end-users | Network operators |
| **Taking advantage of dynamic scheduling transmission** | From core to access network | All type of technology | Inappropriate for users requiring fast transmission rates | Network operators |
| **Providing energy-aware services** | From core to access network | All type of technology | Inappropriate for users requiring high Quality of Services | Network operators and ICT service providers |

This table highlights the role played by telecommunication network operators in the implementation of the practices described. As network operators are mostly large companies, these BEMPs are typically only applicable to large companies.

However, SMEs providing ICT services have the opportunity to facilitate the provision of energy-aware services, by defining appropriate Quality of Services requirements and by choosing relevant network technologies.

### 4.2.7 Economics

The costs and benefits of best environmental management practices aiming at improving the energy management of existing networks are dependent on the characteristics of the existing network, on the penetration of these actions and the

type of technology selected, and on the current practices network operators in terms of network management (human resources, qualifications, tools, etc.).

The implementation of the energy-aware practices defined above may require recruiting additional staff (with specific qualifications), purchasing new equipment with appropriate functions (see BEMP 2.3 on the Procurement of sustainable ICT products and services) and integrated software applications aiming at managing the network in an energy-aware way.

**Table 46: Economics data related to improving the energy management of existing telecommunication networks**

| Technique | Operating costs | Investment costs | Return |
|---|---|---|---|
| **Measure the energy efficiency** | - Staff in charge of monitoring energy consumption and environmental parameters | - Investing in metering equipment | - Prerequisite to implement energy-efficiency actions and to measure achievements |
| **Using smart stand-by functions** | - Staff in charge of the network management system | - Selecting equipment with stand-by function<br>- Investing in software to better manage the network | - Reduction of energy costs (up to 40%) |
| **Using dynamic power scaling opportunities** | - Staff in charge of the network management system | - Selecting equipment with power scaling function<br>- Investing in software to better manage the network | - Reduction of energy costs (up to 40%) |
| **Taking advantage of dynamic scheduling transmission** | - Staff in charge of the network management system | - Investing in software to better manage the network | - Reduction of energy costs (up to 20%) |
| **Providing energy-aware services** | - Staff in charge of the network management system | - Investing in software to better manage the network | - Reduction of energy costs (up to 20%) |

### 4.2.8 Driving force for implementation

Energy consumption has become a strategic issue for telecom operators. It represents between 15 and 50% of operating costs, and significant resources have been committed to innovate and integrate energy efficiency within network management. As energy consumption of networks are set to increase, cost savings are considered to be the main driver for implementing best environmental management practices related to energy-efficient management of networks. Implementing such solutions will directly result in electricity consumption savings, but also in the reduction of cooling requirements in central offices and base stations.

Network management mainly focuses on the performance of the network and on the Quality of Service. On the one hand, the techniques described must take into account both these parameters: in other words, a technique that allows for energy savings can only be implemented if the network performance and the Quality of Service are maintained. On the other hand, energy-efficient practices can take advantage of these parameters to achieve energy savings (sorry servers, filters, etc.).

### 4.2.9 Reference organisations

Nokia, which has already implemented network energy management practices (Nokia, 2009), announced that a new feature of their network energy management software can bring up to 27% power consumption reduction for base stations deployed by China Mobile (Feng, 2013).

Deutsch Telekom[80] has developed a web-based energy application (called Energy Dashboard) that monitors 8,000 fixed-network nodes and 20,000 mobile base stations. The app includes a notification system in case large consumption points exceed certain threshold values that helps identify possible causes early on and take counteractive measures.

TIM (Telecom Italia Group) has developed real time energy usage monitoring through sub-meters installed and connected to 2,700 telecommunication sites which account for 53 % of Telecom Italia usage (TIM, 2016).

Vodafone has deployed sub-meters and smart meters across more than 50,000 base stations and 60% of its technology centres (Vodafone, 2015).

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## 4.3 Improving risk management for electromagnetic fields through assessment and transparency of data

**SUMMARY OVERVIEW:**

**Electromagnetic fields (EMF) are a public concern in relation to the growing telecommunication networks. Strict regulations have been defined and intense research works have been carried out to tackle this issue. It is best practice for telecom operators to:**

- **Improve risk management for electromagnetic fields through assessment and transparency of data on EMF exposure.**

**ICT components**

| Data centre | **Telecommunication network** | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| Energy consumption | Resources consumption | Air emissions | Water use & consumption | **Noise and electromagnetic fields** | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- The percentage of sites assessed for compliance with EMF limits;
- The percentage of the public expressing concerns about EMF from telecommunication networks.

**Cross references**

| | |
|---|---|
| **Prerequisites** | NA |
| **Related BEMPS** | • 2.2 Making the best use of an environmental management system<br>• 4.2 Improving the energy management of existing network<br>• 4.6 Reducing the environmental impacts when building or renovating telecommunication networks |

### 4.3.1 Description

Electromagnetic fields (EMF) are a public concern in some countries in relation to the growing wireless communication networks. Wireless telecommunications and ICT services use electromagnetic fields for operating: radio waves, microwaves, satellite waves, etc. These waves are transmitted by radio and television broadcast stations, transmitting antennas, mobile communication base transceiver stations, etc.

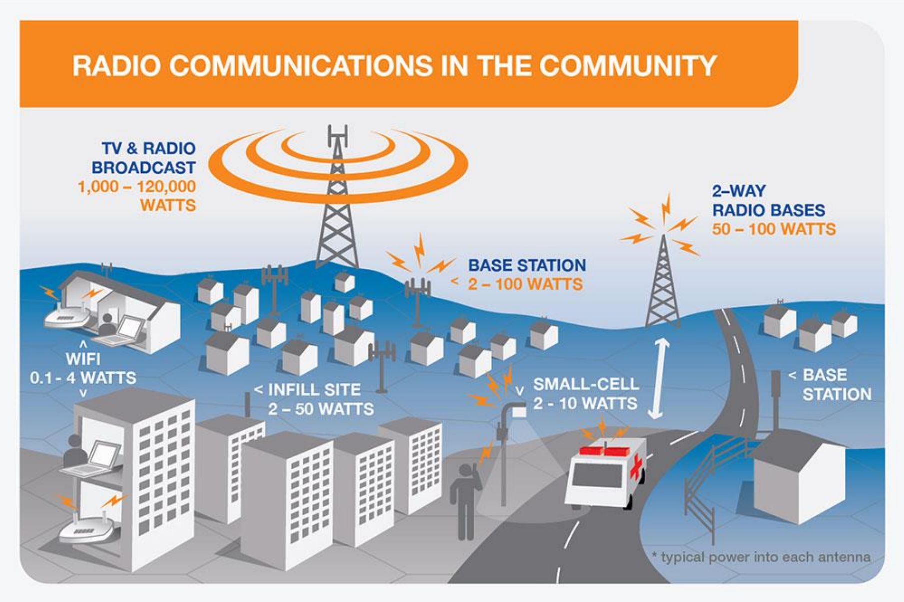


**Figure 86: Typical radio and wireless communications in the community (source: (ITU, 2014))**

It is best practice for telecommunication providers to:

- **Improve risk management for electromagnetic fields through assessment and transparency of data**

  At every stage of the lifecycle of wireless transmitters or receivers (networks antennas, end-user devices, etc.), actions should be implemented to make available information on compliance with EMF exposure limits for the public. It requires assessment, sample measurements or continuous monitoring, making staff aware of EMF issues and deploying a specific communication plan on this topic. Assessing and reporting to the public compliance with EMF exposure limits demonstrates a good level of risk management from telecommunication operators. It proves that the situation is under control and that actions will be taken in any case of EMF exposure levels above recommendations.

### 4.3.2 Achieved environmental benefits

The main benefit linked to an increased assessment and transparency regarding EMF exposure is an improved risk management from telecommunication operators. This helps reduce risks for health and the environment by proving that EMF exposures stay below the limit, and increasing transparency.

### 4.3.3 Appropriate environmental performance indicators

To monitor the performance of the EMF risk management policy, the following indicators can be monitored:

- The percentage of sites assessed for compliance with EMF limits;
- The percentage of the public expressing concerns about EMF from telecommunication networks.

### 4.3.4 Cross-media effects

Developing the techniques described in this section requires processing applications, field trips for measurements or monitoring equipment which can add to network associated power consumption.

Measures related to better informing stakeholders and general public can actually result in higher concerns from these people (Wiedemann et al., 2013).

### 4.3.5 Operational data

**Improving risk management for electromagnetic fields through assessment and transparency of data**

Telecommunication network operators should disclose information on compliance with EMF exposure limits to the public. These assessments can be made through calculations or spot measurements either spontaneous or in answer to a formal request from any stakeholder (single citizen or group of citizens, local authorities, companies etc.) (FFTélécoms, 2004a).

When publishing data on the EMF exposure from antennas, telecommunication operators can use the following indicators to standardise information and increase intelligibility:

- EMF in absolute terms: total amount of exposure from of all antennas at the location of the assessment (the power per antenna changes very dynamically because of the network power management).
- EMF in relative terms: fraction of or times below the recommended exposure threshold based on the EU directive and ICNIRP recommendations, or national requirements.
- Comparisons with other familiar sources of radio frequencies such as broadcast TV and radio.

Telecommunication network operators have also to ensure that all relevant staff has an adequate awareness of EMF issue (especially staff which is likely to handle the concern of the public, including employees answering phones and call centres, and other front line employees and engineering staff). Operators can provide training to their employees on these issues to make them sufficiently knowledgeable (Energy Networks Association, 2013).

| **BEMP implemented: EMF transparency** |
|---|
| Telecommunication networks operators : Cosmote (GR) and Vodafone Greece (GR) |
| **Practices implemented and context** |
| Vodafone and Cosmote have been funding two programmes that initially started as communication tools in order to communicate information regarding EMF issues to the people:<br>• HERMES (Human Exposure and Radiation Monitoring to Electromagnetic Sources), that started in 2002 in partnership with the National Technical University of Athens and the Aristotle University of Thessaloniki;<br>• PEDION24 (pedion means "field" in Greek, and 24 means 24 hours monitoring), that started in 2006 in partnership with the two previous universities and the university of the Aegean and the University of Piraeus.<br>These programmes has evolved to become tools that citizens can use to check the level of EMF exposure where they live and that companies can consult to verify their compliance with the recommended levels. |
| **Technical characteristics** |
| 172 measuring units have been installed in 13 regions of Greece with the Hermes programme, as well as -231 units in 13 regions of Greece with the PEDION24 programme. Both programmes focus on broadband and measure bands between 100 kHz and 3 GHz. These programmes also started to use mobile monitoring station, which measures and records the electromagnetic radiation levels in the environment, expanding the application field.<br>Information regarding EMF and measurement results are published on specific websites: www.hermes-program.gr and www.pedion24.gr. These programmes offer other services, as:<br>▪ Sending information by SMS, with SMS HERMES: the average and the maximum value of equivalent power flux density that the selected station has recorded in the last week and the times below the minimum reference level of Greek Legislation the previous values of equivalent power flux density are);<br>▪ Publishing information in public areas at the place the measurement is done, with i-Hermes: a display screen is connected with a monitoring station installed at the same location, and presents the levels of the emitted electromagnetic radiation in real time (updated every 30 minutes), its comparison to the national reference level and its average over the previous week. |
| **Results** |
| These programmes have produced numerous 6-min measurements: more than 53,000,000 for the Hermes programme and more than 60,000,000 for the PEDION24 programme. No locations that were non-compliant have been identified.<br>The websites have progressively acquired more and more visibility, with about 4,500 or 5,000 new users per year. |

### 4.3.6 Applicability

The implementation of the above mentioned best practices depends on the content of national regulations regarding EMF and on the local context (existence of associations against EMF exposure, media coverage of EMF issues, visibility of antennas, etc.).

**Table 47: Applicability of the best practice aiming at managing electromagnetic fields issues within telecommunication networks**

| Technique | Network segment | Network technology | End-users' requirements | Actor |
|---|---|---|---|---|
| **Improving risk management for electromagnetic fields through assessment and transparency of data** | Access networks | Wireless networks | All types of publics | Network operators |

### 4.3.7 Economics

The economics of best management practices for EMFs are unbalanced, due to a good knowledge of costs but often uncertain and non-measurable benefits.

- Additional costs include the increased public relation activities to deal with authorities and agencies; setting practices beyond the legal requirements; communication and consultation directed towards the public; the systematic measurement of EMFs; and training costs for the staff.
- Potential benefits result from a better image of telecommunication providers. A lower number of complaints and legal issues could also result from a better informed public, more actively involved in consultation processes.

**Table 48: Economics data related to managing electromagnetic fields issues within telecommunication networks**

| Technique | Operating costs | Investment costs | Return |
|---|---|---|---|
| **Improving risk management for electromagnetic fields through assessment and transparency of data** | -Increased communication activities<br>-Staff in charge of EMF monitoring and data analysis | -Installation of meters | Difficult to evaluate, because of diffuse effects (benefits from a better image, reduction of complaints and legal issues related costs) |

### 4.3.8 Driving force for implementation

The main driver for the implementation of best practices regarding EMFs is the strategic risk linked to the public concern. Telecommunication providers can be impacted by the lack of trust of users and authorities. This lack of trust can materialise in a loss of consumers and revenues, delays in for the installation of antennas and other ICT infrastructures, legal issues and complaints. Implementing measures to increase the knowledge of the public on EMFs and answering to their complaints regarding exposure can help mitigate these risks.

### 4.3.9 Reference organisations

The French Federation of Telecommunication Providers (FFTélécoms, 2004a) acknowledged that operators must provide data on EMF exposure whenever they are

asked or whenever the data is available to them, in order not to let fear grow amongst the public. FFTélécoms agreed with the Federation of French Mayors to systematically provide information on the exposure to EMFs if they are asked to by any citizen or organisation. The request for information can concern any location, home, office, school etc. The result (in volt per meter and percentage of recommended threshold) can either come from an onsite calculation or from an estimate, carried out in either case by a certified agency. Telecommunication providers pay for the measurement of the EMF exposure in any case on simple demand from the enquirer. To protect themselves from abusive requirements, telecommunication providers can discuss with mayors to decide upon an appropriate response a case-by-case basis. The recipients of the measurements are mayors, who can then communicate the results to the enquirer. The result is forwarded to the French National Frequencies Agency which aggregates all results on a single database, available publicly on its website (www.anfr.fr).

### 4.3.10 Reference literature

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## 4.4 Selecting and deploying more energy-efficient telecommunication network equipment

**SUMMARY OVERVIEW:**

**Both mobile and wireline networks use ICT equipment that require electricity and specific environmental conditions to properly function. Telecommunication operators have the opportunity when selecting and deploying such materials within their networks to improve its energy efficiency by selecting and configuring appropriate equipment. It is best practice to:**

- **Privilege selection and deployment of the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks (more energy efficient technology, power management features, etc.).**
- **Privilege deployment of integrated and multi-standard solutions, instead of multiple single-standard systems running in parallel and not properly configured.**
- **Privilege selection and deployment of the most energy-efficient cooling systems in base stations (e.g. passive cooling, simple fans, heat exchangers, etc.) and central offices (e.g. hot aisle / cold aisle blanking plates, hot air containments, air ducting, etc.).**
- **Privilege selection and deployment of the most energy-efficient UPS (e.g. high efficient UPS, modular UPS, etc.) in base stations and central offices.**
- **Privilege design of telecommunication sites maximising energy-efficiency by migrating distributed functions to central servers in wireline networks, moving radio equipment closer to the antenna, and using an appropriate design of UPS.**
- **Use software enabling energy savings all along the network, to implement virtualisation (for increasing equipment sharing and reducing the number of needed hardware equipment) or networking functions (for allowing a greater flexibility and efficiency of the network).**

**ICT components**

| Data centre | **Telecommunication network** | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | **Selection and procurement of the equipment** | Operation and management | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic fields | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Percentage of broadband equipment meeting the Broadband Code of Conduct requirements in terms of energy consumptions
- Share of base stations with multi-standard solutions
- Average UPS System Efficiency
- Average COP of cooling systems
- Share of base stations with a Remote Radio Head or Active Antenna System

| Cross references | |
|---|---|
| **Prerequisites** | The implementation of these practices will depend on the cost-benefit analysis, based on the performance of the existing equipment and the level of energy efficiency of equipment on the market. |
| **Related BEMPS** | • 2.3 Procurement of sustainable ICT products and services<br>• 4.2 Improving the energy management of existing network<br>• 4.5 Installing and upgrading telecommunication networks<br>• 4.6 Reducing the environmental impacts when building or renovating telecommunication networks |

### 4.4.1 Description

Telecommunication and ICT systems require electricity for different functions:

- Running ICT equipment (servers, transmitters, receivers, etc.);
- Functioning support equipment (in base stations, data centres, offices, etc.), such as cooling, ventilation or lightning systems;
- Transmitting electrical signals moving along power cables from node to node.

As any electrical equipment, ICT equipment requires power supply and produces waste heat while running. Besides, need for cooling and energy losses related to the power infrastructure (power distribution unit, UPS, building transformers) increase with the number of active hardware.

The approach to reducing energy consumption consists of three steps (Matthews, et al., 2010):

1. Identify the energy consumption hierarchy: which network elements consume the most power and where are they located in the network (an example for a radio base station is given below);
2. Map the chain of energy dependency: how are the network elements connected and what are the dependencies with regard to operation and energy consumption;
3. Prioritise the initiatives or options for reducing energy consumption: which changes in network components will result in the greatest reductions of energy consumption.

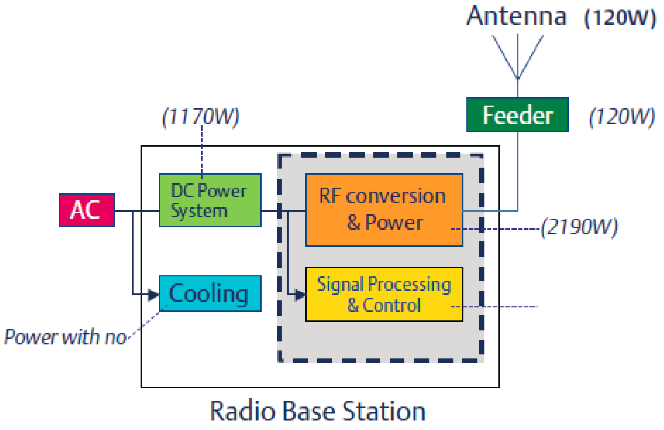


**Figure 87: Radio Base Station block diagram (with associated power losses) (Emerson, 2008)**

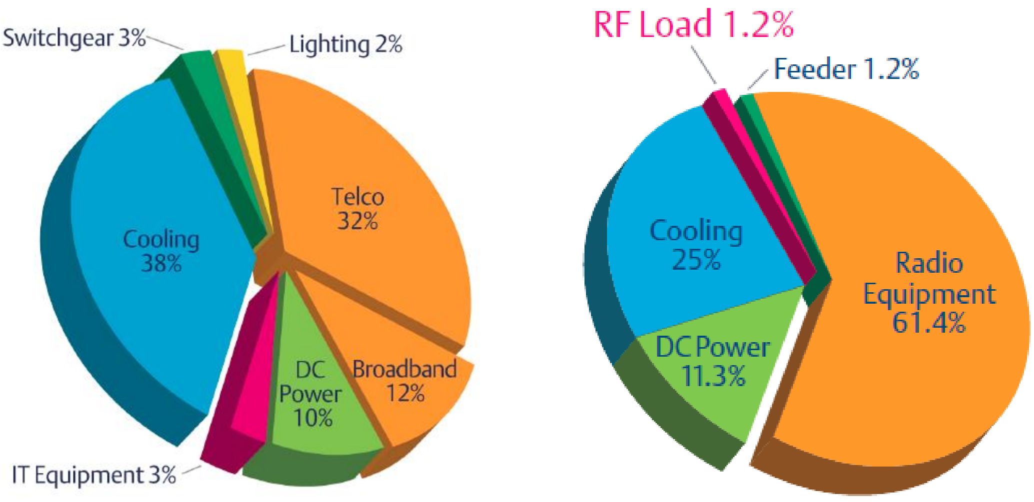


**Figure 88: Energy consumption per function in central offices (on the left) and in base stations (on the right) (Emerson , 2008)**

This chapter develop techniques that can be implemented in order to improve the energy efficiency of network equipment as:

- Radio equipment (power amplifiers, Radio Frequency transceivers and antennas, etc.) in wireless networks;
- Telecommunication equipment (switchers, routers, multiplexers, etc.) in wireline networks;
- Broadband equipment (terminations, interfaces, cables, etc.);
- IT equipment, such as host computers (mainframes), front-end processors (minicomputers) and network servers (microcomputers);
- Power supply and cooling equipment.

NB: the energy-efficiency of end-user devices (such as PC, telephones and fax machines) and customer premise equipment (including routers, modems or adapters) is developed under section 2.3 on the Procurement of sustainable ICT products and services. Here is a summary of the relevant criteria in terms of energy-efficiency for such equipment:

| ICT equipment | Procurement options |
|---|---|
| Broadband equipment (routers, DSL and Wi-Fi network equipment) | • Select energy-efficient equipment, e.g. respecting the EU Code of Conduct on Energy Consumption for Broadband Equipment |
| Set-top boxes | • Select energy efficient equipment, e.g. respecting the Code of Conduct for digital TV Service Systems |
| Personal computers (desktop and laptop), Mobile devices (smartphone, mobile, tablets) and Other peripherals : monitors, scanners, copiers, fax machines | • Select more energy efficient equipment, e.g. purchasing eco-labelled equipment such as EU Ecolabel and EnergyStar or follow the EU Green Public Procurement Criteria for Office IT equipment or Imaging Equipment |

It is best practice to:

- **Privilege selection and deployment of the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks.**

  The first action is to select ICT devices with a more energy-efficient technology (e.g. LSI microfabrication, optical node, multi-core CPU, advanced power-amplifier, etc.), or with power management features.

- **Privilege deployment of integrated and multi-standard solutions**.

  Multi-standard equipment offers an opportunity for reducing the number of different equipment generations on a same base station site.

  Integrated solutions ensure an optimisation of the installed base station, with only required elements and proper configurations (in terms of cooling and power supply for example).

- **Privilege selection and deployment of the most energy-efficient cooling systems.**

  Telecommunication sites, as base stations or central offices, are made of an aggregation of different ICT components that may require cooling supply.

  In base stations, the use of passive cooling, simple fans, heat exchangers and advanced controls can help reducing active cooling.

  In central offices, techniques similar as the ones developed in data centres (see section 3.2.5 on Improve cooling management) can be deployed: hot aisle / cold aisle blanking plates, hot air containments, air ducting, etc.

- **Privilege selection and deployment of the most energy-efficient UPS.**

  Uninterruptible Power Systems are sources of energy losses due to electricity conversion. To avoid such effects, high efficient UPS and modular UPS can be purchased: in the first case, rectifiers are more efficient, while in the second case equipment sources of inefficiency (mainly switching units and batteries) can be easily changed if the electrical load of the facility evolve.

- **Privilege design of telecommunication sites maximising energy-efficiency.**

  After purchasing energy efficient hardware, choosing an appropriate solution design depending can allow for further energy savings. Such solutions aim at reducing energy losses and at adapting the infrastructure to the load requirements.

- **Use software enabling energy savings.**

  Selecting software allowing virtualisation and reduction of the number of hardware equipment needed (please refer to: section 3.2.3 - Define and implement a data management and storage policy).

The selection of more energy-efficient equipment can be addressed by implementing appropriate procurement practices. These aspects are covered in section 2.3 on the Procurement of sustainable ICT products and services, including the origin of the equipment, its components and level of recyclability. Only the functional specificities to be required when selecting energy-efficient telecommunication devices will be addressed in this BEMP.

### 4.4.2 Achieved environmental benefits

The benefits of energy efficiency are:

- **Direct energy savings**, thanks to the reduction of large quantities of non-productive power consumed by the infrastructure;
- **Indirect energy savings** related to the reduction of cooling needs with a decreased production of waste heat;
- **(Indirect) $CO_2$ and other atmosphere pollutant (NOx, SOx, particles…) emissions reduction,** due to the savings from fossil fuel based energy;
- **The reduction of other indirect impacts related to the production of electricity** (issues related to nuclear power production, to hydroelectricity production, etc.).

The annual improvement in energy efficiency of the metro and core network equipment is estimated to be about 10 to 20% (Hinton, 2011).

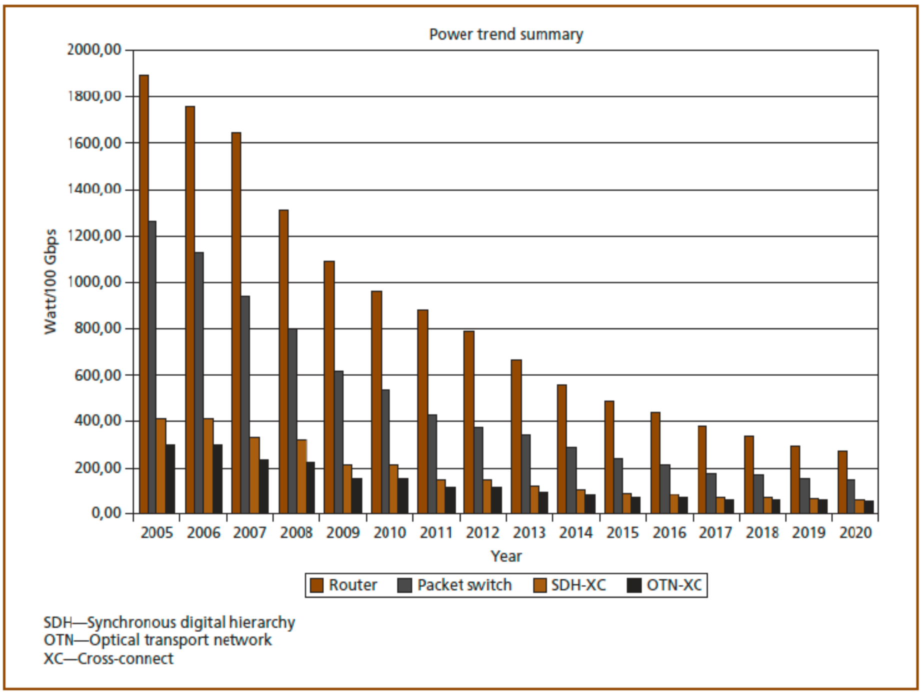


**Figure 89: Energy improvement of core networks (The Institute for Energy Efficiency, 2013)**

It has been estimated that in the case of a large telecom company with an annual power consumption of 8.9 billion kWh, the associated GHG emissions reach 7.1 million metric tonnes of $CO_2$. An increase of the company's power network efficiency by 6% would allow savings of 534 million kWh per year in electricity and a reduction of more than 426,000 tonnes of $CO_2$ emissions (Eltek, 2012).

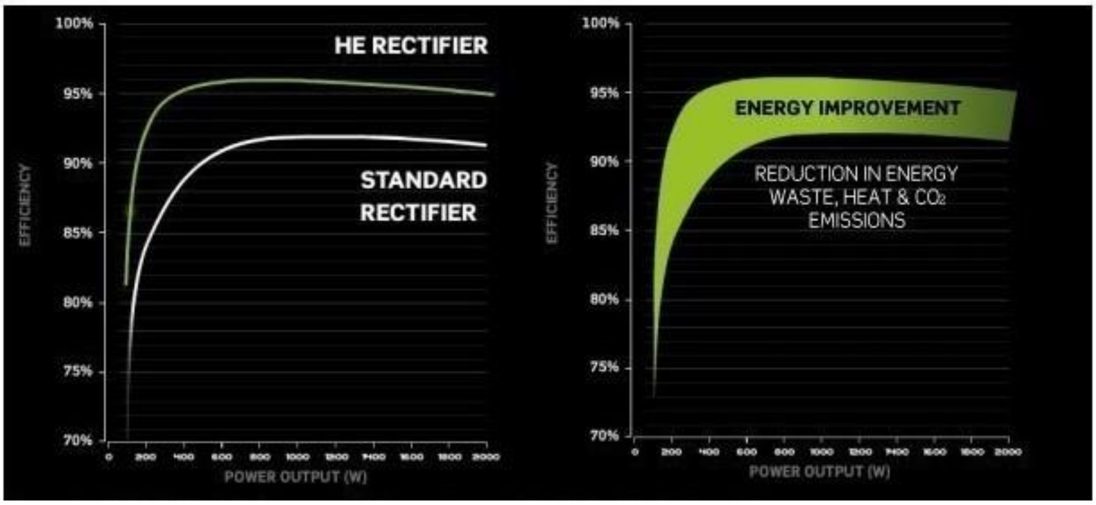


**Figure 90: 96% high efficiency rectifier compared with 92% efficient rectifier (Eltek, 2012)**

### 4.4.3 Appropriate environmental performance indicators

Two types of indicators can be used: process-oriented indicators and outcome-oriented metrics.

First, indicators can be used to measure the share of energy-efficient equipment in the network, such as:

- **Percentage of broadband equipment meeting the Broadband Code of Conduct requirements** in terms of energy consumptions and energy-enabling features;
- **Share of base stations with multi-standard solutions;**
- **Share of base stations with a Remote Radio Head or Active Antenna System.**

Second, indicators can be used to select energy-efficient equipment, e.g. specific metrics defined at component level (see for instance the EU Code of Conduct for broadband equipment (JRC, 2013)):

- **UPS System Efficiency** which can be used to monitor the power efficiency of transceiver systems (EARTH, 2012b): **PE = $P_{RFout}$ / $P_{DC}$** Where $P_{RFout}$ refers to the output power of the transceiver system and $P_{DC}$ to the total supply power. It compares the input power provided by the grid to the UPS with the output power that the UPS provides to the equipment. The industry average is around 90-92% while high efficiency UPS now reach up to 96% (Stanley, 2007).
- **Coefficient of performance or COP** (sometimes CP) which is equal to: average cooling load (kW) / average cooling system power (kW) (U.S. Department of Energy, 2011). Higher COPs equate to lower operating costs, with a COP of 1 meaning that the conversion from electricity into heat is 100% efficient. Including heat pumps or free cooling technologies allows for a COP over 1. A COP over 4 for DX cooling (including free cooling or thermosiphon) can be observed (Penglei Zhang, 2013).

However information about energy consumption of network equipment (e.g. switches, routers, etc.) is rarely available with the correct level of granularity (for example, only a single value for energy consumption is given, typically at maximum load).

### 4.4.4 Cross-media effects

If changing from an existing network technology to a more efficient one (or when old standards are phased out) is expected to lead to significant energy savings, it also induces adding or changing a large number of network components (e.g. cables and fibres, transceivers, power amplifiers, etc.), which means:

- **increasing the consumption of raw materials** (e.g. rare earths, plastics, glass, metals, etc.), **and embodied energy** (the energy used to extract and transform the raw materials into final products);
- **generating waste of electronic and electrical equipment** (WEEE) with a lot of obsolete equipment, which can lead to water and soil pollution, if not treated properly.

Moreover, changing an entire network can require **civil engineering works, leading to nuisances (noise, dust, etc.), landscape and land use changes** (new buildings, antennas or cables) – see chapter 4.6 on Reducing the environmental impacts when building or renovating telecommunication networks.

Increasing the energy efficiency of the network can lead to significant **rebound effect**, with an increase of internet access and demand, which in the end lead to a greater energy consumption.

### 4.4.5 Operational data

**Privilege selection and deployment of the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks**

<u>Radio equipment (power amplifiers, Radio Frequency transceivers and antennas, etc.) in wireless networks</u>

The power amplifier of a base station is the component with the highest energy consumption in large cell-stations (EARTH, 2012a) and represents one of the major sources of power consumption in small cell-stations.

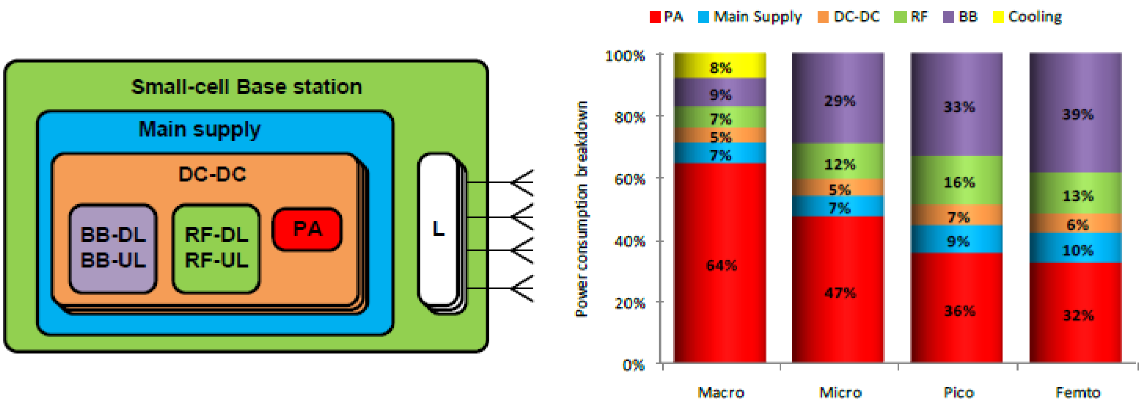


**Figure 91: Simplified block diagram of a small-cell base station (on the left) and the base station power consumption breakdown for different cell-sizes (on the right), (EARTH, 2012e)**

Replacing existing power amplifiers with higher efficiency ones can reduce the power consumption of wireless networks at high loads. But if the power amplifier only operates on high DC power supply independently of the traffic load, then power is wasted at lower traffic loads. In order to enable further energy saving practices and component deactivation features, adaptive power amplifiers should be chosen. It

allows operating point adjustment (to be able to optimise the power efficiency for low, medium and high traffic loads). Further improvements in terms of energy efficiency of base stations are expected to be reached due to the transition to new generations of networks.

The energy efficiency of a small-cell baseband processor is increased by using an Application Specific Instruction Processor's (ASIP) platform rather than a Field-programmable Gate Array's platform (EARTH, 2012e). Four categories of ASIPs for energy-efficient signal processing can be considered according to the EARTH project:

- Digital front-end processors and Analogue-Digital Convertors (optimised for mixed signal filtering, synchronization and data conversion);
- Baseband processors (optimised for various diversified signal processing tasks, such as MIMO-OFDM[81] processing, channel estimation, equalization, etc.);
- Channel error correction processors (optimised for various FEC[82] encoding / decoding tasks);
- Platform control processors (such as power regulation and micro-processors).

The energy efficiency of the Radio Frequency (RF) transceiver can be improved by using CMOS[83] technology. This technology benefits regularly from energy-efficiency improvements due to technology scaling. This results in about 20% energy savings every year or two (EARTH, 2012e).

Changing of antennas can lead to significant energy savings:

- Isolated TX/RX antennas can provide low-loss antenna interfaces particularly effective for small cells.
- Low-loss printed antennas, made of dielectric materials (such as foam) can be used for improving radiation efficiency (EARTH, 2012a).

<u>Telecommunication equipment (switchers, routers, multiplexers, etc.) in wireline networks</u>

Beyond the use of optical equipment, energy savings can be obtained by installing more energy-efficient devices all along the wireline access network: in central offices, splitters, DSLAM, etc. Such technologies rely on the utilisation of novel silicon and memory technologies for packet processors (ITU, 2010).

<u>Broadband equipment (terminations, interfaces, cables, etc.)</u>

Power consumption targets are regularly defined through the European Commission's Code of Conduct on Energy Consumption of Broadband Equipment (JRC, 2015). The Code defines power targets per broadband port for:

- Interfaces (with narrowband network equipment),
- Optical Line Terminations (OLT) for PON- and PtP-networks;
- DSL network equipment (e.g., ADSL, ADSL2, ADSL2plus, and VDSL2);
- Combined DSL/Narrowband network equipment (e.g., MSAN where POTS interface is combined with DSL Broadband interface);

[81] Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM)

[82] Forward Error Correction (FEC)

[83] Complementary metal–oxide–semiconductor (CMOS)

- Cable service provider equipment (I-CMTS, M-CMTS);
- Powerline service provider equipment.

Replacing components should also include energy efficiency enabling features, such as:

- Low power idle mode, as recommended by the EU Broadband Equipment Code of Conduct[84]. The idle mode consists of rapidly turning off subcomponents when no activities are performed.
- Sleep mode, which is characterized by higher energy savings but larger wake-up time, compared to idle mode. As sleep mode is not compatible with many Internet protocols (many of them assume that devices are always available). In order to avoid losing connectivity, a network proxy can be used.
- Adaptive Link Rate (ALR) technology, which allows for temporary reduction of bandwidth during low traffic periods (can be quickly restored to higher bandwidths when needed). By offering more operating modes (compared to a situation with only an idle and a working mode) this technology creates an opportunity for energy savings.

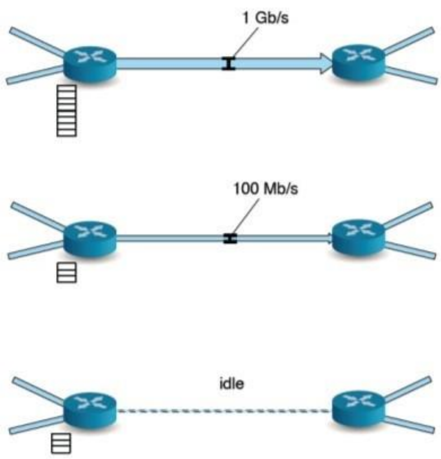


**Figure 92: Adaptive Link Rate strategies: the rate of 1 Gb/s link can be reduced to 100 Mb/s or the link can be made idle to save energy (Rossi et al, 2010)**

**Privilege deployment of integrated and multi-standard solutions.**

Having network equipment that operates multiple standards is an opportunity for reducing the number of network devices functioning while meeting the needs for operating different generations of telecommunication networks (e.g. 2G, 3G, 4G, and etc., for wireless networks). Since each technology shares common auxiliary infrastructure such as cooling system, security, battery backup and backhaul, significant energy savings can be realized. Energy savings of about 40% can be obtained (Ericsson, 2014). Such solutions are deployed through specific equipment and software.

[84] European Commission (2013) Code of Conduct on Energy Consumption of Broadband Equipment - Version 5.0 (20th December 2013). Joint Research Centre. For more information, see: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/energy-consumption-broadband-communication-equipment

Integrated solutions ensure an optimisation of the installed base station. When installing new base stations, such solutions provide base stations made of adapted ICT, cooling and power supply equipment (properly configured, and with the appropriate capacity)

**Privilege selection and deployment of the most energy efficient cooling systems**

Efficient cooling technologies can also be applied in order to decrease energy consumption of base stations. Although the need for cooling has decreased over time (most base stations today can operate without cooling at temperatures up to 45°C), some cooling is still required in hot-climate regions. In most cases, free air cooling or fan cooling is sufficient. But if free-air cooling cannot be implemented, a water cooling system can be installed. The implementation of this technique the CELTIC-plus project OPERA-net2 showed that liquid cooled energy consumption was nine times lower than an air-cooled solution. It enables 45% cooling capacity increase, 75% heat density upgrade and 40% cooling volume reduction on the device level. Zhang P. et al observed Coefficient Of Performance (COP) over 4 for a base station DX cooling system using free cooling or thermosiphon (Zhang P. et al., 2013). In addition, a liquid cooled system allows the re-use of heat for other applications (Celtic-Plus, 2015).

In central offices, techniques similar as the ones developed in data centres (see section 3.2.4 - Improve airflow management and design) can be deployed: hot aisle / cold aisle blanking plates, hot air containments, air ducting, etc.

**Privilege selection and deployment of the most energy efficient UPS**

Uninterruptible Power Supply (UPS) systems often provide a large potential for energy savings. In order to protect the activity from power outages, ICT infrastructures require a backup power supply, which can take over when the primary energy supply is interrupted. Usually, the backup power source takes the form of an uninterruptible power supply, UPS. When the system is functioning normally, power enters the facility and flows through the UPS.

The UPS charges and routes power to the racks. This operation nevertheless implies significant power losses. The average UPS has an efficiency of only about 92% (Fehrenbacher, 2009). The UPS energy losses are due to electrical power conversion inefficiencies (in the charger and inverter) and battery charging losses or energy losses in inertial systems (flywheels). The electric losses (and the heat generation) are more important in double conversion UPS (rectifier, inverter, filter, and interconnection losses), than in line-interactive and standby UPS (filter, transformer, and interconnection losses).

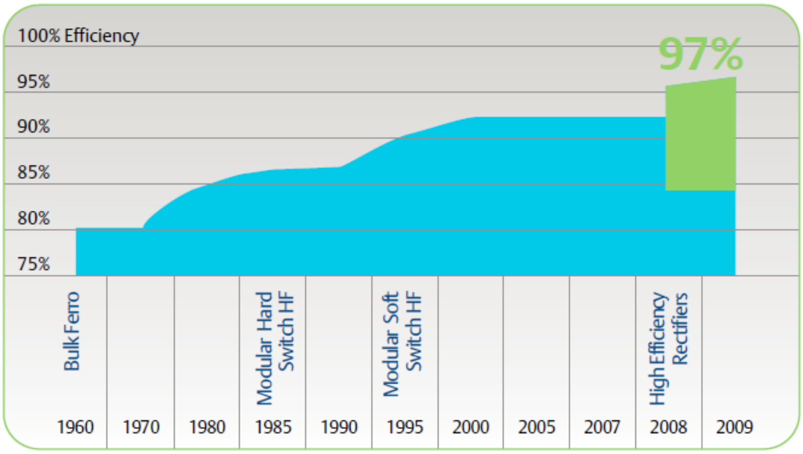


**Figure 93: Telecom Rectifier Efficiency Trend (Emerson, 2010).**

To reduce energy consumption, the first option is to select high efficiency UPS, using rectifiers which can allow a reduction of energy losses due to electricity conversion. Today's typical rectifiers (230V AC to 48V DC convertors) achieve efficiencies of 90% to 91% and some best-in-class rectifiers can even reach 97% efficiency over a very wide load range. These few percentage points can represent a big difference when considered in terms of power loss. Indeed, these efficiency values are misleading and belie the actual amount of power wasted in real installations. When equipment is doubled for redundancy, or when the equipment is operated well below its rated power, efficiency falls dramatically. Furthermore, the heat generated by this "wasted" energy in power equipment must be cooled by the cooling system, which causes the air conditioning system to use even more energy (Rasmussen, 2011).

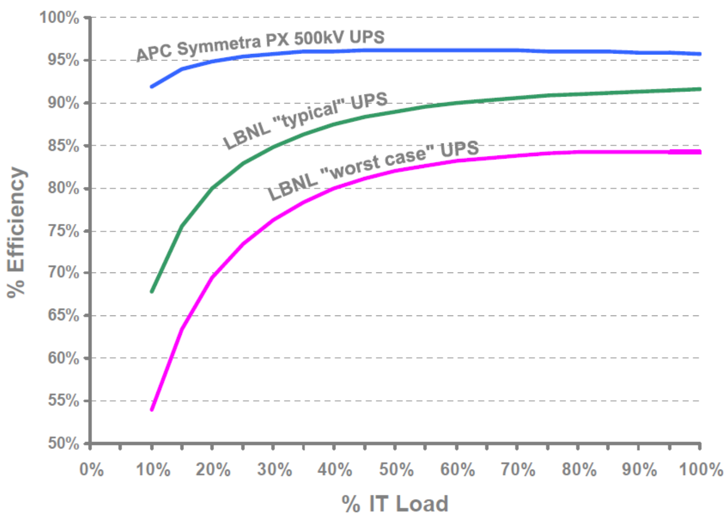


**Figure 94: Comparison of efficiencies of a recently introduced high-efficiency UPS to UPS efficiency data published by Lawrence Berkley National Labs. Source: (Rasmussen, 2011)**

Beyond traditional battery powered UPS, some new highly efficient UPS systems are based on the elimination of the battery/inverter approach. For example, the rotary UPS, which uses a high speed, low friction rotating flywheel coupled with a backup diesel generator that can start instantaneously to provide emergency power. When power fails, the rotational energy of the flywheel is used to drive a generator until the fast start generator can take over the load. Flywheel systems offer the very high

efficiency of line-interactive devices, in excess of 95%. This technology should be considered when selecting an UPS system (Pacific Gas and Electric Company, 2006).

It is now possible to purchase modular UPS systems across a broad range of power delivery capacities. Physical installation, transformers and cabling are prepared to meet the design electrical load of the facility but sources of inefficiency (such as switching units and batteries) are installed in modular units. This substantially reduces both the capital cost and the fixed overhead losses of these systems. In low power environments these may be frames with plug in modules whilst in larger environments these are more likely to be entire UPS units.

### Privilege design of telecommunication sites maximising energy-efficiency

Migrating distributed functions to central server in wireline networks

Mobile networks dissipate a high proportion of their power at customer premises (especially for FTTH broadband networks). Significant power reductions have been observed by migrating functions such as routing, OAM (Operations, Administration & Maintenance) and security from a device on the customer's premises to a central server on the wireline network. (Mott McDonald, 2013)

Moving radio equipment closer to the antenna

In base station sites, Remote Radio Heads (RRH) or Active Antenna Systems (AAS) reduce feeder losses compared to a typical passive antenna (since optical fibres replace electrical cable). With this technique, radio equipment (radio frequency converters and power amplifiers) are located close to the antenna (and away from the base station) and connected via fibre cables (Emerson , 2008) in order to avoid cable losses.

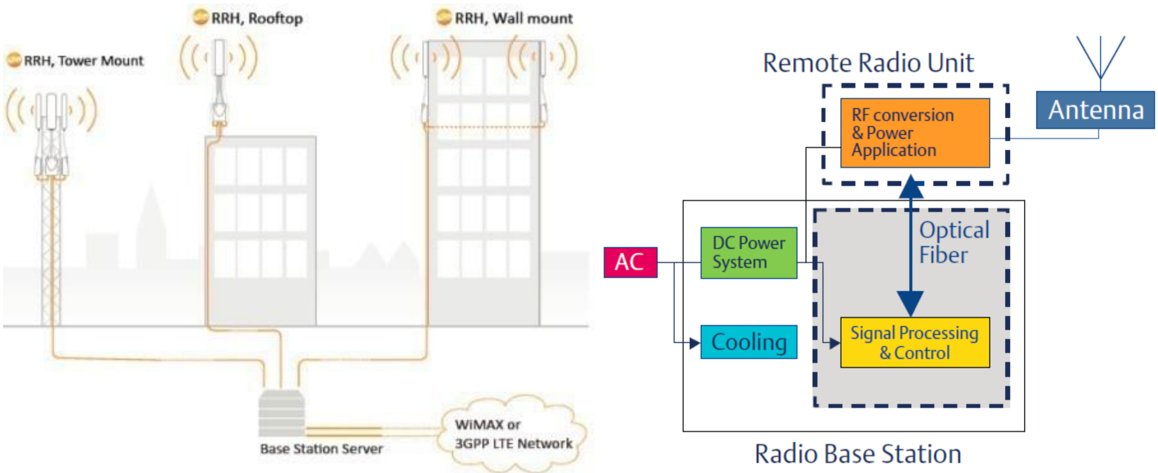


**Figure 95: Example of Remote Radio Heads (on the left (Altera, 2009) and diagram (Emerson , 2008)**

Using an appropriate design of UPS

The energy efficiency of UPS can be improved for certain configurations (identified by ETSI ES 202 336) with base station power supplies directly working from 400V DC supplies.

Investing in the right UPS solution is a good way to reduce power losses and increase the reliability of the system to adapt to varying loads. The most common UPS is the single unit UPS. Newer systems include:

- Cascade/hot-standby UPS;

- Parallel redundant UPS;
- Dual units UPS.

Their different technological design result in different levels of functionality (ability of a UPS system to supply the loads uninterrupted) and reliability (continuous UPS up-time duration between critical failures), as shown on the tables below:

| UPS Configuration | Score Rates Single Feed Loads | Score Rates Dual Feed Loads |
|---|---|---|
| Single Unit | 3 | 3 |
| Cascade | 3 | 3 |
| Parallel Redundant | 4 | 4 |
| Dual Units | 3 | 5 |

| UPS Configuration | Score Rates Single Feed Loads | Score Rates Dual Feed Loads |
|---|---|---|
| Single Unit | 2 | 2 |
| Cascade | 3 | 3 |
| Parallel Redundant | 4 | 4 |
| Dual Units | 2 | 5 |

**Figure 96 Comparison of the functionality (first table) and reliability (second table) of different UPS solution designs (Gutor, 2015)**

**Use software enabling energy savings**

Installation of software and networking functions and virtualisation carry important opportunities for energy consumption. For instance, software can reduce the number of hardware needed which allows for savings from sharing equipment. However, additional energy consumption can occur due to energy consumption from applications. Software also allows more flexibility in networking functions and lead to greater efficiency.

### 4.4.6 Applicability

Only a few telecommunication operators or Internet providers own wireline or wireless networks and can engineer changes within these networks. Most of these companies are large sized companies.

This chapter describes the main practices, but techniques should be adapted to the characteristics of the network:

- Depending on the segment of the network concerned by the upgrade (core, metro or access network);
- In relation to the technology currently used in the network (DSL, PON, etc.);
- In function of end-users' requirements (video demand, connexion stability, workload capacity, etc.).

More precisely, the elements to take into consideration for the adoption of new, more efficient UPS systems vary depending on when a new infrastructure is being built or when upgrading an existing infrastructure. For new installations, the management team must (PrimeEnergyIT, 2011):

- Assess its needs and size the UPS systems correctly (evaluate multiple or modular UPS, scalable and expandable solutions): battery back-up time, cost, size, number of outlets, etc.;
- Analyse the UPS technology and efficiency. Take into account the partial load efficiency of UPS;
- Select correct topology of the power supply systems;
- Select UPS systems compliant with the EU Code of Conduct for UPS (JRC, 2012) or Energy Star (minimum efficiency requirements for UPS are specified

in the EU Code of Conduct for UPS and in the Energy Star programme requirements).

**Table 49: Applicability of best practices aiming at selecting and deploying more energy-efficient telecommunication network equipment**

| Technique | Network segment | Network technology | End-users' requirements | Actor |
|---|---|---|---|---|
| Select more energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) | From core to access network | All type of technology | All type of end-users | Network operators and technology providers |
| Deploy integrated and multi-standard solutions | Access networks | Mobile networks | All type of end-users | Network operators and installers |
| Select and deploy more energy efficient cooling systems | From core to access network | All type of technology | All type of end-users | Network operators, technology providers, and installers |
| Select and deploy more energy efficient UPS | From core to access network | All type of technology | All type of end-users | Network operators, technology providers, and installers |
| Design more energy-efficient telecommunication sites | Access networks | All type of technology | All type of end-users | Network operators and installers |
| Use software enabling energy savings | From core to access network | All type of technology | All type of end-users | Network operators |

### 4.4.7 Economics

Using higher efficient power supplies will directly lower a data centre's power bills and indirectly reduce cooling system cost and rack overheating issues. Regarding the design of UPS, the costs associated with each technology vary. A relative solution cost of each technology is given in the table below:

| UPS Configuration | Relative Solution Costs | |
|---|---|---|
| | Single Feed Loads | Dual Feed Loads |
| Single Unit | 100 % | 120 % |
| Cascade | 180 % | 200 % |
| Parallel Redundant | 180 % | 200 % |
| Dual Units | 200 % | 220 % |

**Figure 97: Relative cost of various UPS solution designs (Gutor, 2015)**

### 4.4.8 Driving force for implementation

Three main driving forces for the implementation of practices to tackle energy losses can be identified.

- The operating expenditure **(OPEX) savings associated with an improvement of the energy efficiency** of telecommunication infrastructures are significant, and represent real incentives for operators to upgrade their power equipment. Some operators are now publicly stating that energy efficiency has become critical to their ability to offer new capabilities and services (Eltek, 2012).
- The investments **(CAPEX) savings associated with the characteristics of energy-efficient equipment:** such equipment is more compact and needs less material for product manufacturing and for packaging. Besides, lighter equipment saves a significant amount of transportation cost and reduces labour requirements, and avoids the need for a crane during installation.
- The **environmental responsibility** and image of operators is another driving reason for looking to high-efficiency technology to power telecommunications networks. As previously mentioned, energy inefficiency triggers interlinked consequences. Power losses, production of heat for non-productive purposes and additional consumption due to increased cooling needs combine to produce massive amounts of $CO_2$ emissions from telecommunication infrastructures.

### 4.4.9 Reference organisations

The Belgian telecommunication company, Proximus (Proximus, 2015), is migrating to a high-tech broadband network, by removing or consolidating older data networks, traditional telephone exchanges and copper networks (more than 25% reduction of total technical space).

In several US and Europe-based facilities (Miami, Culpeper, Amsterdam), Verizon has adopted energy efficient UPS using efficient flywheels. This allows eliminating the energy required to environmentally control battery rooms, thereby reducing non-productive related energy consumption (Verizon, 2013).

Deutsche Telekom[85] operates its own fixed-line and mobile communications networks in Europe and the United States. The company deployed a program to improve the energy consumption of its network, by:

- migrating over to new technologies and consistently removing technology no longer needed;
- optimizing energy supply and conversion (e.g., by improving power converters);
- using more energy-efficient technology for lighting, monitoring and above all cooling facilities.

[85] For more information, see: http://www.cr-report.telekom.com/site16/climate-environment/climate-protection-measures/energy-efficiency-network#atn-8846-8849,atn-8846-8851,atn-8846-8852,atn-8846-8853,atn-8846-8850

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## 4.5 Installing and upgrading telecommunication networks

**SUMMARY OVERVIEW:**

**Beyond the installation of new energy efficient equipment on network sites, organisational solutions can deliver significant energy savings, for instance, by ensuring that unused equipment is plugged off and power and cooling supply are not oversized and optimised to the actual current needs. It is best practice to:**

- **Take advantage of technology transition (e.g. deploying 4G technology in existing base station sites) to optimize network sites (decommission of unused equipment, replacing of obsolete equipment, proper configuration of cooling systems, etc.) through the integration of such practices in a management process focused on upgrading base station sites.**

**ICT components**

| | | | | |
|---|---|---|---|---|
| Data centre | **Telecommunication network** | Broadcasting | Software publishing | End-user devices |

**Relevant lifecycle stages**

| | | | | |
|---|---|---|---|---|
| **Design and installation** | Selection and procurement of the equipment | **Operation and management** | **Renovation and upgrades** | End-of-life management |

**Main environmental benefits**

| | | | | | |
|---|---|---|---|---|---|
| **Energy consumption** | Waste production | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

**Environmental indicators**

- Mobile Network data Energy Efficiency ($EE_{MN,DV}$)
- Mobile Network coverage Energy Efficiency ($EE_{MN,CoA}$)
- Average lifetime of ICT equipment in network sites
- Share of ICT equipment decommissioned and removed from base station sites each year

**Cross references**

| | |
|---|---|
| **Prerequisites** | The installation of new equipment when upgrading existing network sites require to have selected and purchased suitable ICT, cooling and UPS equipment. |
| **Related BEMPS** | • 4.2 Improving the energy management of existing network<br>• 4.4 Selecting and deploying more energy-efficient telecommunication network equipment<br>• 4.6 Reducing the environmental impacts when building or renovating telecommunication networks |

### 4.5.1 Description

Wireless and wireline networks are made of numerous, diverse and apart infrastructures.

Base stations correspond to an assembly of diverse components. Hundreds of elements are combined to create base station site solutions covering the wide range of requirements. Added to the existence of multiple manufacturers from which this equipment is purchased, this results in often very complex site installations.

Some base stations sites support one technology generation only (like basic GSM coverage), while complex sites can provide various combinations of technology generations (GSM, HSPA, LTE and soon 5G). Changes in network technology (e.g. from 3G to 4G) or availability of new frequency bands, require to install new equipment: specific equipment or multi-standard equipment. Telecommunication operators usually use their existing sites to install also the next generation network equipment.

These changes of technology represent an opportunity for deploying more energy efficient equipment. Unlike user equipment, which is often replaced within 2 or 3 years, mobile infrastructure equipment has a typical use time of about 10 years. The average equipment installed at the operator site is therefore rarely state-of-the-art.

If rapid replacement with latest equipment will improve the overall network energy efficiency, it would also cause significant off-side environmental impacts such as:

- Resources and energy consumption from ICT equipment manufacturing;
- Fuel consumption and air pollution from transportation;
- Hazardous pollutions related to WEEE management.

Besides, during network rollout site cleaning can be not properly carried out, due to a lack of time from installation team. When the new equipment is not properly installed and no old equipment is decommissioned, an increased energy consumption can be observed.

Indirectly, energy consumption from cooling system can also increase. The variety of equipment leads to different temperature requirements, but all equipment is usually installed in one single room and cooled to the temperature of the most sensitive equipment. This leads to a loss of overall energy efficiency.

It is best practice to:

- **Take advantage of technology transition (e.g. deploying 4G technology in existing base stations) to optimize network sites.**

  Telecommunication operators regularly perform a transition from one old generation to a new one. This provide a unique opportunity for having a direct access to base network sites (e.g. base stations) and to improve its energy efficiency beyond the installation of new generation equipment. At this stage, the installation team shall replace obsolete equipment and remove unused equipment, and configure the cooling system and the power supply to be in a way to adapt them to the needs of the new ICT equipment design. These results can be achieved through the integration of such practices in a management process focused on upgrading base station sites.

This BEMP focus on the installation and upgrading of telecommunication networks equipment, both in wireless and wireline networks:

- The selection of energy-efficient network equipment is covered by the previous BEMP (4.4 Selecting and deploying more energy-efficient telecommunication network equipment);
- The next BEMP (4.6 Reducing the environmental impacts when building or renovating telecommunication networks) deals with minimising the environmental impacts related to the creation or refurbishment of network infrastructures;
- Smart metering of energy use, which gives important information when installing or upgrading a telecommunication site, is covered by the BEMP 4.2 on Improving the energy management of existing network.
- Installing multi-standard and integrated solutions of base stations is a technique developed within the BEMP 4.4 Selecting and deploying more energy-efficient telecommunication network equipment.

### 4.5.2 Achieved environmental benefits

- **Reduction of direct electricity consumption from network equipment** (ICT equipment, cooling equipment…)

Investigation of some operating parameters of the base station, such as threshold set-points, air vent area, external wall transmittance and reflectivity, gives a total energy consumption savings from 10% up to 30%. (Spagnuolo, 2015).

The deployment of single base station solutions that can support different generations simultaneously offers a possibility of reducing overall power consumption by up to 50% compared to a situation with diverse generations of equipment, and in case of appropriate swapping out of base station cabinets when upgrading a site (ZTE, 2011).

- **Reduction of indirect electricity consumption from cooling** (due to a reduction of the energy consumed by ICT equipment) **and transportation** (due to lighter equipment)

### 4.5.3 Appropriate environmental performance indicators

**Mobile Network data Energy Efficiency** ($EE_{MN,DV}$) and **Mobile Network coverage Energy Efficiency** ($EE_{MN,CoA}$) are the most relevant indicators for assessing the energy efficiency of a base stations. These metrics are both defined by the ETSI standard ES 203 228, and are described within the BEMP on Improving the energy management of existing telecommunication networks (see section 4.2).

Process oriented indicators can also be monitored, in order to assess the implementation of an action plan aiming at installing and upgrading base stations, such as:

- **Average lifetime of ICT equipment in network sites** (especially base station sites). Monitoring such indicator is a prerequisite before assessing the overall environmental impacts of ICT equipment (through a LCA for example), by allowing energy consumption measurement during usage phase and resources consumption at manufacturing phase (to produce new equipment according to the equipment replacement frequency).
- **Share of ICT equipment decommissioned and removed from base station sites each year.**

- Average lifetime of ICT equipment in network sites

### 4.5.4 Cross-media effects

The installation of new equipment in telecommunication networks for energy efficiency purpose leads to several environmental impacts:

- Increased impact from manufacturing (embodied energy, water and raw materials consumption);
- Increased impact from transportation (fuel consumption, air emissions, etc.);
- Increased impact from waste management (hazardous pollutions).

LCA may help defining when replacing older equipment provides higher environmental benefits than repairing and extending the use-time of this equipment.

### 4.5.5 Operational data

**Take advantage of technology transition (e.g. deploying 4G on existing base stations) to optimize network sites**

The transition from one technology generation to another, dictated by business purposes, offers a unique opportunity for having a direct access to the different sites constituting a distributed network.

The previous BEMP (4.4 Selecting and deploying more energy-efficient telecommunication network equipment) highlighted the existence of technical opportunities for improving the energy efficiency of network nodes and links. More energy efficient ICT devices can be selected, as well as energy efficient cooling and power supply systems, in order to design more energy efficient telecommunication sites (base stations, central offices, etc.).

This technique focuses on the organisational aspects related to the installation of such equipment, especially when upgrading existing sites. Telecommunication operators usually use their existing sites to install also the next generation network equipment. Taking advantage of this specific moment –i.e. technological upgrade motivated by business reasons-, is not only more economically viable, but also less environmental impacting. With this approach, transportation is mutualized and no additional environmental impact is observed (related to fuel consumption and air consumption). However such changes at telecommunication base stations sites require also changes in customer premises technology. Otherwise several generations of technologies should be provided by the operator in order to satisfy all customers, and fewer telecommunications equipment can be decommissioned.

During network rollout and before installing new equipment, decommissioning unused equipment appears to be particularly relevant, so as designing an appropriated cooling and power supply system:

- The most important step to achieve efficient cooling is to develop base stations that do not require cooling at all. While early equipment depended on cooling when temperature exceeded 25°C, base stations today can safely operate without cooling at temperatures above 45°C. Limiting the density of ICT equipment within the base station helps minimising its inner temperature.
- The limiting factor are usually back-up batteries (if required), since temperatures above 25°C reduce battery lifetime: in hot-climate regions, battery cooling is usually required.
- In most cases in which site cooling is required (small ICT room heated by the installed equipment) free air cooling or forced air (fan) cooling is sufficient.

Such solutions are available and have been successfully applied at many base station sites. If free air-cooling cannot be applied for any reason, such as noise or contaminated air, water cooling is a very efficient way to cool radio base stations. This technique has been successfully demonstrated in the CELTIC-plus project OPERA-net2 (OPERA-Net2, 2015).

- Devices with different temperature requirements shall be segregated (by using containers), in order to provide cooling supply only to the equipment with cooling needs (e.g. lead batteries only for example). Devices from different operators on shared sites shall also be segregated, in order to allow each operator to keep control over the power and cooling supply of its own ICT equipment.
- This is particularly relevant when the infrastructure is shared between different operators

These results can be achieved through the integration of these techniques within an environmental management system through:

- Assessment of existing equipment and configuration in network sites;
- Development of a specific management plan on the installation of new equipment in existing telecommunication sites, which:
  - sets the objectives (in terms of energy efficiency, equipment decommissioning or cooling supply for example);
  - defines the responsibilities (within the installation team, and in terms of monitoring);
  - specifies the actions to be carried out when installing new equipment (in terms of decommissioning, changes in cooling supply, etc.).
- Communication toward installation teams on the importance of carrying out such actions, and deploying a training program if necessary;
- Utilization of contractors to identify and switch off unused equipment that is no longer in use;
- Checking the implementation of these actions through sites energy consumption monitoring or internal audit on the occasion of sites installation;
- Reviewing the action plan, the objectives and the governance if necessary (on behalf of the results).

### 4.5.6 Applicability

Telecommunication operators and their suppliers in charge of the installation of ICT equipment are the main actors concerned by this technique. This technique is more relevant for large mobile companies which own thousands of sites, and for operators of networks in rural areas (where the sites are more spaced out).

### 4.5.7 Economics

TeliaSonera in Sweden has estimated energy savings related to the shift from compressor cooling solutions to free air cooling to 30% of energy operating costs of telecommunication sites. For its 12,000 telecommunication sites that represents 45-55 GWh/year or 5,000,000 €/year compared to a regular compressor cooling solution.

### 4.5.8 Driving force for implementation

Energy efficient equipment saves not only energy during its use phase but is more compact and needs less material for product manufacturing and for packaging which results in cost savings making the solution more competitive. Lighter equipment saves a significant amount of transportation cost and reduces labour requirements, and avoids the need for a crane during installation. (Enlund S. and Lunden D., 2011).

### 4.5.9 Reference organisations

- TeliaSonera[86] (Sweden) has been deploying a modernization program of its network of base stations focused on reducing energy consumption and costs, through:
    - Installing more energy-efficient ICT equipment (e.g. power active features of 4G equipment);
    - Replacing compressor-based cooling with free air and geo-cooling solutions (99.5% of base stations are currently without compressor-based cooling);
    - Dismantling of legacy equipment;
    - Utilization of contractors to identify and switch off unused equipment that is no longer in use.
- Telecom Italia has installed sensors to monitor the application of temperature alignment policies in Radio Base Stations, in the main fixed network exchanges and in offices. Checking of compliance with technical policies and regulations allows abnormal situations or faults to be corrected promptly, thus ensuring optimum environmental and operating conditions. (Telecom Italia, 2014)

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[86] For more information, see: http://annualreports.teliasonera.com/en/2015/sustainability-work/environmental-/

## 4.6 Reducing the environmental impacts when building or renovating telecommunication networks

**SUMMARY OVERVIEW:**

**Telecommunication and broadcasting infrastructures generate neighbourhood nuisances (aesthetic impact, noise from generators and cooling system, etc.) and are responsible for land-use (potentially associated with biodiversity disturbance). To limit such impacts when building new infrastructures or when renovating existing ones, it is best practice to:**

- **Colocate ICT infrastructures, in order to limit the number of different infrastructures.**
- **Locate network infrastructures (fixe-lined, antennas, buildings, etc.) close to existing access roads and out of conservation areas**
- **Install noise reducing solutions, such as barriers, absorptive material or muflers.**

**ICT components**

| Data centre | Telecommunication network | Broadcasting | Software publishing | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| Design and installation | Selection and procurement of the equipment | Operation and management | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| Energy consumption | Resources consumption | Air emissions | Water use & consumption | Noise and electromagnetic fields | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental performance indicators**

- Percentage of sites shared with other operators (%)
- Spread between the maximum legally authorised sound value in an area and the sound emitted by the equipment of a base station site (power generator and air conditioning system, in dB)
- Noise Reduction Coefficient (from 0 to 1) of the material used to lower the transmission of sound from the base station to the surroundings

**Cross references**

| | |
|---|---|
| **Prerequisites** | The implementation of such techniques will depend on the characteristics of the environmental around the network (urban vs. rural area, species living in the area etc.). |
| **Related BEMPS** | • 2.3 Procurement of sustainable ICT products and services<br>• 4.3 Improving risk management for electromagnetic fields through assessment and transparency of data<br>• 4.4 Selecting and deploying more energy-efficient telecommunication network equipment |

### 4.6.1 Description

Telecommunications and broadcasting infrastructures are composed of different structures such as telephone lines, antennas, dishes, radio masts, towers and base stations, which may have a visual impact on the character and amenity of the local environment depending on the perception of the local community as well as the aesthetic value assigned to the scenery, both in urban and in rural contexts. The need to integrate ICT infrastructures in an urban context without detracting from existing buildings is a real challenge for network operators. Installing antennas, electricity closets and air conditioning equipment on buildings which were not originally designed for this purpose requires putting in place specific processes to deal with the issues arising from the installation. In a rural context, terrestrial and aquatic habitats may be altered primarily during the construction of telecommunications infrastructure depending on the type of infrastructure component and proposed location. Potential impacts to biodiversity may be more significant when creating long distance fibre optic cables, and access roads to transmission towers and other fixed infrastructure. In both contexts, the acceptance of the infrastructure by stakeholders (including inhabitants and local authorities) can vary considerably. A low acceptance by local stakeholders can be damaging for the network operators and result in complaints and reputational issues.

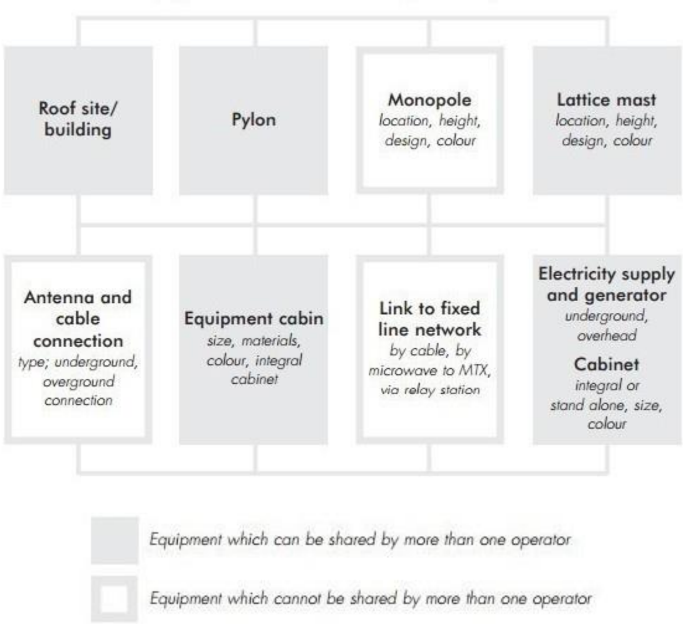


**Figure 98: Mobile telecommunications radio base station equipment required (Scottish Natural Heritage, 2002)**

Noise is another major concern for telecommunication service providers. The operation of backup power generators is the main source of noise from telecommunications facilities. Power generators run once a week for less than an hour to ensure their good functioning in case of a power outage. Another source of noise is the cooling system for the cabinets at the basis of base stations. Unlike backup power generators, air conditioning systems may run on a daily basis to ensure the normal functioning of the base station.

The following techniques can be deployed when planning and designing new infrastructures, or when renovating older ones, in order to minimise their effect on landscape, biodiversity or in terms of noise.

It is best practice to:

- **Collocate ICT infrastructures.**

  Such technique aims at limiting the number of infrastructures, mainly to limit its landscape impact.

- **Locate network equipment close to existing access roads and out of conservation areas.**

  Environmental criteria should be taken into account when selecting the location of new network infrastructures (fixe-lined, antennas, buildings, etc.), as the exclusion of any building from conservation areas, its proximity to existing access roads, or its distance from noise-sensitive areas (e.g. residential areas).

- **Install noise reducing solutions.**

  Barriers, absorptive material or mufflers can reduce the transmission of sound beyond the site where the network equipment is installed.

### 4.6.2 Achieved environmental benefits

A better planning and siting of ICT infrastructures can decrease both visual and environmental impact. If building an additional structure is not inevitable, an operator can install an antenna on an existing tower or building, thereby avoiding building a new structure. If it is a necessity to build a new structure, thorough planning can decrease the need for heavy construction works, by siting the structure close to a road and to the grid. This results in the following potential environmental benefits:

- A **reduced impact on the fauna and flora around the infrastructure**
- A **reduced visual impact of the landscape** for inhabitants and tourists.

The benefit from **noise reduction** measures is a decreased fatigue and stress for people and animals living close to the source of noise.

### 4.6.3 Appropriate environmental performance indicators

Recommended practices can be monitored using the following indicators:

- Percentage of sites shared with other operators (%);
- Spread between the maximum legally authorised sound value in an area and the sound emitted by the equipment of a base station site (power generator and air conditioning system, in dB);
- Noise Reduction Coefficient (from 0 to 1) of the material used to lower the transmission of sound from the base station to the surroundings.

### 4.6.4 Cross-media effects

Installing noise reduction equipment means using additional equipment, thereby triggering new waste both during the first installation of the equipment, and for maintenance purposes.

Colocation requires larger and stronger structures with a resulting increased impact on the surrounding landscape.

### 4.6.5 Operational data

Telecom service providers must apply for construction permission and often demonstrate to local authorities that they have considered options to minimise the visual and environmental impacts when planning and building new infrastructure or when renovating older ones. Telecom service providers can however decide to voluntarily adopt best practices that go beyond local requirements when planning and designing ICT infrastructures.

The best practices to be adopted by telecommunication operators can include:

- **Colocation of ICT infrastructures.**

The increase in the number of radio towers and base stations is a result of an increasing pressure on operators to provide coverage to customers everywhere. To transmit information in an area, an operator usually needs to build a tower or mast, on which an antenna is attached. Electric cables link the antenna to an electrical room or to the grid and to a radio room. As each provider needs its own antenna to transmit its customer' signal, usually each provider would build its own tower (Nagle, 2012). Colocation aims at avoiding building multiple towers close to each other, by placing several antennas on a single tower. Site-sharing now seems to become the norm and network operators now share much of their network infrastructure via joint venture commercial arrangements (Mobile Operators Association et al., 2013).

Using existing buildings to install telecommunication equipment can help reduce the environmental impact of telecommunication networks. Some of the commonly used infrastructures include office blocks, churches, water towers, street works such as lighting columns, floodlighting towers, electricity pylons, chimneys and broadcast masts (Mobile Operators Association et al., 2013).

- **Location close to existing access roads and out of conservation areas.**

In order to be built, a relay antenna needs to be accessible by road, and in order to operate, it needs to be connected to the grid (or to rely on its own power supply system) (FFTélécoms, 2004b). To minimise environmental impacts and disturbance to natural habitats, these factors must be taken into consideration during the planning phase of the ICT infrastructure. Local planning authorities should assist operators with this matter, for instance by helping them find land and structures suitable for their infrastructures. This collaboration can help decrease the environmental impact of the project (e.g. by avoiding building a new road and installing new electricity cables) (Mobile Operators Association et al., 2013).

Operators should bear in mind that there are certain locations where sensitive siting and design are of increased importance. This is the case when operators install equipment on listed buildings or in areas of historic or architectural importance, in national parks, conservation areas, and other registered sites of natural, historic or scientific importance. While some locations can be avoided (e.g. listed building) if in-building coverage is not required, others cannot (e.g. national parks with a large surface require a mobile coverage). In such cases, operators must be extra careful regarding the nature of the proposals, the relevance of the location, the potential impacts of the project and the means put in place to reduce these impacts. They should also not be prominently visible from significant vantage points including tourist routes, viewpoints and recreation sites, in order to preserve the amenity and environmental value of these areas (Western Australia Planning Commission, 2015).

- **Installation of noise reducing solutions**

Certain equipment may necessitate the installation of barriers, absorptive material or mufflers to reduce the transmission of sound beyond the site where it is installed. The level of noise reduction is usually expressed in NRC (Noise Reduction Coefficient), with

0 being perfect reflection and 1 perfect absorption. Unpainted concrete block, for instance, can have an NRC of 0.35 (Hammett & Edison, 2015). Barriers should be solid (>2 kilograms per square meter) and airtight. Examples of sound wall materials include: 10 cm thick poured in place or pre-cast concrete panels, 15 cm thick CMU wall, 4 cm thick board and batten, tongue and groove wood on one side of post, or cementitious wood panels. An earthen berm alone or in conjunction with a wall can be used (Sound Solutions, 2015).
In several countries, network operators have worked together to define good practices regarding the impact of their equipment on environment.

**Mobile Operators Association in England**

**Practices implemented and context**

The Mobile Operators Association has worked together with Arqiva, English Heritage, National Parks England and the Planning Officers Society. This working group has published a Code of best practice on mobile network development (2013). This code *"provides guidance primarily to mobile network operators, their agents and contractors, and to local planning authorities in England."* (Mobile Operators Association et al., 2013). This code intends to support the development of network performance while minimising its impact on the environment. The code gives a framework to allow the engagement of operators with local communities and other interested parties. If the code can apply to all forms of wireless development, it is most relevant for the construction of new equipment (towers, antennas and base stations) and significant additions or extensions to existing sites.

**Technical characteristics**

The so-called "Traffic Light Rating Model" allows a site to be rated by the operator according to its likely sensitivity in terms of environmental, planning and community considerations (first step). Depending on that rating a plan is devised that sets out the likely appropriate level of consultation (second step).

The first step is the definition of a sensitivity profile linked both to community issues and planning and environmental issues. When planning an installation, the company can rate the probability that the following items will constitute an issue for the installation.

Regarding planning and environmental issues, items to be considered include:

- Located within special land use (national parks, world heritage sites, registered parks or gardens, archaeological sites, special landscape areas, etc.)
- Proximity to a listed building
- Siting – matters to be considered include existence of topographical features and natural vegetation, flora and fauna, impact on skyline or horizon, townscape clutter, site in relation to existing masts, structures and buildings (including historical or traditional character), views of recognised importance.
- Design – matters to be considered include height in relation to surrounding area, appearance of the installation, material, colouration, dimensions (other than height), overall shape, solid or open framework, transmission solutions (i.e. impact of dish).
- Site type – new site, upgrade, swap out, mast share. In respect of upgrades, swap outs, or mast shares it is anticipated that the score under siting and appearance will be less than for new installations. The matter that is being given consideration is the impact of the proposed alteration in comparison to the existing installation.

- Proximity to residential property or homes
- Proximity to schools, nurseries, playgroups, play grounds, recreation grounds, hospital property
- Local development plan policies (potentially negative, positive or neutral for the project)
- Precedents/site history (were the previous applications rejected or successful?

The aggregated rating of these items (as well as items related to community issues) allow the operator to position the project in a sensitivity category, from very sensitive in red to less sensitive in green on the graph below:

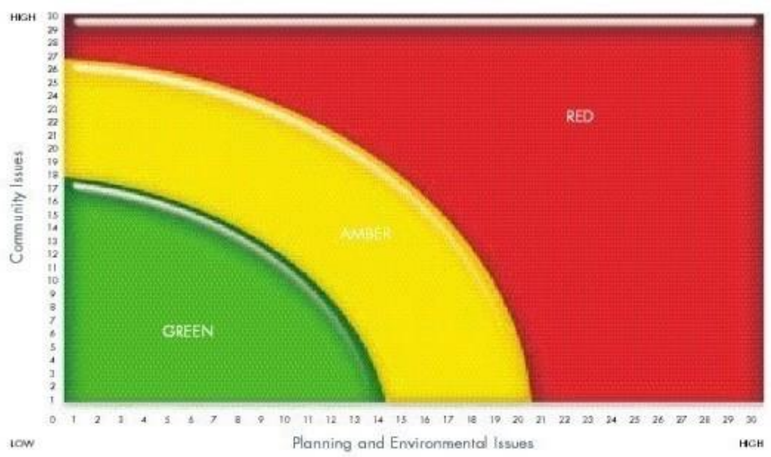


**Figure 99: Traffic Light Rating Model for Public Consultation (Mobile Operators Association et al., 2013)**

The rating in the red category does not mean that the proposal should not be progressed; rather, it simply indicates that a higher level of public consultation may be needed prior to the planning application being submitted.

**Results**

Once the rating has been determined then the consultation strategy is used to provide the options available in respect of the level of public consultation. It is important to seek local planning authority input into the process where possible.

Under the Traffic Light Rating Model, if a site is rated green then generally the statutory consultation is deemed to be sufficient. The more sensitive issues have been identified by the operator, the more consultation tools can be used. The Code of Best Practice identifies the following tools: consultation letter; site notice; informal, drop-in session; key stakeholder briefing session; leaflets; public notice placed in local press.

| Fédération Française des Télécommunications in France |
|---|
| **Practices implemented and context** |
| In 2004, the largest French mobile network operators (SFR, Orange and Bouygues Telecom) published a set of common best practices for the integration of antennas in their environment (FFTélécoms, 2004). |
| **Technical characteristics** |
| These practices include:<br>• Practices regarding new antennas<br>  ○ Universality: Operators apply the set of practices everywhere in the country<br>  ○ Viewpoint: operators look at each potential siting through the eyes of the pedestrian, resident and lessor.<br>  ○ Tailored-approach: new antennas respect the appearance of buildings, infrastructures and landscapes<br>  ○ Simplicity: operators make the design of new antennas lighter<br>• Practices regarding new antennas on buildings<br>  ○ Continuity: new antennas shall look like they are part of the building on which they were installed<br>• Practices for new antennas on towers/pylons<br>  ○ Last-resort: operators only build new pylons on last-resort<br>  ○ Siting: operators take into account the integration in the landscape when deciding where to build pylons<br>• Forbidden practices:<br>  ○ Operators shall not install antennas and cables on facades if these are visible from the street<br>  ○ Operators shall not install antennas on roofs without designing these to match the design of the building<br>  ○ Operators shall not use supports legs for antennas if these are visible<br>  ○ Operators shall not install antennas on water towers without designing these to match the design of the tower; antennas shall not hang loose from water towers |

### 4.6.6 Applicability

Colocation on a single tower might not always be the appropriate solution to environmental issues. Among the issues that can result from colocation are:

- Coverage problems: the antenna may be poorly located or not high enough to provide a good coverage
- Radio interference: to avoid interferences, antennas must be separated from each other, which could increase the breadth of the tower's equipment significantly, hence increasing its visual impact

- Structural loading: Due to an increased weight of the equipment carried by the tower, it may need to be strengthened or replaced with a bigger structure with a consequent effect on visual amenity (Mobile Operators Association et al., 2013).
- Commercial disputes: the relationship between operators due to the status of the tower (e.g. shared property, property by one operator and leasing to another) can lead to disputes, hence making the management of the tower more complicated. (Nagle, 2012)

In some areas, existing infrastructures are not appropriate or adequate to install ICT infrastructures. Additional towers have to be built to increase the network coverage. This is especially true in rural areas, where the coverage is lower than in urban areas. In addition to the visual impact, this can have an impact on the local ecosystem due to the need to dig trenches on several kilometres to connect the tower to the grid, for instance. Stakeholders in a rural context might consider the economic benefits of extended telecommunication coverage as offsetting the visual impact on the landscape. Operators should however still try to minimise the impact of their infrastructure on the landscape.

Local authority planning policies can limit the capacity of ICT operators to develop their network in specific areas, even if EMF and noise-related measures are planned by the operator (GSMA, 2012b). Depending on the country, local authorities can decide to prevent the construction of ICT infrastructures for several reasons, such as environmental and public concern reasons. The size and location of the infrastructure will also often determine which processes must be followed. Smaller sized towers and antennas are not always subject to specific authorisations (in that case, operators can voluntarily decide to adopt some of the best practices mentioned above). Larger projects can necessitate more complex processes; operators can be required to adopt specific measures regarding EMF and noise-related impacts. The same can apply for specific locations (e.g. historic districts).

**Table 50: Applicability of best practices aiming at reducing the environmental impacts when building or renovating telecommunication networks**

| Technique | Network segment | Operation | Actor |
|---|---|---|---|
| **Colocation of ICT infrastructures** | Antennas of wireless networks mainly | New build and renovation | Network operators; owners of other infrastructures |
| **Location close to existing access roads and out of conservation areas** | Any network infrastructure | New build | Network operators; local authorities |
| **Installation of noise reducing solutions** | Base stations and central office (generators and cooling systems) | New build and renovation | Network operators; local authorities |

### 4.6.7 Economics

Most measures linked to the prevention and correction of impacts on landscape can be associated with **cost savings for network operators**. **Colocation** implies that less towers need to be built by operators, and that the cost of existing towers can be

shared among them. In addition, operators implementing these practices in this domain can **avoid costs linked to regulatory issues**.

Additional costs include the installation of noise reducing equipment.

Some practices can also represent an **investment** for operators, and **increased operating and maintenance costs**. **Preliminary engagement with stakeholders** also represents an additional cost to be budgeted by operators prior to planning the construction of an infrastructure, and can delay the construction process.

Potential benefits result from a better image of telecommunication providers. A lower number of complaints and legal issues could also result from a better informed public, more actively involved in consultation processes.

**Table 51: Economics data related to reducing the environmental impacts when building or renovating telecommunication networks**

| Technique | Operating costs | Investment costs | Return |
|---|---|---|---|
| **Colocation of ICT infrastructures** | / | May require stronger or taller structures | Reduction of complaints and regulatory issues, and better image<br><br>Reduction of building and maintenance costs |
| **Location close to existing access roads and out of conservation areas** | May impact coverage objectives | Depending on land price | Reduction of complaints and regulatory issues, and better image<br><br>Reduction of building costs |
| **Installation of noise reducing solutions** | / | Selecting material with a high Noise Reduction Coefficient (cost depends on the material used: cement, wood etc.) | Reduction of complaints and regulatory issues, and better image |

### 4.6.8 Driving force for implementation

Several factors combine to support the development of these practices:

- **Regulation**: One of the major factors boosting the development of such practices is planning policies regarding the construction of ICT infrastructures. Most countries have regulations and policies in place regarding the environment, the telecommunication sector, and on local planning. In addition, legal issues with third parties complaining in court due to impacts on landscape (e.g. impact of an ICT infrastructure on price of properties due to visual impact) or in terms of noise encourage network operators to prevent such events.
- **Costs**: If operators are able to share sites (i.e. colocation of antennas), and install more equipment on each site, this reduces the overall visual impact of network infrastructure. As a consequence, fewer sites are needed to improve network coverage, making the coverage more cost-effective to deploy (Mono Consultants for Kingston Upon Thames Council , 2015).

### 4.6.9 Reference organisations

Portugal Telecom for visual impacts on the landscape.

Orange: the proportion of sites shared with other operators reached 30% at end 2015 for the AMEA region.

### 4.6.10 Reference literature


FFTélécoms. (2004b). *Politique commune aux trois opérateurs pour l'intégration paysagère des antennes-relais de téléphonie mobile.* Retrieved 9 29, 2015, from FFTélécoms: http://www.fftelecoms.org/sites/default/files/Documents/Integration_paysagere_Def1.pdf

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## 4.7 Minimising data traffic demand through green software

**SUMMARY OVERVIEW:**

**To minimise the environmental impacts of telecommunication networks operation and to avoid a rebound effect, a reduction in the growth rate of data traffic can play a significant role. This BEMP is dedicated to practices that can be implemented: either when developing new software or when optimizing existing software, and for both mobile applications (for smartphones and tablets) and computer software (for laptop and desktop), as well as web portals and web-based applications.**

**It is best practice to:**

- **Design demand-adaptive software based on the assessment of end-users needs, in order to avoid energy over-consumption at usage phase and to limit the obsolescence of existing ICT devices.**
- **Assess software environmental impacts through LCA at development phase and performance measurement (CPU, RAM and energy utilisation) at usage phase.**
- **Develop more energy efficient software; e.g. providing different image resolutions, preferably connecting mobile devices via LAN or WLAN (rather than mobile network), or implement mobile apps' solutions when developing software for stationary equipment.**

**ICT components**

| Data centre | **Telecommunication network** | Broadcasting | **Software publishing** | End-user devices |
|---|---|---|---|---|

**Relevant lifecycle stages**

| **Design and installation** | Selection and procurement of the equipment | **Operation and management** | Renovation and upgrades | End-of-life management |
|---|---|---|---|---|

**Main environmental benefits**

| **Energy consumption** | Resource consumption | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |
|---|---|---|---|---|---|

**Environmental indicators**

- Share of demand-adaptive designed software among the portfolio dedicated to internal or external use (published software)
- Share of software for which a LCA has been carried out among the portfolio dedicated to internal or external use (published software)
- Share of software for which the energy performance has been measured among the portfolio dedicated to internal or external use (published software)
- Share of existing software which has been refactored toward higher efficiency among the portfolio dedicated to internal or external use (published software)

**Cross references**

| | |
|---|---|
| **Prerequisites** | • N/A |
| **Related BEMPS** | • 3.4.1 Deployment of new ICT services and software (in data centres)<br>• 4.2 Improving the energy management of existing network |

### 4.7.1 Description

The energy consumption of telecommunication networks is directly related to the traffic load, especially if networks can be dynamically adapted to the demand (see BEMP 4.2 on Improving the energy management of existing network). Telecommunications operators have been continuously developing new technologies in order to provide more and more data traffic to customers. A new generation of network technology results in an increase of both energy efficiency and data traffic: the energy consumption of telecommunication networks remains constant or keep growing.

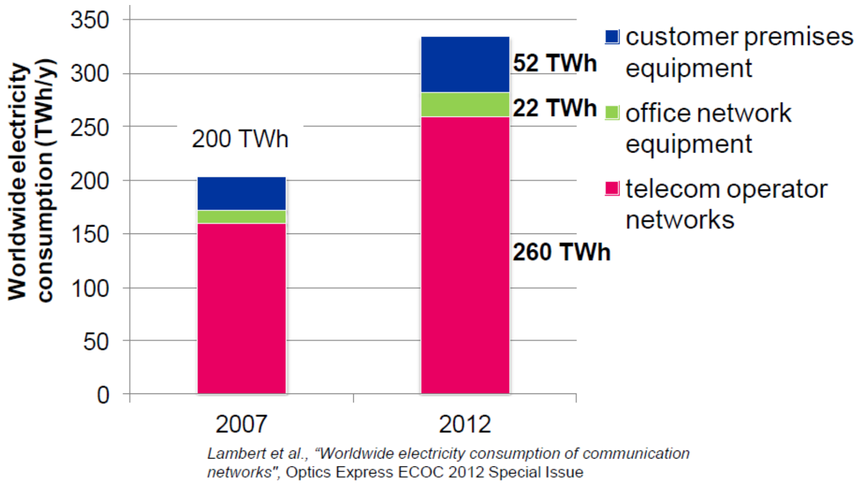


**Figure 100: Worldwide energy consumption of communication networks (Bart Lannoo (iMinds), 2013)**

To minimise the environmental impacts of telecommunication networks operation and to avoid a rebound effect, a reduction in growth rate of data traffic is required.

One solution is to optimize software through the utilisation of eco-design principles while developing new software or optimizing existing ones. This approach aims mainly at reducing energy consumption of ICT hardware (servers, end-users devices, etc.), and at minimising data traffic.

- More specifically, this BEMP focuses on reducing the energy consumption of end-user devices and data traffic on telecommunication networks. This BEMP is applicable for companies developing software on end-user devices, both for an internal or an external use.
- The BEMP 4.2 on Improving the energy management of existing network deals with techniques that telecommunication networks operators can implement to minimise data traffic at peak loads.
- The BEMP 3.4.2 on Developing new ICT services and software minimising servers utilisation refers to the techniques that can be developed in order to minimise the utilisation of servers.

This BEMP is dedicated to practices that can be implemented:

- either when developing a new software or when optimizing an existing one;
- both for mobile applications (for smartphones and tablets), for computer software (for laptop and desktop), and for web portals and web-based applications.

It is best practice to:

- **Design demand-adaptive software.**

  The definition of functionalities based on user needs' assessment can avoid energy over-consumption at usage phase and limit the obsolescence of existing ICT devices. Creating demand-adaptive software allows for publishing software adapted to the specific needs of each user.

- **Assess software environmental impacts.**

  The method of life cycle assessment (LCA) can be applied to the development of software, in order to address the environmental impacts from software conception to its end-of-life, with particular focus on its use phase.

  During software utilisation, measuring software performance (CPU, RAM and energy utilisation) allows for assessing the results of eco-design solutions or for selecting the optimisation solutions to apply.

- **Develop more energy efficient software.**

  This refers to different practices that can be implemented either when developing new software or when optimizing an existing one: providing different image resolutions, preferably connecting mobile devices via LAN or WLAN (rather than wireless networks), or implement mobile apps' solutions when developing software for stationary equipment.

### 4.7.2 Achieved environmental benefits

The techniques described above aim at reducing CPU or RAM utilisation in end-user devices, or data traffic in telecommunication networks. Such effects can lead to:

- **An indirect reduction of energy consumption,** through a decreased energy consumption of end-user and telecommunication networks devices;
- **An indirect reduction of resources consumption,** through a reduction of hardware required to perform the same work.

The environmental benefits that can be expected from these techniques largely depend on the project which is carried out. You will find examples of achievements within the operational data section.

Here are some examples of environmental benefits related to the optimisation of existing software by GREENSPECTOR (GREENSPECTOR, 2016):

- After the audit of an Android smartphone application within the military sector, correcting the application led to 69% of energy savings;
- The use of eco-design principle when developing a web site led to 30% of power savings client-side and from servers-side.

When assessing these environmental impacts, it is particularly important to define the appropriate parameter, and to consider the right relations between the software and its environment (see the description of the technique "Assess software environmental impacts" in the operational data section).

### 4.7.3 Appropriate environmental performance indicators

To assess the results of implementing solutions for minimising data traffic demand, the following indicator can be monitored:

- **Amount of data transferred in relation with software utilisation** (bit / web page view or bit / min of mobile application use)

Depending on the type of solution implemented, different process oriented indicators can be used, such as:

- **Share of demand-adaptive designed software** among the portfolio dedicated to internal or external use (published software);
- **Share of software for which a LCA has been carried out** among the portfolio dedicated to internal or external use (published software);
- **Share of software for which the energy performance has been measured** among the portfolio dedicated to internal or external use (published software);
- **Share of existing software which has been refactored toward higher efficiency** among the portfolio dedicated to internal or external use (published software).

### 4.7.4 Cross-media effects

Measuring software energy consumption requires additional applications, and optimising existing software requires additional IT works. These changes lead to additional energy consumption that can be compensated by energy savings expected from the implementation of such practices (depending on the context).

While minimising data traffic through eco-design principles, increased utilisation of end-user devices and servers can be observed. A global approach shall be adopted when implementing eco-design principles in software development.

### 4.7.5 Operational data

**Design demand-adaptive software**

The user model design stage focus on what the users want to do, within the context of how they want to do it (available equipment, skills and experience level, estimated budget, etc.). This is the perfect stage to implement eco-design principles, as it can allow for avoiding the development of functionalities non required and used by customers (but power consuming), or non-adapted to the clients' equipment (and requiring new devices).

The decision to develop or not a software feature is based upon the software cost during its whole life span, not only during building phase. The additional maintenance and hardware costs shall be taken into account.

Conceiving demand-adaptive software refers to the design of software requiring only the necessary hardware resource to perform a certain task. Such applications are based on a modular software architecture, with modules selected by the user when the software is installed and configured, or during operation. This require information toward customers: to understand the consequences of each available option or whether it is possible to revise such decisions later on.

Another possibility is to adapt the functional level of service to real-time resources availability. For example, at peak hours, a GPS navigation software could provide only 2 possible routes instead of its usual 4, thus lowering software pressure while still serving the user's demand.

**Assess software environmental impacts**

Life cycle assessment (LCA) can be applied to software, in order to:

- Study the environmental impacts of an existing software (resource consumption, energy consumption, pollutant emissions, etc.);
- Identify the most impacting stages of the software lifecycle:
  - Software development (needs analysis, conception, programming, test, deployment, maintenance, etc.);
  - Software delivery or copy, through downloading (which requires servers utilisation, data traffic and end-user device utilisation), hard copy sending (including packaging and transportation), or combined solutions (licence and instructions delivered in stores, and software download online);
  - Software utilisation (including consumption related to hardware, other software and data traffic required to function);
  - Software end-of-life (uninstallation, potential need for data transfer and hardware upgrade).
- Define opportunities for software publisher to improve and minimise the environmental impacts when developing new software ;
- Compare the environmental impacts of different solutions.

Software updates and additional modules can have significant impacts on functionalities and software structure. It is important to identify clearly on which version and configuration of the software apply the LCA (standard installation by default).

During software utilisation, measuring software performance (CPU, RAM, data usage and energy utilisation) allows for assessing the results of eco-design solutions or for selecting the optimisation solutions to apply.

- **CPU utilisation** (Central Processing Unit) related to the use of the software (and relative savings due to optimisation projects);
- **RAM usage** (Random Access Memory) related to the use of the software (and relative savings due to optimisation projects);
- **Power consumption** related to the use of the software (and relative savings due to optimisation projects).

The measurement shall be performed very frequently (e.g. every second), and a maximum number of applications shall be closed to avoid the impact of other software. To assess the consumption of the studied software, consumption of the hardware at idle times shall be subtracted (operating system, anti-virus and firewall, etc.). (O. Philipot, 2014)

Results in terms of energy consumption from web pages display on end-user devices have been produced by a study published on the occasion of the 2$^{nd}$ International Conference on ICT for Sustainability, or ICT4S 2014 (O. Philipot, 2014):

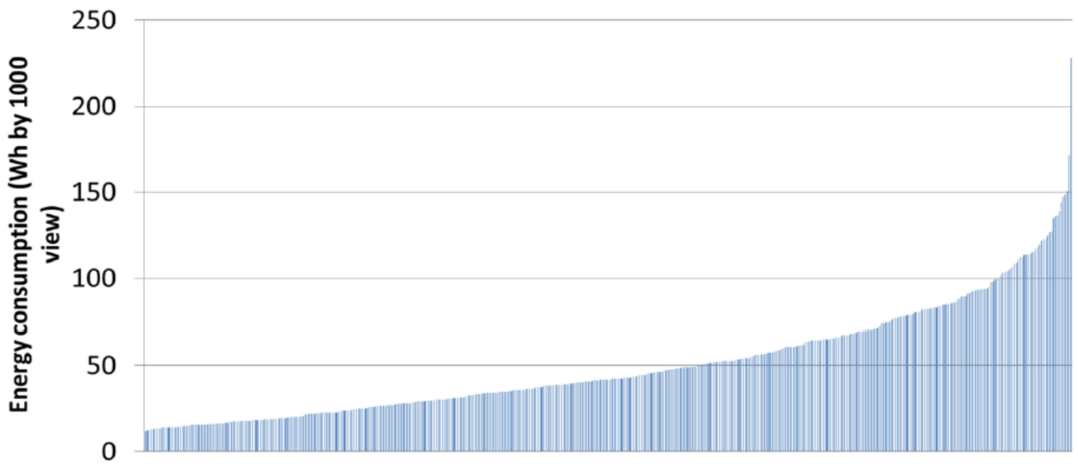


**Figure 101: Energy consumption of 500 different web sites, from the user side (O. Philipot, 2014)**

On this basis, an energy rating of web sites has been established, as shown on the Figure 102 below:

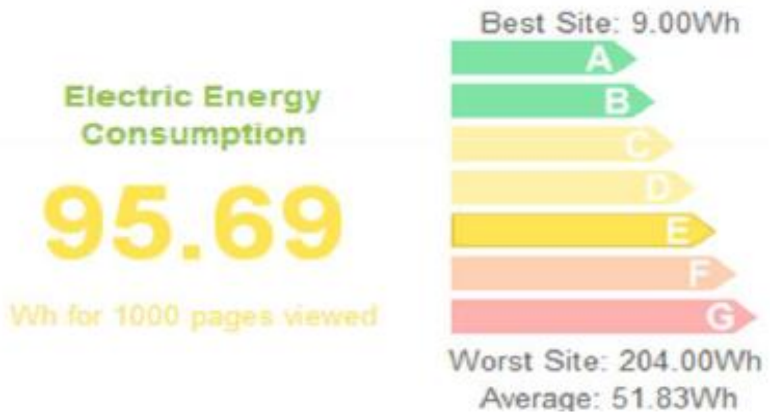


**Figure 102: Example of energy label for web sites (O. Philipot, 2014)**

To measure software energy consumption, a solution such as PowerAPI can be used (http://powerapi.org/). This middleware toolkit is an open-source solution developed by the University of Lille and the French INRIA. It aims at building software-defined power meters that can estimate in real-time the power consumption of software on the basis of raw metrics acquired from a wide diversity of sensors (e.g. physical meters, processor interfaces, hardware counters, OS counters).

**Develop more energy efficient software**

Many techniques exist, and a careful analysis shall be perform to identify the best solution. A technical baseline shall be followed when developing a new software or when optimising an existing one. In such case, an eco-design audit can be carried out to identify over-consuming practices within the source code of the software.

Most of these techniques of optimisation have primarily been developed while implementing mobile applications' solutions. For a matter of autonomy, very efficient applications are required for mobile devices (especially smartphone). One general practice for stationary equipment or web applications is to develop software following

the same approach as the one used for mobile applications (Federal Environment Agency - Germany, 2015).

Multiple techniques can be used, and here is a non-limitative list of best practices that can be integrated within such IT optimisation baseline:

- Provide different image resolution: the customer can choose a lower resolution than what is technically possible, or the resolution can automatically be adapted (e.g. when pasting photo into presentations) (Federal Environment Agency - Germany, 2015). This solution is related to the development of multimedia communications services (such as Skype) and multimedia entertainment services (such as Internet TV and computer games).
- Preferably connect devices via LAN or WLAN: the software should favour the more energy efficient channel, or at least offer the possibility to the customer to make that choice (Federal Environment Agency - Germany, 2015). Mobile networks require a larger amount of energy per bit of data transferred due to the longer transmission ranges, compared to wireless networks.

Here is an example of case study related to the application of such solutions by GREENSPECTOR. The response time of an application used for managing the holidays of 80,000 employees was considered as too long by the users. After an audit, the middleware used as an interface between the Human Resources solution and the smartphone display was identified as the cause of the delay. An optimisation of this software allowed for reducing the response time from 3 to 1 second on end-user devices, and for minimising servers' energy consumption by 35 to 85% for most used features.

### 4.7.6 Applicability

Using eco-design solutions when developing or optimizing applications refer to a set of techniques that can be applied by software publishers (for an external use of software) or by any type of company using applications for its own usage. IT consulting firms (including SMEs) can help these companies develop such innovative solutions.

Eco-design solutions can have impacts on servers' utilisation, on data traffic within telecommunication networks, and on end-users usage (autonomy, obsolescence, etc.). To maximise the environmental benefits that can be expected from such practices, solutions shall involve different stakeholders (users, host, developer, etc.).

### 4.7.7 Economics

Refactoring costs can be avoided by implementing eco-design principles among other software design principles from the very start of software making projects.

Return On Investment is rather indirect through:

- Energy savings;
- Less hardware requirements;
- Reduced software development costs, since selecting only required features makes software cheaper, and detecting energy bugs sooner makes correction cheaper;
- Increased adoption by users (thanks to increased performance).

### 4.7.8 Driving force for implementation

Developing energy efficient software (as web portals, mobile applications, etc.) provide different benefits:

- Increase of user satisfaction, by limiting delays and dysfunction;
- Optimization of IT resources, through an increase of ICT devices autonomy and availability (through a reduction of CPU and RAM utilisation);
- Reduction in signalling overhead on mobile networks;
- Cost reductions, related to a decrease of energy consumption and a decrease of maintenance needs.

### 4.7.9 Reference organisations

GREENSPECTOR (an SME) has achieved software optimisation with different partners: Orange, La Poste or ATOS.

### 4.7.10 Reference literature

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# 5 Improving the energy and environmental performance in other sectors ("Greening by ICT")

## 5.1. Introduction / scope

### 5.1.1 Definition

The rise of ICT has transformed the economy and society in fundamental ways. ICT has and will continue to impact all economic sectors, the public sector and civil society in general.

The previous chapters looked at how organisations in the telecommunications and ICT services sector can improve their own environmental performance (see Chapter 1, Section 1.2). This chapter focuses on the most relevant opportunities for the telecommunications and ICT service sector of contributing to improving the environmental performance of other sectors.

Here is a non-limitative list of solutions that telecommunications and ICT services providers are already providing to bring environmental benefits to other sectors.

- In the transport sector, advanced applications of ICT have been used developing Intelligent Transportation Systems providing innovative services relating to different modes of transport and traffic management (Ericsson Network Society Lab, 2014).
- In the energy sector, digital processing and communications to the power grid have been developed to support smart grid technologies.
- Buildings consume energy mainly through heat, air conditioning and lighting. ICT help monitor energy consumption. A building management system, ICT computer-based system, can be implemented to monitor the energy consumption (European Commission, 2015).
- Other innovative solutions are under development by telecommunications and ICT services providers to help other sectors reduce their environmental impact.

Based on such initiatives, four main change levers for reducing GHG emissions and improving environmental performance in general were identified by the GeSI SMART report (GeSI, 2012) and further developed in the SMARTer report (GeSI, 2015):

- **Digitalization and dematerialization** (see section 5.2) allow substitution and elimination of products or processes consuming huge amounts of energy and resources (transport, printed documents, etc.);
- **Data collection and communication** (see section 5.3) allow real-time data analysis and feedback, in order to enable better decision-making, to reduce risks and to enhance the coordination with stakeholders (suppliers, consumers, etc.).
- **System integration** (see section 5.4) helps to manage the use of resources, by facilitating the use of low-carbon energy and reducing emerging consumption at system level (building, company, grid, etc.).
- **Process, activity, and functional optimisation** (see section 5.5) improve efficiency through simulation, automation, redesign or control of process activity and services.

These solutions are closely related to one another and complementary. These solutions apply at different lifecycle stages:

- While developing the service or products, the principles of digitalization and dematerialization are used to offer a new type of service or product, based on an increased use of telecommunications and ICT services for its operation;
- Every lifecycle stage between the development phase and the utilisation phase (production, retail, installation, etc.) can be optimised through the use of ICT software (to reduce energy and resources consumption at upstream stage);
- At users' place, smart meters allow a better communication between users and operators, while system integration facilitates communication between users, or with other services and products.

The links between the different solutions are illustrated in the figure below.

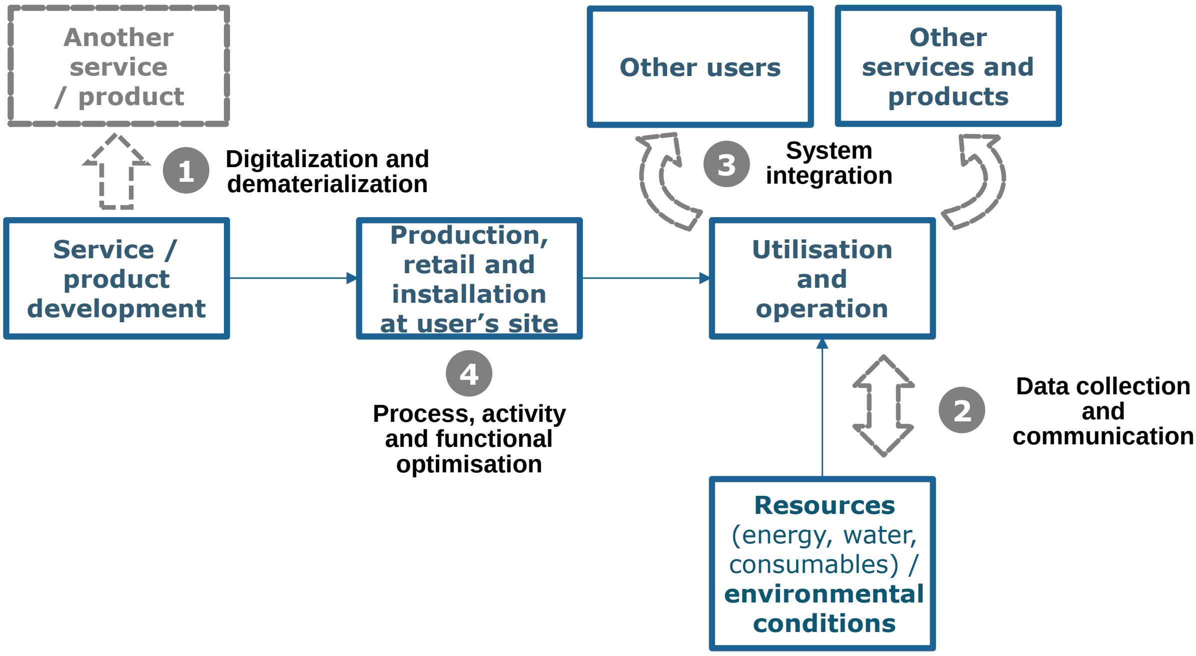


**Figure 103: ICT levers for contribute to environmental benefits in other sectors**

From an ICT company perspective and for each of these four main levers, it is best practice to:

- keep on developing new solutions that offer opportunities to reduce environmental impacts (through R&D investments, partnerships with companies from other sectors, etc.);
- help companies deploying such solutions into their operations and business (by specifically design the solution to its client needs, by providing training and communication, etc.);
- internally deploy these solutions, if relevant.

To develop, commercialize and deploy such solutions refer to business development, based on a strategic positioning: environmental benefits can respond to clients expectations. The following BEMPs do not explain how to create or sell such solutions, but develop the main principles behind and describe solutions already implemented in companies from other sectors.

These BEMPs aim at inspiring telecommunications and ICT services companies to develop and deploy new solutions, but also at proving the environmental benefits of such solutions. Compared to the BEMPs from the three other chapters, the BEMPs on greening by ICT solutions are framed at a more general level and intend to show in which broad areas green ICT companies have contributed the most to reduce the impacts of other sectors.

This chapter was developed on the basis of concrete initiatives implemented by companies of the ICT services sector in partnership with companies belonging to the different sectors targeted by our report (power, transport, etc.). Detailed information on these experiences is given in the section "operational data" and "reference organisations".

### 5.1.2 Applicability

The above mentioned change-levers can be used in different sectors. According the SMART report (GeSI, 2012) and SMARTer report (GeSI, 2015) it can be divided into six main end-use sectors:

- **Power**: this sector includes all companies involved in the extraction, production, distribution and sale of energy including both fossil fuel, nuclear and renewable energy technologies.
- **Transport**: this sector includes transport infrastructures (of public or private operators) such as roads, railways, airway, pipelines and terminals. There is passenger transport or freight transport.
- **Manufacturing**: this sector refers to the production of merchandise for use or sale through the use of labour and machines.
- **Service and consumption**: this sector involves the provision of services or goods to other business or final consumers. It may involve transport, distribution and sale of goods or services from producer to consumer.
- **Agriculture and land use**: refers to the cultivation of plants or livestock. The agriculture sector is confronted to major challenges with growing population and reduced natural resources. Increase and more prosperous population must be fed and issues such as water shortage, soil fertility declination must be taken into account (Stienen, Bruinsma, & Neuman, 2007).
- **Buildings**: it includes process of constructing building or infrastructure and building management system.

The Figure 104 resumes examples of solutions that can be implemented into the 6 previous economic end-use sectors through the 4 ways of change enabled by ICT services.

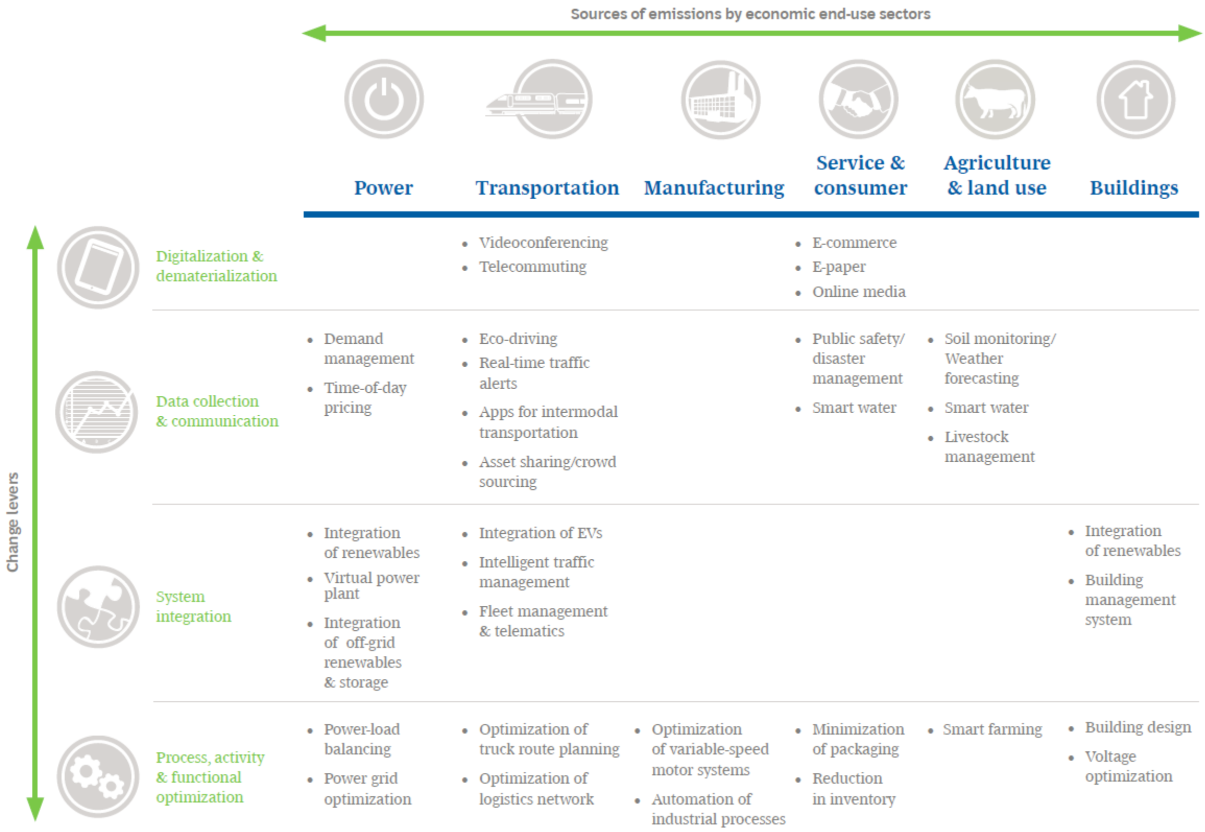


**Figure 104: Example of ICT solutions enabling carbon saving (source: (GeSI, 2012))**

### 5.1.3 Environmental aspects in other sectors

The use of ICT solutions can help reduce energy consumption and resources consumption in the different sectors identified.

- **Power**: the power sector is based on fossil fuel and coal combustion which releases GHG. ICT solutions applied to the power sector increase the efficiency and control of power grid. They help reduce energy consumption and associated **GHG emissions**. (European Commission, 2015) (GeSI, 2015). ICT solutions also help integrate renewable energy on the grid which support GHG emissions reduction.
- **Transport:** ICT has already demonstrated that it can provide **significant fuel savings** by optimising driving, logistics and through fleet management systems. It indirectly reduce **GHG emissions** and **air pollutants**.
- **Manufacturing:** industrial processes are energy-intensive and ICT solutions support optimisation and automation of processes. The main environmental benefit is the **reduction of energy** used in industrial processes and the reduction of associated **GHG emissions**.
- **Service and consumption**: ICT companies developed digitalization, dematerialization and optimization solutions to reduce the need for **resources and material**. Such solutions also indirectly reduce **energy consumption** and associated **GHG emissions.**
- **Agriculture and land use**: ICT solutions improve the efficiency of farming methods and helps increasing yields (GeSI, 2015). ICT solutions help adapting

and monitoring water needed and therefore reduce overall **water consumption**. Soil monitoring solutions also help adapting the level of fertilizer and pesticides needed and indirectly helps **preserving soil, groundwater and biodiversity**. ICT solutions also indirectly reduce **energy consumption** and associated **GHG emissions.**

- **Buildings**: ICT solutions provide more effective monitoring and management of electricity use, heating and cooling (GeSI, 2015) in buildings. Such optimisation reduce **energy consumption** and associated **GHG emissions**. Other ICT solutions such as modelling software for building design help **reduce the use of materials and resources** at the construction stage.

### 5.1.4 Cross-media effects

Certain ICT services may lead to "**rebound effects**" meaning that, despite energy and material savings, the overall consumption continues to grow (Skouby & Windekilde, 2010).

There are different types of rebound effect. It can be broken down into the following categories (IET, 2010):

- Direct rebound effect:
  - Output effect: energy efficiency improvement during the manufacturing process reduces the cost of production and therefore makes it possible to produce more while keeping energy use constant. This increase leads to a decrease in price and stimulates demand and all inputs are increased (Greening, Greene, & Difiglio, 2000).
  - Substitution effect: when energy price drops, manufacturers can use cheaper energy service to substitute for capital labour and other materials whilst maintaining a constant production level.
  - Income effect: energy improvements increase customers' real income and allow them to increase consumption of goods and services.
- Indirect rebound effect:
  - Secondary fuel use effect: resulting from demand increase for goods and services.
  - Embodied energy: equipment used to improve energy efficiency requires energy to manufacture and install.
  - Transformational effect: innovation leads to intrinsic changes in societal behaviour

In general, the development of new ICT solutions encourages the use of ICT equipment and increases the total amount of hardware on the market. It results in an increase in sensors, batteries and rare metals in ICT products that need to be properly managed during use and at end-of-life.

### 5.1.5 Reference literature

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## 5.2. Digitalization and dematerialization

| SUMMARY OVERVIEW: | | | | | |
|---|---|---|---|---|---|
| **Telecommunication and ICT services providers developed services to support digitalization and dematerialization of activities (communication, transportation, etc.). ICT solutions such as video conferencing and online e-commerce services help organisations in any sector improve the efficiency of their activities by saving time and reducing expenses. These drastic changes offer opportunities for reducing the environmental impacts of many activities by reducing the consumption of resources and the emission of pollutants (including GHG).** | | | | | |
| **Sectors** | | | | | |
| **Power** | **Transport** | **Manufacturing** | **Service and consumption** | Agriculture | **Buildings** |

**Environmental indicators**

- GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions
- Number of face to face meetings avoided each year through the use of videoconferencing by the client
- Share of clients' employees using telecommuting solutions
- Share of periodical documents completely digitalized (e.g. invoices, administrative documents, journals, etc.) by the client
- Share of products and services sent online (in terms of turnover) by the client

**Cross references**

| | |
|---|---|
| **Prerequisites** | • Behaviour shift to allow these practices really replacing current habits (printing documents received by email, going to meeting to encounter people, etc.) |
| **Related BEMPS** | • 5.3 Data collection and communication<br>• 5.4 System integration<br>• 5.5 Process activity and functional optimisation |

### 5.2.1 Description

The principles of digitalization and dematerialization cover a large range of ongoing business evolutions, such as miniaturization of products, servicing and reducing material use. In this BEMP, we refer to content switching from physical carrier to digital and online file and service. For instance, in some circumstances, music CDs have been replaced by MP3 files and digital payments.

The notion of digitalization and dematerialization is not new. The advent of personal computer in the early eighties started the dematerialization process with typed words leading to a reduction of physical books, newspaper and magazines. The rise of other smart devices (tablets and smartphones) led to a new wave of digitalization and dematerialization.

Digitalization and dematerialization are helping organisations in any sector improve the efficiency of their activities by saving time and reducing expenses. If these drastic changes have offered opportunities for reducing the environmental impacts of many services, products and activities, a rebound effect can be observed with an increased consumption of services, products and activities.

The ICT sector itself has highly impacted these technologies. ICT solutions are central to the dematerialization of a large variety of products and services, but they also generate significant environmental impacts, as developed in the previous sections of the report. Besides, ICT companies can use the solutions they offer to other sectors.

From an ICT company perspective, it is best practice:

- to keep on developing new solutions based on the principles of digitalization and dematerialisation, in order to offer new opportunities for replacing physical products, services or activities;
- to help companies deploying such solutions into their operations and business;
- to internally deploy these solutions, if relevant.

A non-exhaustive list of digitalization and dematerialization solutions that have been developed by ICT services providers is presented below. These techniques, which illustrate the principles of digitalization and dematerialization, are currently being deployed in a large number of organisations:

- **Developing video and audio conferencing applications to reduce the needs for business travel.**

  ICT service providers developed video and audio conferencing services reducing the need for business travel. Global video and audio conferencing are implemented in organizations also to improve internal communication.
- **Developing ICT solutions to encourage telecommuting.**

  The development of ICT solutions such as groupware, virtual private networks, audio and video conferencing to offer ‘virtual offices’ allows staff to work remotely (typically from home) and reduces the need for commuting to go to work.
- **Developing e-commerce to reduce retail carbon footprint.**

  The development of solutions of on-line shopping offers to customers the ability to order products through the Internet. This may reduce the emissions from transportation, but the main benefit is that it helps retailers reduce their carbon footprints and reducing the need for stores.
- **Developing e-paper and paperless procedures and archive to reduce the use of materials.**

The substitution of printed material such as newspapers, magazines, catalogues, brochures, directories, office documents, invoices and application forms with digital solutions reduces the need for paper, printing and the physical transport and mailing of paper. Procedures can switch to paperless procedures such as signatures and archive.

- **Developing online media to reduce the use of materials.**

  The dematerialization of products such CDs, DVDs and books into digital and / or online content or files reduces the use of materials through electronic delivery of music, games, books and movies.

### 5.2.2 Achieved environmental benefits

Digitalization and dematerialization can result in two main types of environmental benefits:

- **reducing resource use** (materials, energy, water, etc.);
- **reducing emissions and pollution** (GHG and other air emissions related to energy consumption, transport, hazardous waste, noise, etc.).

Videoconferencing telecommuting and e-commerce reduce the need for travelling from home to work and from home to stores or for business meetings. It directly leads to fuel savings and reduces GHG emissions as well as other air emissions and noise. According to the GeSI Smarter 2020 study (GeSI, 2012), the total $CO_2$ potential abatement through the use of such solutions can reach 0.43 $GtCO_2e$ worldwide. It also reduces the demand for lighting, cooling or heating office buildings or stores and reduces the need for office and store space.

E-commerce, e-paper and online media reduce the use of raw material needed to produce or sell products and need for storage and transportation. These reductions indirectly lead to $CO_2$ abatement which can reach 0.17 $GtCO_2e$ (GeSI, 2012).

The Fevad (Fédération e-commerce et vente à distance), the French e-commerce association studied the environmental impacts of e-commerce retail through: transport, packaging and Internet connection. The study demonstrates that the e-commerce model leads to $CO_2$ abatement. Average $CO_2$ emissions are reduced by a factor 4 compared to the traditional retail model (Fevad, 2009).

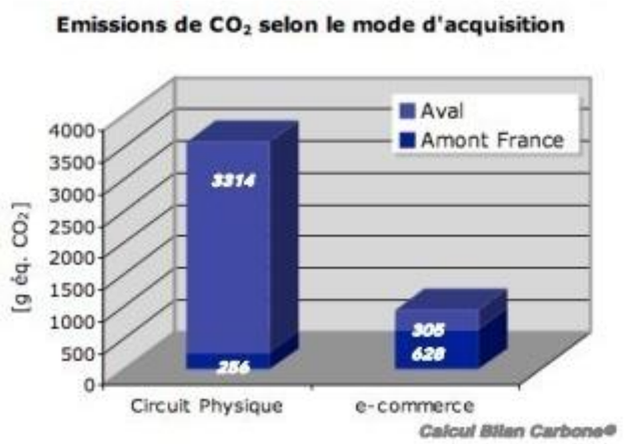


**Figure 105: $CO_2$ emissions in traditional retail (on the left) compared to e-commerce (on the right) (Fevad, 2009)**

As mentioned in the introduction of to this chapter, the degree of environmental benefits depends on many factors and in particular the extent of rebound effects.

### 5.2.3 Appropriate environmental performance indicators

ICT services providers monitor their products and services' environmental performance based on their clients' utilisation and performance. ICT services providers collect data to assess the implementation of their digitalization and dematerialisation solutions.

Depending on the solutions, and with the collaboration of clients, the following indicators can be monitored:

- GHG emissions abatement: some ICT services providers track scope 3 GHG emissions throughout their value chain to measure the environmental impacts of theirs products and services use. The scope 3 indirect emissions measure $CO_2$ abatement from business travel reduction through the use of video conferencing systems, from employees commuting reduction through the use of teleworking solutions. For example, BT developed a methodology to measure its scope 3 emissions in accordance with the Greenhouse Gas Protocol. It is based on a spend-based method which calculates emissions based on procurement data (BT, 2016).
- Number of face to face meetings avoided each year through the use of videoconferencing;
- Share of employees using telecommuting solutions, in order to work from home;
- Share of periodical documents completely digitalized (e.g. invoices, administrative documents, journals, etc.);
- Share of products and services sent online (in terms of turnover).

### 5.2.4 Cross-media effects

The main adverse effect of digitalization and dematerialization solutions is **the increase use of ICT devices**, with the related environmental impacts. The broad use of information solutions and digital devices increase the capacity of users to access information and therefore the time users will spend using them. Overall increase in the use of ICT equipment can increase the overall energy consumption. Therefore, the demand for servers and cloud infrastructure continuously rises. In order to ensure that digitalization and dematerialization is more energy efficient, data centres need to also be more energy efficiency.

Additionally, specific cross-media effects can be observed:

- Teleworking (Bomhof, van Hoorik, & Donkers, 2009):
    - it may mean that people will have more time available and may potentially engage in more carbon intensive activities. Teleworkers tend to spend more private travelling during the day, compared to the situation where they were working at the office;
    - it creates the need for teleworkers to illuminate and heat their homes during the heating season or to cool their homes during the hot season when it would not have been needed while working at the office. Besides, heating houses is usually less efficient than heating offices because in houses only one person occupies the whole building;

  - the reduction of employees at the office does not necessarily proportionally reduce an office's energy need because buildings are not always heated to the actual presence of personnel;
  - teleworking may stimulate workers to live further away from their offices, increasing the travel distance on office days;
  - less traffic during peak hours may attract travellers that would otherwise travel at other times or would not travel at all, thus leads to an increase in traffic.
- Teleconferencing solutions facilitates the organisation of meetings. Only part of teleconference meeting would have been a face-to-face meeting with commuting. The organisation of teleconferencing meeting generates energy use from ICT equipment.
- E-commerce facilitates the purchase of products, and can increase the level of household consumption. Another adverse effect comes from the increase in packaging need and delivery of the items purchased online which generate other GHG emissions.
- A reduction in paper can in some cases result in an increase in digital files and corresponding increase in energy use from server space and screen use.

### 5.2.5 Operational data

- **Developing video and audio conferencing applications to reduce the needs for business travel**

With video and audio conferencing system, ICT services providers help companies to implement global collaborative tools. The implementation of such system enable employees to interconnect in a large network and to connect with their clients.

Video and audio conferencing systems shall be installed on every sites and each employees shall have access to the service. It requires internal communication to make sure that all employees are aware of this service and know how to use it. It also implies a change in habits to organise video conferencing instead of face-to-face meeting.

For instance, BT has over one million IP phones deployed globally and manages over 950 telepresence rooms. The company has carried out work to calculate the carbon footprint and the carbon abatement resulting from the use of its videoconferencing system. BT used a Life Cycle Assessment approach to assess the result of using video conferencing. By using internally conferencing solutions, BT avoids every year around 717,000 face to face meetings, representing 53,000 tonnes of $CO_2$ and 210 millions of euros in travel costs (GeSI, 2012).

- **Developing ICT solutions to encourage telecommuting**

Audio and video conferencing systems encourage employees telecommuting and therefore reduce their need for commuting to go to work. Other ICT solutions give employees opportunity to telecommute such as groupware and virtual private networks. These systems have to be globally implemented in a company in order to give access to all employees.

BT calculates the impact of the use of its video conferencing system by its clients to assess its scope 3 $CO_2$ emissions. For instance, Berkshire Healthcare NHS Foundation Trust uses BT Web Conferencing. It helps participants save travel time of up to 45 minutes and reduce their annual carbon emissions by 1.4 tonnes per year (BT, 2013).

- **Developing e-commerce to reduce retail carbon footprint**

Digitalization transforms companies' business by switching from physical store to online platform, and by creating new online services such as rental of cars, hostels and accommodations.

The development of online shopping helps reduce the environmental impacts of retail companies:

- by reducing the needed infrastructures, with a centralization of products in storehouses, instead of multiple and different physical stores;
- by reducing customers commuting to stores and therefore companies' scope 3 emissions.

The scope 3 emissions also depends on the optimization of logistic and transportation. Different ICT solutions are applied to ensure efficient delivery process:

- Collect data on real-time traffic, creates alerts and install applications for intermodal transportation and eco-driving to adapt driving (see section 5.3 Data collection and communication);
- Use intelligent traffic management system to remotely monitor and control automobile traffic (see section 5.4 System integration);
- Use ICT technologies for a more efficient use of a fleet through vehicle maintenance, vehicle telematics, driver management, speed management and fuel management (see section 5.4 System integration);
- Use truck-route-efficiency software to determine which route requires the lowest amount of fuel for a particular trip (see section 5.5 Process activity and functional optimisation).

eBay, together with carbon-footprint consulting company Cooler Inc., published a white paper showing the environmental benefits resulting from buying on eBay rather than in physical shops. Based on data produced between 1995 and 2010, eBay states that infrastructure savings of transaction on its website have displaced emissions equivalent to 4 million tons of $CO^2$ per year, compared to physical retail companies (ebay, 2010).

- **Developing e-paper to reduce the use of materials**

Digital solutions reduce the need for paper and printing. It encourages the substitution of printed material such as newspapers, magazines, catalogues, brochures, directories, office documents, invoices and application forms with digital forms.

Digitalization has to be global and used both for internal and external process and communication to have a positive environmental impact. The implementation of digitalization process is be done by using cloud-based solutions integrated with the business management system.

ICT solutions are also developed to support companies in switching to paperless procedures and services such as online signatures procedures and dematerialized archive services.

The company Esker developed invoice automation solution helping companies decreasing their paper consumption. It was deployed in one of its clients' office CAPSA. CAPSA communication was largely based on faxing, Esker's services helped adopt a more flexible on-demand solution, saving both employees' time, facilitating communication with producers and reducing the company's carbon footprint. This

cloud-based service allowed for automated faxing integrated with SAP. Employees, producers and customers now send and receive information via emails and SMS. With the implementation of this paperless solution, CAPSA achieved a 50% reduction in paper use, equivalent to €96,000 a year between 2007 and 2012. In addition to money savings, 39,000 trees have been saved from being cut down and CO2 emissions have been reduced by 10,500 tons (Esker, 2012).

- **Developing online media to reduce the use of materials**

With the launch of streaming services and wider access to high-speed internet new ways of consumption emerged with digitalization and dematerialization of the economy. The dematerialization of products impacts many sectors: music, movies, and books, etc. and companies have to adapt their offer.

The switch to online content reduces the use of resources. It reduces the environmental impacts linked to:

- the production process by reducing the use of resources and energy consumption needed;
- the disposal of products reducing waste generation.

The consumption of online content consume energy to transport data from a server to the consumer. Much of the energy consumption comes from heat generated by datacentres, cooling system and air conditioning units. Environmental performance requires efficient energy management of data centres (see to chapter 3 Data centres).

### 5.2.6 Applicability

These different solutions are developed by companies of the ICT sector and implemented in different sectors. They are developed in any organisation that uses significant amounts of paper or that has significant amount of employees travelling and wiling to reduce these impacts. It is more relevant for the service and consumer sectors, but also the public sector. These solutions are also developed in companies of the ICT sector.

The deployment of such solutions depends on behavioural changes regarding personal and professional habits (in terms of travelling, communicating, etc.). As products and services are an important part of people’s life, there can be significant reluctance to adopt new technologies and to change their behaviours. Teleworking creates new challenges to employers too as its application needs them change working procedures.

### 5.2.7 Economics

Development of digitalization and dematerialization solutions requires investments in R&D to develop tailored solutions adapted to client’s needs.

### 5.2.8 Driving force for implementation

Digitalization and dematerialization solutions are at the core of ICT companies businesses and answers rising clients’ needs.

The implementation of digitalized or dematerialized solutions:

- **Reduces costs** through:
    - energy savings by reducing commuting, business travel and products;

    - the reduction of material use by reducing packaging and paper.

- **Improves operational efficiency** by:
    - optimizing time spent travelling;
    - optimizing transportation of products and delivery;
    - increasing customers' interest by developing new services and new online platform.
- Demonstrate environmental **commitment** to customers and other stakeholders and improve employee and other stakeholder engagement in environmental protection.

### 5.2.9 Reference organisations

Apart from the companies already referenced the Operational data section, the following companies are reference organisations in digitalization and dematerialization solutions:

- Schneider Electric, which won the 2016 Digital CFO Award of the Management Events' 600Minutes with its Digital Invoice Management Project (Management Events, 2016).
- INPOST created a national network of locker rooms connected to e-commerce and available 24 hours a day and 7 days a week. It won the E-Commerce Awards 2015 (E-commerce, 2015).

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## 5.3. Data collection and communication

**SUMMARY OVERVIEW:**

**Telecommunication and ICT services providers developed solutions of data management systems that collect, aggregate, analyse and display information. Such solutions have supported companies who have access to great amount of data by improving decision-making process. These systems have especially been used for better managing energy demand, water supply, transportation, and farming inputs. Such solutions have proved their efficiency in reducing resources consumption and related environmental impacts.**

**Sectors**

| **Power** | **Transport** | **Manufacturing** | Service and consumption | **Agriculture** | **Buildings** |
|---|---|---|---|---|---|

**Environmental indicators**

- GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions
- Annual energy savings (kWh) of the client
- Annual water consumption savings ($m^3$) of the client
- Annual reduction of consumables of the client
- Number of smart meters connected by the client

**Cross references**

| | |
|---|---|
| **Prerequisites** | • N/A |
| **Related BEMPS** | • 1.2 Implement an environmental management system<br>• 3.2.2 Implement an energy management system for data centres<br>• 4.2 Improving the energy management of existing telecommunication networks<br>• 5.4 System integration<br>• 5.5 Process activity and functional optimisation |

### 5.3.1 Description

Existing systems efficiency can be improved by collecting data with smart sensors. Smart sensors are devices that convert physical parameters into electrical signal and gather data for remote reporting. Smart meters are a type of sensor used to record electric energy consumption. Data is then analysed and communicated through software in real-time to users.

Real-time information requires the integration of complex physical systems such as electrical grid with networked sensors and with software for data analytics. The great amount of data collected needs to be aggregated and analysed and displayed in a monitoring dashboard through adapted software.  Data analysis and real-time consolidated information allow for better decision making and improve process efficiency.

ICT technologies for data collection and analysis can be used in very different sectors for various activities. Smart sensors and meters can be set on networks such as electrical grid and telecommunication network, roads, pipes, etc. They have to cover a large scope of the operations at a site level or at a company level to ensure global performance analysis.

These types of ICT solutions by improving operations efficiency helps companies reduce their environmental impacts by reducing consumption of resources (energy, water, materials).

From an ICT company perspective, it is best practice:

- to keep on developing new solutions for data collection and communication, in order to offer new opportunities for improving systems efficiency and decision-making process;
- to help companies deploying such solutions into their operations and business;
- to internally deploy these solutions, if relevant.

Are presented below a non-exhaustive list of data collection systems solutions that have been developed by ICT services providers. These techniques based on data collection and communication systems, are currently being deployed among organisations:

- **Energy demand management and time-of-day pricing.**

  Smart meters collect information on the grid to analyse energy consumption. Smart meter systems balance information asymmetries between electricity producers and consumers, and help optimise electricity consumption. Load decomposition analysis quantifies the behaviour dynamics of consumers and helps reducing the peak demand for electricity and the load on distribution system during certain times of the day. Communication through mobile devices of different pricing for electricity during different time of the day allows consumers and enterprises to adjust load during peak demand and reduce their overall demands on the grid.
- **Real-time traffic alerts, applications for intermodal transportation and eco-driving.**

  Alerts can be put in place to help drivers avoid traffic and delays and to drive more efficiently. Applications can be integrated into vehicles providing drivers with feedback on fuel usage and driving style, and helping anticipate upcoming traffic.
- **Smart water systems.**

  It helps analysing water consumption and leaks, and give greater control over water use.

- **Smart farming**.

  These ICT systems are mainly relevant in the agriculture sector, to adapt the amount of fertilizer, pesticide and water required for cultivation. Monitors can analyse weather conditions. Data can be collected remotely or on site.

### 5.3.2 Achieved environmental benefits

Data collection systems can result in one main environmental benefit which is the **reduction of resources consumption**. Depending on the sector and companies activities it can reduce:

- Energy consumption (electricity, fuel, etc.)
- Water consumption
- Consumable consumption

Indirect environmental benefit is linked to the reduction of associated GHG emissions.

Other environmental benefits are the reduction of resources consumption or of the use of chemicals such as pesticides, preserving water, soils and biodiversity.

- **Demand management and time-of-day pricing**

The management of electricity demand and reduction of peak load helps reduce the need for other sources of energy intensive power such as coal-fired power.

Smart meters on the grid reaches the following $CO_2$ abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| Smart Grids - electric network management | 98,000 | 114,000 | 102,000 | 19,000 | 2,434,000 | 1,117,000 |
| Smart Grids - gas network management | 25,000 | 28,000 | 19,000 | 15,000 | 296,000 | 277,000 |

**Figure 106: Carbon emissions abatement from connected energy ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

- **Real-time traffic alerts, applications for intermodal transportation and eco-driving**

The optimisation of transport and real time information on traffic reduces fuels consumption, air pollutants emissions and noise emissions.

Eco-driving can reduce fuel consumption by about 15% (Smartdrive, 2012).

Eco-driving reaches the following $CO_2$ abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| Eco-driving | 24,000 | 19,000 | 16,000 | 17,000 | 108,000 | 252,000 |

**Figure 107: Carbon emissions abatement from eco driving ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

- **Smart water**

Smart water management through data collection allows water consumption reduction by preventing leaks and better allocation water in the network.

Indirect environmental beneficiary is the reduction of production and distributions emissions due to lower water consumption.

Smart water can have specific environmental benefits in the agriculture sector. Sensors can measure moisture and prevent unnecessary irrigation and soil erosion, preserving water, soils and biodiversity.

- **Smart farming**

Soil monitoring prevents surface and ground water pollution by adjusting the quantities of fertilizer and pesticides used for farming to the plants' accurate needs. It helps avoid spreading unnecessary volumes of fertilizer and pesticides which would not have been absorbed by plants, and would have end up in rivers and groundwater. It indirectly helps soil protection and biodiversity preservation.

It can also indirectly lead to a reduction of energy consumption related to the production of fertilizers and pesticides and the use of raw materials associated such as phosphate.

Connected agriculture reaches the following $CO_2$ abatement:

CARBON EMISSIONS FROM CONNECTED AGRICULTURE ABATEMENT[16] ($tCO_2e$/year)

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| **Connected Agriculture** | **53,000** | **125,000** | **28,000** | **170,000** | **2,125,000** | **1,043,000** |
| Agricultural equipment logistics | 5,000 | 12,000 | 7,000 | 22,000 | 235,000 | 121,000 |
| Crop management | 48,000 | 113,000 | 21,000 | 149,000 | 1,890,000 | 923,000 |

**Figure 108: Carbon emissions abatement from connected agriculture ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

### 5.3.3 Appropriate environmental performance indicators

ICT services providers monitor their products and services' environmental performance based on their clients' utilisation and performance. ICT services providers can collect data to assess the implementation of their data analytics software. Depending on the solutions, and with the collaboration of clients, the following indicators can be monitored:

- GHG emissions abatement: some ICT services providers track scope 3 GHG emissions throughout their value chain to measure the environmental impacts

of theirs products and services use. The scope 3 indirect emissions measure $CO_2$ abatement from the use of process and functional.

- Annual energy savings (kWh);
- Annual water consumption savings ($m^3$);
- Annual reduction of consumables ;
- Number of smart meters connected;

### 5.3.4 Cross-media effects

One of the main cross-media effects is the rebound effect (refer to the introduction Chapter: 5.1). The direct rebound effect linked to energy demand management and time-of-day pricing is that consumers may be tempted to consume more energy as their total cost of energy drops (EEA, 2013).

The production of ICT equipment such as meter systems requires resources which will become WEEE and hazardous waste at end-of-life.

Data collection systems also require the use of telecommunication networks and data centres which are energy intensive.

### 5.3.5 Operational data

- **Energy demand management and time-of-day pricing**

In the energy sector, data collection systems consist in smart grids process through the installation of smart meters on the grid. Companies went from one meter collecting information on a month to smart meters reading every 15 minutes which quickly led to millions of reads per day for every meters installed.

It generates great amount of information on the grid and provide companies with capabilities for forecasting demand, shaping customer usage patterns, preventing outages, etc. These new types of available information are advantages for better decision-making and management but also generates data volume and complexity.

To manage the use of this information and get useful insights for decision-making, utility companies must be capable of high-volume data management and advanced analytics to transform data into monitoring information (IBM, 2012). ICT software solutions help companies execute advances analytics using combination of information such as: data on customers, consumption, physical grid dynamic behaviour, generation capacity, energy commodity markets and weather. Analysis gives better understanding on customer segmentation, behaviours and on pricing influences on usage.

Based on this information, companies can implement time-of-day pricing encouraging customers to consume energy at off-peak times. Time-of-day pricing leads to cost saving for customers and less generation capacity from energy providers which reduce environmental impacts.

Smart meters also give information to improve the efficiency of electrical generation and scheduling. The new mix of resources available requires more accurate forecasting and analysis to avoid inefficient energy trading. Advanced data analytics solutions allows making wide range of forecasts such as: energy availability, downtime and power failure, energy fed back to the grid, etc. All this information helps energy providers optimising load on distribution system reducing overall energy consumption.

To get the most value of data available, ICT services providers give real-time data sources and analytics and bring together multiple data sources using tailored analytics tools.

For instance, IBM developed a software application to help reduce consumption on devices such as air conditioners and water heaters and to enable consumers to check their energy consumption from an internet connection. Consumers can authorize to have their appliances off for brief periods during peak energy demand. Smart meters and small controllers are placed on high consumption devices. The application gives real-time energy monitoring. It helps consumers save on average 15% of their energy consumption. Some consumers saved up to 40% (IBM, 2016).

- **Real-time traffic alerts, applications for intermodal transportation and eco-driving**

Data collection systems is used in the transport sector. Data is collected through phone's sensors and GPS information. ICT solutions providers develop applications integrated into vehicles to provide drivers with feedback on different parameters: fuel usage, driving style and upcoming traffic. Applications developed can also display alerts to warn drivers on traffic and delays.

These solutions help drivers adapt their driving style and adapt their route to traffic, which indirectly reduce fuel consumption.

As an example, the company Allianz France launched an eco-driving application for smartphones. The application uses phone's sensors and GPS to record driving parameters on speed, acceleration and braking pace. Data is then analysed by Allianz, and good driving practices are rewarded by a discount in the cost of the insurance policy. Adopting more responsible practices can lead to a 30% discount rate of the cost of the insurance policy. Over 6,000 clients have adopted this eco-driving application between end 2015 and early 2016. Allianz uses this application to analyse driving data and better understand risks linked to driving habits (Les Echos, 2016).

- **Smart water systems**

Water management systems is important for water operators and for industrials using water intensive processes. Smart meters are installed on pipelines and adapted software analyse water consumption and leaks to improve water supply processes.

These types of solutions give operators or industrials greater control over water use and allows for water consumption reduction through management of water balance data, and optimisation of the discharge of water, and real-time information. Real-time information available also helps identifying leaks and reduce the time needed to stop them.

For instance, water management is a critical issue in the Netherlands, with more than half of the Dutch population living in flood-prone areas. The Ministry of Water, the local water authority of Delfland, the University of Delft and the Deltares Science Institute worked in 2013 with IBM to create a system that uses big data to transform flood control and management of the water system. Digital Delta is an intelligent, cloud-based system built on IBM's Intelligent Water software and Smarter Water Resource Management solution including consulting expertise (ITU, 2014). Digital Delta investigates and analyses water data from a wide range of existing data sources: precipitation measurements, water level and water quality monitors, levee sensors, radar data, and model predictions. The system can also use historic maintenance data from sluices, pumping stations, locks and dams. Digital Delta management system addresses different environmental aspects:

- monitoring of weather events to prevent impacts from natural disasters to agriculture fields, buildings and infrastructures.

- identification of leaks to manage maintenance and reduce water losses
- quality of drinking water monitoring ensuring health and safety for Dutch population.

The system uses virtualization and deep analytics to provide real-time intelligent dashboard to water experts that can be shared across organisations and agencies.

Digital Delta is used for several water management projects:

- water predictions and topography to make more informed and timely decisions on maintenance schedules while preventing flooding of tunnels, buildings and streets.
- management of water balance data and optimisation of the discharge of water to improve the containment of water during dry periods to prevent damage to agriculture development of flood warning method and simulation models

There are 450 monitoring stations producing 2 million streaming sets of data every day (IBM, 2013). The use of Digital Delta is expected to reduce cost of water management by 20 to 30 percent. By optimising the data sharing it also reduces the scientific research and development time needed for information sharing reducing the cost associated.

- **Smart farming**

Producers use more and more high-tech equipment to monitor soil conditions and livestock. Data collection systems are used in the agriculture sector to monitor soil conditions. Soil moisture sensing technology has been used for several decades and are widely used.

Data collection systems are used in the agriculture sector to adapt the amount of water, fertilizer and pesticides and crop yield. Data can be collected remotely or on site with different technologies: sensors, decision support systems, big data analytical systems, geo-mapping applications and smartphone apps.

Sensors are useful to understand the composition of the root zone of crops. Electromagnetic sensors are used to measure soil texture, salinity, organic matter and moisture content, residual nitrated or soil pH.

Data collection can be done with remote sensing through satellites information collection on: weather forecasts and soil moisture, groundwater and terrestrial water storage, evapotranspiration, etc. All this information helps determining the right level of water, fertilizer and pesticides to use.

Sensors can also be used for monitoring and detection of reproduction events and health disorders in animals. For instance data such as the body temperature, the animal activity, pulse and GPS position can be analysed. This information helps farmers adapting nutrition and anticipating health issues.

In addition to data collection systems, other ICT solutions are developed to make farming more efficient. ICT software can optimise processes and reduce food waste at all stages (refer to 5.5 Process activity and functional optimisation).

### 5.3.6 Applicability

- **Demand management and time-of-day pricing**

The development of this solution by ICT services providers requires a good knowledge of the market and territory of implementation because of potential public sector involvement and specificities.

It depends on local electricity system if it is centralised or decentralised and involves different actors.  It also depends on the electricity mix and the impact on the grid of the use of different energy sources: coal, natural gas, wind, solar, nuclear, etc.

- **Real-time traffic alerts, applications for intermodal transportation and eco-driving**

ICT service providers need to develop tailor-made applications for specific customers' needs. High level of technical skills is required.

For user, real-time traffic alerts are relatively easy to implement but may depend on public sector investments depending on the country. Highways are more relevant for implementation and congested cities are particularly relevant to consider.

Eco-driving applications require smartphones on-board and technology capabilities.

- **Smart water**

Smart water systems are developed at different scales depending on the type of users (private company, public sector) and the number of sites it has to be implemented on. Therefore, it can require a large amount of ICT equipment.

Smart water system is used in the public sector or private operators on city's network and by the private sector for companies having water intensive processes and high water consumption.

- **Smart farming**

The development of such ICT applications requires a good knowledge of the market which can be specific especially depending on the geographical area impacting soil composition and weather conditions and types of crops used. Regarding livestock management, data will depend on the types of livestock and conditions.

It is mainly used in the agriculture sector to collect data on soils and livestock. It requires training for farmers to encourage them to use this type of ICT equipment and change traditional work habits.

### 5.3.7 Economics

ICT services providers invest in R&D to develop such solutions. The development of specific applications can require high level of upstream investments in developing new systems.

The development of data collection solutions and analytical software is highly dependent on the clients' needs and context. ICT providers develop tailor-made solutions to address these needs.

Smart meters roll-out require an investment to cover a large part of the network. According to the Department of Energy and Climate Change (DECC) in the UK, the cost per household of installing smart meters reach around 145 euros (The Telegraph, 2015).

### 5.3.8 Driving force for implementation

The development of data collection systems answers a need in different sectors for collecting a great amount of data and analysing it to improve decision making.

In the context of global objectives for energy transition, climate change mitigation and resources scarcity, new demand for services to reduce energy and resources

consumption arises. More specifically, the agriculture sector faces new challenges on sustainable yield and organic farming development which create need for data collection and analysing systems.

The implementation of data collection system offers the potential for managing and sharing data in new ways:

- It optimises the time and human resources spent to treat information.
- Real-time information sharing improves the decision-making process.
- The data analysis results in optimisation in resources: water, energy, transportation.

### 5.3.9 Reference organisations

Apart from the companies referenced in the case studies in the section Operational data, the following companies are reference organisations data collection and communication systems. The Smart Energy UK and Europe submit assigned 2016 awards to ICT technologies[87]:

- Nokia, Smart metering & infrastructure security award
- IJENKO: Smart Home Technology of the year
- ONZO: Meter Data Management solution of the year
- Switch2 Energy Limited: Smart Metering Technology of the Year

### 5.3.10 Reference literature

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[87] For more information, see: http://www.smuksummit.com/awards/2016-awards/

## 5.4. System integration

| SUMMARY OVERVIEW: | | | | | |
|---|---|---|---|---|---|
| **The availability of smart solutions for smart cities has risen rapidly. Telecommunications and ICT services providers developed smart solutions in different sectors leading more and more to integrated infrastructures: energy grid, roads, buildings, etc. ICT technologies help connect the various systems in an integrated and dynamic system and reduce environmental impacts by reducing energy consumption and the use of resources.** | | | | | |
| **Sectors** | | | | | |
| **Power** | **Transport** | **Manufacturing** | **Service and consumption** | Agriculture | **Buildings** |
| **Environmental indicators** | | | | | |
| • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Annual energy savings (kWh) of the client<br>• Number of units connected to the grid (number of EVs, wind turbines, etc.) by the client<br>• Share of renewable electricity produced by clients integrated on grid | | | | | |
| **Cross references** | | | | | |
| **Prerequisites** | • Data collection and communication systems are useful to complete system integration systems solutions | | | | |
| **Related BEMPS** | • 2.5 Use of renewable and low-carbon energy<br>• 5.3 Data collection and communication system<br>• 5.5 Process activity and functional optimisation | | | | |

### 5.4.1 Description

With the growing urbanization, the increase of the mobility and broader access to Internet, cities need to improve their efficiency and transform into smart cities. Smart cities designate a process whereby technology providers offer technical solutions to contribute to the integration of infrastructures and services.

The availability of smart solutions for smart cities has risen rapidly and ICT technology providers developed smart solutions in different sectors more and more leading to integrated infrastructures: energy grid, roads and buildings. ICT technologies help connect various systems in an integrated and dynamic system. System integration solutions refer to the management and optimisation of the use of resources. Management solutions help integrate more energy efficient processes in existing ones. ICT services providers create adapted software to gather and analyse different types of information coming from different sources to improve management processes.

They can be used by public authorities or private operators managing public infrastructures or at companies' level to improve the management of their own infrastructures.

The use of system integration solutions help organisations reducing their environmental impact by giving information to optimise the use of fossil fuels resources.

From an ICT company perspective, it is best practice:

- to keep on developing new solutions for system integration, in order to offer new opportunities for improving the integration of energy efficient technologies on existing systems;
- to help companies deploying such solutions into their operations and business;
- to internally deploy these solutions, for instance when using renewable energies (2.5 : Use of renewable and low-carbon energy).

Presented below is a non-exhaustive list of system integration solutions that have been developed by ICT services providers. These techniques based on data collection and communication systems, are currently being deployed among organisations:

- **Integration of renewables on grid or off-grid.**

  It refers to the replacement of electricity from grid with carbon-free energy such as solar power or wind power. ICT allows higher degree of integration of renewables into the grid and a more effective use.

  Renewables energy can also be used off the grid using technologies to integrate storage of energy off-grid power loads such as isolated telecom tower.
- **Integration of Electric Vehicles.**

  It is the development of ICT that promotes the use of Electric Vehicles or bio-fuels.
- **Fleet and traffic management.**

  It is the use of ICT technologies for a more efficient use of a fleet through vehicle maintenance, vehicle telematics, driver management, speed management, fuel management and automobile traffic control.
- **Building management system.**

  It is a computer-based control system installed in buildings controlling and monitoring building's mechanical and electrical equipment.

These different solutions are interconnected and can rely on data collection solutions (refer to section 5.3. Data collection and communication).

### 5.4.2 Achieved environmental benefits

System integration solutions main environmental benefit is the **reduction of energy consumption** and of the use of fossil fuel energy sources. It results in the **reduction of $CO_2$ and atmospheric pollutants** (NOx, SOx, particles…).

- **Integration of renewables:**

The integration of renewables increases the use of carbon-free energy and reduces GHG emissions associated to carbon intensive power. It also reduces the need for nuclear power plants, which can be critical in countries where nuclear power production phases out and would be replaced by fossil-fuel-fired plants.

- **Integration of EV's, intelligent traffic management, and fleet management and telematics:**

It reduces the need for fuel consumption and reduces associated $CO_2$ and other atmosphere pollutant (NOx, SOx, particles…).

EV connection reaches the following carbon emissions abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| Electric vehicle connection | 840 | 1,000 | 650 | 3,000 | 1,000 | 11,000 |

**Figure 109: Carbon emissions abatement from EV ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

- **Fleet and traffic management:**

It reduces fuel consumption and reduces associated $CO_2$ and other atmosphere pollutant (NOx, SOx, particles…).

Fleet vehicle management and smart logistics reach the following carbon emissions abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| Fleet vehicle driver behaviour improvement | 803,000 | 1,060,000 | 203,000 | 1,314,000 | 10,059,000 | 5,800,000 |
| Smart Logistics - efficient routing & fleet management | 293,000 | 315,000 | 65,000 | 495,000 | 3,259,000 | 1,973,000 |
| Smart Logistics - loading optimisation | 117,000 | 126,000 | 26,000 | 198,000 | 1,303,000 | 789,000 |

**Figure 110: Carbon emissions abatement from fleet vehicle management and smart logistics ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

- **Building management system:**

It allows saving energy consumption through more efficient use of ventilation, lighting, etc. It indirectly helps reducing GHG emissions due to energy consumption.

Connected building allow the following carbon emissions abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| **Connected Buildings** | **2,916,000** | **1,148,000** | **2,120,000** | **754,000** | **32,300,000** | **21,333,000** |
| Building energy management systems (electricity commercial) | 470,000 | 78,000 | 1,079,000 | 19,000 | 7,716,000 | 5,347,000 |
| Building energy management systems (gas commercial) | 1,001,000 | 22,000 | 39,000 | 22,000 | 1,421,000 | 4,281,000 |
| HVAC control - commercial buildings | 1,211,000 | 971,000 | 670,000 | 685,000 | 12,724,000 | 8,722,000 |
| HVAC control - residential buildings | 29,000 | 31,000 | 7,000 | 11,000 | 395,000 | 146,000 |
| Smart meters - water commercial | 50 | 250 | 1,000 | 230 | 9,000 | 6,000 |
| Smart meters - water residential | 30 | 80 | 470 | 110 | 9,000 | 2,000 |
| Smart meters (electricity residential) | 109,000 | 44,000 | 318,000 | 15,000 | 9,849,000 | 2,557,000 |
| Smart meters (gas residential) | 95,000 | 2,000 | 5,000 | 2,000 | 175,000 | 273,000 |

**Figure 111: Carbon emissions abatement from connected buildings ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

### 5.4.3 Appropriate environmental performance indicators

ICT services providers monitor their products and services' environmental performance based on their clients' utilisation and performance. ICT services providers monitor their products and services' environmental performance based on their clients' utilisation and performance. ICT services providers can collect data to assess the implementation of system integration solutions. Depending on the solutions, and with the collaboration of clients, different indicators can be monitored:

- GHG emissions abatement: some ICT services providers track scope 3 GHG emissions throughout their value chain to measure the environmental impacts of theirs products and services use. The scope 3 indirect emissions measure $CO_2$ abatement from the use of process and functional;
- Annual energy savings (kWh);
- Number of units connected to the grid (number of EV, wind turbine, etc.);
- Share of renewable electricity produced by clients integrated on grid.

### 5.4.4 Cross-media effects

The use of ICT system integration can imply an increase of the overall energy consumed. The integration of technologies on grids and networks can have different impacts on the environment depending on the energy sources used. The integration of electric vehicle increases the use of electricity. The environmental impacts are different if the electricity is produced with energy intensive fossil fuel or with carbon free energy.

It can increase the use of renewable energies sources using raw materials which can have different impacts on the environment (see 2.5 Use of renewable and low-carbon energy):

- Environmental footprint of some technologies such as photovoltaic panels at production level and end-of-life management stage;
- Landscape impact of some installations such as onshore wind power.

It can also indirectly increase the use of:

- Biofuel source, which can be more energy intensive;
- Nuclear energy which has potential negative impacts. A failure in nuclear installation management can result in risk of nuclear accident impacting people health and environment. Nuclear dangerous waste if not well managed can also impact biodiversity and superficial and groundwater quality.

### 5.4.5 Operational data

- **Integration of renewables on grid or off-grid**

The growing utilisation of renewable energy sources, mainly wind and solar, provide variable energy output depending on the time of the day, location, season, weather, etc. Integrating these renewables into existing electric grid increases the need for smart grid management services. Smart grid is an electrical grid that uses information and communication technologies to gather and act on information reducing inefficiencies in the grid. Smart grid management systems help replacing electricity of the grid with carbon-free energy such as solar power or wind power.

ICT services providers develop software management solutions to gather information and act on the grid to facilitate the integration of renewables.

There are three smart grid technologies that help address renewables integration challenge (GridTalk, 2013):

- Reactive compensation solutions: reactive technology mitigate some of the impacts of varying renewable energy output on power systems. Fast-compensating dynamic statistic compensators provide support and helps renewable energy plants meets interconnection requirements.
- Volt/var optimisation: variable output from renewable energy generation impact supply voltage levels for utility customers and affect power quality. Volt/var optimization technology help address such voltage swings by optimising voltage profiles for all distribution feeders served by a substation. This solution also uses sensing that give utilities greater visibility into how renewable distribution impacts the grid to better manage the effects.
- Energy storage: it is an essential part of integration renewable energies. It tackles issues such as rapid variations in output from renewable energy generation. It helps smoothing variations by aligning actual output from renewable energy plants to scheduled output and storing electricity for use when demand is high whereas renewable energy generation output is low.

Such solutions help remove barriers to the use of renewable energies and accelerate their deployment on national grids and reduce the environmental impacts of electricity generation.

- **Integration of Electric Vehicles**

The Electric Vehicles (EV) growing market create new challenges for service providers and utilities (IBM, 2012):

- Proper management to minimise the impact on grid operations
- New services and customer interactions
- New metering and charge calculation capabilities

ICT solutions are developed to promote the use of Electric Vehicles and allow integration on the grid. ICT solutions can cover:

- Subscriber management
- Analytics, reporting system on off peak and on peak charge and dashboards
- Optimisation and load control
- Charge calculation

- **Fleet and traffic management**

ICT service providers develop software management systems enabling a more efficient management of fleet and traffic. ICT services providers create dashboards to monitor more efficiently fleet vehicles.

For instance, Michelin, French tire manufacturer, launched in 2013 Effifuel solution, a fleet management solution (Michelin, 2014). Fleet management objectives are to optimise the use of vehicle and the fuel consumption. It involves monitoring a larger number of parameters such as vehicle technologies, powertrains, loads and weather conditions.

Effifuel integrates the main factors that influence vehicle fuel consumption through:

- Driver training and support;
- Deployment of a dedicated team of fuel analysts to design actions for fuel efficiency improvement;
- Implementation of systems to ensure real-time and traceability of vehicle data.

Effifuel is implemented in two main steps. The first step consists in the fleet audit. A fuel analyst collects the data and discuss with operators to understand the fleet operating conditions. The second step is the vehicles equipment with the setup of telematics units and the training of drivers to eco-driving. Effifuel solution provides with digital tools to follow consumptions and extract periodic reports and create action plans. It helps carriers and fleet managers to analyse distance parameters of their vehicles and to track consumption. Since it was launched, Effifuel helped saving 1.5 litters per 100 kilometres to trucking companies. If the entire European trucking industry were to achieve the same fuel savings over one year, Michelin estimated that the use of Effifuel could save more than three billion litres of fuel. It will avoid 9 million tons of $CO_2$ emissions. Michelin estimates that its solution allows a saving of more than 1,300 euros per truck per year. If the 2.5 million long-haul trucks in Europe used Effifuel it would represent more than 3 billion euros in additional value

- **Building management system**

Buildings today are complex interlinked structures, systems and technologies. ICT technologies help connect the various systems of a building in an integrated and dynamic system. Smart buildings use information technology during operation to connect subsystems which would otherwise operate independently (Institue for building efficiency, 2015). They are connected and responsive to the smart power grid (refer to the Integration of renewables on grid or off-grid part).

The ICT sector deliver tools to collect, process and manage data to analyse the energy efficiency of a building. ICT solutions are used to achieve energy efficiency through modelling, simulation, analysis, monitoring and visualisation tools. ICT instruments facilitate the adoption of a holistic building approach (European Commission, 2015).

For instance, Geolumen, an Italian startup in smart energy solutions, developed for SRL CELMAC - Cellino Group (group specialised in metals for automotive industry), smart lighting solution. The goal was to optimise the use of energy throughout the building. Geolumen developed wireless emergency buttons to control lighting points. No cabling was necessary and there is an immediate response of the system. GL-RD point to control lighting can also monitor operating status of machinery (eg. Presses) or enable energy-consuming devices such as compressors. Each device in the factory is now monitored and remotely controlled with no wiring or interference with machinery. The implementation of smart lighting helped saving 210 kWh/year. The annual energy consumption reduced by 76%. It also helped avoiding 111 tCO2e per year. The payback time is estimated to be less than 2 years and a half (Geolumen, 2015).

Another example on building management system is the solution developed by Qarnot Computing. The company offers cloud HPC service and created two technologies: Q.ware: software distribution platform and Q.rad: digital heater:

- Q.ware distribution platform: is a Cloud service distributes HPC workloads efficiently on the Q.rad digital heater farm, adapted to the needs of the building and workload constraints.
- Q.rad digital heater: it is a connected electric radiator embedding high performance processors as a heat source. The heat produced by workload processings provides free and efficient heating.

Over the past 2 years, Qarnot has deployed more than 350 Q.rads (first generation) installed in Paris region and is operating more than 5,000 cores. Qarnot's solution reduces HPC energy and carbon footprint by 78%: data centres and heaters represent: 180 g/kWh for heating, 120 g/kWh for construction, 120 g/kWh for HPC and 120 g/kWh for cooling, whereas Qarnot's technologies uses only HPC & heaters for 120 g/kWh. For instance, a computation work of more than 4 days and 6 hours represents 160g of CO2 saved (Qarnot Computing, 2016).

### 5.4.6 Applicability

Any ICT service provider can develop system integration software and applications. The development of such solutions requires high level of technical skills and to develop tailor-made solutions to answer clients' specific needs. It requires communication and partnerships between ICT players and other sectors organisations.

Depending on the client, the development of these systems can require partnerships to ensure the implementation especially with the public sector.

The development of solutions will also depend on different factors:

- The sectors: some sectors have specific needs and specificities. For instance, the energy sector can depend on public investment and regulations.
- Countries: the implementation of ICT systems will depend on the context of the country and the access to existing technologies and existing markets such as renewable energies, micro-CHP.

In the power sector system integration highly depends on the ability of the network to handle intermittent generation and new transmission.

### 5.4.7 Economics

The development of integration system solutions requires high level of investment in R&D and in human resources with technical skills.

Service providers shall develop different solutions depending on the size of the client. Certain technologies and sub-levers do not have a positive Net Present value when it is on small scale deployment such as building management systems for home owners. Some technologies may have too long payback period for private adoption.

If not sustained by standardization and regulation, ICT solutions could deliver reduced benefit and suffer early obsolescence.

### 5.4.8 Driving force for implementation

The transformation of the energy sector and transition to carbon free energy sources increase the need for integration system to connect all energy sources and information. The growing markets of EV and renewable energies have to be integrated to existing systems and ICT solutions have to be developed.

ICT solutions described in this BEMP allow for such new technologies to better function and interact with existing systems.

### 5.4.9 Reference organisations

Apart from the companies referenced in the case studies in the section Operational data, the following companies are reference organisations in system integration:

- BlaBlaCar, a French company leading in ridesharing platform, developed a service to optimise car occupancy. The platform gives access to users to real-time information on car available for ride. The platform reduces the number of empty seats on roads with an occupancy rate of 2.8 people by car compared to an average of 1.6 in Europe.

### 5.4.10 Reference literature

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## 5.5. Process activity and functional optimisation

| SUMMARY OVERVIEW: | | | | | |
|---|---|---|---|---|---|
| **Telecommunications and ICT services providers developed intelligent simulation, automation, redesign, or control modelling software to support companies anticipating or adjusting the production process. It has become critical for companies in today's global markets and intensified competition to adapt to meet customers' expectations. Such solutions aim at optimising processes, activities, functions or services and help reduce environmental impacts by reducing energy consumption and the use of resources.** | | | | | |
| **Sectors** | | | | | |
| **Power** | **Transport** | **Manufacturing** | Service and consumption | **Agriculture** | **Buildings** |
| **Environmental indicators** | | | | | |
| • GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions<br>• Annual energy savings (kWh) of the client<br>• Amount of material saved (kg) by the client<br>• Share of clients' products using modelling to reduce use of materials | | | | | |
| **Cross references** | | | | | |
| **Prerequisites** | • N/A | | | | |
| **Related BEMPS** | • 2.3 Procurement of sustainable ICT products and services<br>• 3.5.4 Design of the data centre building and physical layout<br>• 5.3 Data collection and communication system<br>• 5.5 Process activity and functional optimisation | | | | |

### 5.5.1 Description

Anticipating or adjusting the production process has become critical for companies in today's global markets and intensified competition to meet customers' expectations.

Process activity and functional optimisation designate a large range of solutions that use intelligent simulation, automation, redesign, or control. Such solutions aim at optimising processes, activities, functions or services.

The use of functional optimisation and modelling software helps organisations reduce their environmental impacts by: reducing energy consumption, reducing the use of resources and materials, and reducing end-of-life impacts.

From an ICT company perspective, it is best practice:

- to keep on developing new solutions for processes and functional optimisation in order to offer new opportunities for improving processes and functions efficiency;
- to help companies deploying such solutions into their operations and business;
- to internally deploy these solutions, for instance when building a new data centre (3.5.4 : Design of the data centre building and physical).

Presented below is non-exhaustive list of process activity and functional optimisation solutions that have been developed by ICT services providers. These techniques are currently being deployed among organisations:

- **Optimisation of truck route planning and logistics network.**

  Truck-route-efficiency software not only finds the shortest route available, but also monitors changes in traffic and takes tolls and other barriers into account to determine which route requires the lowest amount of fuel for a particular trip and even how much profit that trip would generate.
- **Optimisation of variable-speed motor systems and automation of industrial processes.**

  It allows machines to detect the strain under which they are working and adjust output accordingly instead of having a constant speed. A process automation system is used to automatically control industrial process.
- **Minimisation of packaging, use of eco-friendly material and design of products for easy and effective dismantlement.**

  It is the reduction in total materials required for a product and the use of eco-friendly materials and designing products for easy and effective dismantlement to lower product footprint by using design software.
- **Reduction of inventory.**

  It helps retailers optimise their inventory and reduces the amount of inventory needed.
- **Building design.**

  It is the design of energy efficient buildings.
- **Food supply chain optimisation.**

  It is about making the agribusiness more efficient through the use of smart information platforms.

These systems are complementary to other ICT solutions such as data collection systems and system integration process.

### 5.5.2 Achieved environmental benefits

The use of functional optimisation and modelling software help organisations reducing their environmental impact by:

- **reducing energy consumption** needed in the production process through anticipation of quantity produced or adjustment of the production systems;
- **reducing indirectly $CO_2$ and other atmosphere pollutant (NOx, SOx, particles…),** due to the savings from fossil fuel based energy;
- **reducing the use of resources** and materials through eco-design or optimisation of quantity produced;
- **reducing end-of-life impacts** through design of easy disassembling product.

There are other specific environmental benefits:

- **Optimisation of truck route planning and logistics network**

It offers significant savings in terms of truck utilisation and fuel use through route optimisation. It reduces indirect environmental impacts related to transportation: $CO_2$ emission, other air pollutants emission ($NO_X$, $O_3$, etc.), noise, etc.

- **Optimisation of variable-speed motor systems and automation of industrial processes**

Load capacity affects the ability of machines to perform on a constant rate of work. Motors operating at constant speed are inefficient and waste electricity. The use of variable-speed motor systems optimises electricity consumption.

Automation of industrial process reaches the following carbon emissions abatement:

| | UK | Germany | Spain | France | USA | Europe |
|---|---|---|---|---|---|---|
| Automation in industrial processes | 37,000 | 92,000 | 20,000 | 7,000 | 324,000 | 319,000 |

**Figure 112: Carbon emissions abatement from automation in industrial process ($tCO_{2eq}$ /year) (GeSI Mobile carbon impact, 2015)**

- **Minimisation of packaging**

The use of design software to minimise packaging helps reducing the amount of resources needed. It indirectly reduces the amount of waste generated.

- **Reduction of inventory**

It reduces the need for inventory therefore lower emissions by reducing logistical and transportation emissions. It also reduces storage space required by optimising logistics.

- **Building design and voltage optimisation**

Buildings can have high energy waste due to inefficient heating, cooling and lighting. ICT technologies and software can be used to design energy-efficient buildings. It has an abatement potential of 0.45 $tCO_2e$ (GeSI, 2012).

- **Food supply chain optimisation**

It helps reducing GHG from agricultural production through adoption of less polluting agronomic techniques (regarding soils, water resources and atmosphere) and increasing energy efficiency and use of renewable energy. It also increases farms resiliency to extreme weather and climate variability through forecast weather analysis and climate change adaptation solutions.

### 5.5.3 Appropriate environmental performance indicators

ICT services providers monitor their products and services' environmental performance based on their clients' utilisation and performance. ICT services providers can collect data to assess the implementation of system integration solutions. Depending on the solutions, and with the collaboration of clients, the following indicators can be monitored:

- GHG emissions abatement: some ICT services providers track scope 3 GHG emissions throughout their value chain to measure the environmental impacts of theirs products and services use. The scope 3 indirect emissions measure $CO_2$ abatement from the use of process and functional.
- annual energy savings (kWh);
- amount of material saved (kg);
- share of products using modelling to reduce use of materials.

### 5.5.4 Cross-media effects

One of the main cross-media effects is the rebound effect (refer to the introduction chapter: 5.1).

### 5.5.5 Operational data

- **Optimisation of truck route planning and logistics network**

Transport planning and logistics management software provide strategic, operational and real-time planning functionality for large and complex transport and distribution network.

Transport management software solutions are capable of planning about thousands of movements in seconds and modelling complex operational rules and constraints. This types of software provides powerful algorithms modelling different information: access constraints, load building rules, trailer compatibility, driver hours, warehouse capacity, availability of docks, etc.

The use of transport management software helps companies optimise vehicle routes and driver schedule based on real-time or forward planning. The real-time planning uses GPS location and transport orders status to automatically update schedule. Forward schedule are optimised using vehicle routing and distribution scheduling systems which assign daily forecast and orders to drivers and vehicles to maximise resource utilisation and balance drivers workloads (MJC2, 2016 ).

By using such solutions, companies optimise vehicle planning and distribution network and therefore reduce their environmental impact by reducing kilometres and fuel consumption.

- **Optimisation of variable-speed motor systems and automation of industrial processes**

ICT solutions are developed to optimise industrial processes. Software helps optimising variable speed-motor systems and automation of processes. Such software are used in any application in which there is mechanical equipment powered by motors. Adjustable speed drives are used to provide extremely precise electrical motor control, so that motor speed can be ramped up or down and adjust speed required.

Motors consume most of energy produced in industrial processes and controlling and adapting speed can realize up to 70% energy savings. The use of motor controlling solutions help companies reduce their energy consumption and associated GHG emissions.

- **Minimisation of packaging, use of eco-friendly material and design of products for easy and effective dismantlement**

ICT technology providers develop modelling software to support the design process in order to optimise product production and functions. Such software provides information on the total materials required in the production process, the use of eco-friendly materials, easy and effective dismantlement. It is mainly used by industrials in their processes and products conception.

Modelling and design software help lower product footprint by: reducing the use of resources, reducing the generation of waste and e-waste.

For instance, Dassault Systèmes, a software firm, developed a 3DEXPERIENCE platform that leverages technologies such as computer-aided design (CAD) modelling, simulation, manufacturing, and product lifecycle management. This platform helps capturing products handprints. Handprinting is the evaluation of a product environmental impact beyond its footprint. Footprint focuses on negative consequences on the environment, whereas handprint also considers beneficial changes.  There are two ways to create a handprint:

- preventing/avoiding footprints that would have occurred reducing
- creating positive benefits which would not have occurred

The development of the platform was based on the analysis of the potential for handprinting in the automotive sector. The handprinting assessment relies on different criteria and information (Norris & Phansey, 2015):

- Estimate of the material, energy inputs to vehicle manufacture which are affected by the innovation;
- Estimate of how the use phase of the vehicle is affected by the innovation (e.g., changes to fuel economy, durability, maintenance requirements);
- Indication of whether or not end-of-life management (e.g., recycling) would be affected by the innovation;
- Estimate lifetime vehicle mileage;
- Value for the Innovation Relevant Time Horizon (IRTH) relevant for automobiles;
- Forecasts of annual sales for the innovated vehicle throughout the IRTH.

Through eco-design optimisation, the Ford F-150 pickup model achieved an overall weight reduction of 317 kilograms with a replacement of 1,623 kilograms of steel plus 111 kilograms of aluminium with 940 kilograms of steel plus 476 kilograms of aluminium. According to the study led by Dassault Systèmes and SHINE, the use this

eco-design tool can enable sectors such as the global automotive sector to create handprints which are on the order of 10,000 times greater than its own footprint.

- **Reduction of inventory**

Effective inventory management is critical to companies to improve their customer service, profit margin and to reduce environmental impacts. Stocking control is at the core of inventory management system which allow controlling amounts of stock, raw materials, spare and finished goods. It is particularly useful for manufacturing companies.

Dynamic inventory modelling software are designed to help companies improving inventory performance. It helps modelling the entire supply chain end-to-end to ensure that inventory strategies simultaneously optimize inventory at each level of the supply chain.

Such modelling solution enable manufacturers create their inventory strategy: reducing safety stock requirements, decreasing unnecessary production of goods, lowering inventory targets and reducing inventory. Inventory optimisation can reduce safety stock by more than 10% (Supply Chain Diggest, 2008).

These reductions improve companies' environmental performance by: reducing the use of resources and materials, saving energy and CO2 emissions.

- **Building design and voltage optimisation**

Modelling and design software are used in building conception. Such software are used before construction and allows companies to forecast the environmental impact of material used and energy efficiency.

For instance, Dassault Systèmes is developing building information modelling (BIM) software for the building industry. BIM is a crucial tool for construction companies to conceive and build more energy-efficient buildings. Modelling buildings prior to construction allows construction companies to understand the global functioning of buildings and their total costs of construction and operation (Dassault Systemes, 2016).

BIM software developed by Dassault Systèmes now cover a large part of the construction process, and allows construction companies to model:

- the environmental impact of material used in the construction;
- the construction and assembly processes of buildings;
- the building's behaviour, to simulate energy usage and optimise building performance.

- **Food supply chain optimisation**

In addition to data collection systems, ICT solutions are developed to make farming more efficient. ICT have a major impact on the ability of farmers, consumers and buyers to trace food they buy and sell. In the same way than for optimisation of manufacturers' supply chain, ICT software can optimise processes and reduce food waste at all stages.

Tracking systems gives real-time tracking of food at production storage and transportation stages. Real-time information helps farmers march demand and optimise supply chain. The adjustment of production and demand allows reduction of food waste as its source.

### 5.5.6 Applicability

The development of such ICT solutions requires a good knowledge of markets maturity and clients' needs. In some sector ICT services providers can encounter barriers to the adoption of such technologies:

- Difficulty to access technology, lack of wireless and broadband coverage;
- Resistance to change in adopting such technologies changing activities.

To overcome these barriers, partnerships have to be developed to access markets.

The selling of such solutions requires the development of support services and training sessions in order to optimise utilisation.

### 5.5.7 Economics

Such technologies require high level of investment in R&D and in human resources with technical skills.

They offer energy savings opportunity in a context of global energy transition and growing renewable energy. Therefore, they can take significant proportion of target sector and have increase forecast sales and profit and short term ROI.

For instance, Endeco Technologies Ltd developed a power-load balancing technology. In the five years following commercialisation, sales forecast reached a total of €124.8 million and the company had a profit of €28.8 million and an ROI of 1:17.5 over 5 years (European Commission, 2015).

### 5.5.8 Driving force for implementation

These technologies can be strategic in a context of global energy transition and growing renewable energy. ICT services providers offer solutions to companies to reduce their energy consumption. It is also strategy in a context of resource depletion to offer solutions to reduce need in resources and raw materials.

Besides, the development of such solutions offers the opportunity to clients to drive their innovation in their activity sector. ICT services providers can highlight the fact that it is an opportunity for their clients to create a competitive advantage. For instance, the automation of processes and functions improve their activity and reduce need for: time, human resources and resources (energy, raw materials, etc.).

### 5.5.9 Reference organisations

Apart from the companies referenced in the case studies in the section Operational data, the following companies are reference organisations in process activity and functional optimisation systems:

- Endeco Technologies Ltd is a pioneering, award winning company recognised as the technology leader in smart grid energy aggregation (European Commission, 2015)

### 5.5.10 Reference literature

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# 6 Applicability of Best Environmental Management Practices

## 6.1 BEMPs applicability and consistency

The Best Environmental Management Practices of the telecommunications and ICT services sector are divided in 4 chapters:

- Cross-cutting measures (in light grey on Figure 113), which refer to practices applicable by any company of the telecommunications and ICT services sector (environmental management system, procurement of sustainable equipment, waste management, optimisation of end-user device energy consumption, etc.);
- Data centre related measures (in medium grey on Figure 113), which refer to practices specific to data centre operators or server owners (and their suppliers);
- Telecommunications network related measures (in darker grey on Figure 113), which refer to practices specific to telecommunication operators (and their suppliers);
- Greening by ICT measures (in dark on Figure 113), which refer to solutions developed by software developers and telecommunication service providers, and to some extend applicable for the telecommunications and ICT services sector.

However, these chapters are not sealed and isolated:

- On the one hand, some generic practices developed within the first chapter are specified within the data centres or telecommunication networks chapters (e.g. energy management).
- On the other hand, some BEMPs refer to techniques developed in other BEMPs (e.g. the selection of network equipment use principles developed within the BEMP 2.3 on the Procurement of sustainable ICT products and services).

Such relations between BEMPs are identified in the introductive table of each BEMP ("related BEMPS") and developed within the description section.

Most of the BEMPs are only applicable to specific lifecycle stages: service development, planning and designing, selection and procurement, installation and upgrades, operation and management, or end-of-life management. The Figure 113 shows that there is at least one BEMP applicable for each lifecycle stage of any ICT asset (data centre, telecommunication network and end-user device). The introductive table of each BEMP specifies to which ICT asset and lifecycle stage the BEMP is applicable.

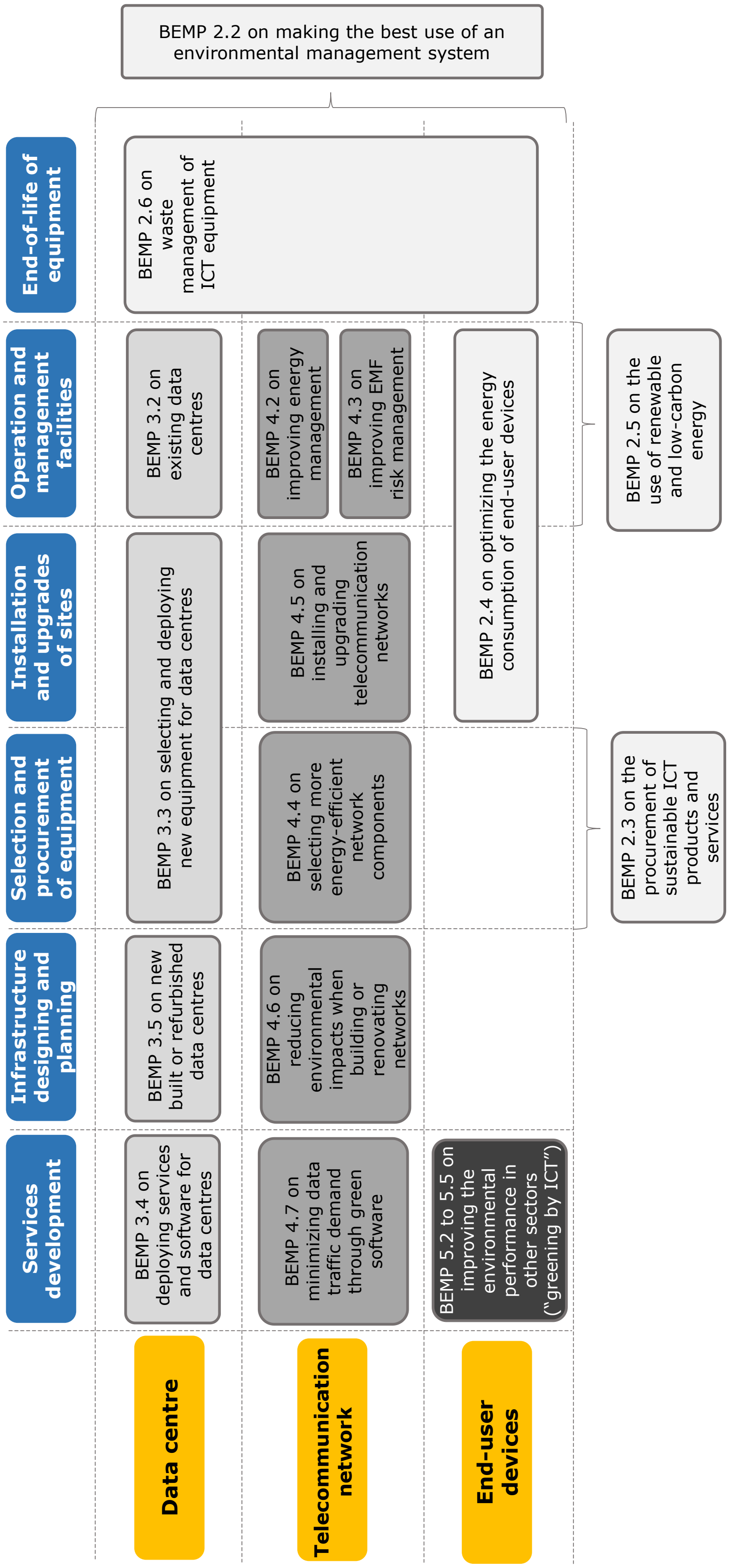


**Figure 113: Overview of the BEMPs applicability**

## 6.2 Applicability to SMEs

The purpose of this section is to facilitate use of this document by small and medium sized enterprises (SMEs). As described in Chapter 1, the Telecommunications and ICT Services sector is made of a large majority of micro-sized firms, with 93% of the total number of companies in the sector employed less than 10 people in EU-28 in 2012 (Eurostat, 2012b). Most of these 740,000 companies belong to the IT services sector, and perform computer programming and consultancy activities (Nace Code 62), or web portal, data processing or hosting companies (Nace Code 63). If the telecommunications sector is also mainly made of SMEs according to Eurostat (Eurostat, 2012b), these data fail to reflect the importance of a few large telecommunication operators in Europe that own and manage, directly or indirectly, a large share of the telecommunication network.

Most of the best environmental management practice techniques described in this document are of direct relevance to SMEs, and will either be directly applicable to them, or will have implications for them via implementation by larger telecommunication operators. Certainly, most of the proposed indicators and benchmarks can be used by SMEs to monitor environmental performance. Being an SME is not a reason to avoid responsibility for monitoring and improving environmental performance.

Nonetheless, some best practice techniques relating to e.g. telecommunications network development or management may be of more direct relevance to large telecommunication operators. In addition, some techniques requiring high upfront investment may not be applicable to smaller SMEs that typically have little capacity to invest in environmental technologies. Finally, management structures and capabilities are usually more limited for SMEs than for larger companies.

This section therefore describes which practices are most applicable and affordable to SMEs. Table 53 characterises all the BEMPs described in this document in relation to four aspects: target group, costs, applicability and achieved environmental benefit, using a user-friendly coloured-coded "traffic light" assessment, as described in Table 52.

**Table 52: Colour coding for the assessment of the applicability of best environmental management practices for SMEs**

| **Colour** | | | |
|---|---|---|---|
| Cost (initial investment) | High | Medium | Low |
| Applicability to SME | Not applicable | Applicable with restrictions | Full applicable |
| Environmental benefit | Low | Significant | High |

**Table 53: Cost and applicability to SMEs, and environmental benefit, of best environmental management practices described in this document**

| BEMP | Target group | Cost | Appl. to SMEs | Env. benef | Comments |
|---|---|---|---|---|---|
| **2. Cross-cutting measures** | | | | | |
| 2.2 Making the best use of an environmental management system | All companies | | | | Any company can implement an EMS. Resources allocated to the process shall be adapted to the size and the environmental impact of the site or company. A simplified EMAS system is available for SMEs. |
| 2.3 Procurement of sustainable ICT products and services | All companies | | | | Large organizations have greater potential to leverage influence over their suppliers, but SMEs may exert considerable influence over local suppliers. Actions towards products sold to customers are more applicable to the telecommunication sector, with a majority of large firms. |
| 2.4 Optimising energy consumption of end-user devices | All companies | | | | SMEs rely more on organisational solutions than on technical and standardized solutions, even if such solutions are affordable. |
| 2.5 Use of renewable energy | All companies | | | | Costs related to the creation of a renewable energy production unit can be significant. Because this technique requires specific location and space availability, it can be non-applicable for companies which share offices in urban environment (most of the IT services companies). |
| 2.6 Waste management of ICT equipment | All companies | | | | LCA services or training can cost significant amount of money. Actions towards products sold to customers are more applicable to the telecommunication sector, with a majority of large firms. |
| 3. Data centres | | | | | |
| 3.2 BEMPs related to existing data centres | | | | | |
| 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment) | Data centre operators | | | | Some technology intensive automated data management tools can be very costly, especially for smaller size structures. The tools are mainly for large size data centres because of heavy upfront investments. |
| 3.2.3 Define and implement a data | Servers owners | | | | These practices can be implemented by most data |

| BEMP | Target group | Cost | Appl. to SMEs | Env. benef | Comments |
|---|---|---|---|---|---|
| management and storage policy | | | | | centres and server rooms. |
| 3.2.4 Improve airflow management and design | Data centre operators | | | | If the best practices identified before can be implemented in data centres of any size, scale effects can be observed in larger data centres with shorter return of investments. |
| 3.2.5 Improve cooling management | Data centre operators | | | | Maintaining the cooling system and carrying out regular reviews of its capacities can be done in most data centres. However, automating the cooling system output can imply costs to purchase smart equipment, making it more appropriate for large size data centres. |
| 3.2.6 Review and adjust temperature and humidity settings | Data centre operators | | | | Raising temperature set points, adjusting volumes and quality of supplied cool air, and reviewing humidity settings can be done in most data centres, irrespectively of their size, security level or purpose. |
| **3.3 BEMPs related to selecting and deploying new equipment and services for data centres** | | | | | |
| 3.3.2 Selection and deployment of green equipment for data centres | Data centre operators | | | | Depending on the type of equipment that is selected, costs can be significantly higher, and more difficult to afford for SMEs. |
| **3.4 BEMPs related to the deployment of new ICT services and software** | | | | | |
| 3.4.2 Developing new ICT services and software minimising servers utilisation | Software developers and servers owners | | | | These solutions require to mobilize internal means (skills and R&D investments) or to purchase consulting work, applicable to larger organisations. |
| **3.5 BEMPs related to new build or refurbishment of data centres** | | | | | |
| 3.5.2 Planning of new data centres | Data centre operators | | | | Building a data centre according to a modular architecture is particularly relevant for big data centres. |
| 3.5.3 Reuse of data centre waste heat | Data centre operators | | | | Opportunities for reusing waste heat from a data centre is more applicable to larger data centres, except with a decentralized system (servers place in the rooms that they directly heat). |
| 3.5.4 Design of the data centre building and physical layout | Data centre operators | | | | These techniques are most relevant for building new, enterprise-class data centres, as these practices aim to shape |

| BEMP | Target group | Cost | Appl. to SMEs | Env. benef | Comments |
|---|---|---|---|---|---|
| | | | | | the aspect and structure of the new built data centre and can be costly to implement. |
| 3.5.5 Selecting the geographical location of the new data centre | Data centre operators | | | | Locating a data centre according to its energy-efficiency potential is particularly relevant for big data centres. |
| 3.5.6 Use of alternative sources of water | Data centre operators | | | | These practices are relevant for large, enterprise-class data centres. |
| **4 Telecommunication networks** | | | | | |
| 4.2 Improving the management of existing telecommunication networks | Network operators | | | | As network operators are mostly large companies, these BEMPs are mainly applicable to large companies. However, SMEs providing ICT services have the opportunity to facilitate the provision of energy-aware services, by defining appropriate Quality of Services requirements and by choosing relevant network technologies. |
| 4.3 Improved risk management for electromagnetic fields thanks to monitoring and transparency of data | Network operators | | | | As network operators are mostly large companies, these BEMPs are typically only applicable to large companies. |
| 4.4 Selecting and deploying more energy-efficient telecommunication network equipment | Network operators | | | | Only few telecommunication operators or Internet providers own wireline or wireless networks and can engineer changes within these networks. Most of these companies are large sized companies. |
| 4.5 Installing and upgrading telecommunication networks | Network operators | | | | Telecommunication operators and their suppliers in charge of the installation of ICT equipment are the main actors concerned by this technique. This technique is more relevant for large mobile companies which own thousands of sites, and for operators of networks in rural areas (where the sites are more spaced out). |
| 4.6 Reducing the environmental impacts when building or renovating telecommunication networks | Network operators | | | | Only few telecommunication operators or Internet providers own wireline or wireless networks and can engineer changes within these networks. Most of these companies are large sized companies. Local |

| BEMP | Target group | Cost | Appl. to SMEs | Env. benef | Comments |
|---|---|---|---|---|---|
| | | | | | authority planning policies can limit the capacity of operators to develop their network in specific areas. |
| 4.7 Design of web portals and mobile applications to limit data traffic demand | Software developers and users | | | | Using eco-design solutions when developing or optimizing applications refer to a set of techniques that can be applied by software publishers (for an external use of software) or by any type of company using applications for its own usage. IT consulting firms (including SMEs) can help these companies develop such innovative solutions. |
| **5 Improving the energy and environmental performance in other sectors ("greening by ICT")** | | | | | |
| 5.2 Digitalization and dematerialization | All companies | | | | These different solutions are developed by different types of telecommunications and ICT services companies, both start-ups and large firms. The development of such solutions may require huge investments. |
| 5.3 Data collection and communication | All companies | | | | These different solutions are developed by different types of telecommunications and ICT services companies, both start-ups and large firms. The development of such solutions may require huge investments. |
| 5.4 System integration | All companies | | | | These different solutions are developed by different types of telecommunications and ICT services companies, both start-ups and large firms. The development of such solutions may require huge investments. |
| 5.5 Process activity and functional optimisation | All companies | | | | These different solutions are developed by different types of telecommunications and ICT services companies, both start-ups and large firms. The development of such solutions may require huge investments. |

## 6.3 Main environmental aspects and impacts addressed by the BEMPs

The main environmental pressure of the Telecommunications and ICT Services sector is its energy consumption and direct and indirect emission of greenhouse gases (GHG). As shown on Figure 114, most of BEMPs developed within this document deal with this environmental pressure, through an action towards all the different assets: facilities (data centres, central offices, base stations, etc.), telecommunication infrastructures (antennas, cables, etc.), ICT equipment (servers, end-user devices, etc.) and software.

The second main environmental pressure is the resource consumption, tackle by BEMPs focusing on ICT equipment, and other equipment that can be found in ICT and Telecommunication facilities (power supply, cooling system, etc.).

Water consumption is a very specific environmental pressure, concerning only certain types of cooling systems in data centres.

All the other significant environmental aspects (noise emissions, land-use, aesthetic pollution, EMF exposure, etc.) are almost exclusively related to telecommunication infrastructures and facilities.

Only certain BEMPs are dealing with all the environmental pressures: environmental management systems for sites and facilities (BEMP 2.2) and the procurement of sustainable ICT and other equipment (BEMP 2.3).

The BEMPs on greening by ICT solutions are quite different from the other ones since they refer to the minimisation of the environmental impacts of other sectors. On the one hand, the deployment of such solutions generate an increase use of Telecommunication and ICT services, and causes more environmental impacts (see above paragraphs on the impacts of this sector). On the other hand, these solutions offer opportunities for reducing a wide spectrum of pressures: energy consumption, greenhouse gas and other air pollutant emissions, resources consumption, etc.

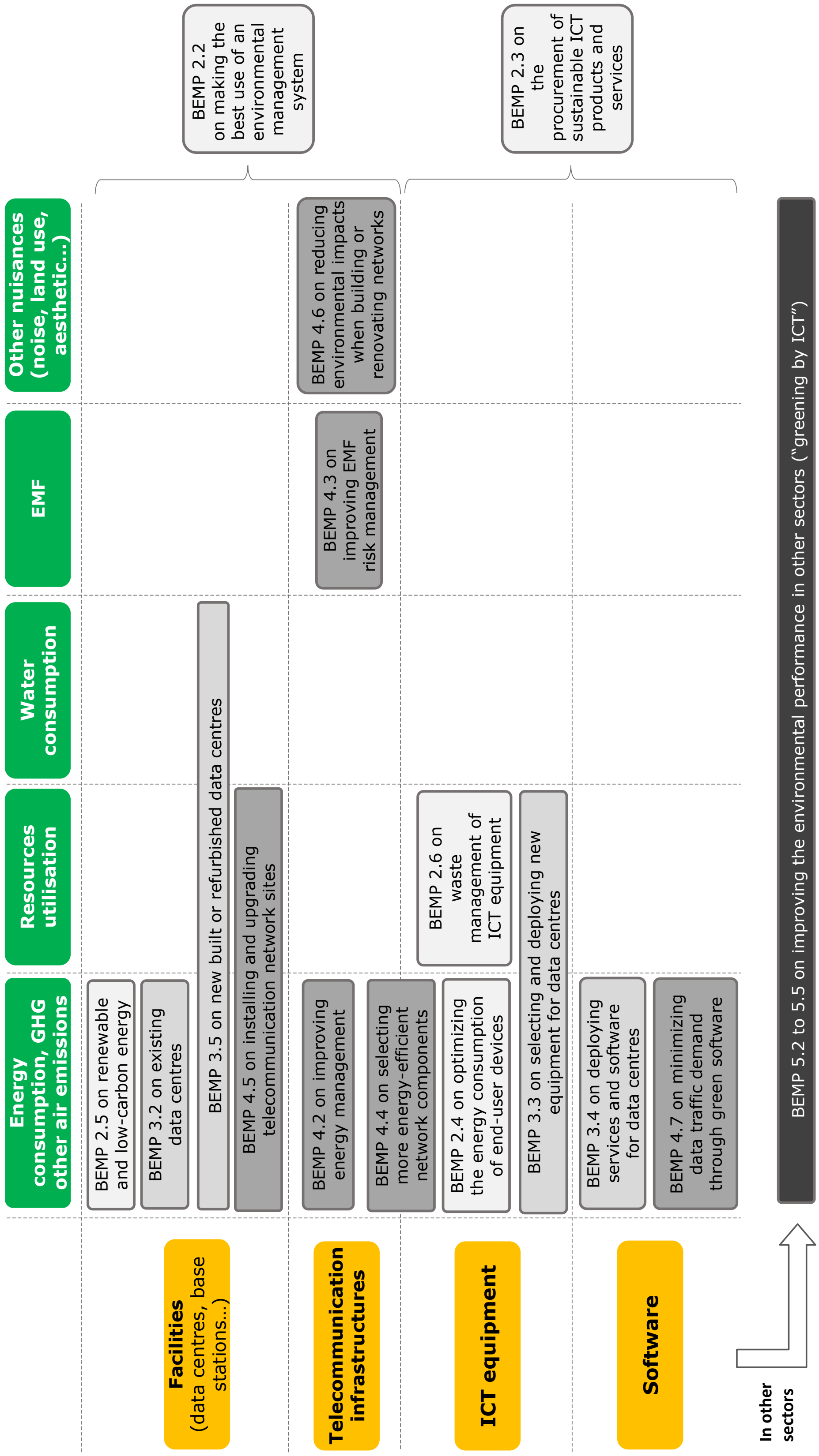


**Figure 114: Overview of the main environmental aspects and impacts addressed by the BEMPs**