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Best Environmental Management Practice in the Telecommunications and ICT Services sector

Learning from front runners

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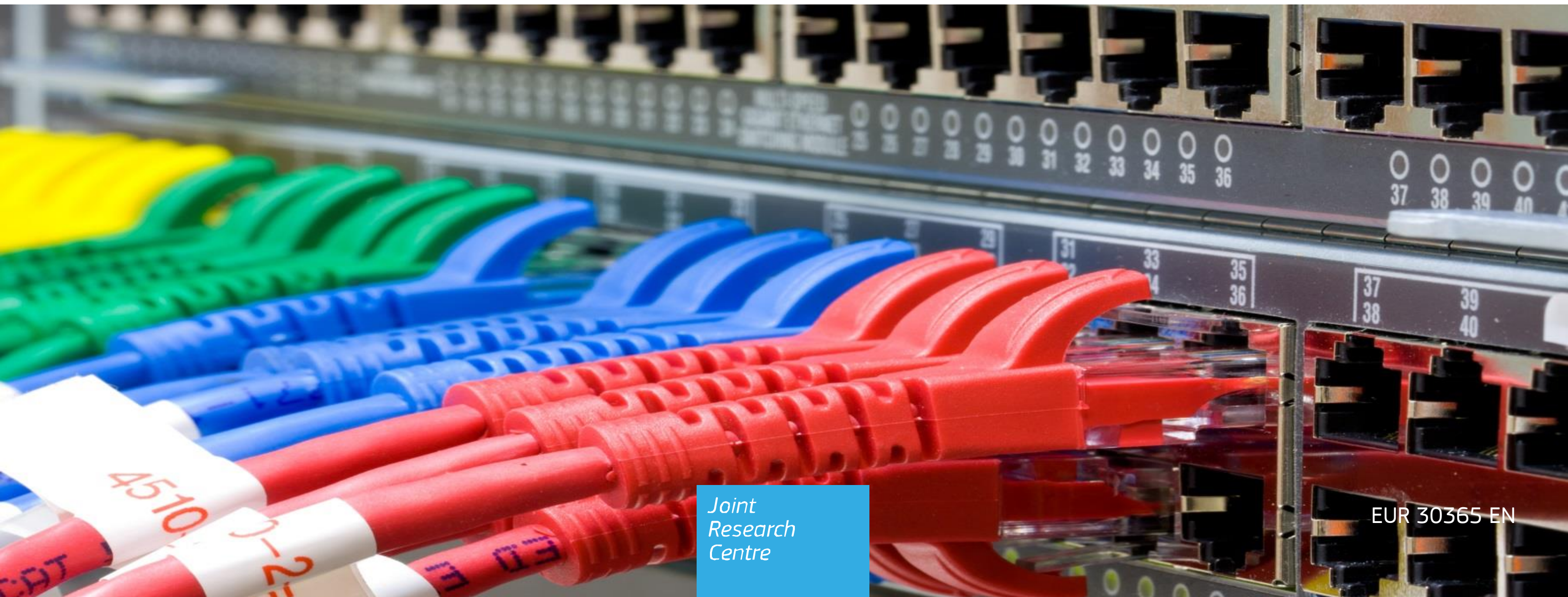

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Best Environmental Management Practice in the Telecommunications and ICT Services sector

Abstract

The steady growth over the past decades of the Telecommunications and ICT Services sector, and its uninterrupted progress with the constant provision of renewed and ever-faster services as well as new applications, has transformed many aspects of our society and lives but has also spurred the development of ever more power- and resource-hungry systems, contributing to the sector's ever-growing environmental footprint.

On the basis of an in-depth analysis of the actions implemented by environmental front runners and of existing EU and industry initiatives addressing the environmental performance of the sector, this report describes a set of best practices with high potential for larger uptake. These are called Best Environmental Management Practices (BEMPs).

The BEMPs, identified in close cooperation with a technical working group comprising experts from the sector, cover improvement of environmental performance across all significant environmental aspects (energy consumption, resource consumption, etc.) at the different life cycle stages (planning and design, installation, operation, end-of-life management, etc.) and for different ICT assets (software, data centres, etc.).

Besides actions aimed at reducing the environmental impact of Telecommunications and ICT Services operations (with a special focus on data centres and telecommunications networks), the report also identifies best practices in the ICT sector that contribute towards reducing the environmental impact of other sectors of the economy ("greening by ICT" measures).

The report gives a wide range of information (environmental benefits, economics, indicators, benchmarks, references, etc.) for each of the proposed best practices in order to be a source of inspiration and guidance for any company in the sector wishing to improve its environmental performance. In addition, it will be the technical basis for a Sectoral Reference Document on Best Environmental Management Practice for the Telecommunications and ICT Services sector, to be produced by the European Commission according to Article 46 of Regulation (EC) No 1221/2009 (EMAS Regulation).

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Preface

Introduction

This Best Practice 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 the European Commission's Joint Research Centre (JRC) on the basis of a background report produced for the JRC by its contractor Ernst & Young et Associés (France) and discussions with technical experts via the forum of a Technical Working Group (TWG) comprising experts from industry, academia, NGOs and public administration, as well as desk research and interviews with further stakeholders.

This Best Practice Report is intended to be a source of inspiration and guidance for any company in the Telecommunications and ICT Services sector wishing to improve its environmental performance. In parallel, its technical content will be used for the development of an EMAS Sectoral Reference Document (SRD) to be officially adopted by the European Commission.

Figure 1 shows the different outputs of this work and the relationship between them, while further information on the EMAS SRDs, their aim and use and the whole structured development 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].

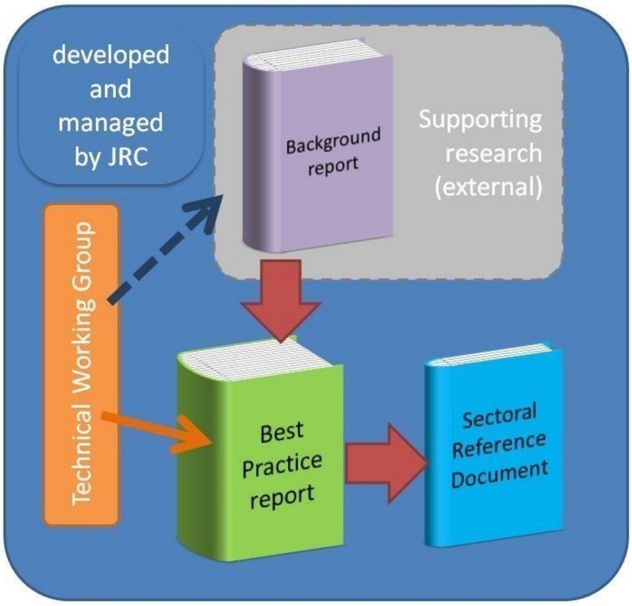

Figure 1: The relationship between the background report, the Best Practice Report and the Sectoral Reference Document (SRD)

Companies from the Telecommunications and ICT Services sector interested in implementing best practices to improve their environmental performance are recommended to refer to the detailed and definitive versions of these practices presented in this Best Practice Report.

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[2]. To support this aim, and according to the provisions of Article 46 of the

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

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

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, the guidance on BEMP is not only for EMAS-registered organisations, but is rather intended to be a useful reference document for any company that wishes to improve its environmental performance or for any actor involved in promoting best environmental performance.

Content

The core element of this report are the BEMPs for the Telecommunications and ICT Services sector.

BEMPs encompass techniques, measures or actions that can be implemented 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, these BEMPs are demonstrated practices that have the potential to be taken up on a wide scale in the Telecommunications and ICT Services sector, and which 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.
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).
Driving force for implementation	Factors that have driven or stimulated the implementation of the BEMP by organisations of the sector to date.
Reference organisations	Examples of organisations that have successfully implemented the BEMP.
Reference literature	Literature or other reference material cited in the previous sections of the text on the BEMP.

Wherever possible, for each of the proposed BEMPs, sector-specific Environmental Performance Indicators and Benchmarks of Excellence are also presented. 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, their environmental performance directly in relation to the aspects covered by the BEMP.
- 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 it 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 were drawn by the TWG at the end of its interaction with the JRC.

Sources of information and development of the document

The information presented in this Best Practice Report was collected and drawn up between June 2015 and December 2017, both as part of the development of a background report by Ernst & Young et Associés (France), under contract with the JRC, and as part of the subsequent interaction with the TWG established for this sector and related further research and elaboration by the JRC.

The main sources of information were scientific literature, technical reports, environmental and/or sustainability reports from companies of the sector that are publicly available, as well as further information obtained directly from Telecommunications and ICT Services providers through interviews or bilateral exchanges or from members of the technical working group.

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 environmental 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/TR 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 Services sector.
- Chapter 6 "**Applicability**" is developed in three sections:
  - The first section explains the relations between the BEMPs, and gives an overview of the applicability of the BEMPs to organisations (telecommunications operator, data centre operator, etc.), life cycle 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 the use of this document by small and medium-sized enterprises (SMEs).
  - The third section summarises the environmental pressures tackled by the different BEMPs.
- Finally Chapter 7 "**Conclusions**" presents a summary table of Environmental Performance Indicators and Benchmarks of Excellence for all the BEMPs.

How to use this document

This document is not conceived to be read from beginning to end, but as a working tool for professionals from the sector, willing to improve the environmental performance of their organisation/company and who seek reliable and proven information in order to do so. Different parts of the document will be of interest and will apply to different professionals and at different stages. The best way to start using this document is by reading the short section (summary overview) about its structure to understand the content of the different chapters and, in particular, the areas for which BEMPs have been described and how these BEMPs have been grouped. Then, Chapter 1 would be a good starting point for readers looking for a general understanding of the sector and its environmental aspects and also to understand the scope of this document and the relation between the scope of this document and other existing documents (e.g. EU Code of Conduct). Those looking for an overview of the BEMPs described in the document could start from Chapter 7 (Conclusions) outlining all BEMPs together with the related Environmental Performance Indicators and Benchmarks of Excellence, i.e. the exemplary performance level that can be reached in each area. For readers looking for information on how to improve their environmental performance in a specific area, it is recommended to refer directly to the concrete description of the BEMPs on that topic, which can be easily found through the table of contents. A summary overview table is laid out at the beginning of each BEMP, presenting its main elements and providing the reader with preliminary information on the applicability conditions, on the key Environmental Performance Indicators and Benchmarks of Excellence where appropriate. For readers interested in more detailed information on how to specifically implement the outlined BEMP within their sites, it is recommended to continue reading the main content of the BEMP.

Acknowledgements

This Best Practice Report was produced by the European Commission's Joint Research Centre in the framework of supporting the development of an EMAS Sectoral Reference Document for the Telecommunications and ICT Services sector. This document is based on a preparatory study (background report) carried out by Ernst & Young et Associés (France).

In the course of preparing that background report, and this Best Practice Report, numerous experts from companies active in the target sector provided invaluable information which greatly enriched the technical content described; their contribution is highlighted in the body of the report for each individual best practice.

Moreover, a technical working group, comprising a broad spectrum of experts in the environmental performance of the Telecommunications and ICT Services sector, supported the development of the document by providing input and feedback. Technical summaries from the meetings of the technical working group are available on the Joint Research Centre's website[3].

[3] http://susproc.jrc.ec.europa.eu/activities/emas/telecom.html

Executive summary

This Best Practice Report describes techniques that are considered **Best Environmental Management Practices** (BEMPs) in the Telecommunications and ICT Services sector. It was produced by the European Commission's Joint Research Centre (JRC), with the support of technical experts and stakeholders from the sector via the forum of a Technical Working Group (TWG).

It is intended to be a source of inspiration and guidance for any company of the Telecommunications and ICT Services sector wishing to improve its environmental performance. In parallel, its technical content will be used for the development of an EMAS Sectoral Reference Document (SRD) for the Telecommunications and ICT Services sector to be officially adopted by the European Commission[4].

Target group

The 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) can also find several BEMPs of relevance to their activities.

Scope

The BEMPs described in the report cover core business activities of organisations in the Telecommunications and ICT Services sector. The report focuses on the following elements which are interlinked:

- 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 within the scope of other EMAS Sectoral Reference Documents and related Best Practice Reports were excluded from the scope of 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 to as “greening of ICT” practices;
- BEMPs that refer to the solutions provided by Telecommunications and ICT Services companies to minimise the environmental impacts of other sectors, referred to as “greening by ICT” practices.

[4] Further information on what the EMAS Sectoral Reference Documents are 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.

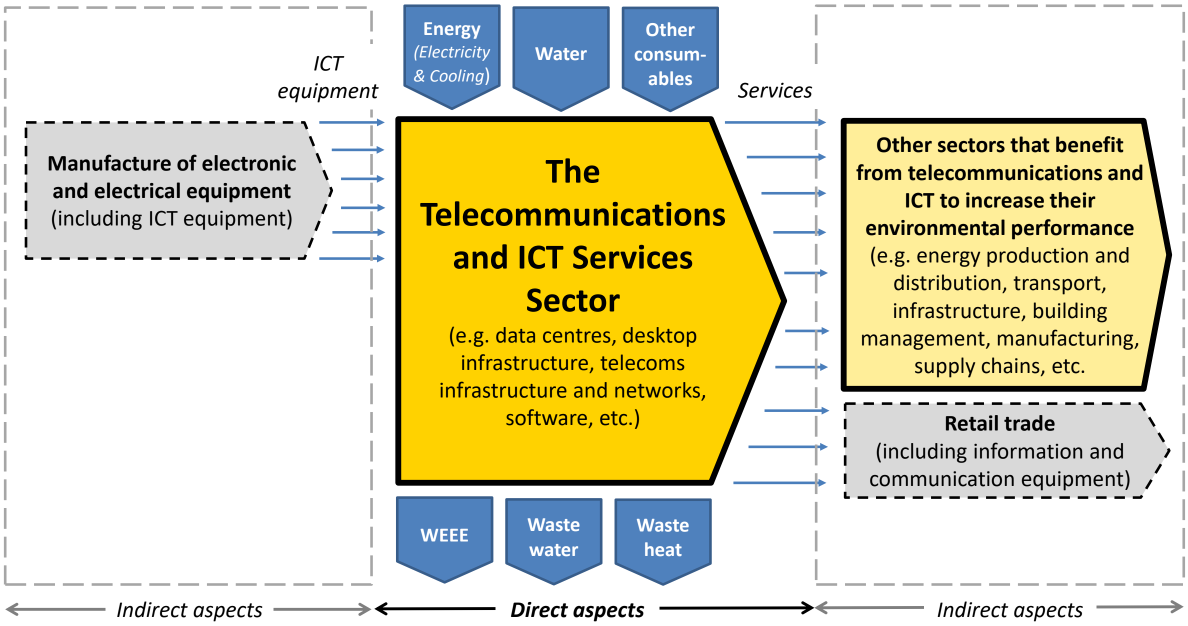

Figure 2: Overview of the scope of the document

The main environmental aspects and associated environmental pressures for the Telecommunications and ICT Services sector are presented in Table 2 (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 2: 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.) - Software (processors) - HVAC and power supply - Buildings	- Electricity consumption and greenhouse gas (GHG) emissions - Resource consumption and waste electrical and electronic equipment (WEEE) generation - Water consumption and waste water - Noise emissions (generators and cooling compressors)
Telecommunication infrastructure and networks	- ICT infrastructure (antennas, cables, fibres, landlines, etc.) - ICT equipment (transceivers, routers, switchers, etc.) - HVAC and power supply - Buildings (central offices, base stations, etc.) - Terminals (phones, computers, modems, set-top boxes, etc.) - Software (processors, controls, etc.)	- Energy consumption and GHG emissions (network equipment, cooling systems, transportation, etc.) - Resource consumption and WEEE generation - Electromagnetic field exposure - Noise emissions (generators and cooling compressors) - Changes to the landscape and habitats due to infrastructure deployment
End-user devices	- ICT equipment (computers, peripheral devices, etc.) - Software	- Electricity consumption to power hardware and GHG emissions - Resource consumption and WEEE generation

Content

The Best Environmental Management Practices are grouped into four 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 life cycle 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 end users.
- **Optimising the energy consumption of end-user devices** used within the offices and facilities of Telecommunications 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 senior management commitment.
- **Use of renewable and low-carbon energy** helps ICT facilities reduce their environmental footprint by reducing GHG emissions associated with fossil fuel energy. It applies mainly to data centres and base station facilities and can be implemented by using biomass co-generation, solar power, wind power or geothermal cooling systems. When renewable–energy-based systems are not technically or economically feasible, natural-gas-based CHP can be considered.
- **Considering the resource efficiency of ICT equipment through waste prevention and fostering of reuse and recycling**, both for the 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.
- **Minimising data traffic demand through green software,** to optimise software so as to reduce the volume of data processed and transmitted, and ultimately reduce the energy consumption of hardware. This can be implemented either when developing new software or when optimising existing software, for servers and networks considering both mobile applications (for smartphones and tablets) and computer software (for laptops and desktops), as well as web portals and web-based applications.

B. Data centres

These are techniques specific to data centres. The structure of the BEMPs is based on the CENELEC Technical Report *CLC/TR 50600-99-1*, which is a development of the best practices identified in the EU Code of Conduct for Energy Efficiency in Data Centres[5]. 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. Co-location providers and customers as well as other suppliers and customers of ICT services may also find the BEMPs

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

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 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 discs, 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 amount 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 new build or refurbishment of data centres** focus on planning and designing the 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 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 data centre waste heat
   - Design the data centre building and physical layout minimising direct solar heating of cooled areas and appropriately locating the cooling equipment
   - Select 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 telecommunications operators (and their suppliers). They aim at better managing existing networks, at installing more environmentally 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 telecommunications networks**, with 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 times of low or moderate traffic.
- **Improving risk management for electromagnetic fields (EMFs) thanks to monitoring and transparency of data**, since this is still a public concern despite the implementation of strict regulations and intense research.
- **Selecting and deploying more energy-efficient telecommunications network equipment**, which covers ICT equipment (radio, telecommunications, broadband and IT devices), as well as cooling systems and UPS. Further energy-efficiency improvement can be achieved while designing telecommunications sites (integrated and multi-standard solutions, remote antennas, etc.) or using software enabling energy savings.
- **Installing and upgrading telecommunications networks** refers to the opportunity for taking advantage of technology transition (e.g. deploying 4G technology in existing base station sites) to optimise 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 telecommunications networks**, with co-location, and appropriate location or equipment which can minimise building aesthetic impact and land use, or noise from generators and cooling systems.

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

This BEMP aims 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 categories, this BEMP on greening by ICT solutions is framed at a more general level and intends 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 (electricity suppliers, transport companies, 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)[6]:

- **Digitalisation and dematerialisation**, 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 improves 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 client companies deploying such solutions in their operations and business (by specifically designing the solution its client needs, by providing training and communication, etc.);
- internally deploy these solutions, if relevant.

Applicability

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

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

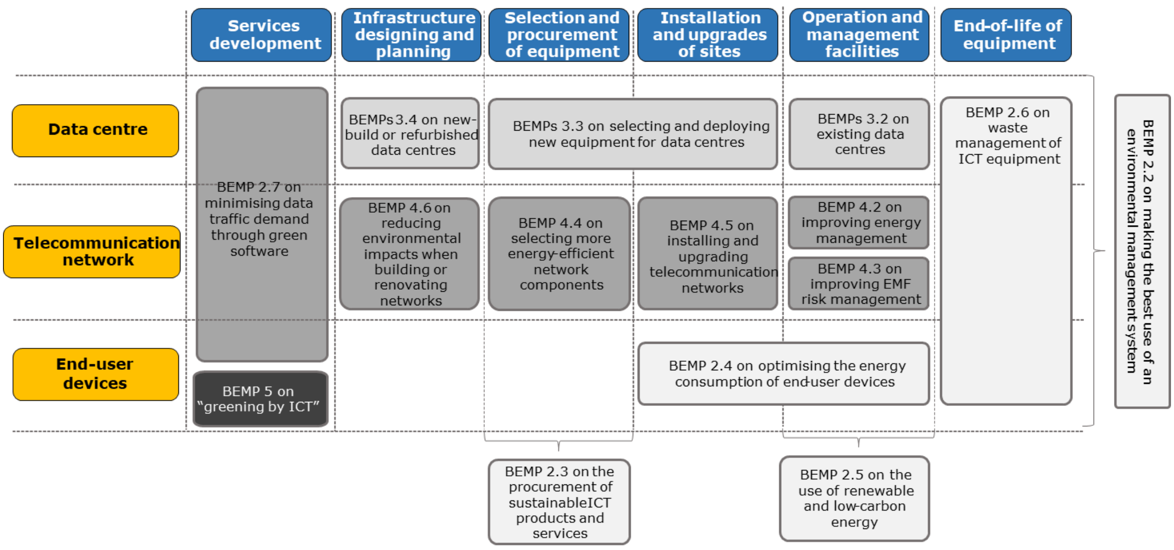

Figure 3: Overview of the BEMPs' applicability

[6] The reports from the GeSI initiative are available online at: http://smarter2030.gesi.org/

The main environmental pressure of the Telecommunications and ICT Services sector is its energy consumption and direct and indirect emission of greenhouse gases (GHG), which is 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 telecommunications facilities (power supply, cooling system, etc.), also deal 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 telecommunications infrastructures and facilities. Only certain BEMPs deal with all the environmental pressures: environmental management systems for sites and facilities and the procurement of sustainable ICT and other equipment. Finally, the BEMP on "greening by ICT" solutions is different from the other ones since it refers to the minimisation of the environmental impacts of other sectors.

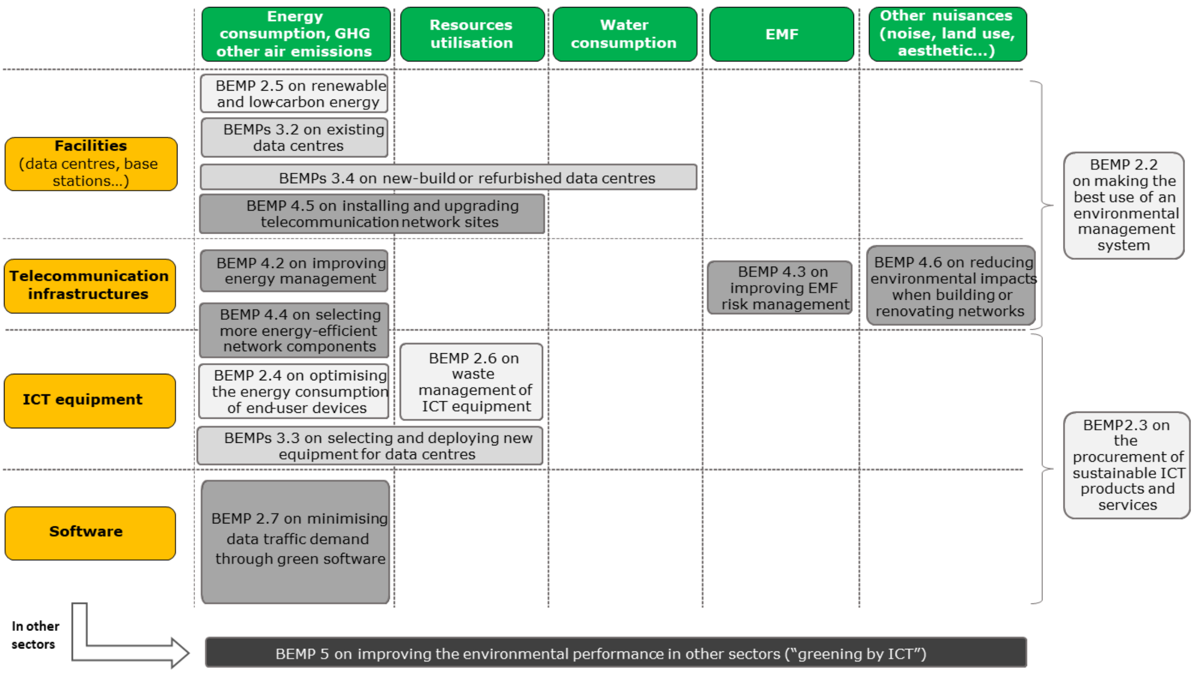

Figure 4: Overview of the main environmental aspects and impacts addressed by the BEMPs

1 Scope and overview of the sector

1.1 Scope

This section describes which organisations, and, within organisations, which ICT assets and activities, are considered, in this report, in the scope of the Telecommunications and ICT Services sector.

1.1.1 Target group

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

- **Telecommunications**: the transmission of voice, data, text, sound and video using electrical signals (both analogue and digital) using wires or cables (wired / fixed) or electromagnetic 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 telecommunications 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).
- **ICT consultancy**: the planning, designing, installing, maintaining and upgrading of ICT systems that integrate computer hardware, software and communication technologies and other professional and technical ICT-related activities.

In the statistical classification of economic activities set out in Annex I to Regulation 1893/2006/EC (NACE Rev.2), these activities are covered in Section J (Information and Telecommunication), corresponding to NACE codes 58 to 63. However, the NACE definitions and classification of the ICT sector have been subject to discussion as the sector has been developing rapidly (JRC, 2012a).

Moreover, the production of content and media products (such as film-making) that is part of those NACE codes is considered outside the scope of this report. This is also coherent with the distinction made by the OECD in its Guide to Measuring the Information Society, 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). This last element of production of content and media products is not included in the scope of this document.

It is thus more appropriate to define the scope of the Telecommunications and ICT Services sector, as considered in this report, at a finer level of NACE classification:

- Only certain subcategories of publishing activities (NACE code 58):
  - 58.21 Publishing of computer games
  - 58.29 Other software publishing
- All the subcategories 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 subcategories 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 subcategories of information service activities (NACE code 63):
    - 63.11 Data processing, hosting and related activities
    - 63.12 Web portals

In addition to this core target group, other types of organisations classified under the NACE J section but not belonging to the NACE code sections listed above can also find several BEMPs of relevance, because of their increasing digitalisation:

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

Other organisations that are classified under other NACE sections and have to manage or operate large data storage, data processing and/or telecommunication infrastructures as a vital part of their activities may also find several BEMPs of relevance. Some examples are organisations belonging to the following sectors:

- Reproduction of software (NACE code 18.20)
- Activities of call centres (NACE code 82.20)
- Architectural and engineering activities and related technical consultancy (NACE code 71.1)
- Technical testing and analysis (NACE code 71.20)
- Research and experimental development on natural sciences and engineering (NACE code 72.1)
- Libraries, archives, museums and other cultural activities (NACE code 91.0)
- as well as large organisations that store and process large quantities of data related to their clients, supply chains and/or products such as public administrations, hospitals, universities, banks, manufacturers, retailers and other service companies.

The Telecommunications and ICT Services sector as defined in this report covers only a specific part of the value chain of such services and related equipment. This choice was aimed at avoiding overlaps with other Best Practice Reports:

- The 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[7];
- The ICT retail trade (NACE code 47.1 and 47.4) can be considered covered by the Best Practice Report for the retail trade sector[8].

[7] The Best Practice Report for the electrical and electronic equipment manufacturing sector is under development and will be available online at: http://susproc.jrc.ec.europa.eu/activities/emas/eeem.html

[8] The Best Practice Report for the retail trade sector is available online at: http://susproc.jrc.ec.europa.eu/activities/emas/retail.html

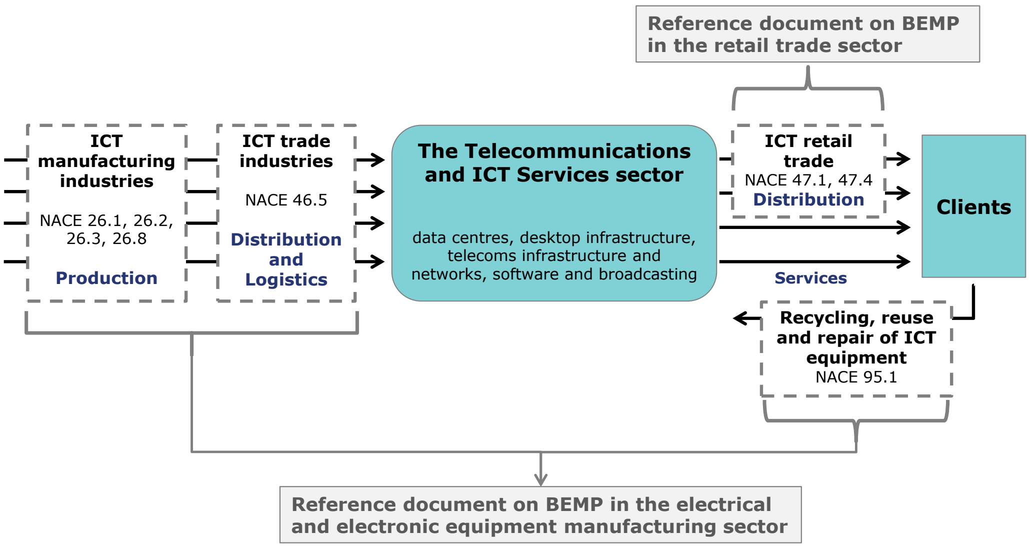

Figure 5: Coverage of the Telecommunications and ICT Services supply chain by other Best Practice Reports and related Sectoral Reference Documents

1.1.2 ICT assets covered

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

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

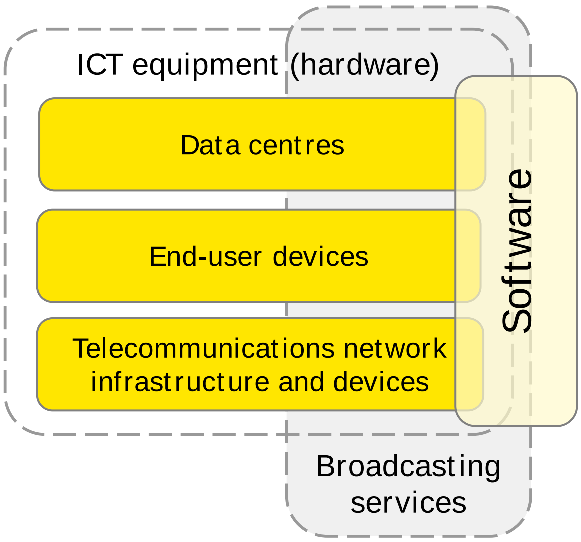

Figure 6: The main assets of the Telecommunications and ICT Services sector

What is referred to by each of these terms is further explained within the introductory sections of the chapters describing BEMPs.

1.1.3 Activities covered

This document covers the core business activities of organisations in the Telecommunications and ICT Services sector. Beyond the direct management of ICT assets, core business activities are considered to also include the relationship with key stakeholders, although limited to practices that Telecommunications and ICT Services providers can implement themselves (e.g. establishing environmental criteria during procurement of ICT equipment, providing information to customers on the energy consumption of devices provided to them).

The management of offices and general company transport are 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 provided in the document on BEMP in the Public Administration Sector[9]. No BEMP that is specific to Telecommunications and ICT Services buildings and transportation was identified in these areas.

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.

This background report distinguishes between:

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

An overview of the scope of the BEMPs for the Telecommunications and ICT Services sector is given in Figure 7.

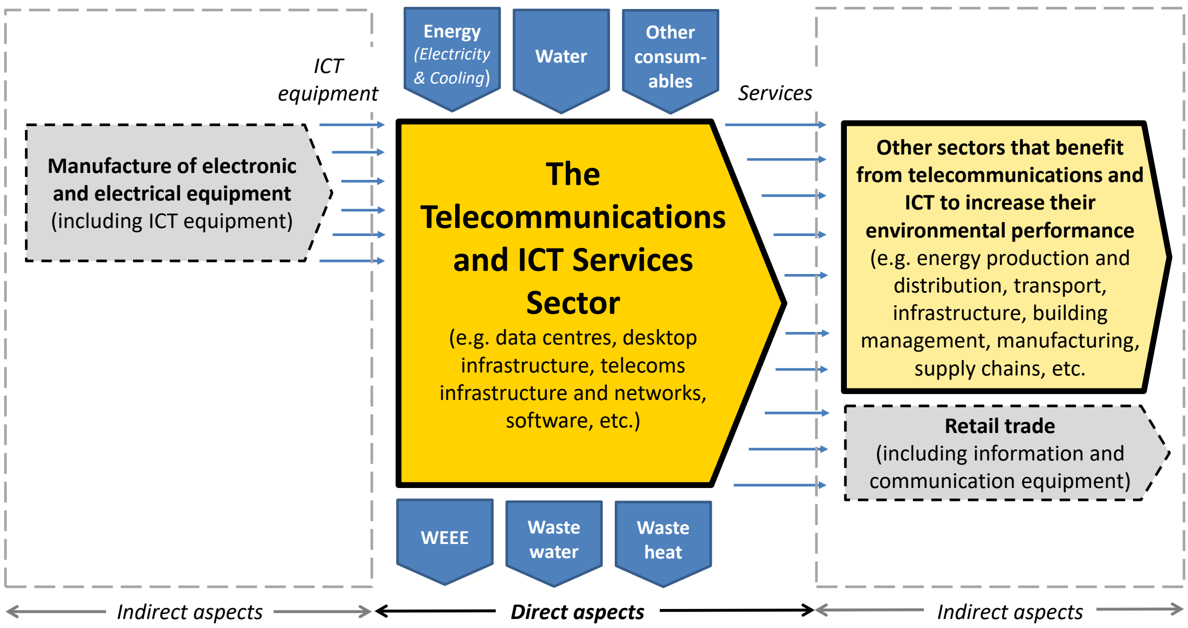

Figure 6: Overview of the scope of the document

[9] The Best Practice Report for the public administration sector is available online at: http://susproc.jrc.ec.europa.eu/activities/emas/public_admin.html

1.2 Economic relevance of the sector

The following description of the economic relevance 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 scope section above) as referring to organisations belonging to the Telecommunications and ICT Services sector were used to perform such assessments. Nevertheless, this method presents some limitations, inherent with the quality of the Eurostat database (in terms of completeness, redundancies, etc.) and with the selection of certain NACE codes.

Based on an analysis of the data available in the Eurostat database[10] for relevant NACE codes[11], 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 the total number of companies (financial sector excluded)[12];
- the sector employed more than 4 million people, i.e. 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 of the EU-28.

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).

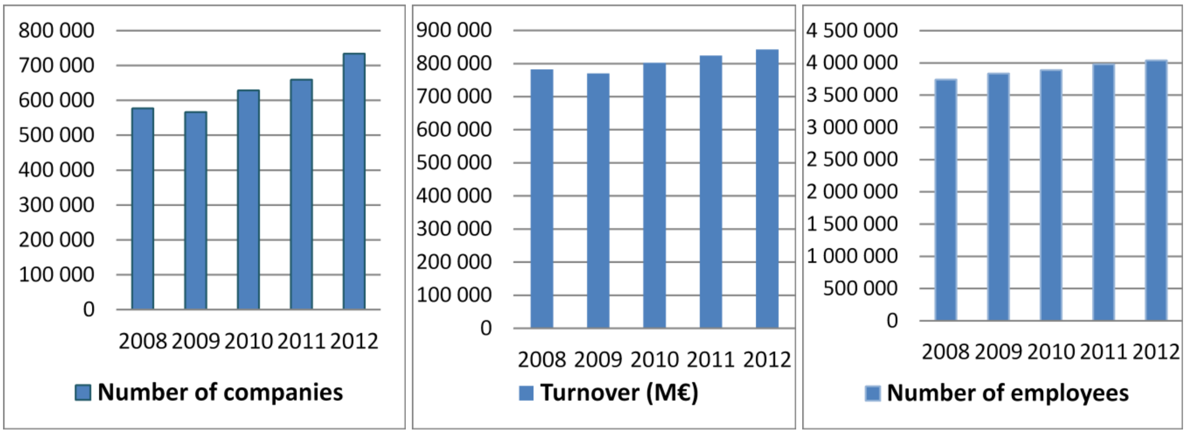

Figure 7: Evolution of the numbers of Telecommunications and ICT Services sector (Source: Eurostat, Annual detailed enterprise statistics for services)

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.

[10] 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

[11] The Telecommunications and ICT Services sector is mainly covered by Section J of the NACE classification, with all telecommunications (code 61), all computer programming, consultancy and related activities (code 62), as well as information service activities (code 63), excluding content production. Other NACE codes refer entirely to the Telecommunications and ICT Services sector: software publishing (code 58.2) and reproduction of software (code 18.20), activities of call centres (code 82.20) and installation of mainframe and similar computers (code 33.20).

[12] 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).

Table 3: 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 codes 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 on average less than 10 employees.

The Telecommunications and ICT Services sector is made up of a large majority of micro-sized firms, with 93% of the total number of companies in the sector employing less than 10 people in the EU-28 in 2012 (Eurostat, 2012b). There were around 2 000 large 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 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 represented more than 75% of all Telecommunications and ICT Services companies in the EU-28.

Beyond the size of the country, the specialisations 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 4: 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 3 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 relevance of the sector

1.3.1 Most significant direct and indirect environmental aspects

According to the 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 5). Environmental aspects are classified into the following:

- 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 direct operations of the Telecommunication and ICT Services sector only, whereas indirect aspects originate from all the other actors except Telecommunications and ICT Services providers, i.e. ICT manufacturers, wholesalers, retailers and consumers.

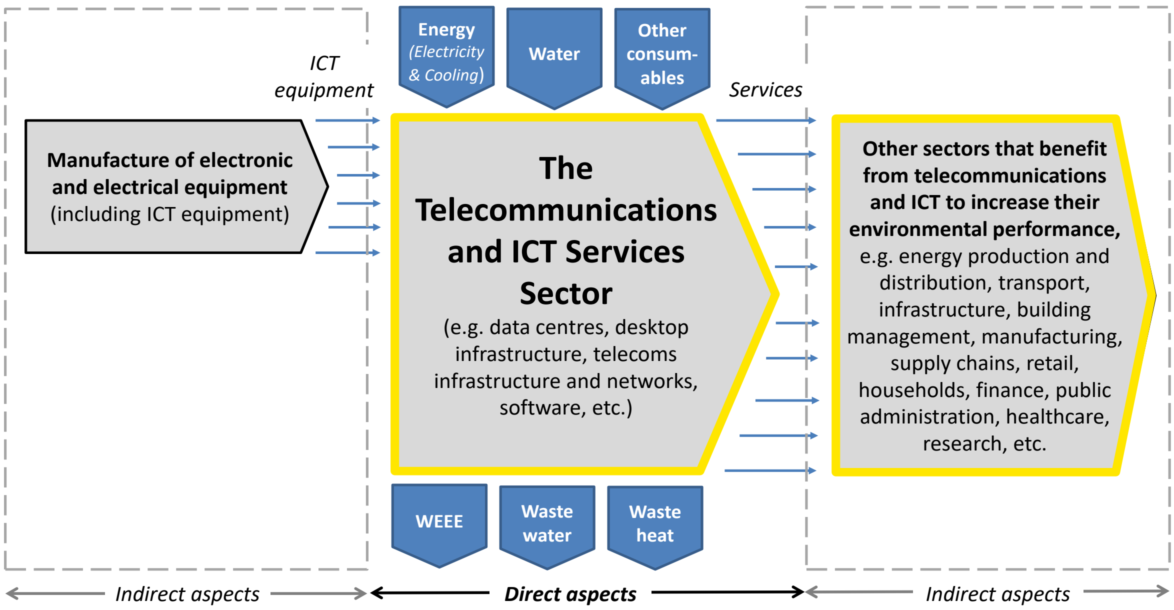

Figure 8: Overview of the environmental aspects of the sector

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[13].

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. Considering 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 focuses on result from the use of applications and ICT services, e.g.:

[13] The Best Practice Report for the public administration sector is available online at: http://susproc.jrc.ec.europa.eu/activities/emas/public_admin.html

- 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 5 lists the main environmental aspects and associated environmental pressures arising from Telecommunications and ICT Services.

Table 5: 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.) - Software (processors) - HVAC - Power supply - Buildings	- Energy and water consumption - Generation of WEEE and waste water - GHG emissions from electricity production and refrigerant leakages
End-user devices	- ICT equipment (computers, peripheral devices, etc.) - Software	- Energy consumption to power hardware - Generation of WEEE - GHG emissions from electricity production
Telecommunications infrastructure and networks	- Buildings (central offices, base stations, etc.) - Nodes (antennas, satellites, routers, etc.) - Links (cables, fibres, landlines, etc.) - Terminals (phones, computers, modems, etc.) - Software (processors, controls, etc.)	- Electricity consumption from network equipment and cooling systems - Fuel consumption related to transportation - Generation of WEEE - Electromagnetic waves generation - GHG emissions from electricity production - Changes to the landscape and habitats due to infrastructure deployment
Broadcasting services	- Buildings (base stations) - Transmitters (antennas, satellites, etc. - Links (cables, fibres, etc.) - Terminals (radios, TVs, etc.) - Software (processor)	- Energy consumption - Generation of WEEE - Electromagnetic waves generation - GHG emissions from electricity production - 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.), telecommunications networks use terminals (phones, modems, etc.) and broadcasting uses antennas. The use of ICT equipment implies similar direct environmental pressures: electricity consumption and waste 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 software that is not well designed 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 which often results in excess heat. In order to maintain a suitable working environment and ensure the integrity of the hardware, the excess heat has to be removed. Due to the density of hardware and the 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. A 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) 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 the reverse). Power supplies directly drive energy consumption, and indirectly GHG emissions (due to electricity production). This is particularly relevant for data centres and antennas 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. Telecommunications 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 (EMFs).

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 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 Main environmental pressures

The following paragraphs present the main environmental pressures that can result from the provision of Telecommunications and ICT Services. Nevertheless, the 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 gas 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 gas emissions reported by the companies of the ICT sector (NACE codes 61, 62 and 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 sector's 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 the EU-27, and resulted in 88.3 million tonnes of CO_2eq. 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 two thirds 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 device's related energy consumption is highly dependent on the way in which it is used. A significant rise in electricity consumption is expected for data centres and telecommunications networks (35% and 150%, respectively), because of increased use of the internet and cloud services.

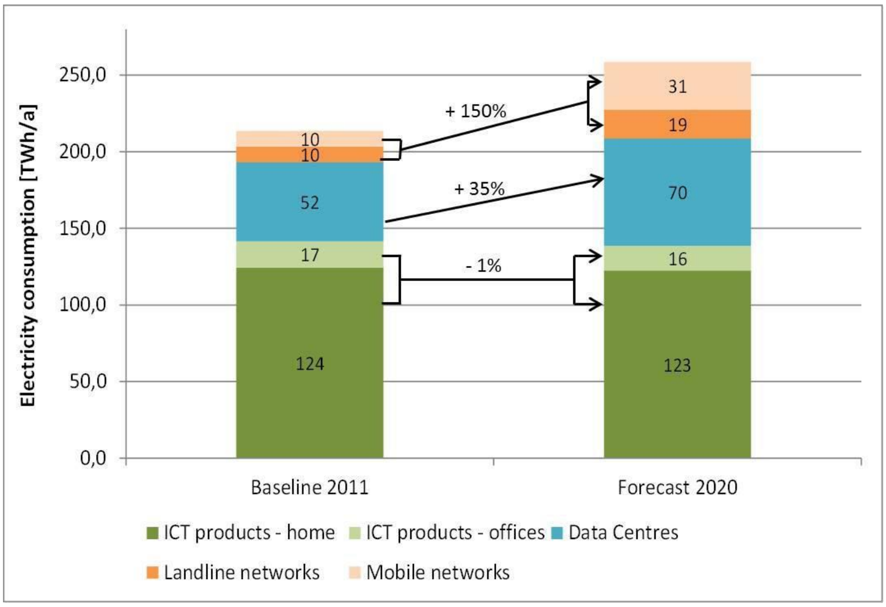

Figure 9: Comparison of the ICT-related electricity consumption in the EU-27 in 2011 and 2020, excluding ICT manufacturing and broadcasting (Source: Öko Institut, 2013)

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 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 waste IT and telecommunications equipment[14] were collected[15] in the 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.

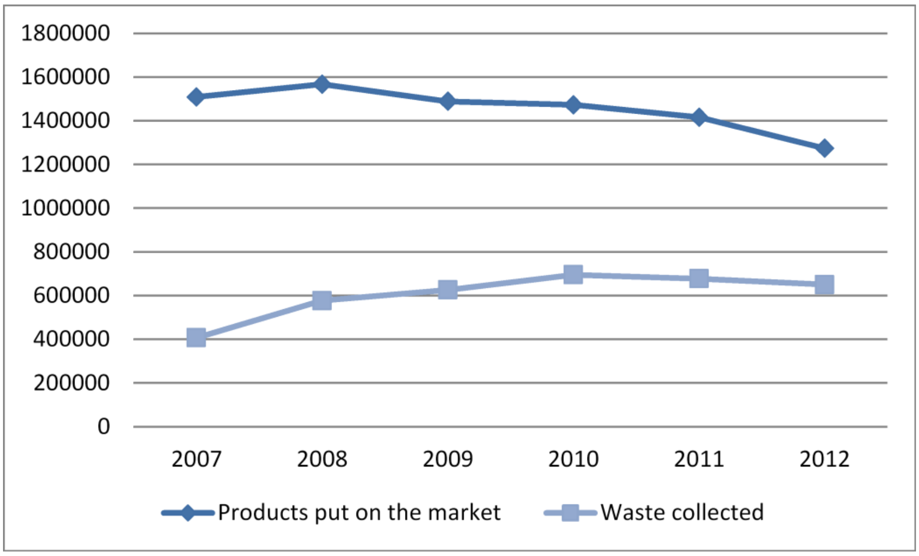

Figure 10:Evolution of IT and telecommunications equipment put on the market and collected as waste in the EU-28, in tonnes (Source: Eurostat, 2012c)

In the EU-28, most of the waste IT and telecommunications 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).[16] According to the European Commission, only one third of e-waste in the EU is reported as appropriately treated (European Commission, 2009a). The other two thirds were sent to landfills or potentially to substandard 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[17].

Water consumption and waste water 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

[14] 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.

[15] 650 871 tonnes 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).

[16] Calculation made on the basis of data given by the Eurostat database for 2012 in the EU-28, except for the United Kingdom (data related to recycling were not available).

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

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 waste water, 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 for concern for citizens and organisations. Exposure limits have been set 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[18] 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 rural contexts. The need to integrate ICT infrastructures in an urban 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 result 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.

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

1.4 Use of environmental management systems in the 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 3 700 organisations and approximately 12 500 sites are EMAS-registered in the EU-28, including many multinational companies and smaller companies as well as public authorities[19]. This study, as well as the related 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), 50 organisations were registered under the NACE codes relevant for the Telecommunications and ICT Services sector.[20] The sites registered belong to the following activity groups (NACE codes):

- 18.20 - Reproduction of recorded media
- 33.20 - Installation of industrial machinery and equipment
- 58.29 - Other software publishing
- 61.10 - Wired telecommunications activities
- 61.20 - Wireless telecommunications activities
- 61.90 - Other telecommunications activities
- 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
- 63.11 - Data processing, hosting and related activities
- 63.12 - Web portals
- 63.99 - Other information service activities n.e.c.
- 82.20 - Activities of call centres

Additionally, it should be noted that many companies are registered for more than one activity, and that different sites of the 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 Italy (18 sites) and Spain (13 sites). The other countries are Austria, Germany, the United Kingdom, Luxembourg, Portugal and Belgium.

1.4.2 Use of standards from the ISO 14000 family

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[21].

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 comprehensive 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.

[19] See the EMAS website: http://ec.europa.eu/environment/emas/index_en.htm
[20] See the EMAS register website: http://ec.europa.eu/environment/emas/register/search/search.do
[21] For more information, see http://www.iso.org/iso/iso14000.

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2 Cross-cutting BEMPs

2.1 Introduction

This chapter focuses on cross-cutting measures which could apply to all types of organisations in the Telecommunications and ICT Services sector at different levels (data centres, telecommunications 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 life cycle stages.

For BEMPs specific to data centres, see Chapter 3 and for telecommunications networks see Chapter 4.

The following BEMPs can be implemented in any type of organisation in the Telecommunications 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[22]) as well as a European scheme set by EU legislation (EMAS[23]) 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:** This 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 section 3.3 on selecting and deploying new equipment for data centres. For telecommunication networks, see BEMP 4.4 on selecting and deploying more energy-efficient telecommunication network equipment.
- **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, mobiles, 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 significantly reduces 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.

[22] For more information, see: http://www.iso.org/iso/iso14000
[23] Further information on EMAS is available at www.emas.eu.

- **Resource efficiency:** This 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 the direct control of organisations in the Telecommunications and ICT Services sector.

Table 6: Scope of BEMPs related to cross-cutting measures

BEMP	Description / Scope	Related BEMPs
2.2 Making the best use of an environmental management system	Techniques: • 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. Applicability: • Facility level (data centre, base station, etc.) • Network level • Company level Environmental aspects: • All environmental aspects (especially energy efficiency)	*Specific for energy management of data centres:* ☒ 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 services	Techniques: • Assess the existing assets of ICT equipment and the needs in the procurement process preparation. • Include in the call for tender specific environmental requirements. • 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. Applicability: • Network equipment (antennas, switching systems, etc.) • Servers and storage equipment • Personal computers (desktop and laptop) • Mobile devices (smartphones, mobiles, tablets, etc.) • ICT equipment used by customers (routers, set-top boxes) • Other peripherals (monitors, scanners, copiers, fax machines, etc.) • Power supply equipment (UPS) • Software Environmental aspects: • All environmental aspects (especially energy efficiency and raw material consumption)	*Specific for equipment and services in data centres:* ☒ Selection and deployment of equipment for data centres – see Section 3.3 ☒ Energy-efficient software – see Section 3.4.2 *Specific for equipment and services in telecommunication networks:* ☒ Selection and deployment of equipment networks – see Section 4.4

2.4 Optimising the energy consumption of end-user devices	Techniques:
	• Adopt technical solutions:
	  ○ Install appropriate devices in terms of energy performance and functionalities depending on the needs of users;
	  ○ Properly configure equipment to minimise unnecessary functionalities and power consumption;
	  ○ Perform regular energy audits to check devices configuration and powered-off devices;
	  ○ Develop power management solutions using different types of power management modes (manual, default, through software) or using dedicated devices (smart
		Specific for energy management of data centres:
		☒ Implement an energy management system for data centres (including measuring, monitoring and managing equipment) – see Section 3.2.2
		☒ Define and implement a data management and storage policy – see Section 3.2.3
		
		Specific for equipment and services in telecommunication networks:

	power strip, etc.).
	• Adopt organisational solutions:
	  ○ Assess individual user acceptance;
	  ○ Raise user awareness.
	
	<u>Applicability:</u>
	• Facility level (data centre, base station, etc.)
	• Network level
	• Company level
	
	<u>Environmental aspects:</u>
	• Energy efficiency
		⊠ Improve the energy management of existing telecommunication networks – see Section 4.2

2.5 Use of renewable and low-carbon energy	<u>Techniques:</u> • Purchase third-party green electricity. • Produce one's own electricity, either on or off site. • Store electricity on site in an efficient way. <u>Applicability:</u> • Facility level (data centre, base station, etc.) • Company level <u>Environmental aspects:</u> • GHG emissions	*Specific for data centres:* ⊠ Select the geographical location of the new data centre (Section 4.5.5) *Specific for free cooling of data centres (i.e. the use of a ground source for cooling):* ⊠ Use alternative water sources (Section 4.5.6)
2.6 Resource efficiency of ICT equipment through prevention, reuse, recovery and recycling	<u>Techniques:</u> • Develop a waste prevention plan. • Promote LCA-based eco-design through procurement. • Increase the service life and limit the obsolescence of ICT equipment. • Implement systems to enable reuse of ICT equipment. • Ensure traceable collection and proper sorting of end-of-life ICT equipment. <u>Applicability:</u> • All ICT equipment (networks, data centres, end-user devices, customer devices, etc.) <u>Environmental aspects:</u> • Raw material consumption • Waste generation • Hazardous waste	
2.7 Minimising data traffic demand through green software	<u>Techniques:</u> • Select or develop more energy-efficient software that minimises power consumption of ICT equipment while running. • 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. • 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. • Assess software environmental impacts through LCA at development phase and performance measurement (CPU, RAM and energy utilisation) at usage phase. • Refactor existing software to improve its energy efficiency. <u>Applicability:</u> • All ICT equipment (networks, data centres, end-user devices, customer devices...) <u>Environmental aspects:</u> • Energy efficiency	*Specific for equipment and services in telecommunication networks:* Improve the energy management of existing telecommunication networks – see Section 4.2

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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 Telecommunications 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 ICT 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;**
- **ensure that set objectives and action plans are part of effective company-wide environmental policies, such as an energy efficiency strategy.**

ICT components

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

Relevant life cycle 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**	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Implementation of an asset management system, e.g. certified with ISO 55001 (Y/N)
- Share of operations with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS-verified, ISO-14001-certified
- Share of 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
- Use of energy efficiency indicators (Y/N)
- WEEE generation (in kg or tonnes) per unit of turnover (€)
- Use of water efficiency indicators (Y/N)
- Total carbon emissions (in t CO_2eq) for scopes 1 and 2
- Total carbon emissions compensated (in t CO_2eq)
- Carbon emissions (in t CO_2eq) for scopes 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 • 2.6 Resource efficiency of ICT equipment through waste prevention, reuse and recycling
Benchmarks of Excellence	• The company has a global and integrated asset management system, e.g. certified with ISO 55001 • 100% of operations implement an advanced environmental management system, e.g. EMAS-verified or ISO-14001-certified • 100% of operations measure and monitor their energy use and water consumption as well as waste management • The company has achieved carbon neutrality (scopes 1 and 2), including through the use of renewable energy and carbon compensation, after having pursued all efforts to improve energy efficiency

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 organisation to reduce its environmental impacts and increase its operating effectiveness. An environmental management system can be informal internal practices as well as being based on internationally recognised standards such as the ISO standard 14001 or on the European scheme EMAS and follows the principle of continuous improvement with the Plan – Do – Check – Act cycle (Figure 11). It also provides the organisation with a framework to monitor key environmental performance indicators.

Figure 11:The principle of continuous improvement of environmental management systems through the Plan – Do – Check – Act cycle (Source: European Commission, 2016)

The main objectives of an EMS are the following:

- reviewing the organisation'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 the progress in achieving the objectives;
- ensuring employees' environmental awareness and competence;
- reviewing the progress of the EMS and making improvements.

The implementation of EMS in organisations in the Telecommunications and ICT Services sector helps reduce 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 of vehicles of the organisation, can also be taken into account.

The main environmental impact of organisations in the Telecommunications 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, a general EMS allows other impacts such as waste generation and water consumption to be taken into account at the same time.

Other related ISO standards are as follows:

- 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 organisational level for the quantification and reporting of greenhouse gas (GHG) emissions and removal.

Other standards, such as the 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 it applies at site or company level. It is based on an iterative sequence that 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.

In Telecommunications and ICT Services organisations, it is best practice to do the following:

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

  It involves 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;
  - encouraging employees and customers to change habits when using ICT equipment.

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

  The analysis of the monitoring process and the benchmarking of best practices help define action plans and objectives. Moreover, this report on BEMP in the Telecommunications 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 the best practices to implement for different ICT assets (End-user devices in BEMPs in Chapter 2, Data centres in BEMPs in Chapter 3**,** Telecommunication networks in BEMPs in Chapter 4) and to position the company's performance for each solution with a view to setting objectives and an action plan for achieving them.

- **Ensure that the objectives and actions defined for managing ICT-related impacts are part of effective company-wide environmental policies, such as an energy efficiency strategy.**

  An EMS covers a company (or site) in its entirety. Managing and minimising the environmental impacts related to ICT operations within the framework of a general EMS ensures that the objectives and action plans developed to address such impacts are coherent and well integrated in effective company-wide environmental policies, such an energy efficiency strategy. For instance, it would be much more effective to consider actions to improve the energy efficiency of ICT assets at the same time as actions to improve the overall energy efficiency of the company or site (building envelope, general HVAC system, etc.).

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 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 Telecommunications and ICT Services sector defined in Chapter 4, the environmental benefits cover the following:

- **Energy use 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, on 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 (in particular due to external temperature conditions) 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 multifunctional devices (such as printers that also make copies, faxes and scans) will also impact the energy consumption. One multifunctional device consumes 50% less energy than four separate 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 equipment on the customer's premises to 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 the 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 a 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):
  - Use of energy efficiency indicators (Y/N), e.g. based on energy used per network traffic or other relevant measures.
  - WEEE generation (in kg or tonnes) per unit of turnover (€) to analyse the waste management system performance.
  - Use of water efficiency indicators (Y/N).
  - Total carbon emissions in t CO_2eq for scopes 1 and 2.
  - Total carbon emissions compensated in t CO_2eq, e.g. through Clean Development Mechanisms (CDM). The best practice is to be carbon-neutral, including green electricity and compensation. Front runners like KPN

and Telenet mobile telecommunications companies reach carbon neutrality by using about 90% green electricity and 10% compensation projects.
    - Carbon emissions in t CO_2eq for scopes 1 and 2 per unit of turnover (€);

- Process-oriented indicators (measures the implementation of environmental management):
    - the implementation of an asset management system, e.g. certified ISO 55001;
    - the share of operations with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS-verified, ISO-14001-certified;
    - the share of operations measuring and monitoring energy use and water consumption as well as waste management;
    - the share of staff having been 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 account the needs and specificities of the 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 disposing of 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

Front runner organisations have third-party-certified or -verified environmental management systems such as EMS based on ISO 14001[24] 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.[25] 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.

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 collection 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 the types of equipment, the 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

[24] ISO 14001 was revised in 2015. For more information on ISO 14001, see http://www.iso.org/iso/iso14000.
[25] Available at http://ec.europa.eu/environment/emas/documents/StepUp_1.htm

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 2.7).

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 do the following:

- **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 has 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 7). 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 to try 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 7: Application and cost comparison of different types of electrical meter devices used in data centres (Source: Kidd & Torell, 2013)

Type of meter	Applications	Installed cost per meter*
Power quality meters	• Power quality monitoring • Electric utility bill verification • Power circuit loading & balancing • Energy management • Maintenance activity support	€4 500 – €10 000***
Power meters	• Power circuit loading & balancing • Energy management • Cost allocation / billing • Maintenance activity support • Critical incident alarming	€500 - €3 000
Digital relay embedded meters**	• Protective device for medium-voltage equipment • Power circuit loading & balancing • Maintenance activity support • Critical incident alarming	~€1 000
Electronic trip unit embedded meters**	• Protective device in low-voltage circuit breakers • Power quality monitoring • Power circuit loading & balancing • Energy management • Maintenance activity support • Critical incident alarming	€500 - €11 600

Uninterruptible power supply (UPS) embedded meters	• Engineering data support • PUE monitoring • Critical incident alarming	Included in UPS price
Power distribution unit (PDU) embedded meters	• PUE monitoring • Management of power capacity • Cost allocation • Critical incident alarming	Included in PDU price
Rack PDU embedded meters	• Most accurate "IT load" measurement per Green Grid • Load balancing • 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 (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 an environmental management system is the staff involvement (IT2Green, 2014), but also that of customers. For example, BT has an ambition to help its 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 an action plan must be determined. Measurement and monitoring of environmental performance helps to determine objectives. Benchmarking sectorial performance levels also supports the establishment of relevant objectives compared to competitors and best practices. Objectives shall be determined over different time frames: short-term, mid-term and long-term objectives.

Table 8 shows examples of benchmarks on targets that major telecommunications 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 8: Examples of energy and carbon targets set by major telecommunications 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 (2010/2025)	Carbon-neutral in 2015, including compensation (achieved)	Save as much energy with our products as our own energy consumption in 2020
Vodafone	-		Reduce CO_2 emissions by 50% against the 2006/07 baseline by March 2020 for mature markets Reduce CO_2 per network node by 20% against a 2010/11 baseline by March 2015 for emerging markets[26]	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 set-up 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 be worth investing further in 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 the 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 staff become familiar with their obligations.

The main economic benefit of environmental management is increased profitability, due to lower costs in energy, water or waste combined with increased turnover. 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%.

Table 9: 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

Note: 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).

[26] Objective achieved with a reduction of 28% against the 2011 baseline.

- 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**[27] 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[28] (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;
- 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, 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 decision. 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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[27] For example, the wiring regulation in the UK requires all equipment using 16A or more to be monitored individually.

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2.3 Procurement of sustainable ICT products and services

<table>
<tr><td colspan="6">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 specific environmental requirements;
provide training and guidance to end users when deploying ICT solutions so they can make the best use of the products and services;
establish energy and environmental performance criteria for ICT equipment provided to customers to help them reduce their environmental impact.</td></tr>
<tr><td colspan="6">ICT components</td></tr>
<tr><td>Data centre</td><td colspan="2">Telecommunication network</td><td>Broadcasting</td><td>Software publishing</td><td>End-user devices</td></tr>
<tr><td colspan="6">Relevant life cycle stages</td></tr>
<tr><td>Design and installation</td><td colspan="2">Selection and procurement of the equipment</td><td>Operation and management</td><td>Renovation and upgrades</td><td>End-of-life management</td></tr>
<tr><td colspan="6">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource consumption</td><td>Emissions to air</td><td>Water use & consumption</td><td>Noise and EMF emissions</td><td>Landscape and biodiversity</td></tr>
<tr><td colspan="6">Environmental indicators</td></tr>
<tr><td colspan="6">Share of products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, top class energy label, Energy Star, TCO-certified etc.)
Use of total cost of ownership as a criterion in calls for tenders (Y/N)
Share of equipment purchased by the company complying with internationally recognised 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 weight 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 end users</td></tr>
<tr><td colspan="6">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="5">N/A</td></tr>
<tr><td>Related BEMPs</td><td colspan="5">2.2 Making the best use of an environmental management system
3.3.2 Selection and deployment of environmentally friendly equipment for data centres
4.4 Selecting and deploying more energy-efficient telecommunication network equipment</td></tr>
<tr><td>Benchmarks of Excellence</td><td colspan="5">All ICT equipment purchased by the company is labelled with the ISO Type I ecolabel (e.g. EU Ecolabel, Blue Angel) (if available) or Energy Star label, or EU Green Public Procurement criteria (if available) are applied in its procurement
All broadband equipment purchased by the company meets the criteria in the EU Code of Conduct on broadband equipment
100% of the packaging purchased by the company is made from recycled material or was awarded the Forest Stewardship Council label
10% of the bid weighting is dedicated to environmental performance when purchasing ICT equipment
100% of products and services provided by the company have related environmental information available to end users
Use of total cost of ownership as a criterion in calls for tenders</td></tr>
</table>

2.3.1 Description

The definition of a policy regarding the procurement of sustainable ICT products and services is the first step towards optimising environmental performance in ICT equipment, based on an environmental strategy established and supported at the highest level of the company (see previous BEMP). 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 the 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 reuse, 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 in the 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 the upstream and downstream supply chain of ICT companies.

It is best practice to do the following:

- **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 technology according to 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 specific environmental requirements.**

It can include required environmental criteria for the supplier 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 materials used, functionalities included, and services included 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 life cycle. 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 labels can be used to benchmark the energy performance of ICT equipment.

During procurement a total cost of ownership (TCO) approach may be taken. Besides the initial purchase cost, other factors might be of relevance. For the case of larger and energy-hungry equipment (like infrastructure equipment, etc.) energy consumption during the use phase has a significant impact on TCO. Telecom operators have a good knowledge of the energy consumption and related cost of the equipment operated under their supervision. Energy costs are today a large part of telecom operating expenditure (around 15% of European cellular network operators' OPEX is related to energy costs). Many operators therefore request, in addition to the usual telecom performance data, energy consumption information for the equipment they purchase.

It is also possible to go beyond and include expected energy consumption figures when contracting products or services; if under expected load conditions the specified energy consumption is exceeded, a contractual penalty for non-performance is charged.

- **Provide training and guidance to end users when deploying ICT solutions so they can make the best use of the products and services:** 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 training 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 centre equipment and network equipment. The following table shows the different procurement options by type of ICT equipment.

Table 10: 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 the environmental performance of equipment • Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as Energy Star • Include energy consumption guarantees when contracting • Select equipment that has extended operating temperature and humidity ranges that allow use of free cooling • Select equipment with power management features and that allows external control of energy use • Select equipment suitable for the data centre airflow direction • Select equipment with power and inlet temperature reporting capabilities • Purchase products that are easily repairable or recyclable with less hazardous materials • Purchase renewable energy sources	• Energy consumption (and CO_2 emissions) • Material consumption and waste management • Toxicity
	Power supply equipment	• Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as Energy Star[29] or following the EU Code of Conduct[30] for external power supplies and Uninterruptible Power Systems (UPS)	• Energy consumption (and CO_2 emissions)

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

[30] The European Code of Conduct for Energy Efficiency in Data Centres 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
		• Select equipment containing high efficiency AC/DC power converters (rated at 90% power efficiency)	
	Cooling system equipment	• Select appropriately sized cooling units • Select more energy-efficient equipment such as: ◦ chillers with a high coefficient of performance ◦ equipment with variable speed (or frequency) controls for compressors, pumps and fans ◦ direct liquid-cooled devices • Select equipment that uses natural refrigerants or with low ozone-depleting potential	• Energy consumption (and CO_2 emissions) • Ozone-depleting substances and GHG emissions (from refrigerants)
	Air handling equipment	• Select appropriately sized air handling units • Select more energy-efficient equipment such as equipment with variable speed (or frequency) controls for fans	• Energy consumption (and CO_2 emissions)
Telecom-munication network	Cabling	• Select cables that minimise transmission losses • Select chlorine- and halogen-free cables and those with insulation that does not produce dioxins if burnt	• Energy consumption (and CO_2 emissions) • Significant pollution 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 the environmental performance of equipment • Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as EU Ecolabel[31] and Energy Star or follow the EU Green Public Procurement Criteria for Office IT equipment[32] • Lease products or require take-back services • Purchase products that are easily repairable or recyclable with less hazardous materials (brominated flame	• Energy consumption (and CO_2 emissions) • Material consumption and waste management • Toxicity

[31] Refer to section 2.3.5 on Operational data.

[32] 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.

Type of facility	ICT equipment	Procurement options	Environmental hotspots
		retardants, mercury and lead) • Purchase packaging made from recycled material or that has been awarded the Forest Stewardship Council label[33]	
	Mobile devices (smartphones, mobiles, tablets)	• Benchmark the environmental performance of equipment • Select more energy-efficient equipment • Lease products or require take-back services • Purchase products that are easily repairable or recyclable with less hazardous materials	• Energy consumption (and CO_2 emissions) • Material consumption and waste management • Toxicity
	Other peripherals: printers, monitors, scanners, copiers, fax machines	• Benchmark performance of the environmental performance of equipment • Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as EU Ecolabel and Energy Star or follow the EU Green Public Procurement Criteria for Office IT Equipment or Imaging Equipment • Lease products or require take-back services • Purchase of multifunction products (e.g. printer/copier/scanner/fax) so as to minimise the number of pieces of equipment • Promote paperless activities and cloud printing • Purchase products that have low power/sleep modes • Purchase products that are easily repairable or recyclable with less hazardous materials	• Energy consumption (and CO_2 emissions) • Material consumption and waste management • 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 services 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 the ICT equipment.

Selecting energy-efficient ICT equipment is expected to primarily reduce the **direct energy consumption** of 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 3 years when the market share of qualified products reaches about 35% (Aebischer and Hilty, 2014).

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

Assessing the impact of energy label programmes is difficult since technology evolves rapidly and the market has seen significant growth. However, energy label programmes 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 a reduction in 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 CO_2 emissions by 47%.

Other environmental criteria besides energy efficiency have different environmental benefits. Criteria on the **reduction of the use of hazardous substances** and chemicals help reduce the use of toxic materials. 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 reductions in the primary materials used and water consumption.

The different environmental benefits can be listed as follows (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 12: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 Star, TCO-certified).
- Share of equipment purchased by the company complying with internationally recognised best practices or requirements (e.g. EU Codes of Conduct).
- Use of total cost of ownership as a criterion in calls for tenders (Y/N).
- Share of packaging purchased by the company made from recycled materials or awarded the Forest Stewardship Council label.
- Share of the weight given to environmental criteria in calls for tenders. Environmental criteria cover overall environmental policy, energy efficiency, CO_2 limitation, natural resource use and eco-responsible design measures. The best practice is to dedicate 10% of the bid score to environmental performance when purchasing ICT equipment. (For an example, see European Commission, 2016).
- Share of ICT products and services provided by the company to customers for which environmental information is available to end users.

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). The best practice is to ensure that all suppliers with a high environmental impact have 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 encourages 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 between 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 life cycle 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-of-life management implemented. Programmes 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 may use 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 those certified with 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 in environmental performance.

2.3.5 Operational data

This section covers operational data and implementation techniques at each procurement level introduced in Section 1.2.

The European Commission Green Public Procurement criteria are a useful reference to facilitate the inclusion of green procurement criteria 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 services is a crucial step to avoid all unnecessary purchases and cross-media effects. Renewing ICT equipment and workstations should not be proceeded with systematically but ought to 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 the overall environmental performance of the ICT equipment can take into account different criteria (Orange, 2016):

- CO_2 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 resources:
  - 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 conversion system.

While selecting IT equipment for data centres, 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 end user utilisation. It can be based on the evaluation of the end 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 specific environmental requirements

<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 office components). The assessment of needs will help determine the criteria necessary for the optimal use of the ICT equipment.

Technical criteria can be set on the following:

- 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 with 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 by 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 must 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 the environmental performance of IT equipment can be more specific for data centre 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 conversion 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 aim for:

- DSL network equipment (ADSL2 and VDSL2),

- Optical Line Terminations (PON and PtP),

- Interfaces (with narrowband network equipment),

- Cable equipment (I-CMTS, M-CMTS).

The Horizon-2020 EURECA project examined procurement practices for data centres and also assisted in the preparation of actual tenders to include sustainability criteria (EURECA, 2016).

<u>Using EU Ecolabels and energy labels as tools to achieve better environmental performance</u>

The benchmark of the existing technologies on the market can help determine the level of environmental performance required. The identification of environmentally well-performing products can be made by referring to the different ecolabels. The International Organisation for Standardisation (ISO) classifies 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 standpoint as it is 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).[34] 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.

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

- 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. The 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, was established in 1989 by the Nordic Council of Ministers to provide an 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/).
- **TCO-certified**[35] 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's 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-of-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 11: Ecolabel comparison (Source: 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

35 From the name of the organisation that initially developed it, the Swedish Confederation of Professional Employees (Tjänstemännens Centralorganisation). Not to be confused with total cost of ownership.

Table 12: European Ecolabel criteria for electronic equipment (Source: 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 13: Comparison of the key non-energy Ecolabelling criteria for ICT office equipment (Source: 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 labels can be used to benchmark the 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.) helps customers to choose a 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 that apply 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 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 Codes of Conduct, 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** the environmental performance of products or services:
    - Vendors can display the environmental performance 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 relies not only 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 the purchasing cost. These costs are evaluated over the expected useful lifetime of the product. The different costs may be handled 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 user awareness is important to ensure the proper use of the ICT equipment.
- External deployment: through communication and environmental criteria display, and a 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 telecommunications sector can ensure that they offer products which meet specific environmental criteria to help customers improve their environmental footprint. The selection of the product can be integrated into 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 the mobile life cycle as follows:

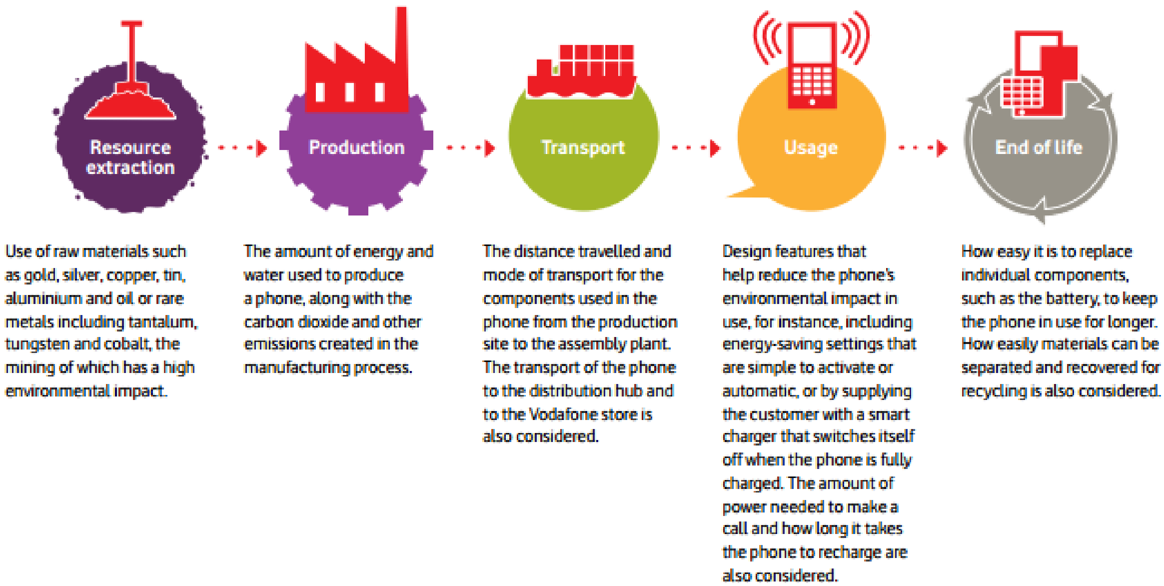

Figure 13:Mobile phone life cycle stages (Source: Vodafone)

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

- **Select energy-efficient products:** the main challenge regarding mobile phone energy efficiency is to improve battery performance and reduce the energy consumption during standby mode (refer to Chapter 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 cornstarch or glucose, which are 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 using special screws. Preventing those elements will prevent planned obsolescence. Some combinations of materials are difficult to recycle. The variety of different plastics used in ICT equipment makes plastic recycling particularly difficult. The goal is to minimise the 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, so 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 greater use of universal equipment (e.g. chargers, modems), in order to reduce the need for new products and parts.
- **Implement virtualised solutions**: Telecom operators can propose virtualised set-top boxes to their clients, to replace hardware equipment. Such a shift aims at reducing material consumption (1.8 kg per end user according to Deutsche Telekom) and CO_2 emissions (20.44 kg of CO_2 saved per year according to Deutsche Telekom).

Environmental criteria can be set on the IT equipment service that providers offer to customers. In 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.

Product ratings can be based on the different stages of the product life cycle. The rating requires that the telecommunications company works with the manufacturers to obtain the information needed to carry out the evaluation. No global methodology has been developed but some telecommunication companies have established their own methodologies. The eco-rating scheme primarily aims at providing customers with environmental information to help them make more sustainable choices, but it also improves the sustainability throughout the supply chain. It encourages manufacturers 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 baselines 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 the ADEME environmental impact analysis and reviewed by the consulting firm Bio Intelligence Service. Vodafone's questionnaires to manufacturers are verified by two independent third parties, BUREAU VERITAS and SKM Enviros. The best practice is to cover all products and services with environmental information available to customers. For instance, 100% of Orange mobile phones have an environmental score.

Telecommunication companies can also use ecolabels to communicate the environmental performance of products. LCA and other tools can be used to better inform customers of the environmental impacts of the products they purchase (e.g. PEP ecopassport (http://www.pep-ecopassport.org/)). When communicating on these issues, care should be taken 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 customers of 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 for 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 14: 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 yet totally reliable. However, it may be feasible to do so 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 life-cycle benefits. As specified in the previous section 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.

Table 15: IT equipment CAPEX and OPEX (Source: PrimeEnergyIT, 2012)

CAPEX	OPEX
• IT hardware purchase and installation • Software licenses and installation	• IT equipment energy costs • IT equipment maintenance • Software operation and maintenance • IT operation

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

Table 16: Indication of costs and benefits for procurement options

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 pieces of equipment purchased To be defined	Replace 5 000 computers and monitors with ENERGY STAR qualified products and activate power management (EPA, 2011): • USD 290 21 (EUR 255 000) • USD 663 428 (EUR 583 000)
Using other specific criteria	Man hours	Depends on the number of pieces of equipment purchased	NA

Bid evaluation	Man hours	NA	NA
Deploying ICT devices			
Internal deployment: training and raising awareness of users	Man hours Requires the involvement of managers	Investment in training sessions	NA
External deployment: communication and environmental criteria display, scorecard display	Man hours Requires the involvement of managers	Marketing and communication costs	NA

2.3.8 Driving force for implementation

- **Economic benefits for the company from product and service rationalisation**: energy cost savings and life-cycle cost savings are the main drivers 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 for an assessment process and the benchmarking of products. It will also lead to a decrease in maintenance costs. Energy-efficient products have longer productive lifetimes than less efficient products. Use of the former helps reduce the number of times a product needs to be replaced.
- **Demand for capacity increase** drives the replacement 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 a formal process for reviewing suppliers' offers. This can respond to potential regulations on due diligence.

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 the following:
  - Telefonica (Spain).
  - Telecom Italia (Italia).
  - Deutsche Telekom (Germany): the company put in place a supplier development programme 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 score. Measures implemented with the suppliers in this programme helped save 160 000 metric tonnes of CO_2 in 2 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 UK's Environmental Association for Universities and Colleges published guidance relative to sustainable ICT procurement for institutions (EAUC, 2011), which is followed by many academic institutions.
- 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 has certified seven IBM Power® servers and three storage machine types to the Energy Star requirements (IBM, 2015).

2.3.10 Reference literature

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2.4 Optimising the energy consumption of end-user devices

SUMMARY OVERVIEW:

There is large potential to reduce the energy consumption of end-user equipment used within the offices and facilities of Telecommunications and ICT Services companies thanks to specific power management measures. It is best practice to do the following:

- **Adopt technical solutions:**
  - **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 user awareness.**

ICT components

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

Relevant life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental indicators

- Energy use of offices (kWh) per unit of turnover or number of workstations or employees working on site (excluding HVAC and lighting if possible)
- Share of end-user ICT devices having been configured on installation at optimal power management
- Share of end-user ICT devices audited on power management at an appropriate frequency (e.g. yearly, only once during the lifetime of the product)
- Share of staff trained at least once on energy savings

Cross references

Prerequisites	The implementation of power management depends on: • the leadership commitment to support overall energy savings objectives • the implication of the staff • the size of the company
Related BEMPS	• 2.2 Making the best use of an environmental management system • 2.3 Procurement of sustainable ICT products and services • 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment) • 3.2.3 Define and implement a data management and storage policy • 4.2 Improving the energy management of existing networks
Benchmarks of Excellence	• All end-user ICT devices are configured on installation at optimal power management • All end-user ICT devices have been audited on power management at least once during their lifetime • All staff have been trained at least once on energy savings

2.4.1 Description

There are substantial opportunities to achieve energy and cost reductions from existing equipment by managing its energy performance and adjusting its settings and optimising its 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 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 section focuses on the use of the ICT equipment of end users[36] 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 the ICT field regarding office equipment. Studies show that, within the scope of office equipment, printers and copiers consume as much electricity as computers (Aebischer and Hilty, 2014).

This BEMP develops different solutions to optimise the energy consumption of end users' ICT equipment.

It is best practice to do the following:

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 specialists.
- 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 user 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 multifunctional devices will also impact energy consumption. One multifunctional device consumes 50% less energy than four separate devices (Buy Smart +, 2012).

Standby mode and switch-off constitute the main areas with potential for 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. This behaviour results in the generation of about 700 000 tonnes of CO_2 emissions (World Economic Forum, 2009).

[36] In this section, end user is used to refer mainly to the organisation's employees; however the solutions described here also apply to end users located outside company premises (e.g. customers), which is covered more broadly in the "greening by" (Chapter 5) BEMP.

Evenings 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 the 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 the 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 lighting if possible) in kWh, compared to the turnover or number of employees.

From a more organisational and managerial point of view, other performance indicators can be put in place regarding the following:

- Energy use of offices (kWh) per unit of turnover or number of workstations or employees working on site (excluding HVAC and lighting if possible).
- Share of end-user ICT devices that have been configured on installation at optimal power management. For instance as a best practice, Orange (Orange, 2015) is finalising 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 at an appropriate frequency (e.g. yearly, only once during the lifetime of the product)
- 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 consumption, related to a more frequent renewal of ICT devices;
- hazardous pollution, related to an inappropriate end-of-life management of replaced ICT devices.

A 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 cause 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 the 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 are 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. This ultimately results in energy consumption optimisation (IT2Green, 2014):

- modern energy-efficient 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 an energy-efficient 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 installation is critical to optimise energy consumption. The configuration of the equipment shall be set to the lowest energy factor possible. Appropriate peripherals shall be set such as energy-efficient Ethernet.

To ensure proper configuration, installation 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 configuring them in energy-efficient modes:

- synchronise updates of always-on applications (such as emails), since a parallel network access consumes less energy than multiple separate accesses;
- automatically turn off positioning information when unnecessary (for smartphones, tablets, etc.);
- detect and delete energy-greedy bugs and malware.

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

Perform regular energy audits

- Check powered-off devices after working hours. Software can be used to log which desktops are powered on (SEAI, 2013).
- Run desktop power management audits 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 a topical issue:

- Energy requirements for computers or other peripherals are sometimes 10 times greater when turned on compared to standby mode (Buy Smart +, 2012)
- Printers, fax machines, copiers and multifunctional devices consume a significant amount of energy while in standby mode, while no energy is necessary when turned off. The total amount of energy consumed overnight by such a peripheral not being switched off is equal to or above the energy consumed on a typical day. Other devices consume electricity even after being turned off.

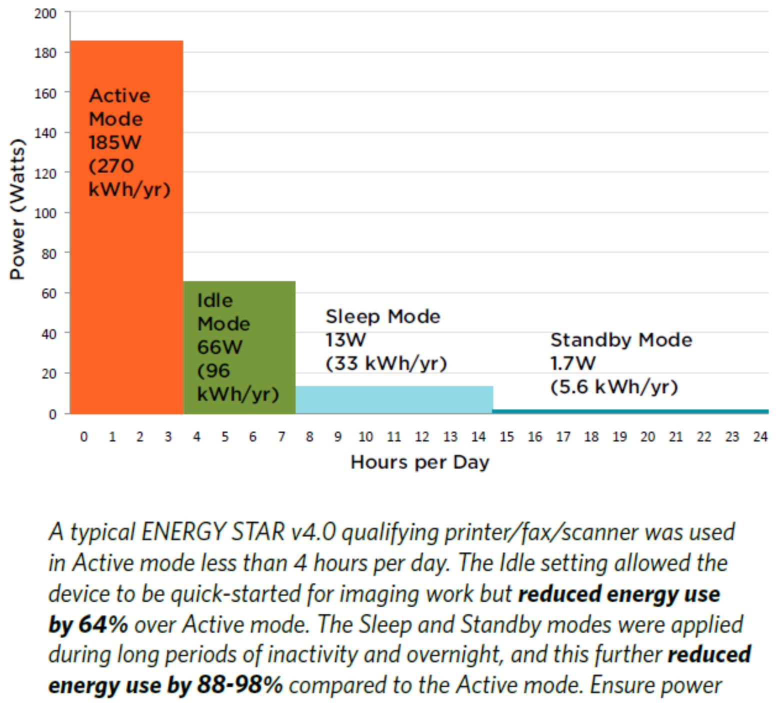

Figure 14:Power use in a typical multifunctional peripheral in different power modes (Source: New buildings institute, 2012)

- To manage the 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 physically turning to low power mode or switching off equipment (screen, laptop, smartphone, etc.). Manual power management relies more on educating staff. An ongoing education programme and reinforcement can help achieve significant energy savings through power management (Bray, 2006).
- Use of default modes: default modes for switching to power-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 the network (Aebischer and Hilty, 2014). Theoretically, automatic power management reaches 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 into computers' USB port can help reduce 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).
- A 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. The computer is 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, 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 into 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 in can automatically turn off or on in response to physical presence. The user can define a period of time to elapse before the device responds.
    - 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 determine 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 saving energy.

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 to the acceptance of power management.

The user's acceptance is improved by adequate communication about the power management policy. Organisational solutions can be considered to help the integration of power management in an organisation.

Raise user 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 (as well as for mixed use, e.g. bring-your-own-device – BYOD – policy):

- 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 power management 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 policy, an educational programme can be run. The staff can also be motivated through questionnaires to ask employees their opinions and 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 utilisation. 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-energy office building: NREL's research support facility, 2011). Better space planning and evaluation of requirements can help optimise the overall number of devices needed and therefore the electricity consumption related to those devices, especially while idle.

Centralisation of shared multifunctional 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 focus on educating staff.

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

In addition, it is also relevant to raise employees' awareness on the data processing and energy consumption impact of software and applications, as periodically removing unused software for example can improve computer utilisation and performance.

2.4.6 Applicability

Implementing power management depends on the leadership commitment to support overall energy savings objectives and environmental performance. It is also dependent on the willingness 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 and the procurement department must exchange information.

The applicability of the different techniques detailed in Section 1.3.5 depends on the company size:

- Small to medium-sized companies rely more on employees to set up their own computers. Manual power management requires each user to physically turn off their computer or put it into low power mode. It relies on educational programmes and communication. It is harder to reach a consistently 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 is less likely to be implemented in SMEs. However, the use of controlling devices to set up directly on devices (like a smart power strip) applies 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 EUR 8 to EUR 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 into computers' USB port cost around EUR 17 whereas a smart power strip costs between EUR 25 and EUR 30 (IREC, 2012).

To calculate accurate cost savings, the payback time shall be calculated for the energy-saving 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 in competitiveness, in particular against a trend of increasing energy prices;
- the improvement of personal motivation;
- the improvement of the company's image and reputation.

2.4.9 Reference organisations

The review of sustainability front runners in the ICT and telecommunications sector allowed the identification of reference organisations on energy efficiency and power management:

- Orange (Orange, 2015) is finalising for all European countries the deployment of consumption measurement tools for office and IT equipment. While 40% of equipment was formerly 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 a 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	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 (%) • Renewable Energy Factor (REF) according to EN 50600-4-3 • Carbon Usage Effectiveness (CUE) = CO_2eq emissions from the energy consumption of the facility (kg CO_2eq) / total ICT energy consumption (kWh) • Carbon content of the energy used = CO_2eq emissions from the energy consumption of the facility (kg CO_2eq) / total energy consumption (kWh)					
Cross references					
Prerequisites	• Depends on the geographical location of the facility and its size				
Related BEMPS	• 3.4.4 Design of the data centre building and physical layout • 3.4.5 Selecting the geographical location of the new data centre • 3.4.6 Use of alternative sources of water				
Benchmark of Excellence	• 100% of electricity used is from renewable energy sources (either purchased or produced on site)				

2.5.1 Description

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

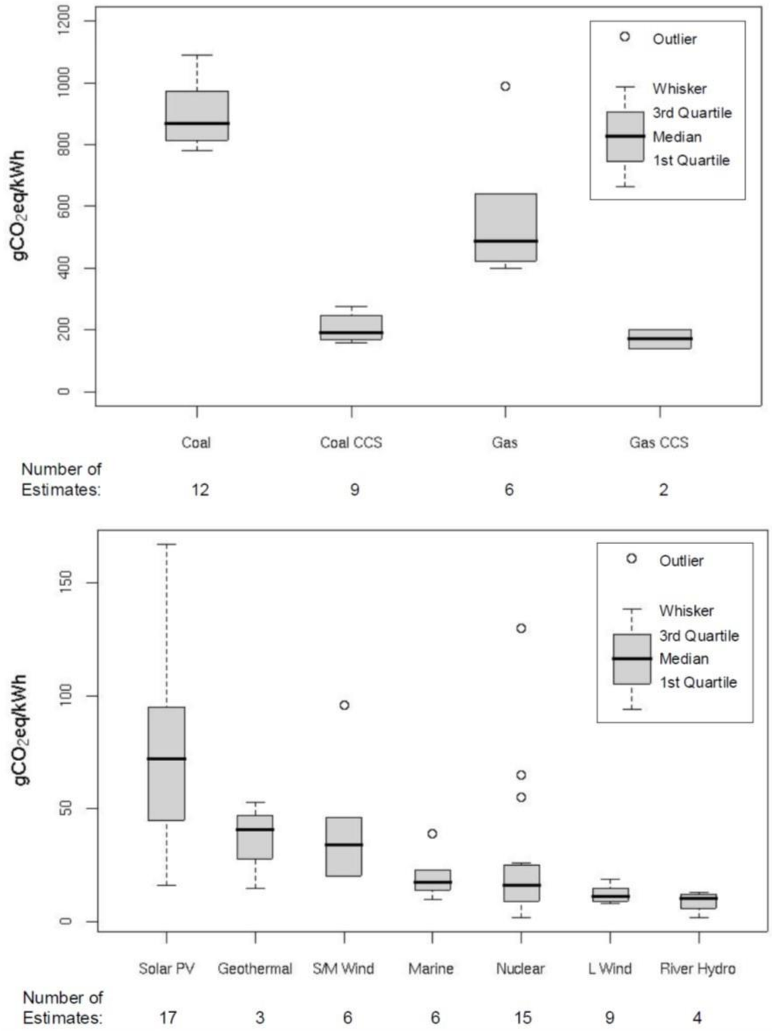


Figure 15:International carbon footprints for electricity from different energy sources (Source: UK Parliamentary Office of Science and Technology, 2011)

It is best practice to do the following:

- **Purchase third-party green electricity from the grid** produced from renewable sources**.**
- **Invest in renewable sources** that will provide electricity for the company's operation, or sign **power purchase agreements** with green electricity suppliers.
- **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 photovoltaics (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 the following:

- Biomass tri-generation: Woody biomass can be burnt on site to produce high-pressure steam that drives a turbine generator to make electricity and for example an absorption chiller to produce refrigeration, with increased efficiency for Combined Cooling, Heat and Power systems or CCHP. In many ICT sites the primary need is for cooling rather than heating so the system can be sized to be mostly CCP (Combined Cooling and Power).
- Solar power requires surfaces for sun exposure. Large installations of photovoltaic solar panels can be set up on roofs or in 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 serving as a heat exchanger for data centres and telecom centres.

The use of renewable energy is more developed in data centres and in base station facilities. Renewable energy from solar panels and small wind turbines offers a viable alternative to diesel although, due to the erratic availability of such energy, they will need addition of relevant energy storage (batteries). Renewable energy sources powered 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, while the business case is strong to adopt renewable energy 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 1.4.7).

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

- natural-gas-based CCHP plants which combine use of the electric energy produced heat, and cooling, allowing a highly efficient use of the resource (more than 80%).

- Store electricity on site in an efficient way.

  Sites with local renewable energy generation can be integrated with local energy storage, as developed within BEMP 1.1 (Integration of renewables on- or off-grid) depending on the grid. Within the framework of smart grid systems, UPS that power supply ICT facilities can also be used as a 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 does the following:

- **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 ran 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 systems helps reduce 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 the reduction of 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. Front runners sign agreements to purchase 100% 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 is needed to power sites such as data centres. Front runners cover up to 15% of their energy needs with 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 towards an emission-neutral site.

The indicator that can be used to assess the type of energy used to power ICT infrastructures is the **Renewable Energy Factor** (REF)[37] according to EN 50600-4-3.

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

The consequence of the decision to use renewable energy 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_2eq) 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.

While PUE may not be adapted as a universal efficiency metric (see discussion in Section 3.2.2.3), 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 on the technology of renewable energy production used, and of the country in which the installation is located.

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

[37] Note that the REF covers both renewable energy purchased for the utility (with a Guarantee of Origin) and that produced on site. However, renewable energy produced on site that is not consumed on site and partly or in total sold to the grid shall be excluded from the REF.

2.5.4 Cross-media effects

If the environmental benefits from renewables are largely agreed upon, 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.

Energy source	Potential cross-media effects	Mitigation options
Solar thermal	The production of solar thermal collectors requires energy and materials, and emits gases such as CO_2. Paid back within 2 to 3 years of operation depending on site-specific application, so energy produced over the remaining 20-year operating lifetime creates a large positive balance.	Maximise output through optimised siting and installation (e.g. south orientation). Ensure a long operational lifetime.
Solar photovoltaic	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. Payback times are estimated at 3 to 4 years against 30-year operating lifetimes.	
Wind turbines	Damage to wildlife (e.g. bird strike – although evidence on the severity of this impact suggests that it is relatively small). Embodied energy in wind turbines typically represents less than 1 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). 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, and occur especially during start-up, shutdown and load variation. Woodchip 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 woodchip 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 "electricity tracking certificates". Organisations can purchase certificates that guarantee that 1 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 energy sources to power their infrastructures. This is the case of Telecom Italia which 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 energy 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 of 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-metre 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 the following:

  - **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, a large amount of 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. The EU expects that geothermal will represent 0.3% of electricity consumption in 2020 and 1.3% of heating and cooling consumption (GENiC, 2014).
- After installing renewables, the second best option is to install the following:
- **Combined heat and power** (CHP), or tri-generation: CHP and tri-generation installations generate the most of these thermal energy production systems 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 heat is collected and used to heat or, through absorbers, is used to produce cold.

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

- assessment of the Renewable Energy Solutions (RES);
- theoretical planning of a 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 calculate 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 energy to cover part of their energy needs (GENIC, 2014a).

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

Location	Size	Power installation	Alternative energy type	Energy needs covered by renewables
Valencia (Spain)	600 m^2, 294 racks	4.5 MW	Solar PV on roof	130 kW (3%)
			Biomass boiler	100 kW (2%)
Pamplona (Spain)	100 m^2, 50 racks	1.5 MW	Solar PV on roof	22 kW (3%)
Cork (Ireland)	80 m^2	50 kW	Wind turbines on roof	4 kW (8%)
			Biomass boiler	50 kW (100%)
Helsinki (Finland)	270 m^2	600 kW	Wind turbines on roof	13.5 kW (2%)
			Biomass boiler	100 kW (17%)
Luxemburg	410 m^2	275 kW	Wind turbines on roof	20 kW (7.5%)
			Biomass boiler	100 kW (36%)
Brno (Czech Republic)	100 m^2	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 towards 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 all the thermal energy needs.

Use local storage solutions

Use fuel cells to replace backup diesel generators

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 the lower heating value of hydrogen.

2.5.6 Applicability

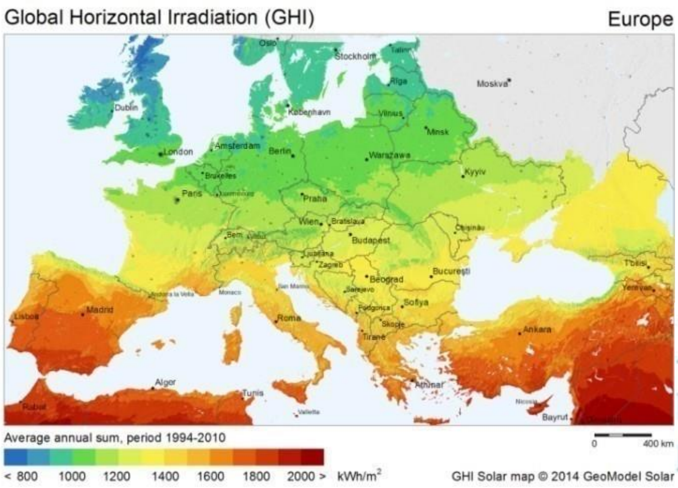
The applicability of the renewable energy sources presented in Section 2.5.5 depends on several factors, including the **geographical location** of the facility and its **size**.

- 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 17 shows the global yearly irradiation map, for solar PV installations;
- Figure 18 shows the wind average speed, for wind turbines;
- Figure 19 shows the biomass availability for cogeneration.

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

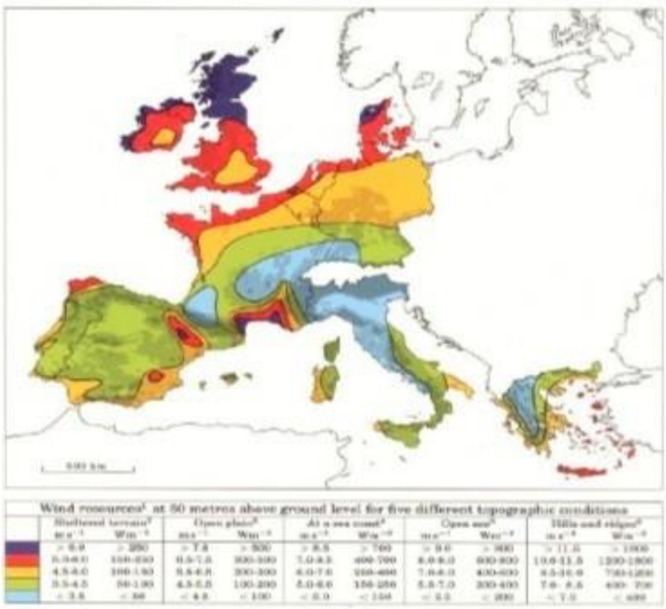


- Average Global horizontal irradiation level Classification:

Table 3. Solar irradiance level classification

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

Figure 16:Irradiation map (Source: GENiC, 2014)

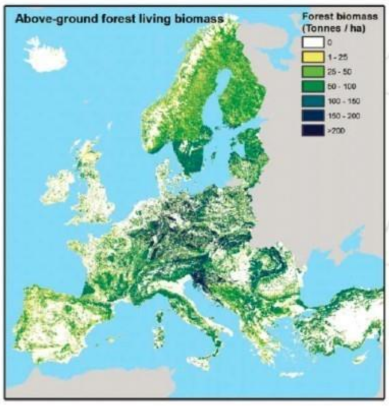


- Average Global Wind Speed level Classification:

Table 4. Wind speed level classification

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

Figure 17:Wind speed map (Source: 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 18:Biomass availability (Source: GENiC, 2014)

Based on the climate characteristics detailed above, GENiC established the following merit order for 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 (Source: 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*	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

*NB: 1 = high recommendation; 2= medium recommendation; 3 = low recommendation

- 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 are usually 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 (localised 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 in electricity prices.

Large data centres

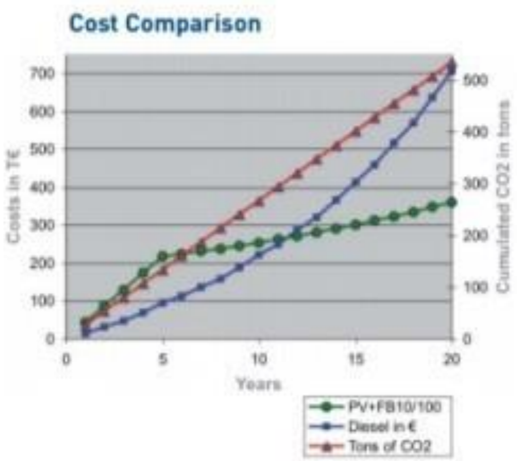
Due to their size, large data centres are built in isolated, often colder, locations (see BEMP on data centres). They can benefit from free cooling and from a high availability of natural resources. Large data centres allow a combination of several power sources, including solar PVs, wind turbines, biomass, geothermal and hydropower. Although these renewables usually account for a small part of the energy needs of large data centres, some best performing 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 EUR 0.8 and EUR 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 EUR 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[38] would be significantly lower (EUR 0.0952/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 EUR 500 to EUR 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 EUR 1 100/kW to EUR 1 390/kW, which is expected to remain stable but with an increased capacity factor (40% today). Offshore turbines have higher prices (around EUR 2 415/kW and experiencing a downward trend) along with higher capacity factors (50%) (RenewIT, 2014).



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

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

Figure 19:Cost comparison of a solar-powered vs diesel-powered telecom base station (in South Africa) (Source: Cellstrom, 2015)

The following table provides indicative economic costs, excluding 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 20:Indicative costs comparison for renewable energy (Source: 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 them, 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 drivers 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 Services 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 an annual electricity consumption over 6 000 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 its 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 publicly available 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% renewable energy. It uses 100% 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 majority of the 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 so far, the 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 this type of power supply in the Slavonija region of Croatia. This system is made of three components: fuel cells, solar PVs and wind turbines. Vipnet has announced that this combination allows for 99.9% energy effectiveness, 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 on a large scale.

2.5.10 Reference literature

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2.6 Resource efficiency of ICT equipment through waste prevention, reuse and recycling

<table>
<tr><td colspan="6">SUMMARY OVERVIEW:
Resource efficiency and appropriate waste management in the ICT sector are 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 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:
• develop a waste prevention plan;
• promote LCA-based eco-design through procurement;
• increase the service life and limit the obsolescence of ICT equipment ;
• implement systems to enable reuse of ICT equipment;
• ensure traceable collection and proper sorting of end-of-life ICT equipment.</td></tr>
<tr><td colspan="6">ICT components</td></tr>
<tr><td>Data centre</td><td>Telecommunication network</td><td>Broadcasting</td><td>Software publishing</td><td colspan="2">End-user devices</td></tr>
<tr><td colspan="6">Relevant life cycle stages</td></tr>
<tr><td>Design and installation</td><td>Selection and procurement of the equipment</td><td>Operation and management</td><td>Renovation and upgrades</td><td colspan="2">End-of-life management</td></tr>
<tr><td colspan="6">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource consumption</td><td>Emissions to air</td><td>Water use & consumption</td><td>Noise and EMF emissions</td><td>Landscape and biodiversity</td></tr>
<tr><td colspan="6">Environmental indicators</td></tr>
<tr><td colspan="6">• Share of facilities or sites with a certified zero-waste management system or with a certified asset management system (% of facilities/sites)
• Average service life of ICT equipment to be calculated for different product groups (e.g. servers, routes, end-user devices)
• Share of ICT waste generated from own operations recovered for reuse or refurbishment or sent for recycling
• Share of WEEE or ICT waste generated from clients recovered for reuse or refurbishment or sent for recycling
• Amount of ICT waste sent to landfill (t)</td></tr>
<tr><td colspan="6">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="5">• N/A</td></tr>
<tr><td>Related BEMPS</td><td colspan="5">• 2.2 Making the best use of an environmental management system
• 2.3 Procurement of sustainable ICT products and services</td></tr>
<tr><td>Benchmarks of Excellence</td><td colspan="5">• 100% of facilities have a certified zero-waste management system or a certified asset management system
• 90% of own ICT equipment recovered for reuse or refurbishment or sent for recycling
• 30% of ICT equipment from clients taken back and recovered for reuse or refurbishment or sent for recycling (for ICT companies providing equipment to customers)
• Zero ICT waste sent to landfill</td></tr>
</table>

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[39].

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

Table 19: Overview of metals found in ICT equipment (Source: OECD, 2010)

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

[39] This BEMP deals with resource efficiency for resource flows that are 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 Environmental Management Practice Report for the Public Administration Sector available at: http://susproc.jrc.ec.europa.eu/activities/emas/documents/PublicAdminBEMP.pdf.
For resource efficiency in EEE manufacturing, see the relevant BEMPs in the Best Environmental Management Practice Report for the EEE Manufacturing Sector available at: https://susproc.jrc.ec.europa.eu/activities/emas/eeem.html

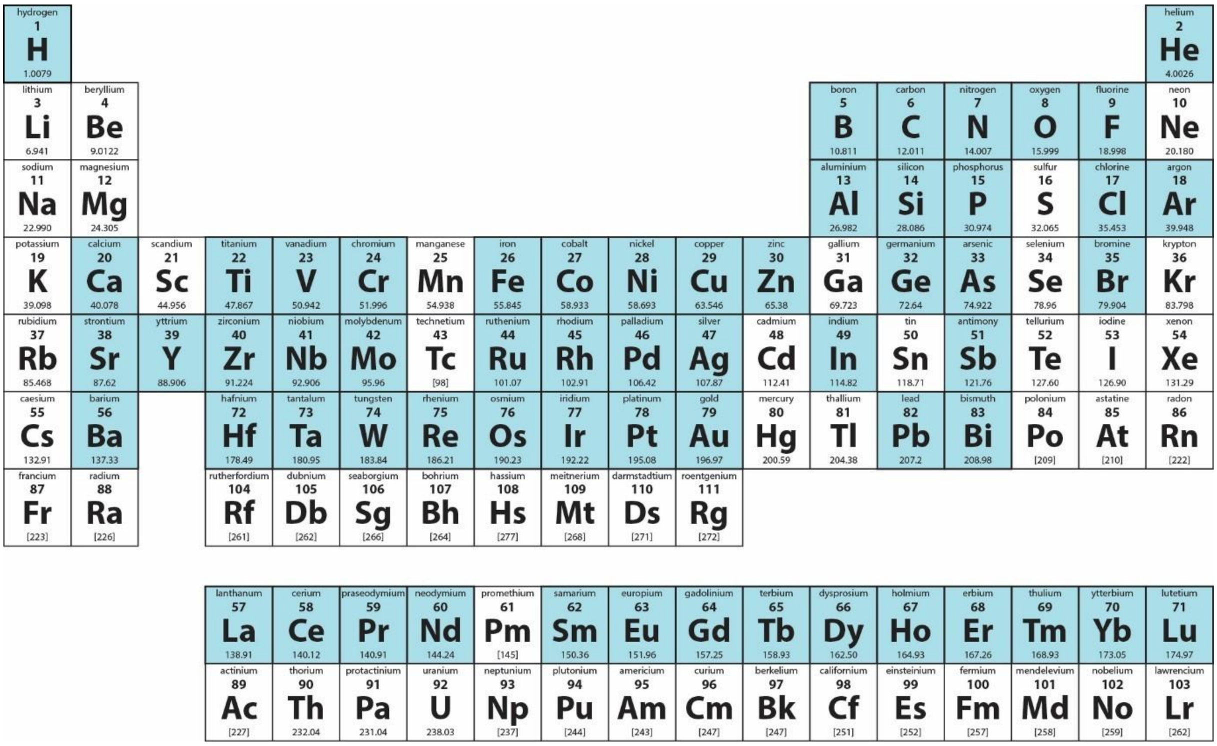


Figure 21:Material content of a mobile phone (Source: IGEM, 2014)

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 reuse, recycling, other recovery (e.g. energy recovery) and, finally, disposal.

Figure 22:The waste hierarchy (Source: 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 which extends the product life. Prevention measures also apply to the procurement of ICT services and products. A specific type of prevention is **product reuse**. 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. reuse of computers, set-top boxes and Wi-Fi routers). The product may undergo **refurbishment, reconditioning or remanufacturing** before it can be ready for reuse.
- **Preparing for reuse:** any operation by which products or components that become waste are processed in order to be used again for the same purpose for which they were conceived. The difference with product reuse 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 as or different to that of the original product.
- **Recovery:** any operation which results in replacing materials with waste serving 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 lay down 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's 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 23:Type of EEE producer (Source: ETSI, 2016)

Telecommunications 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 device's suppliers.

In any case, Telecommunications 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, and addressing the waste generated by their customers.

It is best practice to do the following:

- **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's life cycle. An eco-design process based on LCA helps reduce both the initial amount of resources used and the final waste generated while also minimising the environmental impact through the use phase. Its use in procurement can help to select 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 reuse 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 a take-back programme and collecting mobile phones, set-top boxes and routers for reuse.

- Ensure traceable collection and proper sorting of end-of-life ICT equipment.
- It consists of using waste treatment professionals to separate the different components and dispose of the final waste. It implies the verification of the contractor's skills and its accreditation.

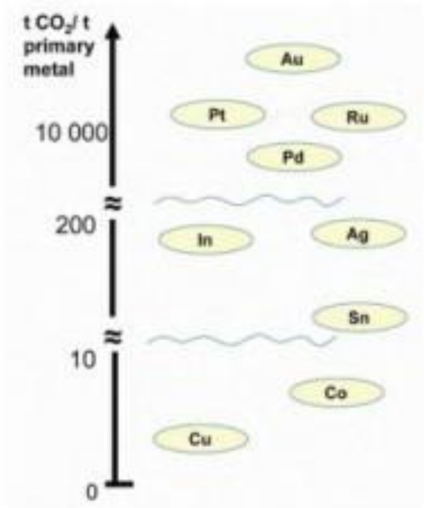
2.6.2 Achieved environmental benefits

Minimising the amount of waste generated and maximising reuse 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 the 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 24:CO_2 emissions of primary metal production calculated (Source: 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 (Bayer refining, Halle-Heroult smelting)	22.4	1.07	• Typical (world) – 40% • Extruded forms – up to 85% • Sheet products – up to 50%-63% • Electronic components – < 5%
Metal – zinc (electrolytic process)	4.6	1.84	• Typical (world) – 36% • Die castings – 10%
Metal – lead (lead blast furnace)	2.1	0.74	• Typical (world) – 47% • Battery plates – ~50% • Sheathing/foil – ~50% • Solder – <5%
Metal – steel (integrated route – BF and BOF)	2.33	0.53	• Typical (world) – 47% • Structural forms – ~80% • Rolled sheet goods – 25% to 35%
Metal – stainless steel (electric furnace and argon-oxygen decarburization)	6.8	1.8	• Rolled sheet goods
Metal – copper (smelting/converting and electro-refining)	3.33	0.55	• Typical (world) – 38% • Structural – 75% • Electrical/electronic – < 5%
Metal – nickel (flash furnace smelting and Sherritt-Gordon refining)	11.4	NDA	• Typical (world) – 34%
Metal – titanium (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 25:GHG emissions from materials used in ICT equipment (Source: ITU, 2012)

The following table shows the potential dangerous substances concentrations 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 26:Potential environmental contaminants arising from ICT waste (Source: 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.

- The **amount of ICT waste sent to landfill (t).**
- To assess the implementation of the waste management system, the **share of facilities, sites or installations with a certified zero-waste management system** or the **share of facilities, sites or installations with a certified asset management system** are good indicators.
- 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, routers, end-user devices).

Different indicators can be used 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) collected for reuse and recycling, such as the following:

- **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 recovers or recycles 97% of its own waste (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 taken 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.

Bashroush (2018) shows that optimising IT equipment (e.g. hardware refresh or increased utilisation) can yield better results in a data centre than decreasing the PUE, and also that the embodied energy of existing equipment is not a deciding factor when it comes to calculating the best data centre hardware refresh rate from an environmental impact perspective.

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

Some reuse/refurbishment channels aim to send equipment to other countries. However, by doing so, there is a risk that a reused product will not be properly disposed of 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 of) 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 is disassembled and reused the telecom and ICT companies must ensure that data is safely removed.

2.6.5 Operational data

An effective ICT waste management programme 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[40] 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 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[41]-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 authorities, other businesses and NGOs.

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

[41] Specific, Measurable, Achievable, Relevant, Time-bound

4. The waste prevention plan can also be based on a SWOT[42] analysis and implemented within a time frame. 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 27: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, leasing services can also be considered to reduce the potential amount of waste generated. Indeed, providers of leasing services have more incentives at providing products for use that are durable and easy to repair, and can better tackle the product at end-of-life (e.g. for reuse) than end users.

The waste management prevention plan can adopt a Zero Waste approach. It is a waste management system that emphasises 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's 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 shown in the following scheme.

[42] Strengths, Weaknesses, Opportunities, Threats

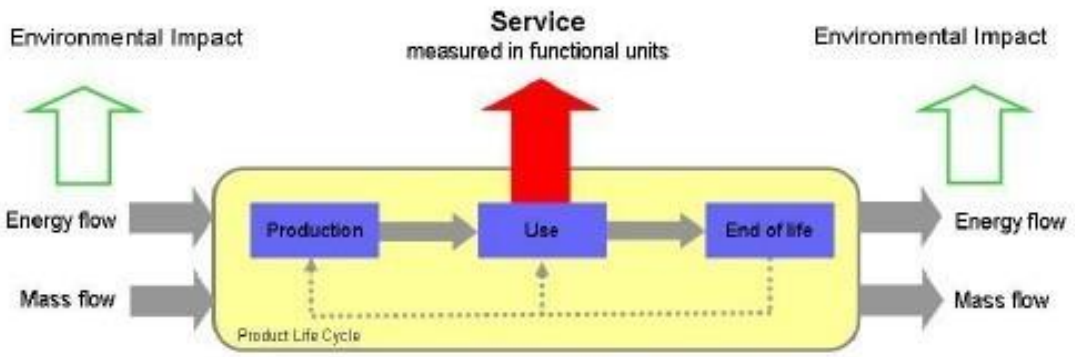


Figure 28:ICT product life cycle (Source: OECD, 2010, based on Hilty 2008)

An eco-design process aims to reduce the initial amount of resources used and to reduce the 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 immaterialisation which is the replacement of a physical product with a non-physical product or service or dematerialisation using fewer new raw materials.
- Physical optimisation:
    - by increasing the reliability and enhancing 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, use less material, have a 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 services providers can review in partnerships with manufacturers the composition of the products to ensure that they use or that they will sell products with a reduced environmental impact. For example, telecom operators and broadcasting companies can have a great influence on manufacturers through product specifications: they can encourage increased 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

After reducing the amount of materials used, and thus 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 little 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 programmed to function for a determined number of cycles;

- customer service: excessively long repair period making customers more willing to buy a new product than repair an old one.

Some ICT equipment is 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 endeavour to limit the obsolescence of their products.

From a service provider point of view, i.e. 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 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 use 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 reuse of products;
- promote repair: by manufacturer, suppliers, specialised social companies, independent repairers;
- promote services of maintenance;
- limit replacement: by raising consumers' awareness of usage conditions, developing functionalities to improve existing products, making the replacement of components easier.

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

Implement systems to enable reuse of ICT equipment

Optimisation of the reuse 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 and IT equipment. ICT equipment from staff shall be reported separately from the company's equipment.

A take-back programme to better recover end-user devices

The WEEE Directive (2012/19/EU) imposes take-back obligations on the producers of equipment (Article 5.2). As explained in the description section, Telecommunications 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 end users, such as mobile phones and set-top boxes.

Customers tend to replace their mobile phone based on trends and the evolution of technology. This replacement cycle drives the need to put in place solutions to collect, decommission, reuse and recycle 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 a 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 collection and recycling solutions. During the first stage of reverse logistics, handling and transportation of the equipment should be managed with care to avoid damage which could reduce the potential for reuse and refurbishment. Waste will be transported from different locations to the warehouses where it will be stored. This first step also involves the inspection and cleaning of waste to prepare it for the next step.

Figure 29:Mobile phone supply chain integrating recycling and reuse (Source: Vodafone)

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

Once the customer has returned their old mobile phone, different solutions can be considered:

- Refurbishment[43] 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 parts 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 longer a 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 into various types to be reprocessed by specialist recyclers. Some materials can be recycled into new products such as nickel cadmium and lithium ion/ polymer batteries which can be recovered and reused 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 carried out properly.

[43] The stage of refurbishment depends on the type of components or product. The refurbishment consists of 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 instruction sets may be installed. The goal is to ensure that the product fully fulfils the required functions. The components or ICT products entering the refurbishment process and destined to be reused must be handled in a 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 sales channels can be considered, e.g. in specialised second-hand shops or on the internet. This process will extend products' useful life and overall life cycle.

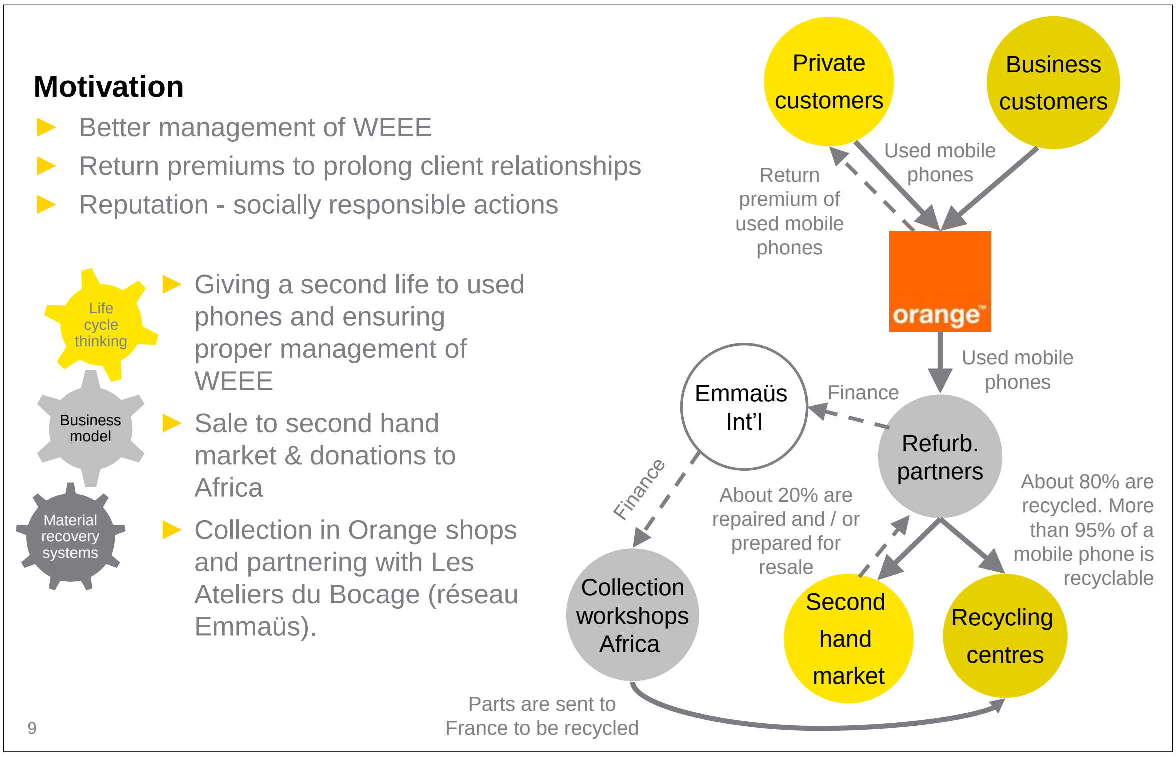


Figure 30:An example of a take-back programme and donations (Source: Orange, 2016)

Telecom operators have an influence on the eco-design characteristics of end-user devices and can play a role at their end-of-life (ETNO, 2011). 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 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 a suitable and traceable collection, transport and treatment scheme.

The responsibility of the telecommunication and ICT companies is to check that the contractor follows the rules to properly dispose of the waste and optimise the possibility of recycling. The waste treatment professional will carry out different steps to manage waste. This 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 have an environmental management system in place. 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 of 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 technologies available.

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

- Check information security: check the secure policy in place to protect your information.
- Check risk management:
    - verify that asset management minimises 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 emergency planning and monitoring;
    - ask about employee training and tracking of the data;
    - check the company has taken out the insurance policies needed to protect assets, employees and equipment handled including during transportation.
- Monitor environmental performance:
    - ICT life cycle improvement, assets losses, etc.
- Check operations:
    - process and optimisation of transportation and storage;
    - check the solution the facility provides to cover all types of equipment;
    - require that facilities operate using the 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 licence of the facility by all appropriate governmental authorities;
    - check the consistency between the licence, permits and local regulation;
    - verify specific permits: storage permit, air emission permit, water permit, hazardous waste permit, etc.;
    - ensure proper handling of transboundary movements.

2.6.6 Applicability

The company's responsibility regarding its product's 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 the device's suppliers. It also depends on local application 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)) reiterates the regulatory context in the 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 determines the applicability of certain techniques. In a data centre, the servers can be owned by the operator, leased or owned 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 draw up a contract with a professional waste treatment 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). This explains why replacing servers every 2 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 with and concerned by the environmental objectives.

2.6.7 Economics

Using LCA for ICT products 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 in the supply chain.

Waste prevention solutions can foster innovation at the product level or at the services level. For instance, eco-design and life cycle assessment will help with the development of new products and new technologies such as multifunction products. The waste prevention plan can establish services to extend products' 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 sends to landfill by recycling and reusing products will lower this tax. However, the collection of end-user devices such as mobile phones increases the amount of waste and can entail additional costs for their disposal.

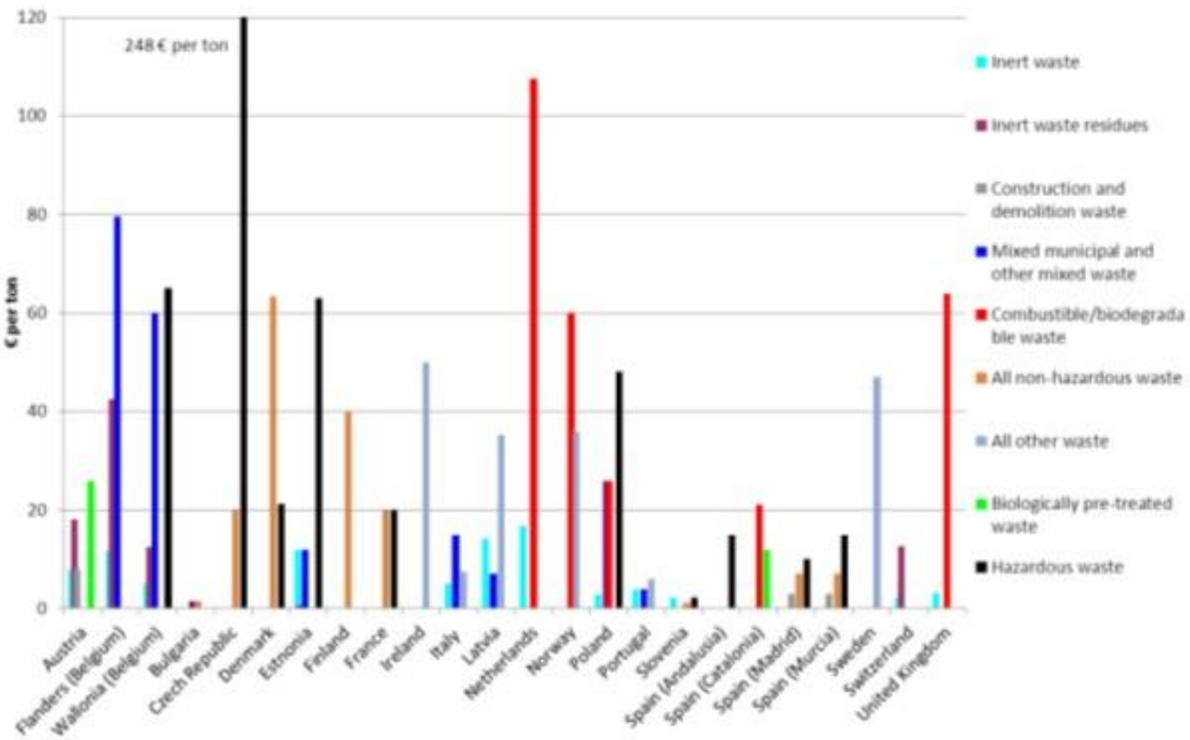


Figure 31:Comparison of landfill tax levels in European countries (EUR per tonne) in 2011, excluding VAT (Source: European Topic Centre on Sustainable Consumption, 2012)

The cost-effectiveness of WEEE collection depends on the operating country. Total fees have been estimated at around EUR 132 per tonne of EEE put on the market and EUR 384 per tonne of EEE collected in France and EUR 68 per tonne put on the market and EUR 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 lowers procurement costs for supplies required by offices, and recycling often costs less than landfilling residual waste.

The main driving force for implementation of the recycling, recovery and refurbishment process is the potential to extend the life cycle of the ICT equipment used. The extension of the life cycle of assets will also create economic benefits for the company. It will allow the company to invest in other strategic areas besides 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 the disposal process also ensures 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 sustainability actions to the final customers.

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

2.6.9 Reference organisations

A benchmarking of major companies in the ICT sector highlighted front runners 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 its servers through its asset management and recovery services. Only 0.7% of recovered equipment is sent for disposal (IBM, 2015).
- Orange (Orange, 2016) has developed mobile collection programmes in Europe, reaching for example a figure of 31% of old mobiles collected in Romania (buy-back programme) and 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 its remarketing partner. Regarding end-of-life: SAP has signed a global contract with a global recycler company that has all the necessary certificates. A global remarketing and recycling process has been established that allows all SAP group companies to participate.
- Proximus has improved packaging of mobile phone SIM cards, namely the replacement of the ABS carrier and paper information booklet by an information card packed in polypropylene, which has led to annual waste savings of 9 tonnes (Proximus, 2015).
- Telefonica (Telefonica, 2013):
  - develops equipment purchase policies for its 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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2.7 Minimising data traffic demand through green software

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, reduce the volume of data processed and transmitted, and ultimately reduce the energy consumption of hardware. This BEMP is dedicated to practices that can be implemented either when developing new software or when optimising existing software, for servers and networks considering both mobile applications (for smartphones and tablets) and computer software (for laptops and desktops), as well as web portals and web-based applications. It is considered best practice to: • select or develop more energy-efficient software that minimises the power consumption of ICT equipment while running; • design demand-adaptive software based on the assessment of end users' needs, in order to avoid energy over-consumption in the usage phase and to limit the obsolescence of existing ICT devices; • 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; • assess software environmental impacts through LCA at the development phase and performance measurement (CPU, RAM and energy utilisation) in the usage phase; • refactor existing software to improve its energy efficiency.					
ICT components					
Data centre	**Telecommunication network**	Broadcasting	**Software publishing**	**End-user devices**	
Relevant life cycle 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**	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity
Environmental indicators					
• 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/TR 50600-99-1 regarding the development and deployment of new IT services • Amount of data transferred in relation to software utilisation (bit / web page view or bit / min of mobile application use) • Share of newly acquired software for which the energy performance has been used as a selection criterion within procurement (%) • Share of newly developed software for which the energy performance has been used as a development criterion (%) • Share of demand-adaptive designed software • Share of existing software which has been refactored or which has undergone code reviews towards higher energy efficiency (%) • Share of software for which the energy performance has been assessed or monitored (%) • Share of software for which a LCA has been carried out • Share of software developers (staff) trained on energy-efficient software (%)					
Cross references					
Prerequisites	• N/A				
Related BEMPS	• 4.2 Improving the energy management of existing networks				
Benchmarks of Excellence	• All data centres have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding the development and deployment of new IT services • All staff (software developers) trained on energy-efficient software • At least one project for minimising data traffic demand through green software was implemented during the year				

2.7.1 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).

Energy-efficient software can have an impact throughout all components of hardware infrastructure, from data centres through to networks and finally (but significantly) end-user devices. One solution is to optimise software through the utilisation of eco-design principles while developing new software or updating the existing one. This approach aims mainly at minimising data traffic and at reducing the energy consumption of ICT hardware (servers, end-user devices, etc.).

General "eco-design" or "green software" principles include the following:

- **Select or develop more 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. Both software developed internally and outsourced should use the least possible energy to perform the required tasks.

  Different practices can be implemented either when developing new software or when optimising the 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.

- **Design demand-adaptive software.**

  The definition of functionalities based on an assessment of users' needs can avoid energy over-consumption in the usage phase and limit the obsolescence of existing ICT devices. Creating demand-adaptive software allows for the publication of software adapted to the specific needs of each user.

- **Monitor the energy consumption of software.**

  In order to assess the real performance of the acquired software, or to assess the opportunity for improving the energy efficiency of existing software, the energy consumption of software shall be monitored.

- **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.

- **Refactor existing software.**

  Based on energy monitoring and a green IT audit, existing software can be modified in order to improve its energy efficiency.

Specific considerations can be made in different parts of the industry.

For data centres, CENELEC, 2016 considers the above elements as best practice:

- **Select energy-efficient software.**
- **Develop energy-efficient software.**
- **Monitor the energy consumption of software.**
- **Refactor existing software.**

For telecommunication networks, the energy consumption 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 networks). 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 in both energy efficiency and data traffic: the energy consumption of telecommunication networks remains constant or keeps growing.

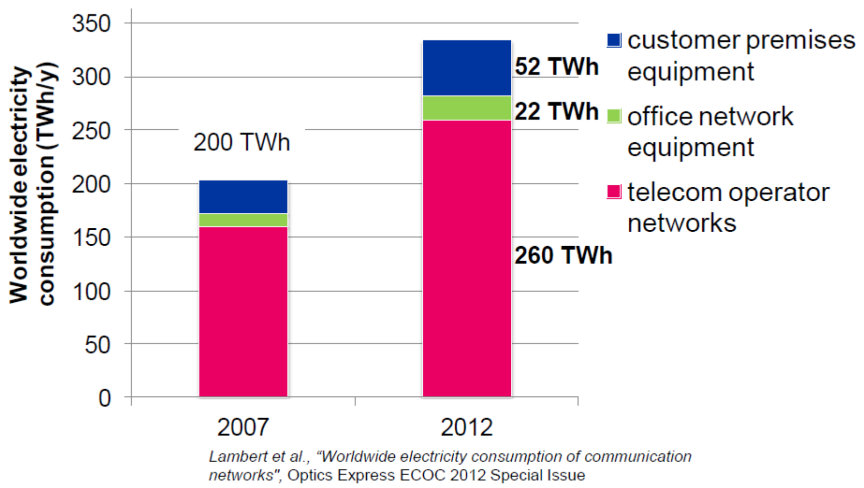

Figure 32:Worldwide energy consumption of communication networks (Source: Bart Lannoo (iMinds), 2013)

To minimise the environmental impacts of telecommunication networks' operations and to avoid a rebound effect, a reduction in the growth rate of data traffic is required.

For networks, it is therefore best practice to do the following:

- **Design demand-adaptive software.**
- **Develop more energy-efficient software.**

2.7.2 Achieved environmental benefits

The techniques described above aim at reducing CPU or RAM utilisation in data servers as well as 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 data centres, end-user and telecommunication networks devices;
- **an indirect reduction of resource 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. (Examples of achievements are in the operational data section).

In data centres, using more energy-efficient software leads to a decrease in the utilisation rate of servers, and opens up opportunities for consolidating some servers. Fewer servers are required for operating IT processes, 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. Saving 100 watt at the software level saves approximatively 1 000 watt at the data centre level (SEFLab, 2014).

Reducing hardware utilisation is an opportunity for extending the 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 with these phases are indirectly reduced (resource consumption, embodied energy, etc.).

For end-user devices, examples of environmental benefits related to the optimisation of existing software by GREENSPECTOR (Greenspector, 2016) include the following:

- After the audit of an Android smartphone application within the military sector, correcting the application led to energy savings of 69%.
- Case studies have shown that the application of eco-design principles allowed the following savings: 25% to 70% less energy consumption on native mobile applications; 30% fewer physical machines in a data centre (which also

brings a quick return on investment for the operator); 90% of IT resources consumption (client and server sides) on a simple "image carousel" on a web site.

- When assessing these environmental impacts, it is particularly important to define the appropriate parameters, and to consider the relations between the software and its environment (see the description of the technique "Assess software environmental impacts" in the operational data section).

2.7.3 Appropriate environmental performance indicators

At company level, process-oriented indicators on efficient software **for data centres** 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/TR 50600-99-1 regarding the development and deployment of new IT services.

For **networks**, assessing the results of implementing solutions for minimising data traffic demand can be monitored through:

- amount of data transferred in relation to software utilisation (bit / web page view or bit / min of mobile application use).

More generally, green software deployment can be monitored through:

- share of newly acquired software for which the energy performance has been used as a selection criterion within procurement (%);
- share of newly developed software for which the energy performance has been used as a development criterion (%);
- share of demand-adaptive designed software;
- share of existing software which has been refactored or which has undergone code reviews towards higher energy efficiency (%);
- share of software for which the energy performance has been assessed or monitored (%);
- share of software for which a LCA has been carried out.

For software designed to **run on end-user devices**, the indicators apply to the portfolio of software dedicated to internal or external use (published software).

Finally, at corporate level companies can monitor:

- share of software developers (staff) trained on energy-efficient software (%).

2.7.4 Cross-media effects

Measuring software energy consumption requires additional applications, and optimising existing software requires additional IT work. 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).

The techniques described above primarily intend to minimise the energy consumption of specific elements of the networks – e.g. servers, by reducing their utilisation. However, the approach must be global, and also include the energy consumption related to (in this case) 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.

A global approach shall therefore be adopted when implementing eco-design principles in software development, such as implementing software LCA (Greenspector, 2019).

2.7.5 Operational data

Developing efficient new software

Energy performance optimisation should be made a high priority in the development process. Consequently, software developed should use the least possible energy to perform the required tasks whilst ensuring it meets the stated needs.

Principles

Bashroush (2017) identifies three core principles for achieving energy-efficient systems:

- Energy efficiency metrics must relate business transactions to energy consumption in a meaningful way to key system stakeholders.
- Identifying sources of energy waste at the system level produces the biggest savings.
- Addressing the energy optimisation problem requires a cross-disciplinary team.

Energy-efficient software will provide benefits throughout the data processing chain. While general principles apply, collaboration between specialists for different segments will provide the greatest benefits at system level. For instance, for servers the main goal when developing energy-efficient software is to get the workload achieved as fast as possible in order to get the server back to idle and to reduce energy consumption (Intel, 2011). For end-user devices, many optimisation techniques have primarily been developed while implementing mobile applications' solutions (to safeguard autonomy, very efficient applications are required for mobile devices, especially smartphones). 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).

Techniques of computational efficiency consist of delivering better performance and as well as better energy efficiency (Intel, 2011). Programmers should develop new software[44] 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). This can be achieved by:

- designing algorithms minimising data movement;
- memory hierarchies that keep data close to processing elements;
- application software that efficiently uses cache memories.

An eco-design audit can be carried out to identify over-consuming practices within the source code of the software. During software utilisation, measuring software performance (CPU, RAM and energy utilisation) allows the assessment of the results of eco-design solutions or the selection of the optimisation solutions to apply.

Application

Multiple techniques can be used within such an IT optimisation baseline; examples include the following:

- 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 photos 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 a 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 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 the response time to be reduced from 3 seconds to 1 second on end-user devices, and to minimise servers' energy consumption by 35% to 85% for the most used features.

[44] 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.

Selecting energy-efficient software

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.

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.

For instance, smarter software for data centres must take into consideration both its own parameters and the parameters of all the 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)[45].

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 33 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[46]. 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).

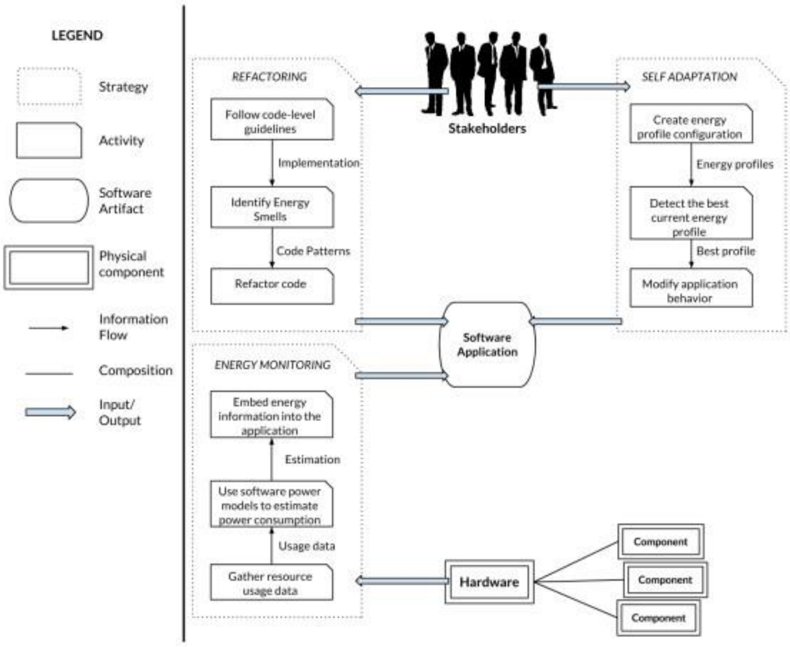

Figure 33:Framework for energy-efficient software strategies (Source: Procaccianti, 2015)

[45] 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.

[46] Examples of existing profiling tools based on energy models include Joulemeter, ARO, Power TOP and PowerTutor (Procaccianti, 2015).

The main objective of optimising software is to minimise the 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 the server level);
- **RAM usage** related to the use of the software (and relative savings due to optimisation projects at the server level);
- **power consumption** related to the use of the software (and relative savings due to optimisation projects at the server level).

Refactoring existing software towards greater efficiency

Refactoring means identifying code patterns responsible for high energy usage. However, because software execution depends not only on its internal structure and environment but also on the input it receives, the results of refactoring might differ depending on the situation. To prevent unsuccessful research, the most frequent usage scenarios must first be identified. Guidelines for refactoring include the following (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 a 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 is 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 a metric to estimate the energy consumption induced by data transfers for each software component.

Design demand-adaptive software

The user model design stage focuses 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 do away with the development of functionalities not required or used by customers (but that are power-consuming), or not adapted to the clients' equipment (and requiring new devices).

The decision to develop a software feature or not is based upon the software cost during its whole life span, not only during the 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 requires that information be passed on to 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 resource availability. For example, at peak hours, a GPS navigation software could provide only two possible routes instead of its usual four, 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 piece of software (resource consumption, energy consumption, pollutant emissions, etc.).
- Identify the most high-impact stages of the software life cycle:
    - 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 the 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 clearly identify to which version and configuration of the software the LCA applies (standard installation by default).

During software utilisation, measuring software performance (CPU, RAM, data usage and energy utilisation) allows the assessment of the results of eco-design solutions or the selection of 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, the 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 the display of web pages on end-user devices have been produced by a study published on the occasion of the 2nd International Conference on ICT for Sustainability, or ICT4S 2014 (O. Philipot, 2014):

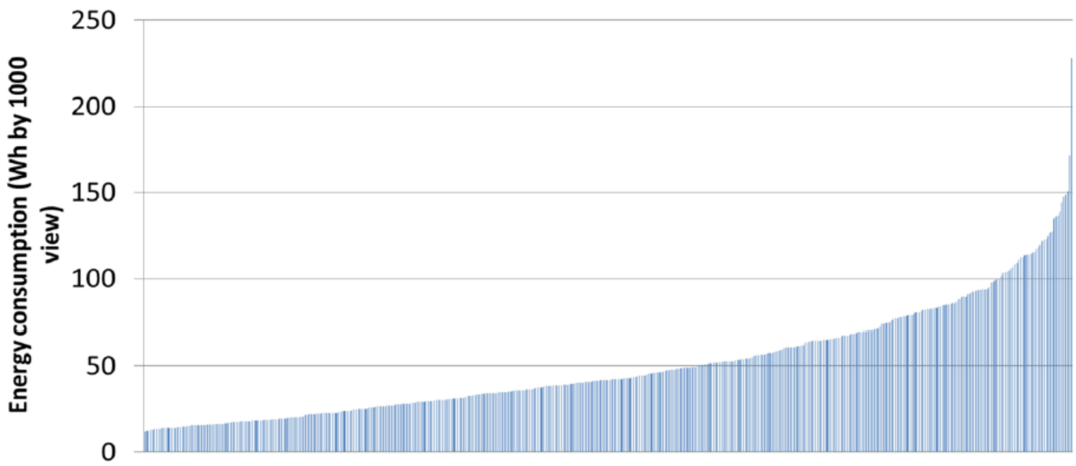

Figure 34:Energy consumption of 500 different web sites, from the user side (Source: O. Philipot, 2014)

On this basis, an energy rating of web sites has been established, as shown in Figure 36 below:

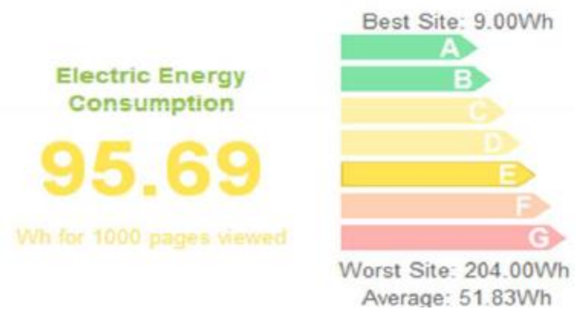

Figure 35:Example of an energy label for web sites (O. Philipot, 2014)

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).

2.7.6 Applicability

Using eco-design solutions when developing or optimising applications refers to a set of techniques that can be applied by software publishers (for the external use of the 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.).

2.7.7 Economics

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

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

Refactoring costs can be avoided by implementing eco-design principles among other software design principles from the very start of software projects.

2.7.8 Driving force for implementation

Similarly to previous BEMPs, decreased energy costs are the main incentive for actors throughout the value chain to adopt energy-efficient software.

Bashroush (2016) identifies that the explosive growth in data processing drives a growing concern for software architects to address energy efficiency.

Reducing the energy consumption of servers can be associated with an improved performance, since servers are able to process data for more users. Green Code Lab (2014) investigated energy efficiency for websites and highlighted the lack of correlation between performance and energy efficiency.

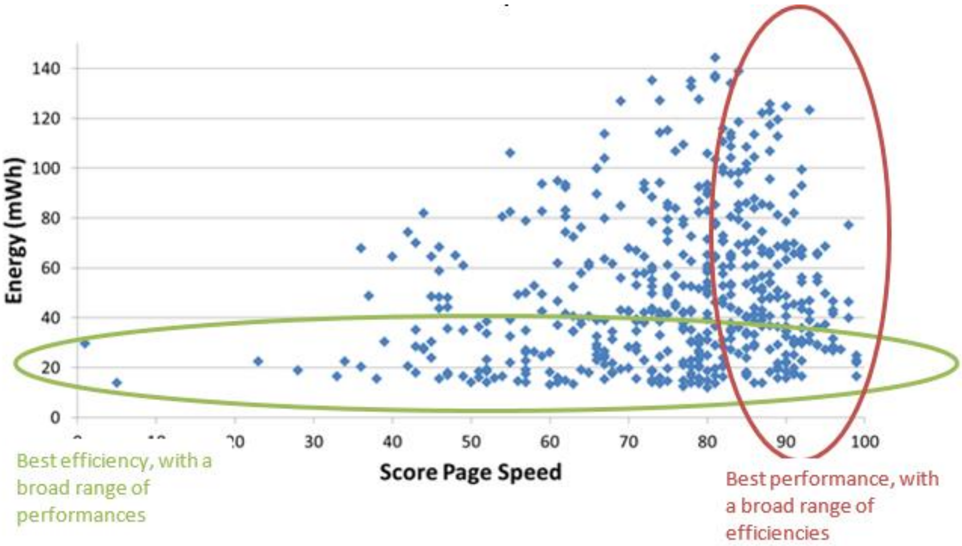

Figure 36:Software performance vs energy (Source: GreenCodeLab with analysis by Greenspector)

This is confirmed by findings from Greenspector on client applications (cf. operational data section above).

In addition, developing energy-efficient software can increase the innovation capacity of the organisation running the hardware, and help identify opportunities to optimise activity. Optimised software will be more performant and deliver an efficient service, even in less energy-consuming hardware, e.g. data centres.

For data centres, providing more energy-efficient software is also a way to enhance the quality of service provided to clients, who may demand less energy-consuming data storage services, while maintaining a high quality of data management.

Developing energy-efficient software (web portals, mobile applications, etc.) therefore provides several benefits:

- increase of user satisfaction, by limiting delays and dysfunction;
- optimisation 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 in energy consumption and a decrease in hardware costs and maintenance needs.

2.7.9 Reference organisations

- GREENSPECTOR (a SME providing tools including “green rules” for optimising software, and energy and resources metering) has achieved software optimisation with different partners: Orange, La Poste and ATOS.
- Intel (Green Software).
- Oracle (Green Software).

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3 Data centres

3.1 Introduction / scope

3.1.1 Definition

According to the European Standards EN 50600 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 up 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.

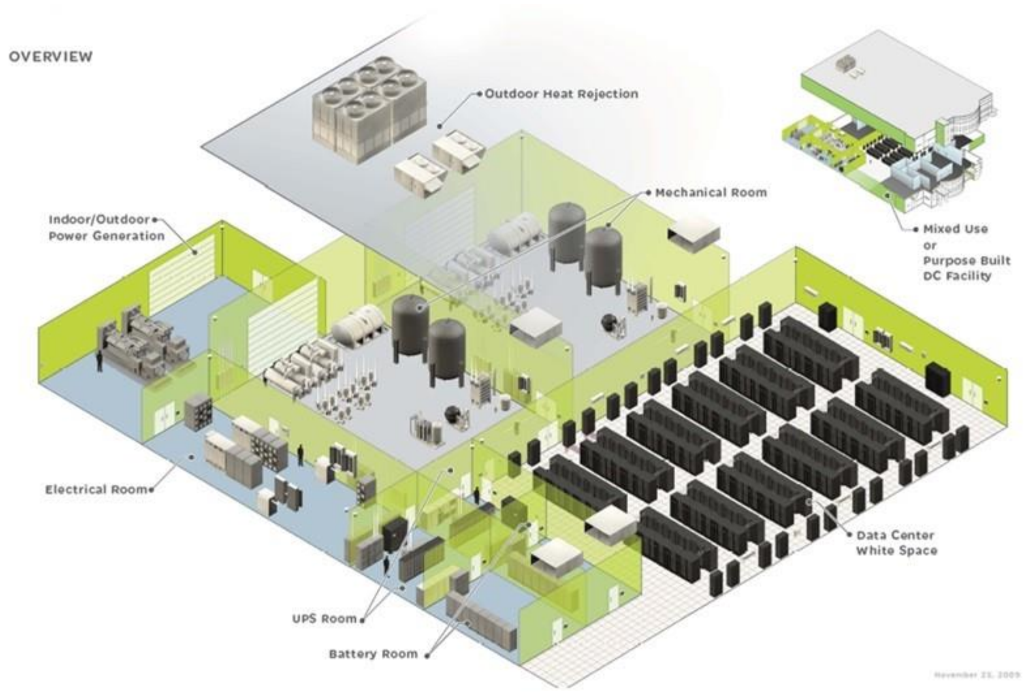

Figure 37:Example of data centre architecture (Source: Schneider Electric – Reference Design 23 – Performance-Optimised 1MW E-Class data centre)

3.1.2 Categorisation

There are 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 computer space (floor area), is one of the factors that influences the dimensioning of the cooling and air management systems.

Table 20: Typical characteristics of different sizes of data centre (Source: GENiC, 2014)

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
Localised 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 underfloor 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

- **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.
- **The purpose or type of operator**: It is possible to differentiate between enterprise data centres, co-location, co-hosting, and network operator facilities.

[47] HVAC = heating, ventilation and air conditioning.
[48] CRAC = Computer Room Air Conditioner.

Table 21: Different types of data centre operators depending on who owns and manages the data centre and its equipment (Source: CENELEC, 2016)

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.

- **The security level**: The level of security can vary, depending on the requirements of the end user. It is possible to 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).

Table 22: UpTime Institute Tier Requirements Summary (Source: Seader, Brill, & Turner, 2006)

	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 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
Compartmentalisation	No	No	No	Yes
Continuous cooling	No	No	No	Yes

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 utilisation, etc.

3.1.3 Environmental aspects of data centres

The Joint Research Centre (JRC, 2012b) has estimated the 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 have increased 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, backup generators, etc.) and the need for cooling of the servers to maintain optimal operating temperatures.

While the majority of energy in a data centre 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).

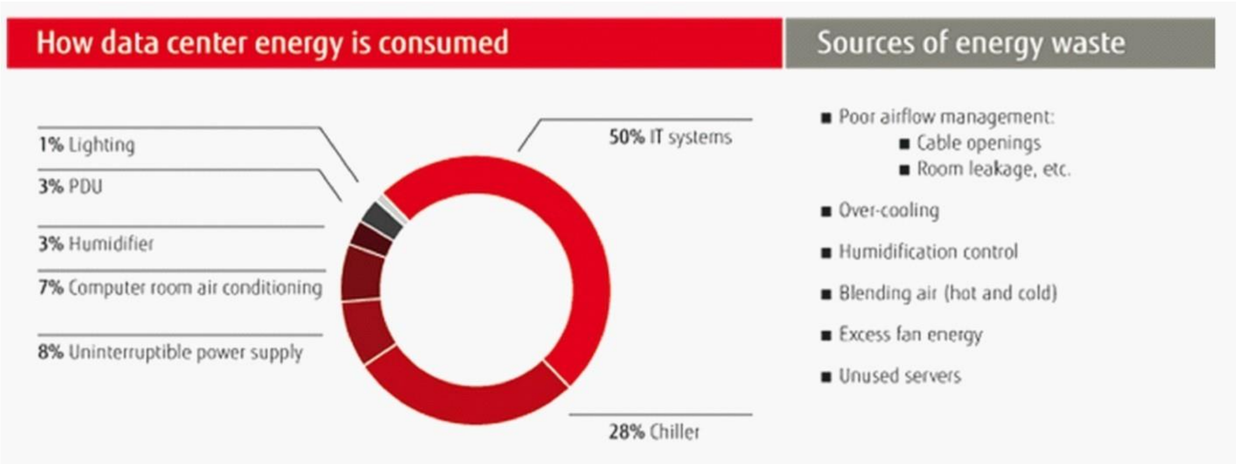

Figure 38:The breakdown of energy consumption in a typical data centre (Source: Fujitsu, 2016)

In addition, a significant share of energy consumption cooling systems may require large volumes of fresh water and refrigerants.

The indicators suggested within the BEMPs aim to monitor such impacts. Nevertheless, they should be mainly used to monitor the progress of a data centre, rather than to compare different data centres because of 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 Centres (JRC, 2015)[49]. The Code of Conduct was created in response to increasing energy consumption in data centres and the need to 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 into a CENELEC Technical Report: *CLC/TR 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 in the CENELEC Technical Report:

[49] For more information, see: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

1. Existing data centres (Section 3.2).
2. ICT equipment (new or replacement) (Section 3.3).
3. Software installation or upgrade (Section 3.4).
4. New build or refurbishment of data centres (Section 3.5).

Table 23: Structure of BEMPs related to data centres and relationship with CLC/TR 50600-99-1

Best practices according to CENELEC CLC/TR 50600-99-1	Applicability			
	Existing data centres	ICT equipment (new or replacement)	Software installation 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 the CENELEC Technical Report *CLC/TR 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 and noise, are also described under the above BEMP structure:

- Land use and noise issues are dealt with in the BEMP 3.4.5 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 Resource efficiency of ICT equipment through waste prevention, reuse and recycling.

ETSI European standards have been developed to provide guidelines on data centres' best practices. They mainly tackle 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) on Thermal management guidance for equipment and its deployment.

3.1.5 Reference literature

- CENELEC. (2016). CENELEC Technical Report CLC/TR 50600-99-1. Information technology - Data centre facilities and infrastructures – Part 99-1: Recommended practices for energy management
- ETSI EN 300 019-1-3 Ver. 2.4.1. (2014). Environmental conditions and environmental tests for telecommunications equipment. ETSI.
- ETSI TR 102 489 V1.4.1. (2015). Thermal management guidance for equipment and its deployment. ETSI.
- ETSI TR 102 489 V1.4.1. (2015). Thermal management guidance for equipment and its deployment Guidance on Thermal Management of racks, cabinets and locations.
- Fujitsu. (2016). *Fujitsu Practical methods for improving ICT sustainability*. Retrieved February 2016 at the following web address: http://www.sustainability-perspectives.com/article/practical-methods-for-improving-ict-sustainability/
- GENiC. (2014). Renewable energy requirements analysis and GENIC data centre sites energy audit.
- JRC. (2012a). ICT Sector Definition - Transition from NACE Rev. 1.1 to NACE Rev.2 - A Methodological Note
- Rasmussen. (2011). *Electrical Efficiency Measurement for Data Centers*. Schneider Electric White Paper 154.
- Seader, J. H., Brill, K. G., & Turner, W. I. (2006). Tier classifications define site infrastructure performance. Santa Fe, USA.

For reference, the list of published EN 50600-X documents is (2017):

EN 50600-1:2012, Information technology — Data centre facilities and infrastructures — Part 1: General concepts;

EN 50600-2-1:2014, Information technology — Data centre facilities and infrastructures — Part 2-1: Building construction;

EN 50600-2-2:2014, Information technology — Data centre facilities and infrastructures — Part 2-2: Power distribution;

EN 50600-2-3:2014, Information technology — Data centre facilities and infrastructures — Part 2-3: Environmental control;

EN 50600-2-4:2015, Information technology — Data centre facilities and infrastructures — Part 2-4: Telecommunications cabling infrastructure;

EN 50600-2-5:2016, Information technology — Data centre facilities and infrastructures — Part 2-5: Security systems;

EN 50600-3-1:2016, Information technology — Data centre facilities and infrastructures — Part 3-1: Management and operational information;

EN 50600-4-1:2016, Information technology — Data centre facilities and infrastructures — Part 4-1: Overview of and general requirements for key performance indicators;

EN 50600-4-2:2016, Information technology — Data centre facilities and infrastructures — Part 4-2: Power Usage Effectiveness;

EN 50600-4-3:2016, Information technology — Data centre facilities and infrastructures — Part 4-3: Renewable Energy Factor;

CLC/TR 50600-99-1:2016, Information technology — Data centre facilities and infrastructures — Part 99-1: Recommended practices for energy management.

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 of 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 to significantly reduce the total energy consumption.

The following BEMPs could be considered to improve the energy efficiency of existing data centres.

Table 24: Structure of BEMPs related to data centres and relationship with CLC/TR 50600-99-1

BEMPs related to existing data centres Expected (5.1) and Optional (6.1) Practices for Existing Data Centres in CLC/TR 50600-99-1	
Techniques from EU CoC / CLC/TR 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)* • Consider the embodied energy in devices *(5.16.02)* • Implement a plan for life cycle assessment (LCA) *(6.16.86)* • Implement a plan for environmental management (e.g. ISO 14001) *(6.16.87)* • Implement a plan for energy management (e.g. ISO 50001) *(6.16.88)* • Implement asset management for all ICT, mechanical and electrical equipment (e.g. ISO 55000) *(6.16.89)* • 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) For general environmental management refer to: ▪ Environmental management systems (Section 3.2.2)
• Use renewable / sustainable energy sources *(6.16.90)* • Use alternative power generation technologies *(6.16.93)*	Refer to: ▪ **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)* • Decommission and remove unused equipment *(5.16.04)* • Audit existing ICT equipment requirements for allowable intake temperature and humidity ranges *(5.16.05)*	**Implement an energy management system for data centres** (Section 3.2.2)
Data management and storage	
• Implement a data management policy *(5.16.06)* • Implement a policy defining storage areas by retention policy and level of data protection *(6.16.95)* • Separate physical data storage areas by protection and performance requirements *(6.16.96)* • Select low-power storage devices *(6.16.97)* • Reduce total data volume *(6.16.98)* • Reduce total storage volume *(6.16.99)* • Employ service charging models and tariffs in co-location and managed service environments *(6.16.85)*	**Define and implement a data management and storage policy** (Section 3.2.3)

[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).

• Consider the impact of mobile / shifting workloads *(6.19.92)* • 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)*	
Airflow management and design	
• Install blanking plates to manage cabinet/track airflow *(5.16.07)* • Ensure appropriate airflow volume to ICT equipment *(5.16.08)* and reduce obstructions *(5.16.09)* to better manage the raised floor airflow • Segregate equipment *(5.16.10)* and separate environmental zones *(5.16.11)* (including co-location or Managed Service Providers *(5.16.12)*) • Implement containment techniques to separate hot and cold air *(6.16.100)* • Consider the use of a return plenum to return heated air from the ICT equipment directly to the air conditioning units *(6.16.101)* • Minimise fan losses associated with moving air by adjusting the raised floor or suspended ceiling height *(6.16.102)* • Minimise air recirculation 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)* • Review the cooling strategy *(5.16.14)* • Employ effective regular maintenance of cooling system *(5.16.15)* • Install the cooling system in a scalable or modular arrangement allowing unnecessary equipment to be shut down *(6.16.104)* • Shut down unnecessary cooling equipment *(6.16.105)* • Review CRAC/CRAH settings (optimise the temperature and relative humidity settings of CRAC/CRAH units) *(6.16.106)* • 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)* • Review and if practical widen the working humidity range *(5.16.15)* • 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)* • 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)* • 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)* • Install metering equipment capable of measuring the total energy consumed by ICT equipment within the computer room space(s) energy consumption *(5.16.23)* • Measure ICT power consumption at cabinet / rack level *(6.16.110)*	**Implement an energy management system for data centres** (Section 3.2.2) For general environmental management refer to:

• Measure ICT power consumption at ICT device level *(6.16.113)* • Install monitoring equipment to monitor supply air temperature and humidity for the ICT equipment at room level *(5.16.24)* • Monitor supply or return air temperature at CRAC/CRAH unit level *(5.16.25)* • Measure and monitor temperature at row or cabinet / rack level *(6.16.111)* • Measure and monitor intake and/or exhaust temperature at ICT equipment level *(6.16.112)* • Provide an automated energy and environmental reporting console and report on PUE or DCIE *(6.16.116)* • Provide an integrated energy and environmental reporting capability in the main ICT reporting console and report on PUE or DCIE *(6.16.117)* • Monitor and report server / processor utilisation *(6.16.118)* • Monitor and report network capacity and utilisation *(6.16.119)* • Monitor and report storage capacity and utilisation *(6.16.120)* • Undertake periodic manual readings of energy consumption, temperature and humidity data *(5.16.26)* or implement automated daily *(6.16.114)* / hourly *(6.16.115)* readings • Report periodically on energy consumption, PUE and temperature and humidity ranges *(5.16.27)* • Define a business-relevant dashboard and report upon business-specific metrics relating to data centre services *(6.16.121)*	▪ Environmental management systems (Section 2.2)

NB:

- For an updated list of best practices, see the latest version of the CENELEC Technical Report CLC/TR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices.

The next 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 on the operation of data centres. Co-location 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 of 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 investment in new material; • 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity	
Environmental performance indicators						
• KPI_{DCEM} Global KPI for Data Centres according to the ETSI standard • 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/TR 50600-99-1 • Share of ICT, cooling or power equipment with specific metering equipment (for measuring 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 senior management					
Related BEMPS	• 3.2.3 Define and implement a data management and storage policy • 3.2.4 Improve airflow management and design • 3.2.5 Improve cooling management • 3.2.6 Review and adjust temperature and humidity settings					
Benchmarks of Excellence	• The KPI_{DCP} for existing data centres is equal to or lower than 1.5 • All data centres have an energy management system certified according to ISO 50001 or integrated in EMAS, or complying with the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1					

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 organisational practices, as illustrated in Figure 39. 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 organisation'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).

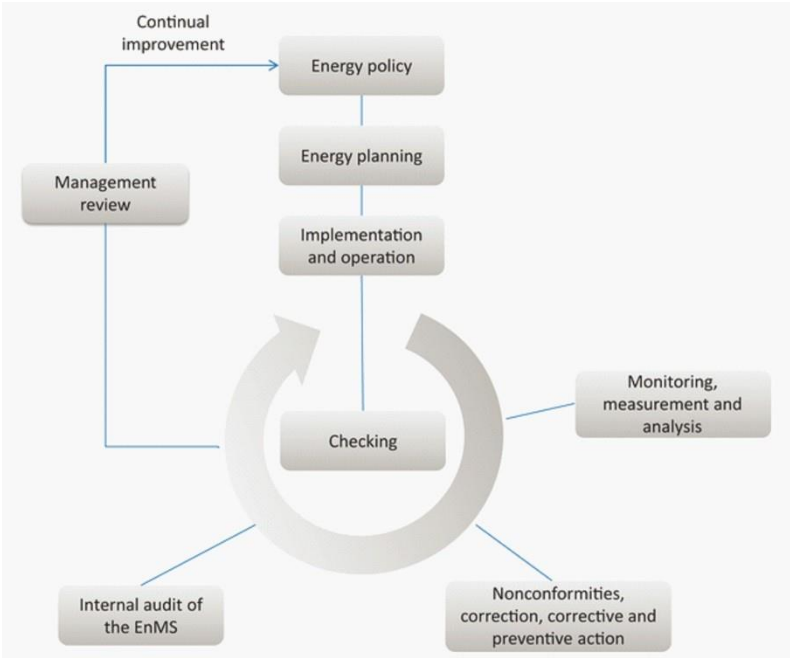

Figure 39:The ISO 50001 energy management system model (Source: ISO 50001, 2011)

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 do the following (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 its 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 should ICT equipment requirements for allowable intake temperature and humidity ranges. Then, an asset management plan should be implemented for all ICT, mechanical and electrical equipment (e.g. ISO 55000), to maximise any unused capability prior to investment in new material. 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 pieces of metering equipment should be installed to improve the visibility and granularity of data centre infrastructure energy consumption. Besides measuring the total incoming energy consumption of the data centre, such equipment should allow the measurement of 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 the 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 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 an environmental management system (e.g. ISO 14001 or EMAS) are presented in Chapter 2 (cross-cutting BEMPs). Specific practices are also described in EN 50600-3-1, which addresses both operational and management processes.

The implementation of a plan for a 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 Resource efficiency of ICT equipment through waste prevention, reuse and recycling. It can allow the embodied energy of ICT devices (including devices used in data centres) to be better taken into account

Turning off lights (preferably automatically) whenever areas of the building are unoccupied is considered a cross-sector best practice when speaking of service provider companies in general. This technique is described in the Best Practice Report for sustainable offices (public administration).

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 pieces 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.** Like any electrical equipment, IT equipment requires a 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) increase with the number of pieces 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 other 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 (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 (measuring the energy performance of the data centre): this type of indicator tracks energy consumption in relation to a performance metric.

  NB: A basic example of such an indicator is the PUE[52], a common energy performance indicator for data centres; while it can be used to track the performance over time of a specific site given a certain level of service/load, care must be taken not to expand its use to, for example, compare PUEs of different types of data centres or use it too broadly when other factors in the energy consumption of the site render it meaningless.

  - **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. The calculation method for this indicator can be found in the indicated standards.
- The DCEM Global KPI is based on a formula with four different component KPIs defined in the new ETSI standard ES 205 200-2-1: Energy consumption, KPI_{EC}; Task efficiency, KPI_{TE}; Energy reused, KPI_{REUSE}; Renewable energy, KPI_{REN}.
- Process-oriented indicators (measuring the implementation of environmental management) such as the following:
  - 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/TR 50600-99-1.
  - Share of ICT, cooling or power equipment with specific metering equipment (for measuring their use, energy consumption, temperature or humidity conditions).

[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).

[52] Power Usage Effectiveness (PUE) is defined as the ratio of the total power to run the data centre facility to the total power drawn by all IT equipment. The PUE is defined by the standard ISO/IEC 30134-2. 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), currently less used than the PUE.
Using PUE as a raw metric for improvement without context and for its own sake may drive energy use up rather than down. Use of PUE in an operational context should always be qualified with overall energy consumption in kWh.

- 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 accurate data to be gathered, it implies 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 an energy management system (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 senior 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 with 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

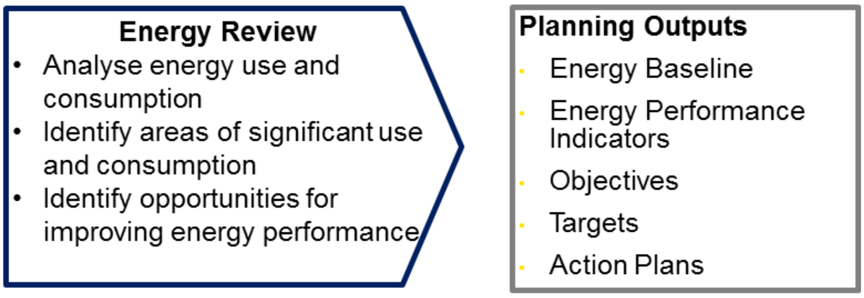

Figure 40:Components of an energy review

Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified.

Performing an audit of the IT services and analysing reported data (when useful indicators are monitored, such as server and network utilisation) 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 the following:

- 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 onto 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 measure 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 the following (CLP Power, 2013):

- Transformer, where the total facility power can be measured. Electricity travels through the service entrance and into a transformer, which feeds everything downstream: switchgear, UPS, lighting, CRAC/CRAH, and, eventually, the IT equipment.

- Uninterruptible Power Supply (UPS), where the total IT load can be measured. Downstream from the transformer, measurements can also be taken at transfer switches and 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 unit (where the IT equipment is actually powered), these floor-mounted 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 pieces 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, more precise monitoring can be implemented if necessary by installing more metering equipment.

Monitor and report ICT devices' utilisation, energy consumption and environmental conditions.

This involves measuring and monitoring the energy usage of ICT devices and calculating 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 42 below shows the different sources of energy consumption in a data centre besides IT equipment.

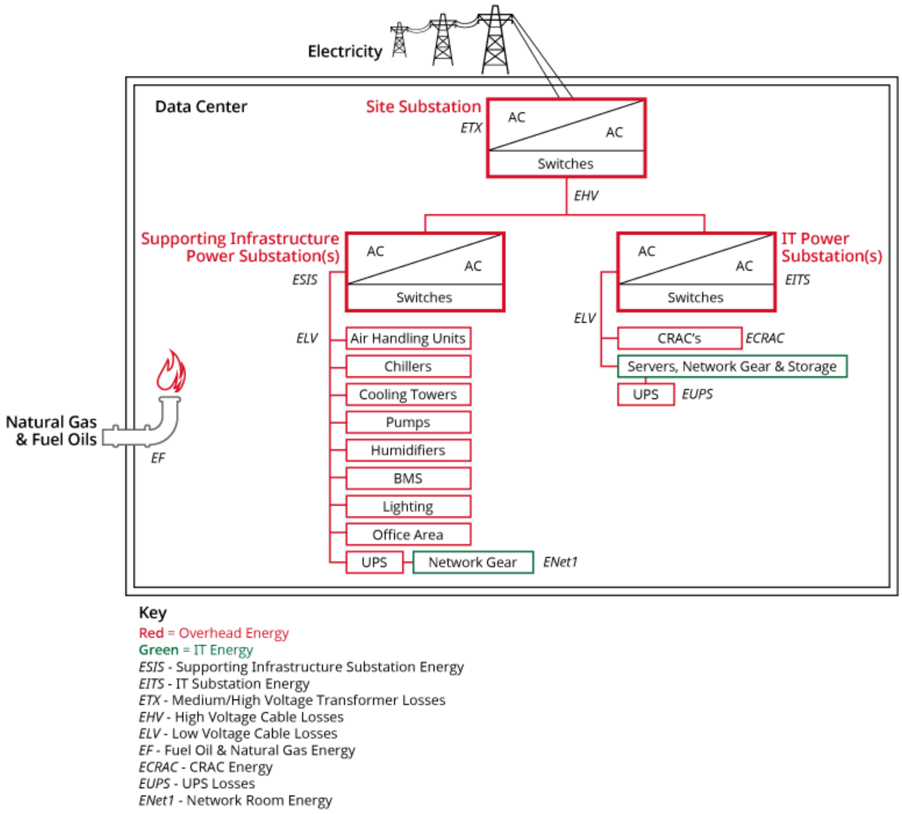

Figure 41:An overview of the different pieces of equipment that consume energy besides the IT equipment (servers, storage and network equipment) (Source: Google, 2016)

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 pieces of equipment include the following:

- 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 the 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 the load increases. Matching the battery count to the load allows the reduction of 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 half, 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 operators to benefit from an extensive data flow. This data flow in turn allows better benchmarking, data analysis, and ultimately decision-making.

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.

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 43 shows how the performance (measured in PUE[53]) of Google's data centres increased.

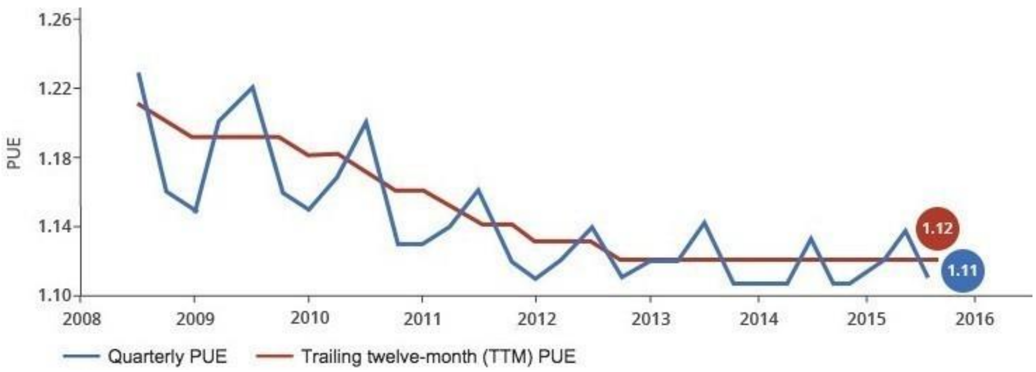

Figure 42:PUE data for all large-scale Google data centres (Source: Google, 2016)

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.

[53] NB: There are caveats to using PUE as a general indicator, as discussed in Section 3.2.2.3.

<table>
<tr><th colspan="2">BEMP implemented: Data centre monitoring</th></tr>
<tr><td colspan="2">Within this case study, the following techniques were implemented:
Audit of the IT, cooling and power equipment.
Installation of additional metering equipment.
Collection and analysis of IT equipment workload, energy consumption and temperature conditions.</td></tr>
<tr><th>Operator of the data centres</th><th>Technical characteristics and context</th></tr>
<tr><td>CIT Campus - Cork (Ireland)

2013 (GENIC, 2014)</td><td>Surface: One room of 35 m² and one of 55 m²

Number of physical and virtual servers: around 100 in total

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.

The other one houses servers for students completing online courses, among other equipment.</td></tr>
<tr><th>Practice implemented</th><th>Results</th></tr>
<tr><td>Prior to the project, the metering equipment consisted of a power meter integrated in the supply board that fed all the IT equipment.

The project was composed of three parts:

- A survey of the systems installed at the data centres was conducted with the campus' electrical maintenance staff.

- 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.

- 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.</td><td>Metering allowed for the measurement of IT equipment 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 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.</td></tr>
</table>

3.2.2.6 Applicability

The applicability of the above-mentioned best practices depends 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 25: Applicability of energy management best practices in existing data centres

Best practice	Size	Security	Purpose
Implement an energy management system (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 structures. The tools are mainly for large data centres because of the sizeable 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 increased profitability, due to lower energy costs combined with increased business opportunities. 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, staff do not 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 26: Application and cost comparison of different types of electrical meter devices used in data centres (Source: Kidd & Torell, 2013)

Type of meter	Applications	Installation cost per meter*
Power quality meters	• Power quality monitoring • Electric utility bill verification • Power circuit loading & balancing • Energy management • Maintenance activity support	€4 500 – €10 000***
Power meters	• Power circuit loading & balancing • Energy management • Cost allocation / billing • Maintenance activity support • Critical incident alarming	€500 - €3 000
Digital relay embedded meters**	• Protective device for medium-voltage equipment • Power circuit loading & balancing • Maintenance activity support • Critical incident alarming	~€1 000
Electronic trip unit embedded meters**	• Protective device in low-voltage circuit breakers • Power quality monitoring • Power circuit loading & balancing • Energy management • Maintenance activity support • Critical incident alarming	€500 - €11 600
Uninterruptible power supply (UPS) embedded meters	• Engineering data support • PUE monitoring • Critical incident alarming	Included in UPS price
Power distribution unit (PDU) embedded meters	• PUE monitoring • Management of power capacity • Cost allocation • Critical incident alarming	Included in PDU price
Rack PDU embedded meters	• Most accurate "IT load" measurement per Green Grid • Load balancing • 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.*

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

Table 27: Overview of costs and return estimates for each best practice

Best practice	Operating costs	Investment costs	Return on investment
Implement an energy management system (e.g. ISO 50001 or through EMAS)	Staff time for an energy manager Related to logistics for holding regular meetings	Certification or verification process	Reduction of energy consumption Reduction of maintenance costs
Audit existing equipment and services to ensure that all areas with potential for optimisation and consolidation are identified	Staff time of the IT service Related to logistics and time for holding regular meetings	NA	Savings from equipment decommissioned: Small data centre: €1 000 - €2 000 Large data centre: €200 000 - €400 000[54]
Install metering equipment capable of measuring energy consumption and environmental parameters at different levels	NA	Selecting and installing metering equipment (approx. €11 000 (Therkelsen et al., 2013)	Reduction of energy from IT consumption Reduction of energy cost from cooling Reduction of energy cost from humidification [55]
Monitor and report IT equipment utilisation, energy consumption and environmental conditions	Staff time to perform meter readings or data analysis and reporting	Selecting and installing automated monitoring and reporting devices	Reduction of energy from IT consumption 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 the chilled water temperature).

Another benefit of 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 **source of knowledge and expertise** that can improve the performance of the ICT equipment and reduce risks linked to decision-making.

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:

[54] Method: yearly savings from the decommissioning of 1% to 2% of total racks.
[55] If complemented with an energy management plan.

- 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 with ISO 50001 (Equinix, 2011).
- 100 % of EDF data centres are certified with ISO 50001 (EDF, 2016).
- EDH is 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 have the ISO 50001 certification (Google, 2014).
- Getronics (Getronics, 2016).
- TIM (formerly Telecom Italia S.p.A.) data centre in Milano-Rozzano received ISO 50001 certification in 2016.

3.2.2.10 Reference literature

Reference literature is consolidated in Section 3.2.7.

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/TR 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

<table>
<tr><th colspan="6">SUMMARY OVERVIEW:</th></tr>
<tr><td colspan="6">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 amount 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 that is 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 (and virtual machines) to rely on a reduced number of pieces of highly resilient and reliable powered hardware (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.</td></tr>
<tr><th colspan="6">ICT components</th></tr>
<tr><td>Data centre</td><td>Telecommunication network</td><td>Broadcasting</td><td>Software publishing</td><td colspan="2">End-user devices</td></tr>
<tr><th colspan="6">Relevant life cycle stages</th></tr>
<tr><td>Design and installation</td><td>Selection and procurement of the equipment</td><td>Operation and management</td><td>Renovation and upgrades</td><td colspan="2">End-of-life management</td></tr>
<tr><th colspan="6">Main environmental benefits</th></tr>
<tr><td>Energy consumption</td><td>Resource consumption</td><td>Emissions to air</td><td>Water use & consumption</td><td>Noise and EMF emissions</td><td>Landscape and biodiversity</td></tr>
<tr><th colspan="6">Environmental performance indicators</th></tr>
<tr><td colspan="6">▪ Energy use (kWh) per rack
▪ Average storage disc space utilisation (%)
▪ Average server utilisation (%)
▪ Average cabinet utilisation (%)
▪ Share of servers virtualised (%)
▪ Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services (%)</td></tr>
<tr><th colspan="6">Cross references</th></tr>
<tr><td>Prerequisites</td><td colspan="5">• Commitment from senior management</td></tr>
<tr><td>Related BEMPS</td><td colspan="5">• 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment)
• 3.2.4 Improve airflow management and design
• 3.2.5 Improve cooling management
• 3.2.6 Review and adjust temperature and humidity settings</td></tr>
<tr><td>Benchmarks of Excellence</td><td colspan="5">• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services</td></tr>
</table>

3.2.3.1 Description

IT systems traditionally consume about 50% of the data centre energy power. Servers and storage drives are supplied with power 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 pieces of storage hardware powered within the data centre and optimising the performance of all hardware regarding its energy consumption. These practices deal with the operation of applications, databases and services run on servers, and with the data stored on drives.

It is best practice to do the following (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 capacity reduces the number of pieces 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 tiered 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 and virtual machines.

  Services can be consolidated in order to reduce the amount of highly resilient and reliable hardware being 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 may be decided to implement a combination of applications or to use N+1 server clustering. The same approach can be used towards virtual machines – 20% of virtual machines can typically be unused in a data centre. Decommissioning virtual machines leads to even higher efficiency improvements.

  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-power sleep state.

Decommissioning can be part of an effort to shape the service offered to the customers' requirements. In the event that 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[56] also refer to practices related to data centres' data management practices.

[56] It describes Best Practice Guidelines related to the 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

3.2.3.2 Achieved environmental benefits

Direct decrease of energy consumption

Reducing the number of pieces of IT equipment being powered and optimising the use of servers' sleep 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[57].

Indirect decrease of energy consumption

Like any electrical equipment, IT equipment requires a 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) increase with the number of pieces 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 the hardware utilisation rate and lead to indirect electricity consumption.

The potential for combined energy savings (i.e. both direct and indirect effects) is 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 44 below).

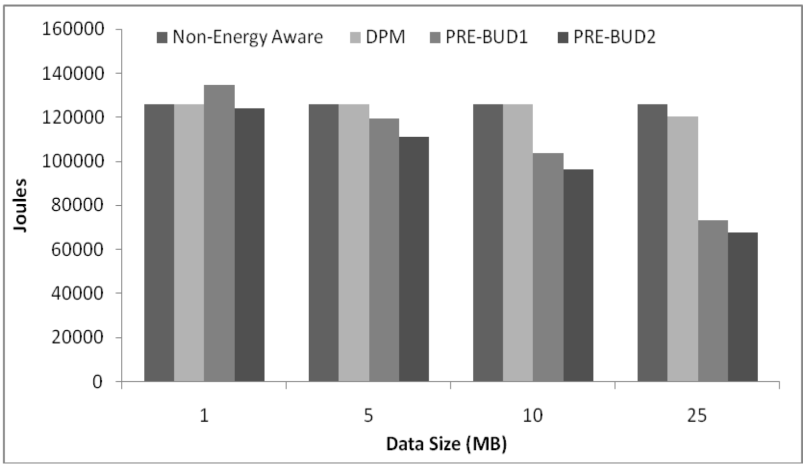

Figure 43: Evolution of storage practices' energy consumption vs size of data to be stored (Source: Manzanares A. and Qin Z., 2015)

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 in Figure 45, 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.

[57] 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).

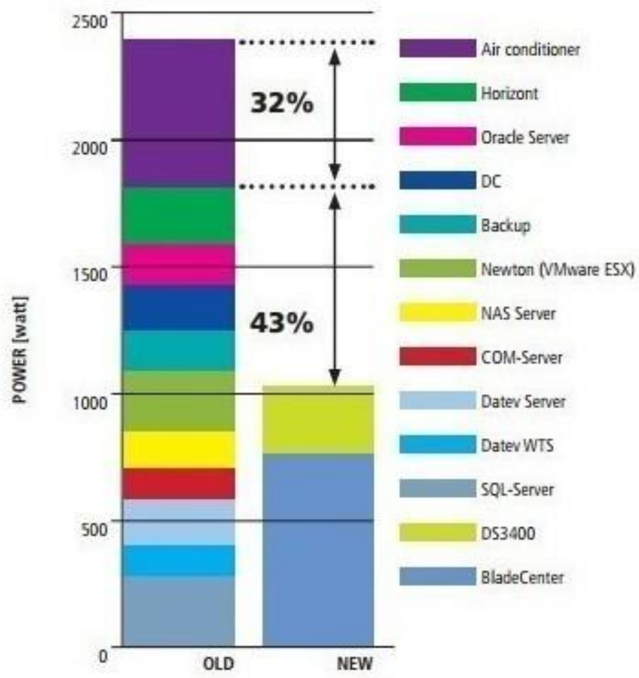

Figure 44:Reduction in servers' energy demand by virtualisation (Source: Case study from the PrimeEnergyIT project (PrimeEnergyIT, 2011))

3.2.3.3 Appropriate environmental performance indicators

An outcome-oriented indicator can be used, e.g. based on the **dynamic range of servers** (idle server consumption / full load consumption).

In addition to outcome-oriented indicators, process-oriented indicators can be defined, such as the following:

- **Average storage disc space utilisation** (%): the ratio between the storage disc space currently used (on all the storage devices of the data centre) and the overall storage capacity of the data centre. The higher this utilisation rate, the more energy efficient 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.

  On average, server utilisation is between 12% and 18%, while best performances are assessed to be between 40% and 70% of server utilisation (NRDC, 2014).
- **Average cabinet utilisation** (%): similar concept as above applied at rack cabinet level.
- **Share of virtualised servers** (%): the number of virtualised servers over the total number of servers. This reflects the ability of the servers' owner to virtualise servers in order to increase their utilisation rate
- **Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency** or the Expected Practices of CLC/TR 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, automatic 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. The number of virtual-servers can increase quickly and lead to an increased power demand.

3.2.3.5 Operational data

Implement an effective data management and storage policy.

One of the most visible storage inefficiencies is low disc-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.

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 disc space unnecessarily and require more storage devices. Deduplication software finds and eliminates 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 an optimum way[58]. 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 consumes energy), on uncompressed formats (e.g. JPEG, MPEG and 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 the initial state (PrimeEnergyIT, 2011).
- *Tiered storage* - also referred to as Information Life Cycle Management or Hierarchical Storage Management - refers to the dynamic 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;
    - high-priority data (expected to be in immediate demand) can be stored on low-latency storage equipment that consumes more energy (Energy Star, 2011).
- Applications for 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 enable the implementation of the techniques described above.

Deploy grid and virtualisation technologies.

Storage virtualisation refers to different techniques of mapping from physical locations to virtual locations. 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, the idle power consumption of a virtualised server is close 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 standpoint) or with very high-level service requirements should be isolated 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 off-peak hours for example) up to the targeted utilisation level, i.e. 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 directly provide energy savings, since it does not allow reductions in dataset size or ensure the utilisation of energy-efficient servers (SNIA, 2012). However, storage virtualisation is needed for using some energy-efficient technologies, such as the following:

- *Thin provisioning* enables more efficient disc 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

[58] For example, not wasting a large amount of the capacity in order to perform deduplication.

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% and 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 discs) combines multiple disc drive components into a single logical unit and requires 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 discs' failure). According to the National Renewable Energy Laboratory: "For a 10-disc array, increasing to an 11-disc RAID 5 level (one extra disc) from a 20-disc 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, such 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).

Consolidate 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, server and network utilisation for example) is an essential preliminary step before implementing a consolidation 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 the following:

- 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 high-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 unused (Energy Star, 2011). Then, examining the CPU utilisation of each server through Data Centre Infrastructure Management (DCIM) may allow the identification of 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 servers, 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

The practices presented can be implemented by most data centres, irrespective of their size, security level or purpose, although application may be different for enterprises or co-location data centres.

Even if virtualisation is more frequently used in bigger data centres, this technique can also be implemented in smaller server rooms. The PrimeEnergyIT project (PrimeEnergyIT, 2011) identified several side effects of virtualisation, which can lead to difficulties while implementing such a 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 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 that are 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 28: Economics data related to the definition and 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 for IT services	Purchase of data management systems	Increase of storage available and decrease in energy consumption
Deploy grid and virtualisation technologies	Human resources for IT services	Costs for one virtual server (Siebert, 2009): • €9 000 Costs for two servers, to ensure high availability for organisations running critical activities (Siebert, 2009): • Physical server cost: €13 500 • Shared storage: €8 000 • Software: €3 000	Increase of storage available and decrease in energy consumption
Consolidate existing services and decommission unnecessary servers	Human resources for IT services	Purchase of software	Savings from decommissioning a single rack (Energy Star, 2011): • Energy: €440 • Operating system licences: €440 • Hardware maintenance costs: €1 320

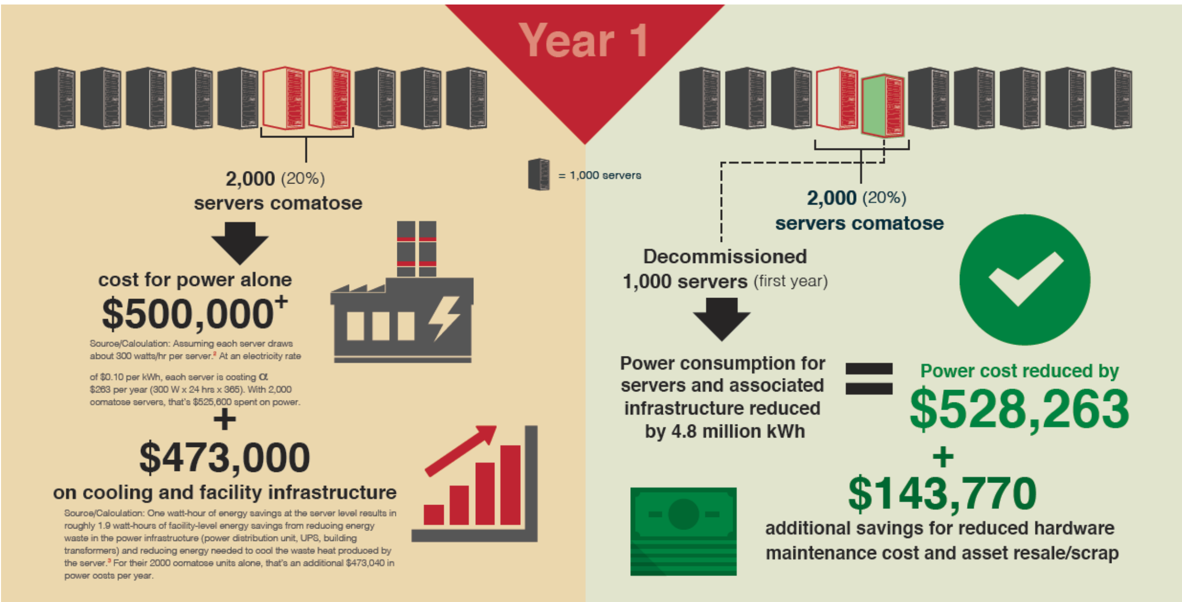

Figure 45:Cost savings from decommissioning idle servers (Source: Uptime Institute, 2014)

The Uptime Institute organises an annual Server Roundup contest where participants have to decommission the highest number of existing servers. The 2013 winners were:

- Barclay's, which decommissioned 9 124 servers, resulting in savings of USD 4.5 million (~EUR 4 million) in power costs and EUR 1 million in legacy hardware maintenance costs.
- Sun Life Financial, which decommissioned 441 servers, resulting in savings of EUR 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 a reduction in the number of pieces of IT equipment and space requirements. The benefits of consolidation largely exceed costs related to software purchasing. Economics represents 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 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 preconfigured systems, standardised environments, etc.).

3.2.3.9 Reference organisations

- TIM (formerly Telecom Italia S.p.A.) uses extensive virtualisation in its data centres (TIM, 2011).
- Dassault Systèmes has virtualised more than 90% of its servers within its principal data centre (Dassault Systèmes, 2016).

3.2.3.10 Reference literature

Reference literature is consolidated in Section 3.2.7.

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 to and hot air expelled by 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 hot and cold air;**
- **ensure aisle separation and containment to avoid the recirculation of air around the servers;**
- **segregate ICT equipment according to its environmental requirements (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 recirculated air, and to reduce obstructions created by cabling or other structures;**
- **adjust volumes and quality of cooled air supplied to meet 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 minimises the production of waste heat.

ICT components

Data centre	Telecommunication network	Broadcasting	Software publishing	End-user devices

Relevant life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Airflow efficiency (fan power in kWh / fan airflow in m^3/hour)
- Return Temperature Index (identification of air recirculation)
- Flow performance of the air handler
- Thermal performance of the air handler
- Rack cooling index (difference between allowable intake temperature and the one recommended by the ASHRAE)
- Share of racks installed with a hot aisle / cold aisle configuration (with containment)
- Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 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) • 3.2.3 Define and implement a data management and storage policy • 3.2.5 Improve cooling management • 3.2.6 Review and adjust temperature and humidity settings
Benchmarks of Excellence	• 100% of new racks are installed with a hot aisle / cold aisle configuration (with containment) • All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding airflow management and design, and installation of ICT equipment to optimise airflow management.

3.2.4.1 Description

The reliability of IT systems relies on environmental 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).

Airflow management is intended to maintain the data centre operating environmental envelope and to optimise the functioning of the cooling system, humidifiers and filters. It will depend on:

- the data centre architecture, including layout and arrangement;
- the existing IT equipment performance, and especially on the number and the utilisation rate of devices;
- 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 to and the hot air expelled by 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 once through IT equipment and has to absorb heat.

It is best practice to do the following (CENELEC, 2016):

- Implement a hot aisle / cold aisle configuration for ICT equipment.

  Configuring a hot and cold aisles layout ensures that hardware shares an airflow direction without mixing cold and hot air. Specific equipment can be installed to implement a hot aisle / cold aisle configuration, such as a return plenum to return heated air from the ICT equipment directly to the air conditioning units.

- Ensure aisle 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 floor layout and equipment deployment such as:
  - blanking plates between racks that help minimise the contamination of one device's intake air by the waste heat of another device;
  - aperture brushes (draught excluders) or cover plates and panels that help minimise all air leakages in each cabinet/rack.

- Segregate equipment and separate environmental zones.

  Segregating IT equipment according to its environmental requirements (mainly humidity and temperature) is intended 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 (air conditioning) system avoids the cooling system set points being dictated by non-IT equipment.

- Improve the floor and ceiling design to optimise airflow.

  Improving the floor airflow management can contribute to reduce bypass air flow and prevent recirculated air. Similarly, adjusting suspended ceiling heights 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 airflow.

- 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.

In addition, useful reference can be made to EN 50600-2-3:2019; this European Standard addresses environmental control within data centres based upon the criteria and classifications for "availability", "security" and "energy efficiency enablement" within EN 50600-1.

3.2.4.2 Achieved environmental benefits

Improving the energy efficiency related to airflow management is expected to directly **reduce the energy consumption** of data centres.

Below are a few estimates of the energy savings related to several of the best environmental management practices identified above (42U, NA):

- aisle containment systems increase the efficiency of the hot/cold aisles arrangement, and can lower energy consumption by 5-10%;
- blanking panel installation, which aims at improving airflow through the IT equipment and avoiding inefficient airflow around it, can reduce energy consumption by 1-2%;
- floor plenum management intends to avoid airflow 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:

- **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).
- A RTI of 100% should be the target 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 bypass of air (the cold air does not contribute to cooling the electronic equipment and returns directly to the air handler). However, calculating such an indicator requires numerous temperature sensors or measuring the air flow rate which companies do not usually 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.

Monitoring these indicators requires the installation of specific metering equipment, to measure temperatures, outflows or energy consumption. In the case of numerous pieces of equipment, specific equipment can be selected for monitoring.

In addition to outcome-oriented indicators, process-oriented indicators can be defined, such as:

- share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding airflow management and design;
- share of racks installed with the 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 (such as blanking panels) requires additional resources and generates additional waste.

3.2.4.5 Operational data

Implement a hot aisle / cold aisle configuration.

This technique is intended to optimise the 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 airflow, with the same direction and coming from the cold aisle, passes through each rack and is exhausted into the hot aisle behind the rack, as shown in the figure below.

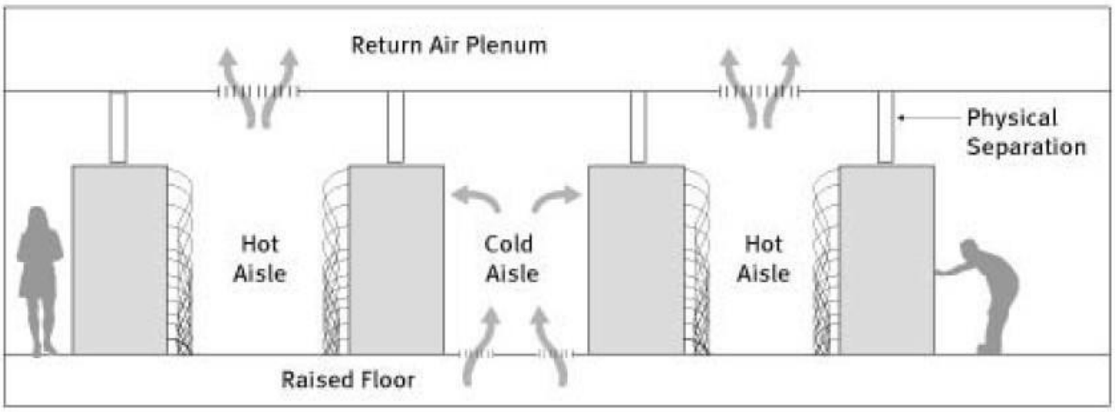

Figure 46:Hot aisle / cold aisle approach (Source: Greenberg, 2006)

Both overhead and underfloor 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 underfloor air distribution system, because the underfloor plenum is used as a duct, attention should be paid to avoiding obstructions (see the technique of cable management above), preventing bypass and negative pressure air flows (see the technique below), and 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 in part-load conditions).

Ensure 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 reinforce the energy efficiency of a hot aisle / cold aisle arrangement:

- blanking panels 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 bypass and negative pressure flows;
- enclosing panels should be installed in such a way as 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).

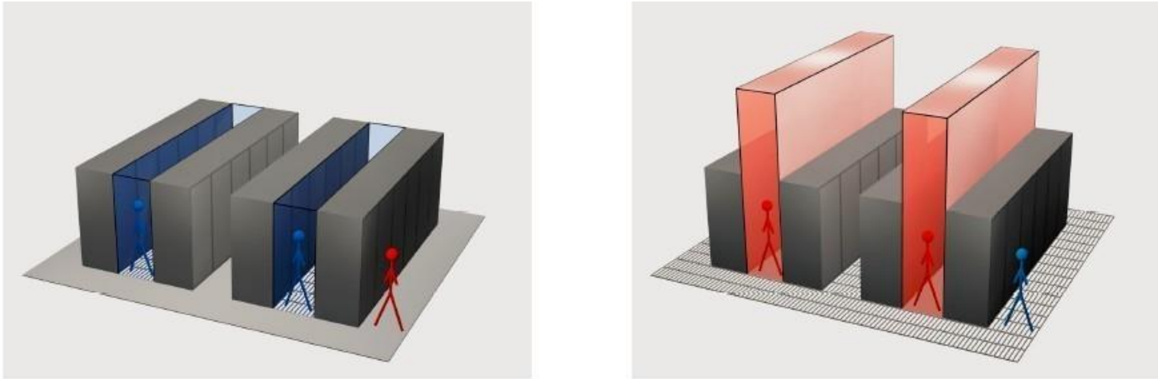

Figure 47:Cold aisle containment (left) and hot aisle containment (right)

Since the supply air volume is dramatically reduced, fan speeds and the cold air supply can be reduced, and therefore the energy consumption related to the 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.

Segregate equipment and separate environmental zones.

Beyond the containment of hot and cold aisles, pieces of IT equipment should be segregated according to their environmental requirements. Such a configuration will allow the provision of appropriate airflows (mainly in terms of humidity and temperature) 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 the cooling performance.

Improve the floor and ceiling design to optimise airflow.

The distribution of cooling air can suffer from interferences under the floor (cable congestion in raised-floor plenums for example) or overhead. This can significantly reduce the airflow and promote the development of hotspots. A cable management strategy aims at minimising airflow obstructions. It should target the entire cooling air flow path and insure a 60 cm clear height within a 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 floors, suspended ceilings, aisle containment or ducts.

Adjust 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 (bypass air flow and recirculation air flow percentage), raised floors (pressure differentials within plenums) and CRAC/CRAH (air flow supply).

With such measurements, the 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 contaminants (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 subsection can be more or less relevant.

For example, segregating equipment and creating separate environmental zones can be particularly interesting in the case of co-location: 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, evolution of the design of the facility or installation of new equipment.

Whereas the best practices identified above can be implemented in data centres of any size, scale effects can be observed in larger data centres with shorter returns on 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 29: Applicability of airflow management best practices

Best practice	Size	Security	Actor
Implement a hot aisle / cold aisle configuration	Any size	Tiers I, II, III[59]	Data centre operator
Ensure aisle 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
Improve the floor and ceiling design to optimise 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 virtually all data centres (Energy Star, 2014). However, retrofitting an existing data centre layout may have significant costs and designing appropriate airflow management may require professional expertise.

Table 30: Economics data related to the implementation of airflow 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 Cost of additional equipment such as return plenum	Energy savings: • Up to 40-45% in annual cooling system energy costs (Niemann, 2011).
Ensure aisle 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 optimise 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

[59] The compartmentalisation of Tier IV data centres prevents contamination of waste heat.

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 the reduced 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 the operating temperature of the UPS and electrical switchgear.

The data centre of CSC Sevenoaks (UK) has specific airflow management design. Computer rooms are divided into low-density and high-density areas. All data equipment racks are laid out forming hot and cold aisles, improving airflow 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 maximising the cooling ability of the air. The data centre won the EU 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 is consolidated in Section 3.2.7.

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

3.2.5.1 Description

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 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 in optimum condition depending on IT load requirements to preserve its efficiency; • review and adapt the cooling system capacity by shutting down unused equipment and better taking into account specific equipment's operating requirements; • optimise and automate the cooling system output by connecting CRAC units or using smart and multifactor units.					
ICT components					
Data centre	Telecommunication network	Broadcasting	Software publishing	End-user devices	
Relevant life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	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 (%) • Carbon Usage Effectiveness (CUE) • Water Use Efficiency (WUE) • Share of data centres that have implemented the expected minimum 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/TR 50600-99-1 regarding cooling management					
Cross references					
Prerequisites	• Commitment from senior management				
Related BEMPS	• 3.2.2 Implement an energy management system for data centres (including measuring, monitoring and management of ICT and other equipment) • 3.2.3 Define and implement a data management and storage policy • 3.2.4 Improve airflow management and design • 3.2.6 Review and adjust temperature and humidity settings				
Benchmarks of Excellence	• Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems • All data centres have implemented the expected minimum 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/TR 50600-99-1 regarding cooling management				

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.

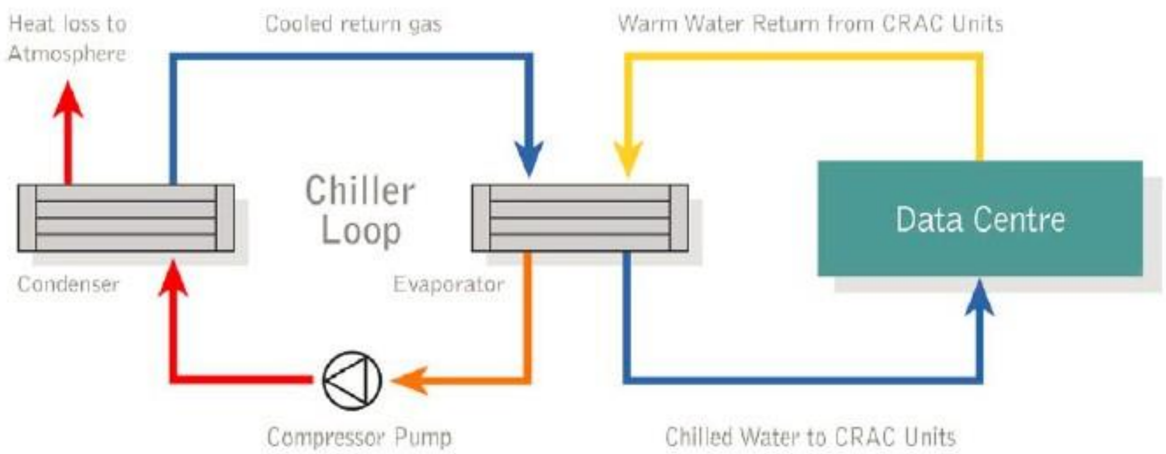

Figure 48: Simplified chiller schematic – typical cooling system (Source: BCS, 2010)

Sizing the necessary cooling system of a data centre depends on the environment where the data centre is located (see also BEMP 3.4.5 Selecting the geographical location of the new data centre), on the effectiveness of IT equipment used in the data centre (see also BEMP 3.2.3 Selection and deployment of equipment for data centres) and on the airflow management performance (see also BEMP 3.2.4 Improve airflow management and design).

In order to improve the cooling management of existing data centres, it is best practice to do the following (CENELEC, 2016):

- Maintain the cooling system in optimum condition depending on IT load requirements.

  Ensuring effective regular maintenance of the cooling system allows the system to be kept in good working condition and hence preserve its efficiency.

- Review and adapt the cooling system capacity.

  Regular reviews of the cooling system capacity helps monitor its evolution against its original design. Following a review of capacities, several measures can be decided, such as:

  - shutting down unused equipment (which is easier 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 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 the following:

- At the cooling plant level:
  - selecting chillers with a 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 kept for later use;
  - designing recooler and fans for free cooling conditions up to 18 °C (PASM, 2016);
  - installing chillers to reuse ICT heat in winter in building heating systems (PASM, 2016);
  - using refrigeration fluid with a GWP of 1 (e.g. 1234ze).
- At the computer room air conditioner or handler level:
  - 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 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 the **direct energy consumption** of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply[60].

Mechanical cooling is often considered to be the major part of the energy consumption overheads. 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). In practice, the measurement of the COP is often impractical; the COP provided by the manufacturer will be used.

To assess the energy efficiency of the entire cooling system within the data centre, the following indicator 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.

The Green Grid Association developed indicators relevant for measuring and comparing the environmental performance of data centres, inlcuding:

- 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).[61] Note that there is a trade-off between water usage (captured by WUE) and energy use.

Besides these outcome-oriented indicators, process-oriented indicators can be defined, such as:

- Share of data centres that have implemented the expected minimum 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/TR 50600-99-1 regarding cooling management.

[60] Energy production and transmission generates huge pressure on the environment: greenhouse gas emissions (related to fossil-fuel burning), water consumption (for running steam turbines of fossil-fuel and nuclear plants), natural resources consumption (fossil fuels, wood, etc.) or landscape disturbance (plants, electrical lines, etc.).

[61] For more information about the WUE : https://www.thegreengrid.org/en/resources/library-and-tools/238-Water-Usage-Effectiveness-%28WUE%29%3A-A-Green-Grid-Data-Center-Sustainability-Metric-

3.2.5.4 Cross-media effects

Energy consumption and second-order environmental pressures (water consumption and GHG emissions) are closely linked to the different measures described in this section: if ambient outdoor air is not appropriate (e.g. in the case of damp climate, forest fire, etc.) when a direct air-side economiser is functioning, it can lead to 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, but require water. The National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 million litres per MW each year (NREL, 2014).

3.2.5.5 Operational data

Environmentally efficient cooling management can be implemented through different practices. Operational specificities of these practices are presented below.

Maintain 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. Specific attention should be paid to aspects of equipment such as belt tension, condenser coil fouling, evaporator fouling and filter changes.

Review and adapt 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 the identification of the 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 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 others. 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. Differentiated environmental management (temperature, humidity setting) can also be implemented to answer clients' demands. Computer rooms can be designed to enable areas with additional control for clients requiring strict environmental monitoring. Areas with additional control can be priced differentially to cover additional costs. Of course, these practices apply to data centre operators that rent out their computing or storage space, not for companies that manage their own data centres.

Optimise and automate 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, irrespective 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 data centres.

Table 31: Applicability of cooling management best practices

Best practice	Size	Security	Purpose
Maintain the cooling system close to its original condition	Any size	Any tier	Any purpose
Review and adapt the cooling system capacity	Any size	Any tier	Any purpose
Optimise and automate the cooling system output	Localised to enterprise-class data centres	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 the 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 32: Economics data related to the implementation of cooling management best practices

Best practice	Operating costs	Investment costs	Return on investment
Maintain the cooling system close to its original condition	Maintenance costs	NA	Energy savings due to the cooling system working at the designed efficiency
Review and adapt the cooling system capacity	Review costs	Cost of designing a modular arrangement	Energy savings due to decreased consumption
Optimise and automate the cooling system output	NA	Cost of smart equipment	Energy savings due to decreased consumption: • Automatically adjusting fan speeds can result in energy savings as high as 30% of the total cooling cost (CES Group, 2014) 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 practices 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 is consolidated in Section 3.2.7.

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 range (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 need for humidifiers.**

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

Relevant life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Airflow Efficiency (fan power in kWh / airflow in m^3/hour)
- Return Temperature Index (RTI)
- Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 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) • 3.2.3 Define and implement a data management and storage policy • 3.2.4 Improve airflow management and design • 3.2.5 Improve cooling management
Benchmarks of Excellence	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding temperature and humidity settings

3.2.6.1 Description

To properly operate, IT equipment has standardised operating environments (temperature, humidity and air quality) that must be maintained. The standardised operating environments for different types of equipment are set 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 performance (e.g. reliability, energy consumption). The last set of values published by the ASHRAE in 2011 is given in 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).

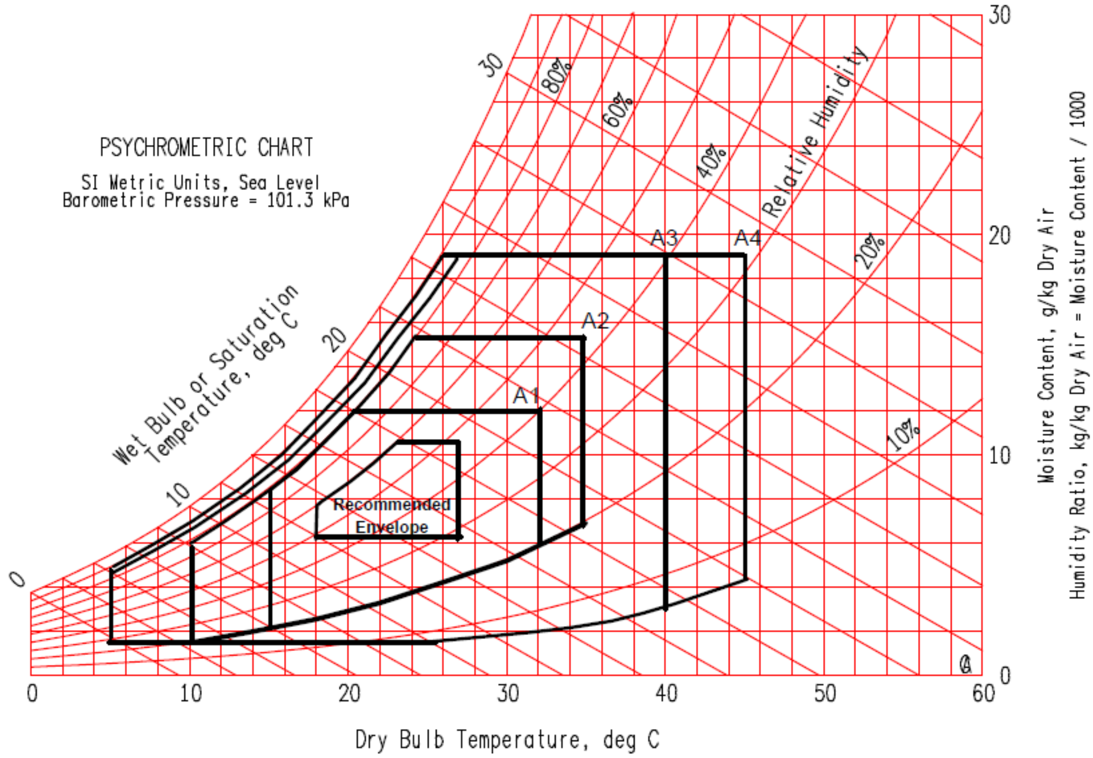

Figure 49: ASHRAE environmental classes for data centres (Source: ASHRAE, 2011)

ETSI standard *ETSI EN 300 019- Part 1-3: Classification of environmental conditions (Stationary use at weather-protected locations)* defines classes of environmental conditions and their severities to which telecommunications equipment may be exposed. Usually, facilities are overcooled, and the server intake temperature can be raised within the recommended or allowable temperature ranges. Such an 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.

62 The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) signed a memorandum of understanding in order to strive to harmonise international standards with the ASHRAE. We assumed that the operating environment parameters were similar.

Regarding temperature and humidity settings, it is best practice to do the following (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 human comfort standards, leading to unnecessary cooling), without overcooling the building:

  - the 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 rack 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 the 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 the server inlet temperature reduces energy consumption, due to a reduction of the cooling needs (similarly to humidity). Energy savings related to changes in inlet temperature will depend on the initial inlet temperature (how far it is 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 data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the/ Expected Practices of CLC/TR 50600-99-1 regarding temperature and humidity settings.

3.2.6.4 Cross-media effects

Raising operational temperature settings in a data centre for energy efficiency purposes can only be done up to a certain point (The Green Grid, 2013) due to the following reasons:

- The server power utilisation increases above a certain temperature (roughly 25 °C), 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 increased amount of air needed 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 will increase.

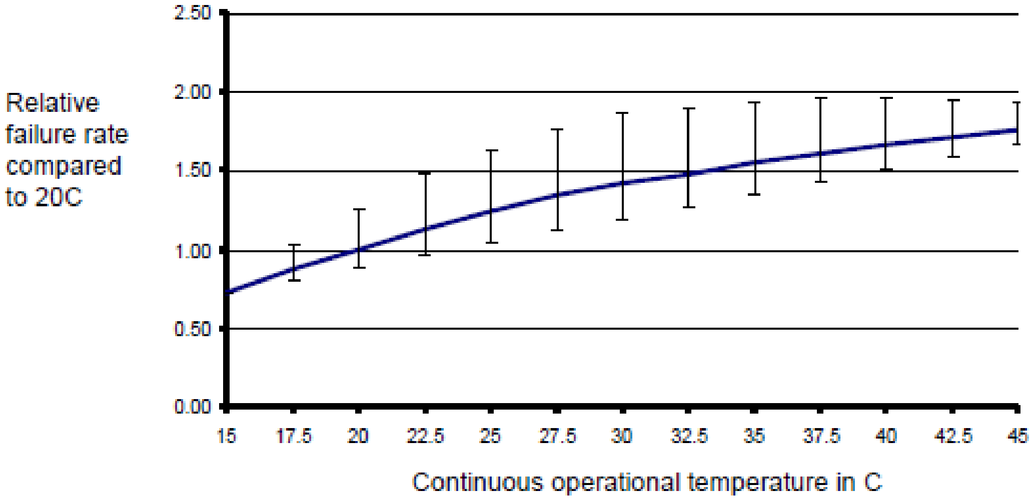

Figure 50: Relative server failure rate increase with temperature (Source: ASHRAE, 2011)

3.2.6.5 Operational data

Environmentally efficient cooling management can be implemented through different practices, keeping in mind that a holistic approach is preferred to define temperature and humidity requirements rather than considering them in isolation. Operational specificities of these practices are presented below.

Review and raise temperature set points if practical.

The whole Heating, Ventilation and Air Conditioning unit should use the server intake temperature as the temperature set point (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 that they are quick to deploy 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 the heat produced and environmental requirements.

In order to further increase temperature set points, technical areas of data centres should be considered industrial space (instead of setting the 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 the temperature set point or widening the humidity range of servers can only be done within the operational specifications 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 **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 m^2 Number or racks: 900 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.
Practice implemented	**Results**
One of the upgrades of the data centre consisted of an adjustment of the temperature set points of the CRAH sensors and the chiller units. The temperature of the water leaving the chiller plant 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 the 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 did not have to be lowered as much. Eventually, this triggered savings of over 893 000 kWh per year, i.e. a PUE improvement from 1.71 to 1.69.

Adjust 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 (bypass airflow and recirculation airflow percentage), raised floors (pressure differentials within plenums) and CRAC/CRAH (airflow supply). With such measurements, the fan speed can be adjusted (if multiple-speed fans are used), in order to produce a slight oversupply of air compared to the IT equipment flow demand, so as 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 contaminants (due to industries, forest fires, etc.) which could damage IT equipment. A mitigation strategy may involve filtration, which increases the fan power required.

Review humidity settings.

Humidity should be monitored at rack and CRAC/CRAH level, in order to optimise the operation of humidification and dehumidification. Equipment specifications related to humidity range should be met: most modern IT equipment is usually designed to operate in an environment with a humidity between 20% and 80%. The widest possible humidity range (like the one given by the ASHRAE in the figure above) should be used in order to reduce the demand for humidification and the humidifier's' load (in accordance with recommended environmental conditions).

Centralising the humidity control is achieved 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 competition (one unit dehumidifying and another humidifying).

Further energy savings can be obtained 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 (PG&E, 2012).

3.2.6.6 Applicability

Raising temperature set points, adjusting the volume and quality of supplied cool air, and reviewing humidity settings can be done in most data centres, irrespective of their size, security level or purpose.

Raising the temperature set point or widening the humidity range of servers can only be done within the operational specifications 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 33: Economics data related to the implementation of temperature and humidity settings best practices

Best practice	Operating costs	Investment costs	Return on investment
Raise temperature set points	NA	No additional cost if the equipment is already capable of working in a broader temperature range Selection of ICT equipment with a broader working range	Savings from decreased energy consumption from cooling
Adjust 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 Section 4.2, the main drivers 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 the 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 the 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 is consolidated in Section 3.2.7.

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.

3.2.7 Reference literature

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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 pieces of equipment and ICT services used in data centres:

Table 34: Structure of BEMPs related to data centres and relationship with CLC/TR 50600-99-1

BEMPs related to selecting and deploying new equipment and services in data centres • Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/TR 50600-99-1	
Techniques from EU CoC / CLC/TR 50600-99-1[63]	**BEMP**
Selection and deployment of new ICT equipment	
• Include energy efficiency performance when choosing new ICT equipment *(5.16.28)* • Purchase ICT equipment which operates within higher temperature and humidity ranges *(5.16.29) (5.16.30) (6.16.122)* • Select ICT equipment suitable for the data centre power density and cooling delivery capabilities *(5.16.31)* • Select ICT equipment which performs the required task within the lowest power consumption in the expected environmental conditions (temperature and humidity) *(5.16.32)* • Select ICT equipment suitable for the airflow direction in the area in which it is to operate *(5.16.33)* • Enable power management features on ICT equipment *(5.16.34)* • 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)* • Use the Energy Star labelling programmes as a guide to selecting the most efficient ICT equipment *(5.16.36)* • Select ICT equipment that is capable of reporting energy consumption and inlet temperature *(5.16.37)* • 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)* • Select ICT equipment containing high efficiency AC/DC power converters *(5.16.39)* • Select ICT equipment which provides mechanisms to allow the external control of its energy use *(6.16.123)* • Operate direct liquid cooled devices with supply coolant liquid temperatures sufficient to meet manufacturers' minimum cooling requirements *(6.16.124)*	**Selection and deployment of equipment for data centres (Section 3.3.2)** For general BEMPs related to procurement of ICT equipment and services refer to: ▪ Procurement of sustainable ICT products and services (Section 2.3)
Management of existing ICT equipment and services	
• Virtualise and archive legacy services *(6.16.125)* • Consolidation of existing services *(6.16.126)* • Identify and decommission low business value services *(6.16.127)* • Shut down and remove or put into a low poser 'sleep' state servers, networking and storage equipment that are idle *(6.16.128)* • 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: Define and implement a data management and storage policy (Section 3.2.3)

[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).

Selection and deployment of new ICT services	
• Deploy grid and virtualisation technologies wherever possible to maximise the use of shared platforms *(5.16.40)* • Reduce ICT equipment resilience level *(5.16.41)* • 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: 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)* • 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)* • 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:

- For an updated list of best practices, see the latest version of the CENELEC Technical Report *CENELEC technical report CLC/TR 50600-99-1:2016*.

The next sections will describe best practices related to the following areas:

- 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 on the operation of data centres. Co-location 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 environmentally friendly 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 centre equipment, from process preparation to bid evaluation;**
- **select and install environmentally performant servers and storage equipment, i.e. equipment with the option to 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 environmentally performant cooling equipment, i.e. equipment with a high CoP or variable speed controls, appropriately sized cooling units, centralised cooling systems, economisers, etc.;**
- **select environmentally performant power equipment, i.e. highly efficient UPS, modular UPS, etc.**

ICT components

Data centre	Telecommunication network	Broadcasting	Software publishing	End-user devices

Relevant life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Design PUE (dPUE)
- Share of ICT products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, Energy Star, sourced renewable energy)
- 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 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
Benchmarks of Excellence	• All new data centre ICT equipment is labelled with the ISO Type I ecolabel (e.g. EU Ecolabel, Blue Angel, etc.) (if available) or Energy Star label • All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding the selection and deployment of new ICT equipment / of cooling systems / of new power equipment / of other data centre equipment • UPS meet the requirements of the Code of Conduct for UPS • Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems

3.3.2.1 Description

ICT devices 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 do the following (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 35: An overview of the main priority equipment, software and services relevant for the procurement of sustainable data centre equipment

ICT equipment	Procurement options	Environmental hotspots
Servers and storage equipment	• Benchmark performance of the environmental performance of equipment • Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as Energy Star • Select equipment that has extended operating temperature and humidity ranges that allow free cooling • Select equipment with power management features and that allows external control of energy use • Select equipment suitable for the data centre airflow direction • Select with power and inlet temperature reporting capabilities • Purchase products that are easily repairable or recyclable with less hazardous materials	• Energy consumption (and CO_2 emissions) • Material consumption and waste management • Toxicity
Cooling system equipment and air handling equipment	• Select appropriately sized cooling units • Select more energy-efficient equipment such as: - chillers with high Coefficient of Performance - equipment with variable speed (or frequency) controls for compressors, pumps and fans - direct liquid cooled devices • Select equipment that uses natural refrigerants or with low ozone-depleting potential • Select appropriately sized air handling units • Select more energy-efficient equipment such as equipment with variable speed (or frequency) controls for fans	• Energy consumption (and CO_2 emissions) • Ozone-depleting substances and GHG emissions (from refrigerants)
Power supply equipment	• Select more energy-efficient equipment, e.g. purchasing ecolabelled equipment such as Energy Star, SERT or SPECPower; or following the EU Code of Conduct for external power supplies and Uninterruptible Power Systems (UPS) • Select equipment containing high-efficiency AC/DC power converters (rated at 90% power efficiency)	• Energy consumption (and CO_2 emissions)

- Select and install environmentally performant servers and storage equipment.

  Direct energy efficiency performance criteria should be included when selecting new ICT equipment, such as ICT equipment with the option to enable power management features (including external controls), ICT equipment containing high-efficiency AC/DC power converters or ICT equipment with the Energy Star label.

  When selecting new ICT equipment, the characteristics of the data centre should also be taken into account, to perform the required tasks with 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. This can indirectly reduce energy consumption.

- Select and install environmentally performant cooling equipment.

  Selecting and installing energy-efficient cooling equipment covers several types of practices:

  - selecting cooling equipment with a 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 defining 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 unit (distributed) 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;
  - installing blank panels and control fans.
- Select and install environmentally 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 the technical specification ETSI TS 102 121 V1.3.1) 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 requirements (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 implemented 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.

Besides the specific characteristics of each type of equipment, it is important to round off any deployment of environmentally friendly equipment with checks to ensure how all types of equipment work together, and avoid any rebound effect from incompatibility.

Finally, collaborative approaches on architecture development such as Open Compute can support the deployment of efficient data centres.

3.3.2.2 Achieved environmental benefits

Selecting energy-efficient technologies (cooling, power supply, IT, etc.) is expected to primarily reduce the **direct energy consumption** of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply[64]:

[64] Energy production and transmission generates huge pressure on the environment: greenhouse gas emissions (related to fossil-fuel burning), water consumption (for running the steam turbine of fossil-fuel and nuclear plants), natural resources consumption (fossil fuels, wood, etc.) or landscape disturbance (plants, electrical lines, etc.).

- 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 eliminate the need for the chiller or compressor entirely.

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. Fresh water 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, waste water and seawater have already been used.
- **Direct greenhouse gas emissions**, via refrigerant gas 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 the following:

- **Design PUE** (design power usage efficiency, based on standard EN 50600-4-2). The dPUE requires a capacity assessment of what can be expected from the data centre, and allows the operator to understand where the data centre will be losing energy.
- **Share of ICT products or services purchased by the company complying with specific environmental criteria** (e.g. EU Ecolabel, Energy Star, Blue Angel, 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency** or the Expected Practices of CLC/TR 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 closely linked to the different measures described into this section:

- If ambient outdoor air is not appropriate (e.g. in the case of damp climate, forest fire, etc.) when a direct air-side economiser is functioning, it can lead to 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 million litres per MW each 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 electrical and electronic 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 of the environmental performance.

3.3.2.5 Operational data

Environmentally efficient cooling management can be implemented through different practices. Operational specificities of these practices are presented below.

Implement 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 the energy consumption of 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 a 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].

Select environmentally 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 possible 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 complying with specific environmental criteria (e.g. EU Ecolabel, Energy Star, Blue Angel);
- 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 purchasing new software. Poorly behaved software inhibits the energy-saving features of the servers' Core Process Unit (CPU) (Sabharwal, Agrawal, & Metri, 2013).

Select environmentally performant cooling equipment.

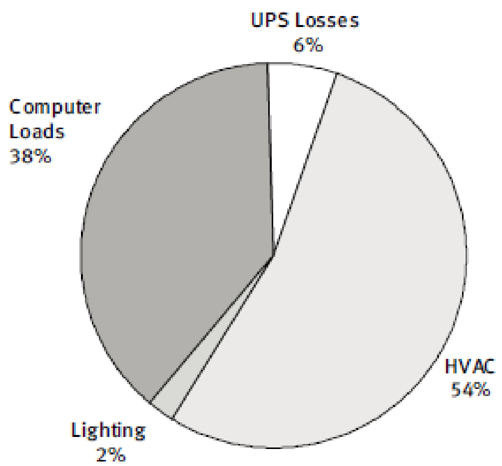
<u>Select energy-efficient air handling</u>

In a centralised air handling system, cooling is done 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 unit (distributed) system (Computer Room Air Conditioners) since:

[65] Parts 4.5.3.6 and 4.5.3.7 will focus solely on the deployment of cooling equipment. For other types 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.

- 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 the 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).



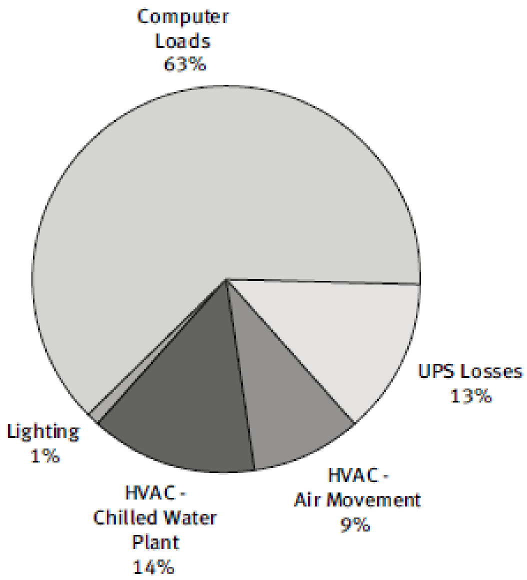


Figure 51:Distribution of electricity consumption of two data centres, one using multiple CRAC units (left) and one functioning with centralised air handling (right) (Source: PG&E, 2012)

Select energy-efficient cooling equipment

The different solutions which can be implemented (described below) rely on transforming or improving indoor or outdoor heat exchange, or changing of transport fluid (e.g. refrigerant, chilled water, air, etc.).

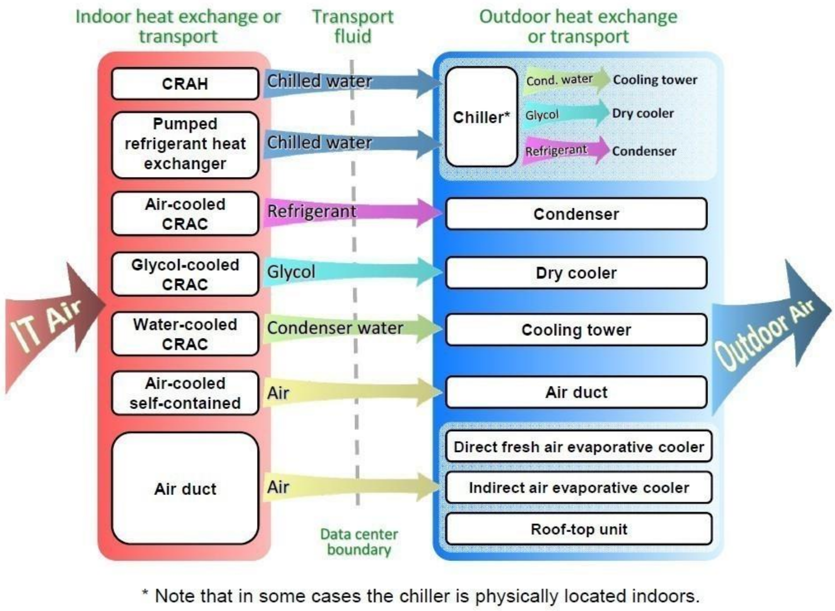


Figure 52:The different technologies for cooling data centres (Source: Evans, 2012)

The first step when designing an energy-efficient cooling system relies on the selection of the most appropriate technology. Several technologies are presented in this section:

- free cooling;
- water source cooling;
- direct liquid cooling;
- centralised air handling.

Free cooling

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 lower–temperature outside air.

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), backup mechanical cooling or compressors should be used instead. These are called 'economised cooling systems', which use 'free cooling' for part of the year. Cooling designs should allow the use of free cooling as much as possible.

Free cooling consists of introducing the outside air for complete or partial cooling of the data room. When outside conditions are suitable for the use of free cooling, 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% (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 an 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).

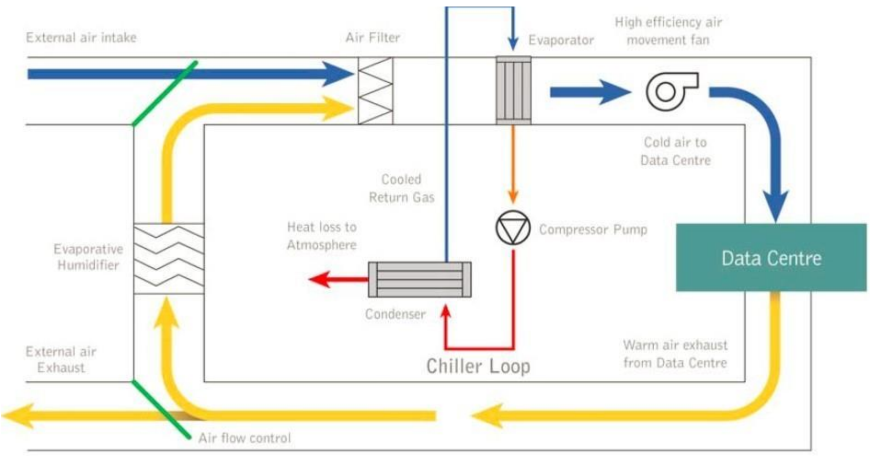


Figure 53:Simplified layout of air-side free cooling (Source: BCS, 2010)

The use of air-side free cooling 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.

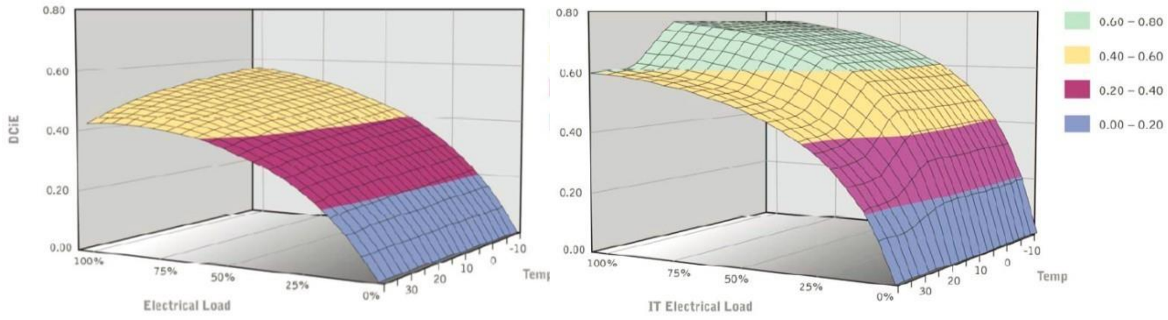


Figure 54:DCIE by IT electrical load and external temperature for traditional cooling (left) and while using direct air free cooling (right) (Source: BCS, 2010)

Fluid economisers can be used in a wider range of climates since they allow 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 in 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.

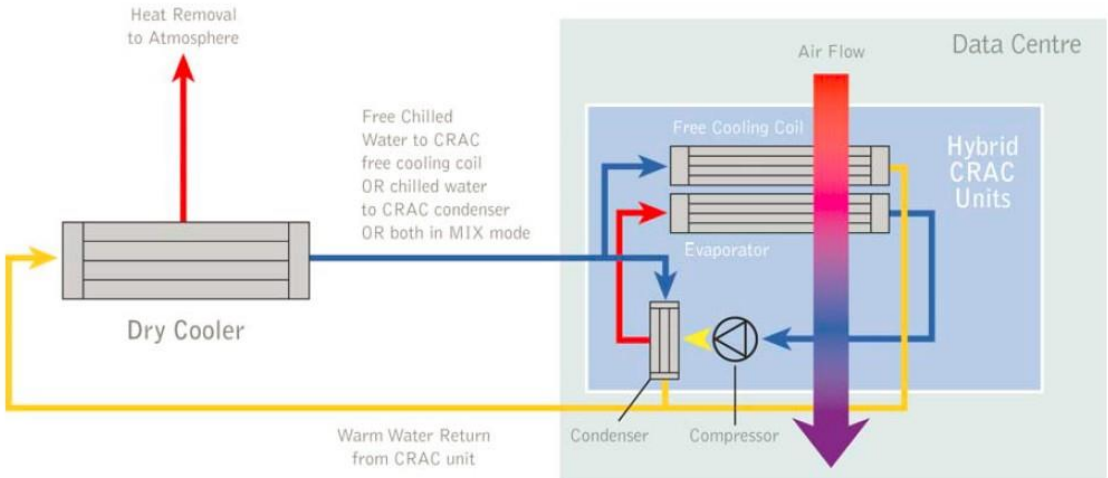


Figure 55:Simplified layout of a water-side economiser (Source: BCS, 2010)

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 it 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 in warmer conditions than parallel economisers and can provide free cooling for a longer time during the year.

Water source cooling

This technique, which can be implemented by data centres located in close proximity to a lake or a river, is very similar to a fluid (water-side) economiser. The water is used for dissipating the thermal load of the data centre, but without a cooling tower as shown in the figure below.

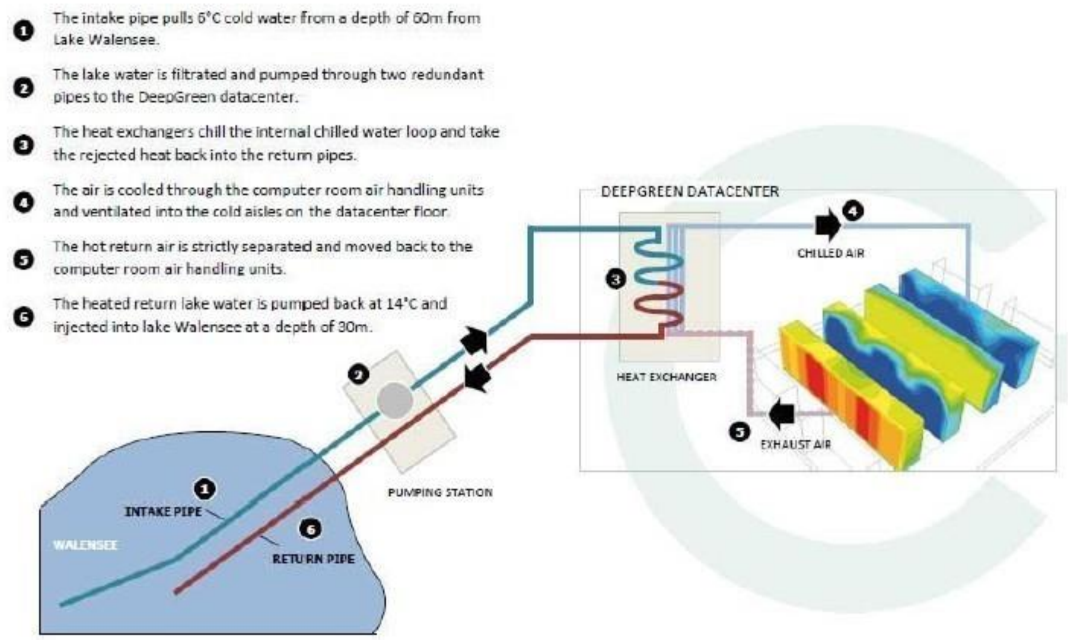


Figure 56:Example of the water source cooling process (Source: GENIC, 2014)

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 under the floor;
- 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).

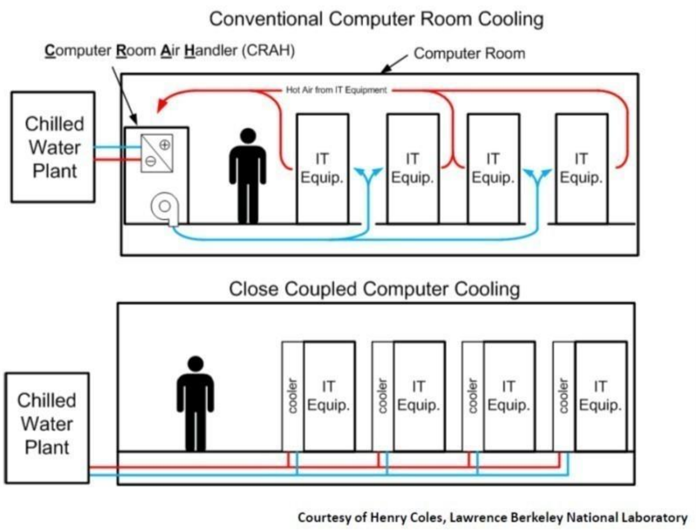


Figure 57:Schematic view of traditional computer room cooling (top) and water-cooled rack cooling (bottom) (Source: Henry Coles, Lawrence Berkeley National Laboratory)

Select 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 Energy Efficiency in Data Centres* (JRC, 2015)) can be implemented in order to increase the energy efficiency of power systems providing the energy used by data centres:

- Selecting highly efficient Uninterruptible Power Systems (UPS), using rectifiers which can allow a reduction of energy losses due to electricity conversion. UPS with an efficiency over 97% can be considered best performance (Emerson, 2010; UPS Ltd, 2015).

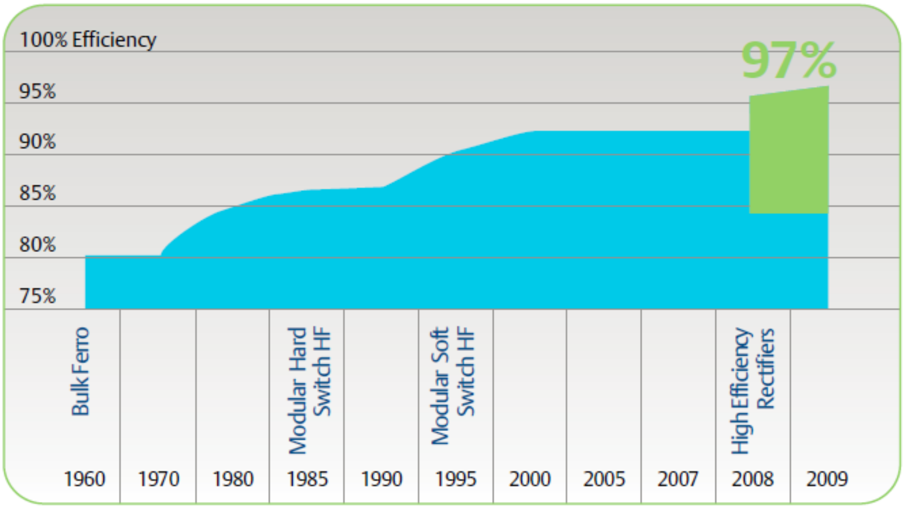


Figure 58:Telecom rectifier efficiency trend (Source: Emerson, 2010)

- Installing modular UPS, where equipment sources of inefficiency (mainly switching units and batteries) can be easily replaced if the electrical load of the facility evolves.
- Choosing an appropriate UPS solution design depending on the load requirements of the infrastructure.

3.3.2.6 Applicability

Cooling equipment

Free cooling can only be used when the temperature of the return flow of the cooling system is 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, as is the temperature and humidity range of IT equipment. A few years ago, free cooling was said to be 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% of Europe (extremely hot areas in north-west Spain and in Sicily, and one excessively damp area in south-west 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 free up 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 as 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 closely linked to the activity and the size of the company. For example, chilled water systems are suitable for data centres of 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 the new infrastructure is being built or when upgrading the existing infrastructure. For new installations, the management team must do the following (PrimeEnergyIT, 2011):

- Assess its needs and size the UPS systems correctly (evaluate multiple or modular UPS, scalable and expandable solutions): battery backup time, cost, size, number of outlets, etc.
- Analyse the UPS technology and efficiency. Take into account the partial load efficiency of UPS.
- Select the correct topology of the power supply systems.
- Select UPS systems compliant with the EU Code of Conduct for UPS or Energy Star (both of which specify minimum efficiency requirements for UPS).

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 36: 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
Select environmentally performant servers and storage equipment	Any size	Any tier	Any purpose
Select environmentally performant cooling equipment	Localised to enterprise-class data centres (depending on the technology implemented)	Any tier	Any purpose
Select environmentally performant power equipment	Server room to enterprise-class data centres Localised to enterprise-class data centres (depending on the technology implemented)	Any tier	Any purpose

3.3.2.7 Economics

Table 32 below gives an overview of costs and return estimates for each best practice.

Table 37: 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
Implement a green procurement policy	Costs of applying the policy to procurement processes	NA	Savings from decreased energy consumption
Select environmentally 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
Select environmentally performant cooling equipment	Costs of applying the policy to procurement processes	Additional costs from purchasing higher-quality equipment	Savings from decreased energy consumption (PG&E, 2012): • Up to 60% cooling costs reduction, depending on the climate • Up to 50% reduction in electricity costs with a centralised air handling system
Select environmentally performant power equipment	Costs of applying the policy to procurement processes	Additional costs from purchasing higher-quality equipment; • Modular UPS is 10-15% more expensive than a traditional UPS system (UPS Ltd, 2016)	Savings from decreased energy consumption: • 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 the 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 that the amortisation period is 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 costs 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 EUR 1 800 (for a 10 kW rack) to EUR 6 200 (for a 25 kW rack), on the basis of a cost of electricity at EUR 0.12/kWh. Similarly, selecting a 5% higher efficiency model of UPS can save over EUR 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.

Additionally, maintenance remains an important issue when selecting a new cooling technology, as 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 front runner in terms of data centre energy efficiency. A large part of its data centres' very high PUE (slightly above 1.1) is due to the integration of 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 a UPS efficiency of 99.9% (DataCenterKnowledge, 2009).

Among other good practices included in the EU Code of Conduct on Data Centre Energy Efficiency, the 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 chapters 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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3.4 BEMPs related to new build or refurbishment of data centres

3.4.1 Scope and structure of BEMPs related to new build or refurbishment of data centres

The design and siting of a data centre has a major influence on 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 utilisation, etc. Nowadays, data centre 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 38: Structure of BEMPs related to data centres and relationship with CLC/TR 50600-99-1

BEMPs related to new build or refurbishment of data centres • Expected (5.1) and optional (6.1) Practices for Existing Data Centres in CLC/TR 50600-99-1	
Techniques from EU CoC / CLC/TR 50600-99-1[66]	**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)** For general BEMPs related to procurement of ICT equipment and services refer to: ▪ 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)* • Consider building a data centre to provide multiple levels of power and cooling resilience *(5.19.50)* • Limit provisioning of power and cooling to a maximum of 18 months of computer room growth capacity *(5.16.51)* • 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 3.4.2)**
Airflow management and design	
• Implement hot/cold aisle alignment of ICT equipment *(5.16.53)* • 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)* • Install aperture brushes (draught excluders) or cover plates and panels to minimise all air leakage in each cabinet / rack *(5.16.55)* • Replace solid doors with perforated doors to ensure adequate cooling airflow to ICT equipment *(5.16.56)*	**Improve airflow management and design (Section 3.2.4)**
Selection of cooling system	
• Select chillers with high Coefficient of Performance *(5.16.57)* • Design the cooling system infrastructure to maximise its efficiency under partial load conditions *(5.16.58)* • Utilise variable speed (or frequency) controls for compressors, pumps and fans to optimise energy consumption during changing load conditions *(5.16.59)* • Select cooling designs and solutions which facilitate the use of economisers *(5.16.60)* • Segregate chilled water systems from those designed to provide human comfort	**Selection and deployment of equipment for data centres (Section 3.3.2)** For general BEMPs related to procurement of ICT equipment and services refer to: ▪ Procurement of sustainable ICT products and services (Section 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).

(5.16.61) • 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)* • Review chilled water systems configured with dual pumps (one active, one standby) for options to improve energy efficiency during operations *(5.16.63)* • Install free cooling in all new builds and retrofits or upgrades of cooling systems *(6.16.133)* • Implement air free cooling / cooling of the data centre by using external air *(6.16.134)* • Implement indirect air free cooling / cooling using an air-to-air heat exchanger *(6.16.135)* • 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)* • 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)* • Implement indirect water free cooling with CRAH and free cooling chiller / cooling using chilled water produced by the free cooling chiller *(6.16.138)* • 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)* • Use alternative cooling sources *(6.16.106)* • Install variable speed fans *(5.16.64)* • Control CRAC/CRAH units based on cold air supply temperature only *(5.16.65)* • Centralise humidity control at the supply air handling unit / Do not control humidity at CRAC/CRAH unit *(5.16.66)* • Select appropriately sized cooling units *(5.16.67)* • Implement direct liquid cooling of ICT equipment *(6.16.141)* • Operate CRAC/CRAH units with variable speed fans in parallel *(6.16.142)* • 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)* • Select high efficiency UPS systems *(5.16.69)* • Deploy UPS units in their most efficient operating modes *(5.16.70)* • 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)* • Eliminate isolation transformers from distribution to ICT equipment *(5.16.72)* • 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)** For general BEMPs related to procurement of ICT equipment and services refer to: ▪ 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)* • Use pale/light colours on walls, floor fixtures and fittings including cabinets, etc. to reduce the amount of lighting required *(5.16.75)* • 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)* • Use additional heat pumps to raise the temperature of waste heat to a useful point *(6.16.145)* • Use computer room waste heat to warm office, generator and fuel storage areas *(6.16.146)*	**Reuse of data centre waste heat (Section 3.4.3)**

• Measure and report on energy reuse *(6.16.147)*	
Data centre building physical layout	
• Locate mechanical and electrical equipment which generate heat outside the cooled data centre spaces *(5.16.77)* • 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)* • 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)* • Locate cooling equipment in an area with free air movement *(5.16.77)* • Minimise direct solar heating (insolation) of the cooled areas of the data centre *(5.16.77)*	**Design of the data centre building and physical layout (Section 3.4.4)**
Data centre geographical location	
• Locate the data centre where there are available opportunities for the reuse of waste heat *(6.16.148)* • 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)* • 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)* • Locate the data centre near a source of free ground source cooling such as a river or lake *(6.16.151)* • 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 3.4.5)**
Water sources	
• Capture and store rain water for evaporative cooling *(6.16.153)* • Use local non-utility water sources for evaporative cooling *(6.16.154)*	**Use alternative water sources (Section 3.4.6)**
• 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)* • Implement collection and logging of full economiser, partial economiser and full refrigerant and compressor based cooling hours throughout the year *(5.16.83)* • 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:

- For an updated list of best practices, see the latest version of the CENELEC Technical Report CLC/TR 50600-99-1 Information technology – Facilities and infrastructures – Data centre – Energy management – Recommended Practices.

The next sections will describe the following BEMPs:

- Planning of new data centres – Section 3.4.2.
- Reuse of data centre waste heat – Section 3.4.3.
- Design of the data centre building and physical layout – Section 3.4.4.
- Selecting the geographical location of the new data centre – Section 3.4.5.
- Use of alternative sources of water – Section 3.4.6.

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.

3.4.2 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 high 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Energy use of the data centre per floor area (kWh/m^2)
- Design PUE (dPUE)
- Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres

Cross references

Prerequisites	NA
Related BEMPS	• 3.4.3 Reuse of data centre waste heat • 3.4.4 Design of the data centre building and physical layout • 3.4.5 Selecting the geographical location of the new data centre • 3.4.6 Use of alternative sources of water
Benchmarks of Excellence	All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding utilisation, management and planning of new build and refurbishment of data centres

3.4.2.1 Description

The planning sequence should establish the location and design requirements of the data centre's equipment and physical infrastructure (e.g. power, cooling, building, security). It can be divided into four 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.).

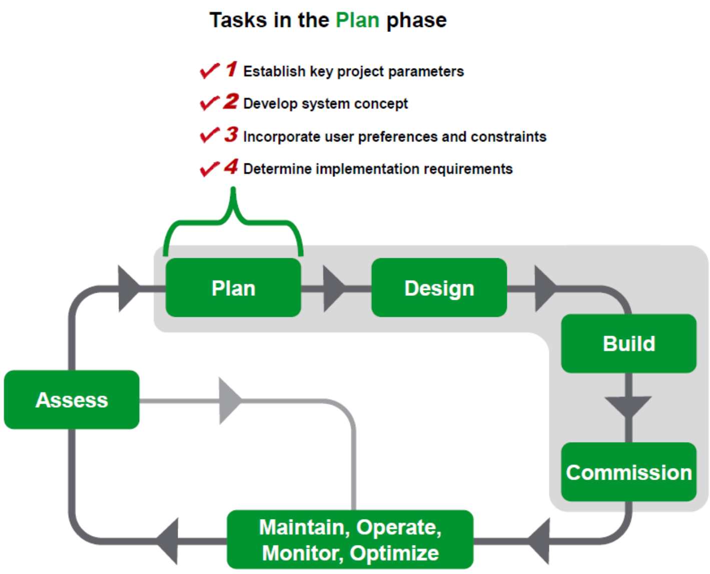


Figure 59:System planning of data centre projects (Source: Rasmussen, 2013)

The planning of projects to build or upgrade data centres remains a major challenge for many IT departments (lack of communication, inadequacy for needs, extra costs, delays, etc.), especially in terms of building an environmentally friendly data centre.

The energy and environmental goals for the data centre infrastructure system should be one of the key parameters defined initially (along with criticality, capacity, growth plan, density and budget) by consulting key stakeholders: finance executives, CEO, key IT executives, IT operations manager, etc. (Rasmussen, 2013). Two main issues rely on avoiding oversizing the data centre and building a data centre using 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, 2014).

When planning data centres, it is best practice to do the following (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. Multipath 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 backup. A new data centre should be designed to maximise infrastructure's efficiency under partial and variable load conditions.

3.4.2.2 Achieved environmental benefits

By avoiding oversizing the data centre and building a data centre using practical modular architecture, this will:

- reduce energy and material consumption as less space is needed;
- lower the land footprint of the facility (soil sealing).

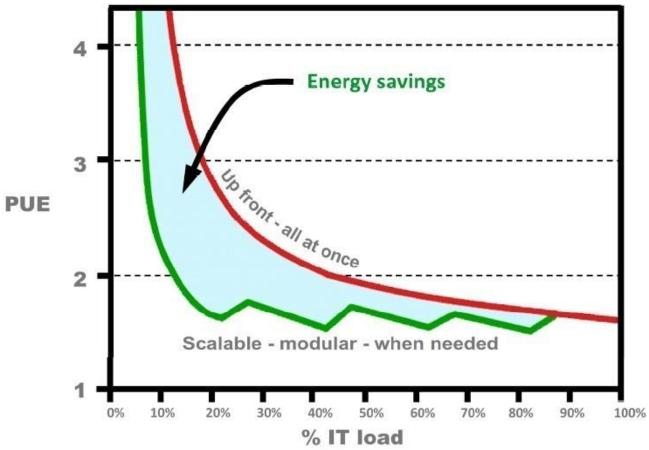


Figure 60:PUE improvements due to data centre modularity (Source: Rasmussen, 2011)

3.4.2.3 Appropriate environmental performance indicators

The major metrics for defining energy efficiency goals, and then to monitor results are as follows:

- **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).
- **Design Power Usage Effectiveness (dPUE)**, 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres

3.4.2.4 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)

3.4.2.5 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 occurs when the design value of the power and cooling equipment exceeds the IT load (Rasmussen, 2011). This situation can be observed in the following cases:

- 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 too large for the IT load.
- The power and cooling systems are sized for a future larger load. The expected IT load is usually about 90% of total capacity, but the IT load is 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 use gradually increases 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.

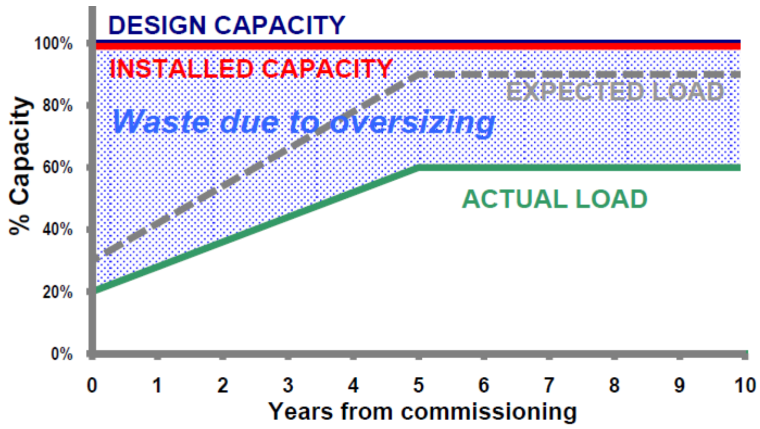


Figure 61:Evolution of the IT load of a typical data centre (Source: (Rasmussen, 2011)

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 of this: 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, and also for the consolidation of such equipment.

Another solution to avoid extra energy consumption related to oversizing is to continuously adapt the power and cooling equipment to the 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 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 the ultimate design capacity).
- The installation of the UPS, battery system, power distribution units, bypass switchgear and rack power distribution wiring can be phased, and should be able to use the existing/initial cable distribution (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 optimise the switching on and off of the cooling system (or adjust the fan speed if possible) in line with the required temperature[67].
- Special site preparation such as raised floors would be reduced.

[67] Wireless sensors (i.e. temperature sensors distributed on racks and control units on cooling units) implement adaptive algorithms in order to maintain the set point defined for each sensor, and switch the cooling unit on and off or adapt the fan speed.

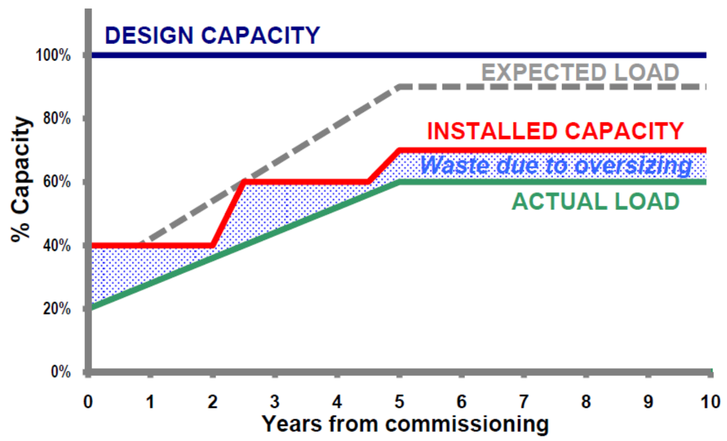


Figure 62:Mitigation of the oversized power capacity over the lifetime of a data centre through modularity (Source: Rasmussen, 2011)

3.4.2.6 Applicability

Building a data centre according to modular architecture is particularly relevant for big data centres (since cost savings can overcome the constraints resulting from 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 consumption.

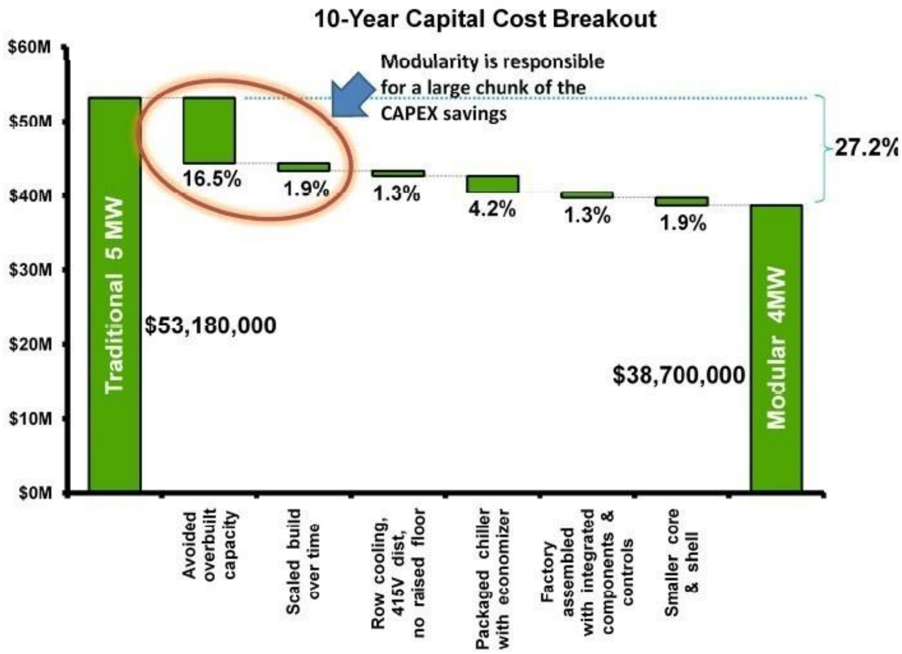
Table 39: Applicability of best practices regarding the planning of new data centres

Best practice	Size	Security	Purpose
Limit the level of physical infrastructure resilience and service availability according to business requirements	Localised, mid-tier and enterprise-class data centres	Any tier	Any purpose
Consider building a data centre to provide multiple levels of power and cooling resilience	Localised, mid-tier and enterprise-class data centres	Any tier	Any purpose

3.4.2.7 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).



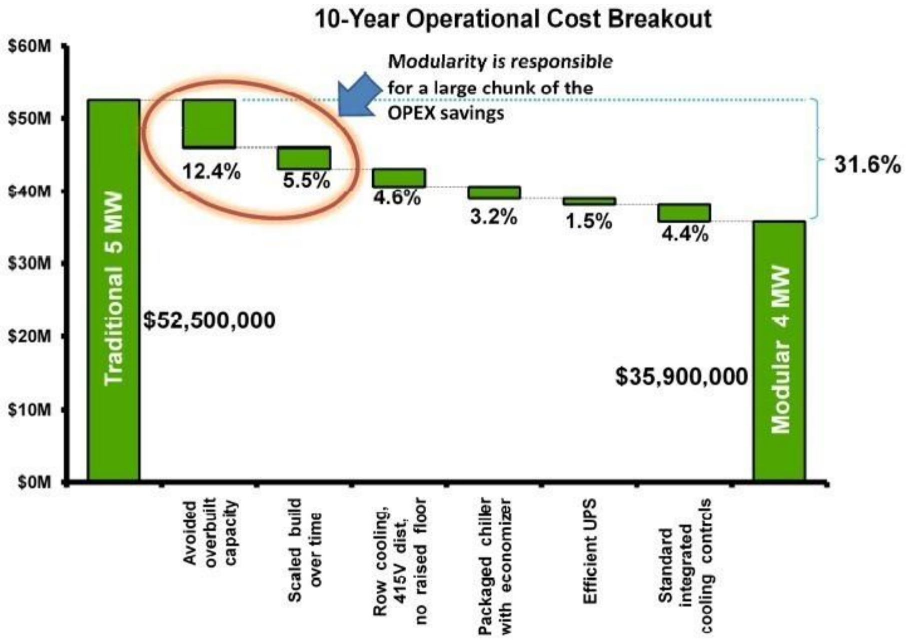


Figure 63:Major CAPEX (top) and OPEX (bottom) cost savings related to the implementation of modular architecture (Source: Torell, 2014)

Table 37 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 planning of data centres

Best practice	Operating costs	Investment costs	Return on investment
Limit the level of physical infrastructure resilience and service availability according to business requirements.	NA	Selecting modular equipment and design	Savings from decreased energy consumption: • Up to 30% decrease of TCO in a modular data centre compared to a traditional oversized data centre (Torell, 2014)
Consider building a data centre to provide multiple levels of power and cooling resilience	NA	Selecting modular equipment and design	Savings from decreased energy consumption

3.4.2.8 Driving force for implementation

As demonstrated previously, the main driver when designing modular architecture relies on the important cost reductions allowed during the lifetime of the data centre. But other parameters can benefit from such practices as well since the reliability of the data centre will be improved by the easier maintenance and replacement of power and cooling equipment.

However, 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 oversized risks.

3.4.2.9 Reference organisations

The Citigroup Frankfurt (Miller, 2009) data centre obtained a Platinum Leadership in Energy and Environmental Design (LEED) rating from the U.S. Green Building Council (USGBC) for its optimised design, while the Lamda Hellix Athens 1 data centre (USGBC, 2016) obtained a Gold rating. Among other things, both data centres optimised 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 its cooling system. It uses sensor average temperatures and supply and return temperatures of the cooling system to alter fan and pump speeds on indoor and outdoor equipment to optimise free cooling (JRC, 2016).

The FCO Services Milton Keynes DC data centre (UK) installed modular, scalable power and cooling architecture that allows deployment as needed (JRC, 2016).

3.4.2.10 Reference literature

Reference literature is consolidated in Section 3.4.7.

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.

3.4.3 Reuse of data centre waste heat

SUMMARY OVERVIEW:					
Like any electrical equipment, IT equipment requires a 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: • **reuse 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 life cycle 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	Emissions to air	**Water use & consumption**	Noise and EMF emissions	Landscape and biodiversity
Environmental performance indicators					
• Energy Reuse Factor (ERF) • Energy Reuse Effectiveness (ERE) • Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding reuse of data centre waste heat					
Cross references					
Prerequisites	NA				
Related BEMPS	• 3.4.2 Planning of new data centres • 3.4.4 Design of the data centre building and physical layout • 3.4.5 Selecting the geographical location of the new data centre • 3.4.6 Use of alternative sources of water				
Benchmarks of Excellence	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding reuse of data centre waste heat				

3.4.3.1 Description

Like any electrical equipment, IT equipment requires a power supply and produces waste heat while running. As explained in the 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 the following (CENELEC, 2016):

- Reuse 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 by warming 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, generators 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 the 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, in situations where waste heat produced by the data centre cannot be directly reused due to an insufficient temperature.

3.4.3.2 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 there are connections between the two heating systems.

3.4.3.3 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 currently be used 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 could be:

- share of sites that have implemented the EU Code of Conduct on Data Centre Energy Efficiency / Expected Practices of CLC/TR 50600-99-1 regarding reuse of data centre waste heat

3.4.3.4 Cross-media effects

As long as the BEMP is implemented correctly, no significant cross-media effects seem to exist.

3.4.3.5 Operational data

Reuse 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 the data centre's hot aisles (typically between 27 °C 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 places which need to be warmed (offices, industrial buildings, swimming pools, animal and fish breeding, hydroponic cultivations, etc.).

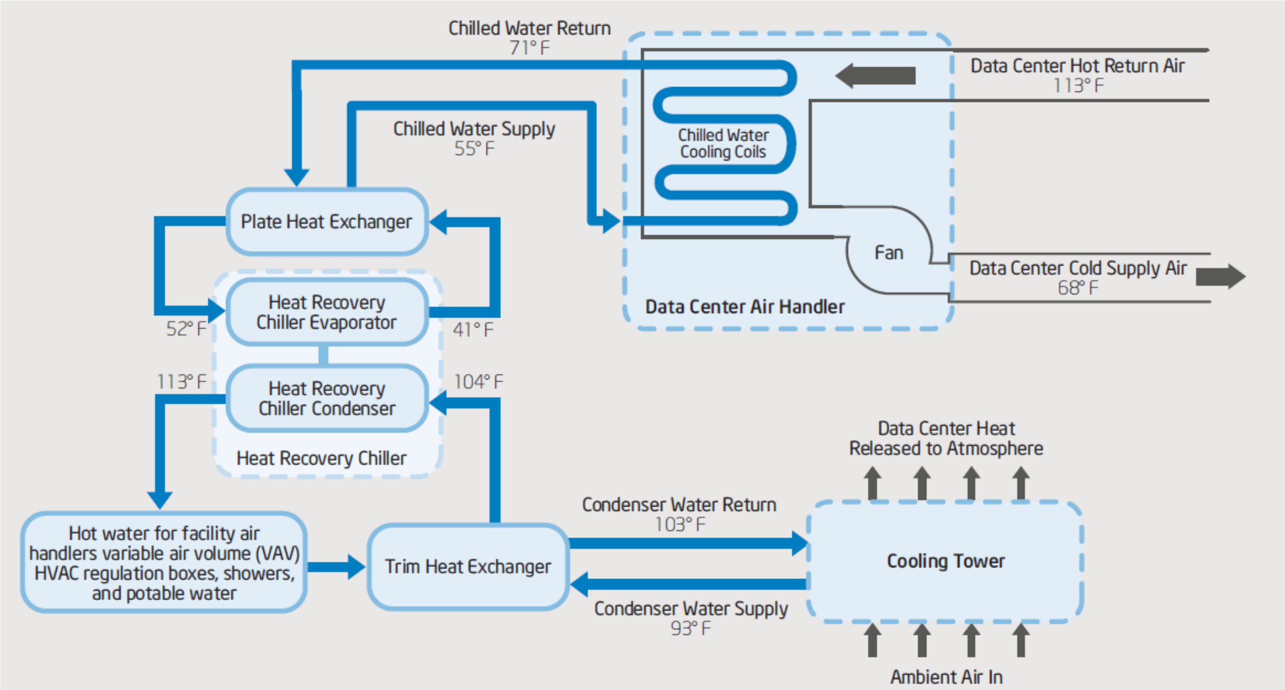


Figure 64:Heat recovery system implemented in an Intel data centre (Source: Intel, 2007)

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.

3.4.3.6 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 Section 3.4.3.5.

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 the exhaust temperature. Consequently, opportunities for reuse of waste heat will be growing.

3.4.3.7 Economics

Table 38 below gives an overview of costs and return estimates for each best practice.

Table 41: 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
Reuse 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: • Up to €1 500 per metre for trenching and installation to run a hot water pipe to a heat user (Monroe, 2016) Additional capex to reuse ICT heat via two chillers of 400 kWth: €174 000 (PASM, 2016)	- Some heat and power systems sell waste heat to district heating for € 0.1-0.3 per kWh (i.e. € 300 000 per year for a 1.2 MW data centre) (Monroe, 2016)

Intel developed a heat recovery system in 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.

3.4.3.8 Driving force for implementation

Data centres can transform waste heat into financial income 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.

3.4.3.9 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.

The Resilience Centre Luxembourg South (KAYL) data centre was awarded an EU Code of Conduct award in 2016. It reuses energy with heat pumps for offices (2 000 m^2) within the data centre, and for offices in another adjacent building (3 000 m^2).

3.4.3.10 Reference literature

Reference literature is consolidated in Section 3.4.7.

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.

3.4.4 Design of the data centre building and physical layout

SUMMARY OVERVIEW:					
The physical layout of the data centre significantly influences 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 optimise 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity
Environmental performance indicators					
• Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data centre building physical layout					
Cross references					
Prerequisites	NA				
Related BEMPS	• 3.3.2 Selection and deployment of environmentally friendly equipment for data centres • 3.4.2 Planning of new data centres • 3.4.3 Reuse of data centre waste heat • 3.4.5 Selecting the geographical location of the new data centre				
Benchmarks of Excellence	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding data centre building physical layout				

3.4.4.1 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 the following:

- Environmental criteria for site selection (see Section 3.4.5);
- Equipment technologies of the data centre, and especially powering, cooling and air management systems, since this equipment consumes important amount of energy in a data centre[68]. 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):

[68] Section 3.3.2 demonstrates that important energy-savings can be made when choosing more energy-efficient technologies

- 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 do the following (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 optimise cooling performance, areas free of obstructions and free of equipment generating heat.

After the design sequence, implementation requirements should be set. These correspond 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 select more-efficient models within the equipment technologies already chosen (see Section 3.3.2).
- 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 performance (see Section 3.3.2).

3.4.4.2 Achieved environmental benefits

Energy needed for cooling can be decreased by implementing the practices presented in this section. For instance:

- locating equipment which generates heat (such as UPS) outside the cooled data centre spaces reduces the loading on the data centre cooling plant;
- reducing obstructions of airflows 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.

3.4.4.3 Appropriate environmental performance indicators

An overall process-oriented indicator that can be monitored is:

- share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data centre building physical layout.

3.4.4.4 Cross-media effects

In order to have separate 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.).

3.4.4.5 Operational data

Minimise 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 roof 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 shade roofs using photovoltaic panels producing local renewable energy that can directly power UPS batteries with the DC current produced.

Locate 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 floors, suspended ceilings, 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.

3.4.4.6 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-build data centre and can be costly to implement.

3.4.4.7 Economics

The table below gives an overview of costs and return estimates for both best practices.

Table 42: 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	Decreased 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	Decreased cost of energy for cooling purposes

3.4.4.8 Driving force for implementation

Similarly to other practices related to new-build data centres, integrating an 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.

3.4.4.9 Reference organisations

NIA

3.4.4.10 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.

3.4.5 Selection of 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:

- **favour brownfield locations over greenfield;**
- **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;**
- **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 reduction 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	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 a heat reuse system
- Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data centre geographical location

Cross references	
Prerequisites	NA
Related BEMPS	• 3.4.2 Planning of new data centres • 3.4.3 Reuse of data centre waste heat • 3.4.4 Design of the data centre building and physical layout
Benchmarks of Excellence	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected and optional practices of CLC/TR 50600-99-1 regarding data centre geographical location

3.4.5.1 Description

After establishing key project parameters (capacity, costs, etc.), the system concept shall be developed and the site 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 do the following (CENELEC, 2016):

- Favour brownfield locations over greenfield.
- 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 reduce 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 such 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).

3.4.5.2 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-depleting substances) due to a reduced need for cooling;
- reduced GHG emissions from reduced energy consumption and the use of available renewable energy resources;
- -a lower impact on natural habitats and wildlife (avoids land use and soil sealing);
- lower energy consumption due to the low temperature of the location chosen (depending on the geographical location).

3.4.5.3 Appropriate environmental performance indicators

One indicator related to the implementation of the techniques recommended by the CENELEC technical document CLC/TR 50600-99-1 can be monitored:

- share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data centre geographical location.

Selecting the appropriate geographical location of the data centre aims to facilitate the use and production of more sustainable sources of energy, cooling or heating through the production of renewable energy 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. Environmental performance indicators can be:

- **share of new data centres with free cooling solutions** (air-side economisers, geothermal cooling, etc.);
- **share of new data centres with renewable energy production on site** (photovoltaic panels, wind turbines, etc.);
- **share of new data centres with a heat reuse system.**

3.4.5.4 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. insolation, share of renewable energy in the local energy mix).

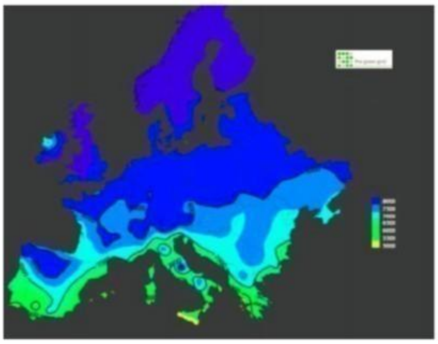
Locating a data centre in order to reduce its direct impact can lead to significant indirect impacts, caused by the transportation of data over a longer distance (requiring additional energy consumption for the telecommunication networks).

3.4.5.5 Operational data

Select 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 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 65:Average yearly number of free-cooling usage hours (Source: GENiC, 2014)

Free-cooling usage hours above apply to data centres. Telecom centres aim for a higher free-cooling usage rate due to the much wider temperature ranges accepted by the telecommunications equipment. Telecom centres can reach a 100% usage rate.

Locate 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 opportunities available for the reuse of waste heat.

Minimise 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 which may be included in local planning documents.

New data centres should also be located close to a telecommunications network and other public infrastructure (e.g. roads).

3.4.5.6 Applicability

Locating a data centre according to its energy-efficiency potential is particularly relevant for big data centres (since cost savings can overcome the constraints resulting from 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 43: Applicability of best practices regarding the choice of the geographical location of new data centres

Best practice	Size	Security	Purpose
Select favourable environmental conditions (temperature, humidity)	Mid-tier and enterprise-class data centres	Any tier	Any purpose
Locate the data centre close to an energy source	Mid-tier and enterprise-class data centres	Any tier	Any purpose
Minimise impacts on the environment	Mid-tier and enterprise-class data centres	Any tier	Any purpose

3.4.5.7 Economics

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

Table 44: Economics data related to the choice of the geographical location of new data centres

Best practice	Operating costs	Investment costs	Return on investment
Select favourable environmental conditions (temperature, humidity)	NA	Additional costs for analysis	Savings from decreased energy consumption for cooling and humidification
Locate the data centre close to an energy source	NA	Additional costs for analysis	Less transmission losses
Minimise impacts on the environment	NA	Additional costs for analysis	Avoidance of potential legal fees

3.4.5.8 Driving force for implementation

Integrating an 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. In addition a greater focus on the Total Cost of Ownership when building a data centre can favour 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 with the highest energy-efficiency potential. (Grid, 2013)

Moreover, regulations vary according to territories and do not allow the same possibilities in terms of building a data centre (town planning constraints, incentives for renewable energy sources, etc.). Also, use of ground water for cooling purposes may be prohibited.

Other parameters can benefit from such practices since the reliability of the data centre will be improved by the easier 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.).

3.4.5.9 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 meet all of its energy needs with biogas (CH_4).

3.4.5.10 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.

3.4.6 Use of alternative sources of water

SUMMARY OVERVIEW:
Water is used in data centres for two purposes: cooling and humidification, which are closely linked. In particular, evaporative chillers require significant amounts of water. It is considered best practice to: • **monitor water consumption from all sources in all data centre spaces;** • **limit the impact on potable water resources by using non-potable water sources (rainwater, waste water, etc.).**

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

Relevant life cycle 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	Emissions to air	**Water use & consumption**	Noise and EMF emissions	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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding water sources

Cross references	
Prerequisites	• NA
Related BEMPS	• 2.5 Use of renewable and low-carbon energy • 3.2.5 Improve cooling management • 3.3.2 Selection and deployment of environmentally friendly equipment for data centres • 3.4.5 Selection of the geographical location of the new data centre
Benchmarks of Excellence	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding water sources

3.4.6.1 Description

Water is specifically used in data centres for two purposes: cooling and humidification, which are closely linked. The consumption of water depends on the type of cooling system installed in the facility (see BEMP 3.2.5 Improve cooling management). In particular, evaporative chillers require significant amounts of water: the National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 million litres per MW each year (NREL, 2014). Other cooling technologies use water in closed circuits that do 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 deals with the consumption of water in buildings, while the BEMP on the use of renewable and low-carbon energy addresses the topic of energy production (see BEMP 2.5 Use of renewable and low-carbon energy).
- The following figure gives an example of total water consumption levels (including energy-production-related water consumption) for different cooling technologies.

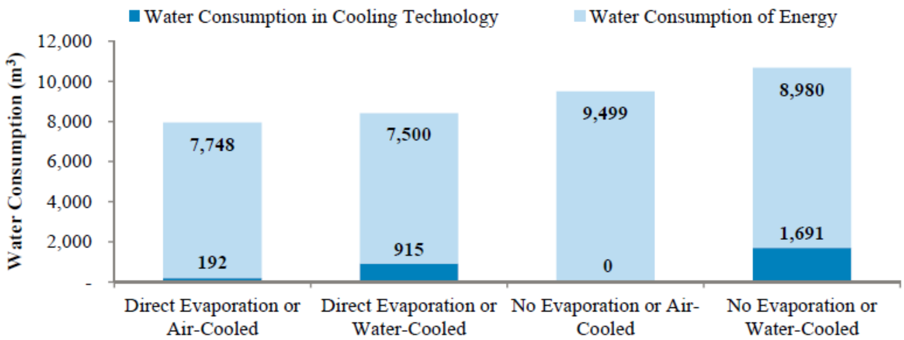


Figure 6. Annual water consumption of different cooling technologies in a DC cooling technology with a capacity of 61,164 m^3/min, based on inlet supply temperature to servers of 27 °C in Phoenix, Arizona. (After Vokoun [74] who reports United Metals Products values. Vokoun uses National Renewable Energy 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 66: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 do the following (CENELEC, 2016):

Monitor water consumption.

Water consumption from all sources in all data centre spaces should be metered and monitored.

Limit the impact on potable water resources.

Data centres should be designed to be able to use non-potable water sources, thereby limiting their ecological impact.

3.4.6.2 Achieved environmental benefits

Using alternative sources of water can decrease the environmental impact of water consumption by data centres. Indeed, fresh water 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, waste water and seawater have already been used.

3.4.6.3 Appropriate environmental performance indicators

Standardised metrics in terms of water consumption are evolving rapidly, and here is an example of an outcome-oriented indicator that can be monitored:

- **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 of information on the measurement of water consumption include the works on ISO/IEC 30134 and EN 50600-4.

Additionally, the water consumption of the data centre per floor area could be measured with the following metrics: m^3 consumed / m^2 of data centre.

Regarding the use of alternative water sources for cooling, an appropriate metric could 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 monitored is:

- share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding water sources.

3.4.6.4 Cross-media effects

As stated in Section3.2.5.2, 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 million litres per MW each 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.

3.4.6.5 Operational data

Monitor water consumption

Water consumption from all sources in all data centre spaces should be metered and monitored, by using 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.

Limit impact on potable water resources

New-build data centres should be designed to capture and store rainwater for non-potable purposes, such as evaporative cooling[69]. Alternatively, other local non-utility water sources should be used (waste water for example), in order to reduce the overall energy consumption.

3.4.6.6 Applicability

The choice of the cooling system solution depends on the size of the data centre, which is closely linked to the activity and the size of the company. For example, chilled water systems are suitable for data centres of 200 kW and larger, and air evaporative cooling systems are used in data centres of 1 000 kW and larger with high power density (Evans, 2012).

Consequently, the best practices presented in this section are relevant for large, enterprise-class data centres.

3.4.6.7 Economics

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

[69] "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 Section 4.3.7.6).

Table 45: 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
Monitor 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
Limit impact on potable water resources	Maintenance of equipment	Selection of more complex water supply	NA

3.4.6.8 Driving force for implementation

Two main drivers exist regarding the source of water used by data centres:

- first, data centres can achieve savings, as rainwater collection can be a substitute for some of the water needs (mostly for cooling);
- second, data centres can benefit in terms of image, especially in areas where water scarcity is an issue.

3.4.6.9 Reference organisations

The Resilience Centre Luxembourg South (KAYL) data centre was awarded an EU Code of Conduct award in 2016. It has installed a rainwater recycling system (300 m^3 rainwater tanks) for hybrid cooling towers (JRC, 2016).

3.4.6.10 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.

3.4.7 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.

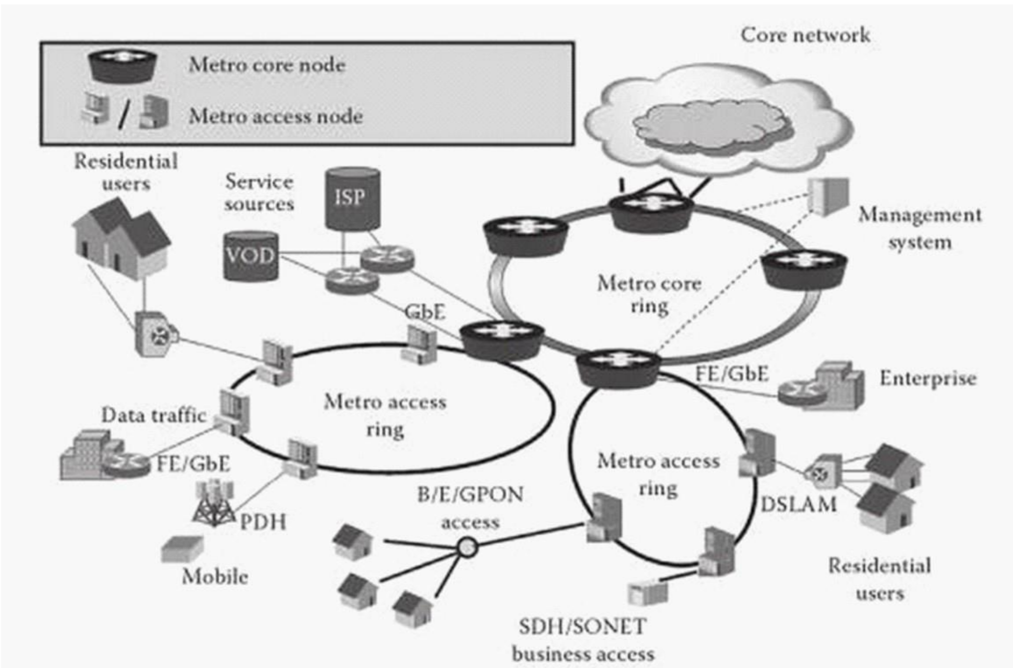

Figure 67:An overview of telecommunication networks (Source: Iannone, 2012)

A mobile communications radio base station is a transmission and reception station in a fixed location, consisting of one or more receive/transmit antennas, a 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.[70] This assembly of different components varies, depending on:

- the location of the base station, since a rural site often consists of three symmetrical sectors with high RF power and only 1-2 carriers per sector, while urban and suburban sites typically vary 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 also install 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).

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 recently been 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).

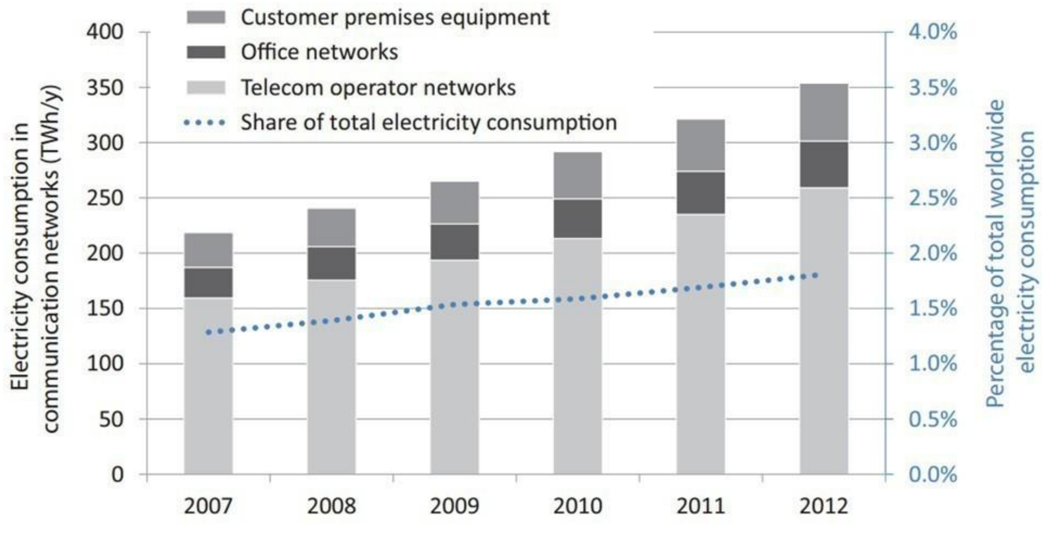

Figure 68:Worldwide electricity consumption of telecommunication networks (Source: Lambert, Van Heddeghem, Vereecken, Lannoo, Colle, & Pickavet, 2012)

[70] http://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields/glossary/abc/base-station.htm

The Code of Conduct on Energy Consumption of Broadband Communication Equipment set 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 follows (JRC, 2013):

- between 340 W and 480 W of power load (at low-load state and busy-hour-load state respectively) for a WiMAX radio base station (three sectors, 3.5 GHz, 10 MHz bandwidth channel, 4x4 MIMO, 29:18 DL/UL subframe ratio);
- between 540 W 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 W 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 W 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 also host 3G and 4G equipment), for different frequency bands or for different operators. A “typical” base station 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 breakdowns 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 all locations for a 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 a heated area (e.g. under the roof in poorly isolated attics) and if backup batteries are installed in 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-bit-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.

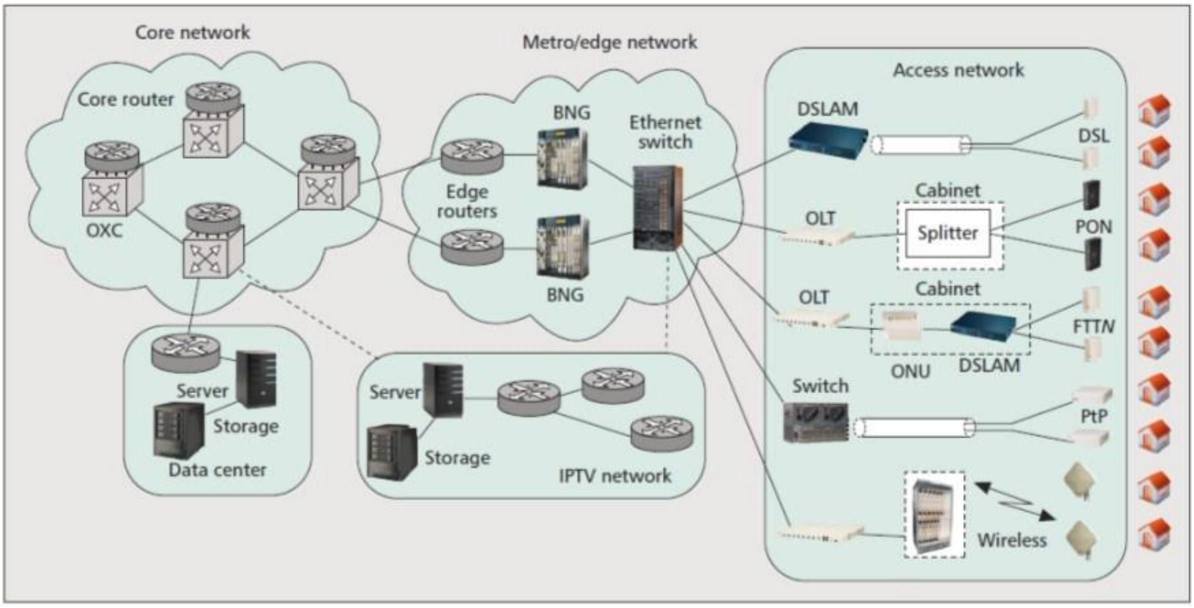

Figure 69:A high-level network structure with various options for the access network (Source: Hinton, 2011)

- **Technology** used by the wireless or wireline network.
  - Technologies used in wireless networks can primarily be divided between the following:
    - 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 Wi-Fi (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 the following:
    - 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' homes 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 premises.
    - Point-to-Point optical (PtP) uses a dedicated fibre between each customer and the terminal unit and optical media converters at customers' homes to convert the optical signal into an electrical signal.

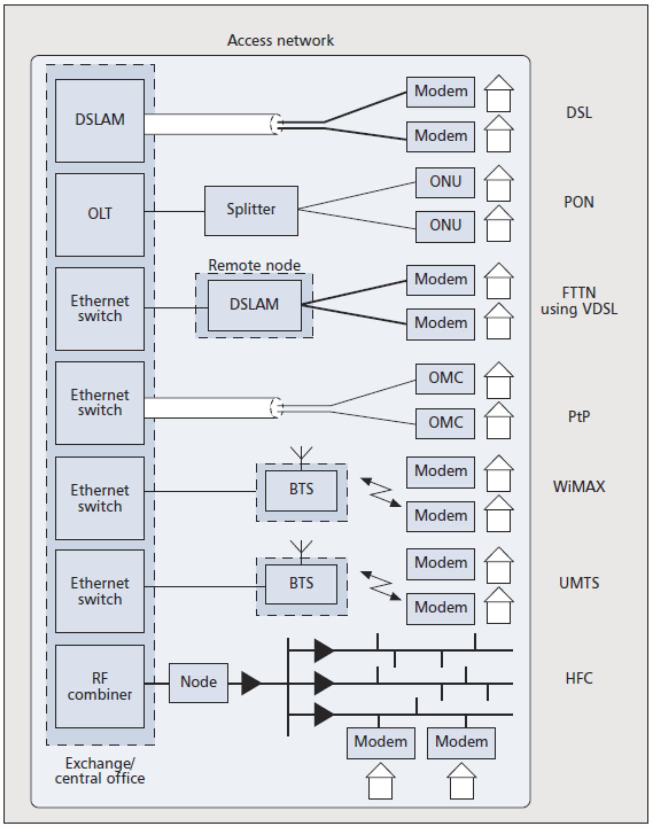

Figure 70:Overview of the main access network technologies (Source: Baliga J. e., 2011)

- 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 connection with a fast transmission rate, a high workload capacity and a very low resumption 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 services 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 (EMFs); for more information on potential health issues of EMFs 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, in both urban and 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. In contrast 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.

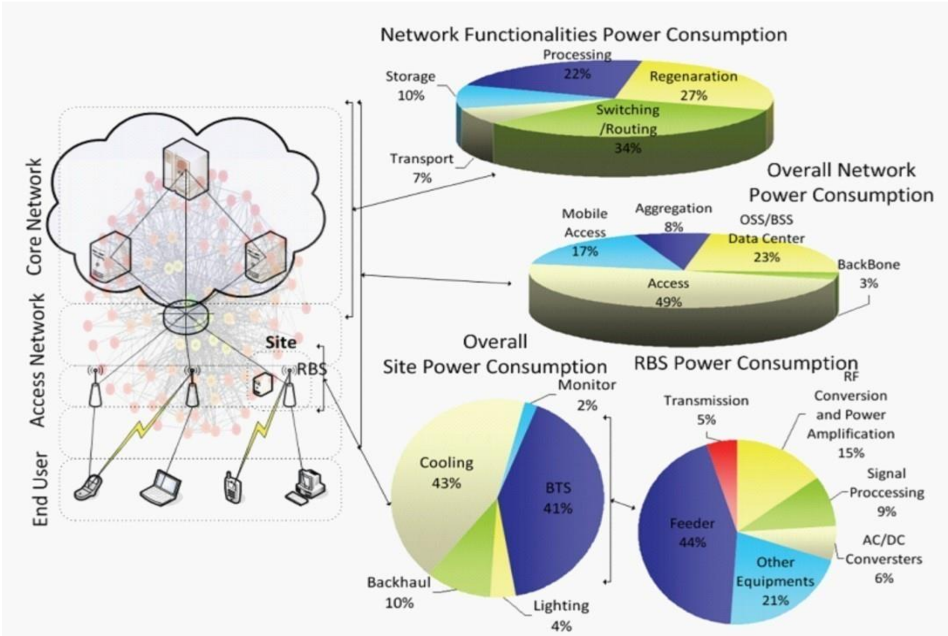

Figure 71:Power consumption in different layers of the network (Source: Koutitas & Demestichas, 2010)

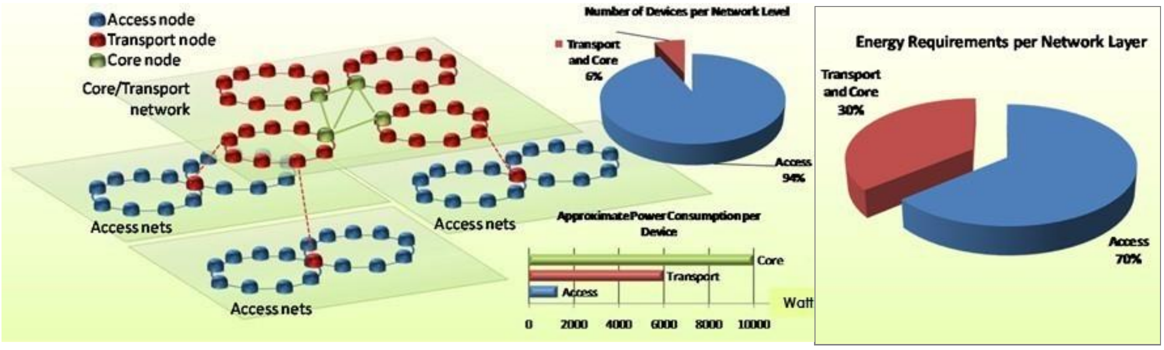

Figure 72:Typical core, metro and access device density and energy requirements (Source: Bolla, 2010)

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.

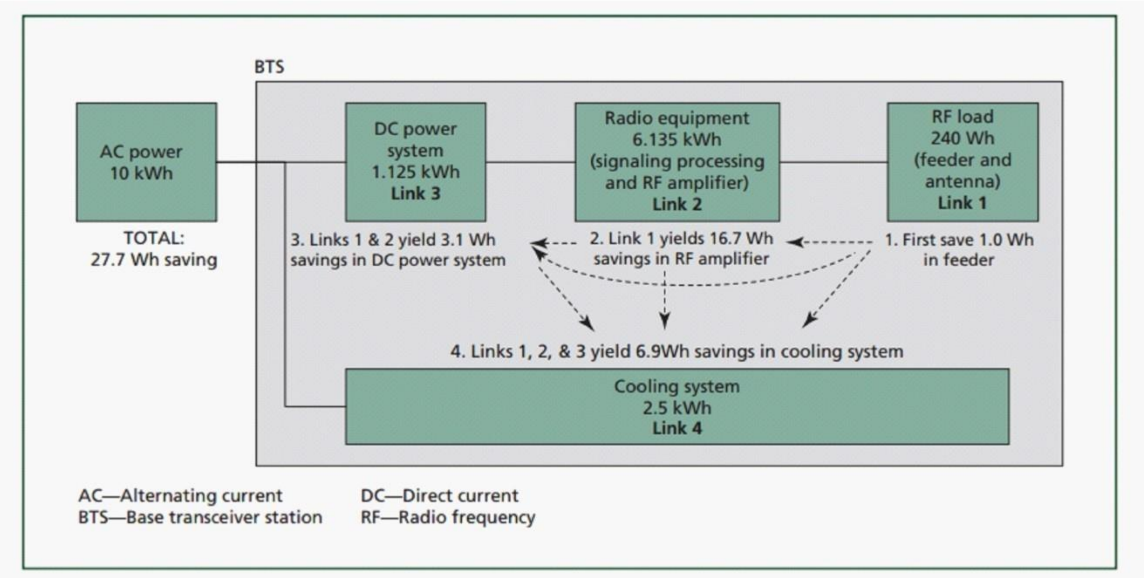

Figure 73:Example of energy dependencies of a base transceiver station (BTS) (Source: Matthews, et al., 2010)

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 networks, 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 to that used in the section on data centres. The following subsections intend to describe the BEMPs that reduce the environmental impacts of telecommunication networks by focusing on:

1. Improving the energy management of existing networks (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).

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4.2 Improving the energy management of existing networks

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 standby 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators
• Average energy consumption per customer or subscriber (in kWh / customer or subscriber) • Mobile/Fixed Network coverage Energy Efficiency (the area covered by the network / the energy consumption) (in m^2/J) • Mobile/Fixed Network data Energy Efficiency (the data volume delivered / the energy consumption) (in bit/J) • Share of network energy usage 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 %)

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).
Related BEMPS	• 2.2 Making the best use of an environmental management system • 4.4 Selecting and deploying more energy-efficient telecommunication network equipment • 4.5 Installing and upgrading telecommunication networks • 4.6 Reducing the environmental impacts when building or renovating telecommunication networks • 2.7 Minimising data traffic demand through green software
Benchmarks of Excellence	• 50% of the network energy usage is monitored in real-time at telecommunication sites level (base stations and/or fixed-network nodes), or above • An energy management system is in place for telecommunication networks

4.2.1 Description

Communications networks are very spread out, 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 busiest 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, the majority of broadband equipment is typically idle most of the time and exchanges data only to maintain its network status.

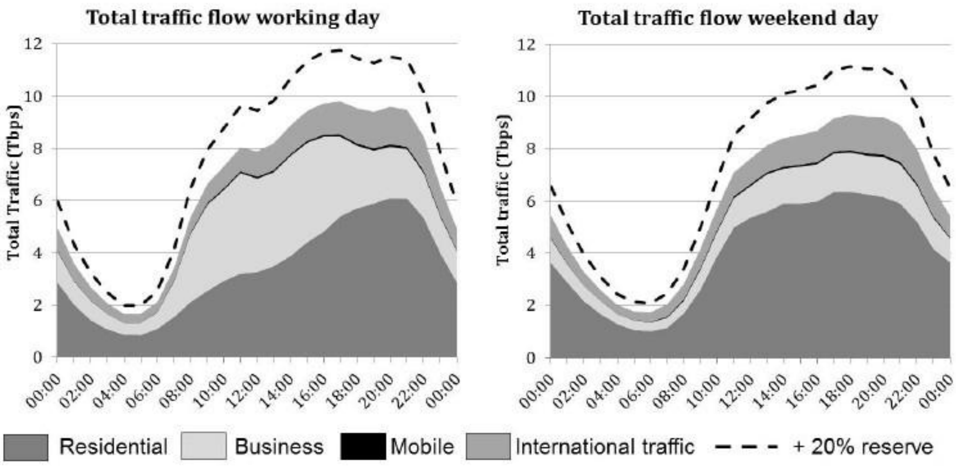


Figure 74:Example of traffic flow composition in a backbone network (Source: ZIB report, 2014)

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 76). Existing network equipment can be optimised in terms of energy consumption and activity, by being adapted to the workload. As an overarching measure, putting in place energy management systems (e.g. compliant with ISO 50001) across telecommunication networks will support the improvement of the network's energy performance.

It is best practice to do the following:

- **Measure or estimate the energy consumption of network elements (devices and functionalities).**

  To face the challenge of measuring the energy consumption of manifold and widespread sites, and to provide relevant information for improving the energy management of the entire network, solutions include smart energy meters[71] and automated analysis, as well as other methods such as estimates. For networks with a large number of elements and sites, an initial review allows the prioritisation of the most energy-consuming and the use of, as appropriate, measurement for larger energy consumers and estimation for minor ones.

- **Use smart standby 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 standby, 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 subsystems, dynamic power savings, power islands and Energy-Efficient 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-user 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) can reduce the workload at peak loads, as well as the overall capacity of the network. Telecommunication operators and internet service providers can also create 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, cache servers, shared services, scheduled distribution, etc.) or network connectivity proxying which can result 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 cells can lead to an 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 load traffic is able to provide energy savings of 25% to 40% at network level (EARTH, 2012d);
- dynamic scheduling allows short sleep periods that can be utilised by Multicast Broadcast Single Frequency Network (MBSFN) which provides energy savings of 20% to 30% per bit or by Cell Discontinuous Transmission (DTX) which can save up to 45% energy when combined with power control;

[71] Smart energy meters provide frequent readings that can be brought together in real time and at a single point. Using automated analysis systems can facilitate the analysis of numerous data, by spotting anomalous behaviour (through benchmarking between sites or trends analysis).

- delay constraints allow the reduction of the power transmitted by adaptively scheduling the data packets at the "best" time within the delay of the QoS requirements and provide up to 20% 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% 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.

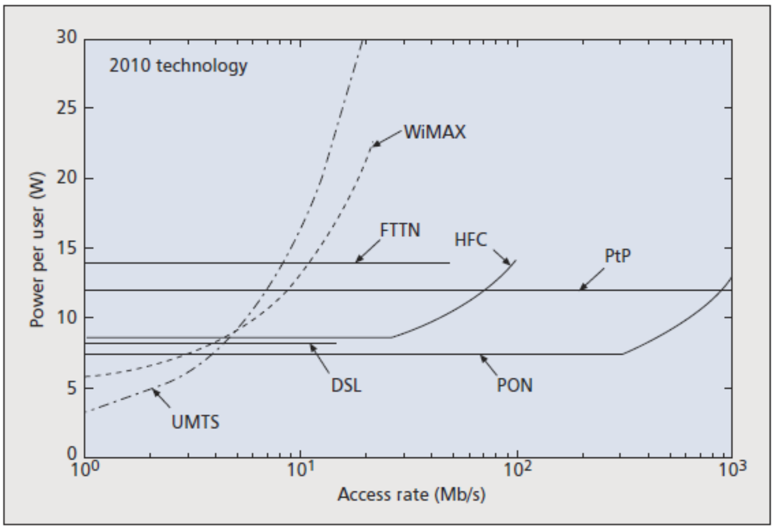
- The energy efficiency of an access network can be defined as the **average energy consumption per customer** or subscriber (in kWh / subscriber or customer). This metric, called P_a, can be split into three parts (Baliga J. e., 2011):

1. The power consumed by the equipment on the customer's premises (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} [72]customers or subscribers, is named P_{TU}.

Therefore, P_a can be expressed in the form[73]:

$$\mathbf{P_a = P_{CPE} + P_{RN} / N_{RN} + 1.5 * P_{TU} / N_{TU}}$$

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 pieces of equipment installed on a customer's premises 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).



[72] Number of terminal unit customers.

[73] Baliga et al. (2011) considered that the equipment at the customer premises 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 (accounting for 50% of the power consumed by the equipment only).

Figure 75: Power consumption of different access network technologies (Source: Baliga J. e., 2011)

- **Mobile or fixed Network data Energy Efficiency** ($EE_{MN,DV}$ / $EE_{FN,DV}$) is the ratio between the data volume delivered by the equipment of the 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 or fixed Network coverage Energy Efficiency** ($EE_{MN,CoA}$/ $EE_{FN,CoA}$) is the ratio between the area covered by the network under investigation and the energy consumption when assessed during one year. EE_{CoA} is mainly used to complement the previous performance indicator for networks handling low data volumes, in particular in rural or very rural areas. EE_{CoA} is expressed in m^2/J, and defined by the ETSI standard ES 203 228.

Beyond outcome-oriented indicators, process-oriented indicators can be monitored in order to assess the effectiveness of the energy management action plan implementation, such as:

- ***share of network energy usage for which energy consumption is measured (in %)***, which reflects the achievements in terms of better measuring the consumption of network elements by using, among others, 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) 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

Measure the energy consumption of network elements.

ETSI standards give guidelines on measurement methods and give 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.

Use smart standby functions.

Effective energy-aware network management consists of 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), 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 a few "active" nodes, so that the others can be put in standby mode[74]. 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).

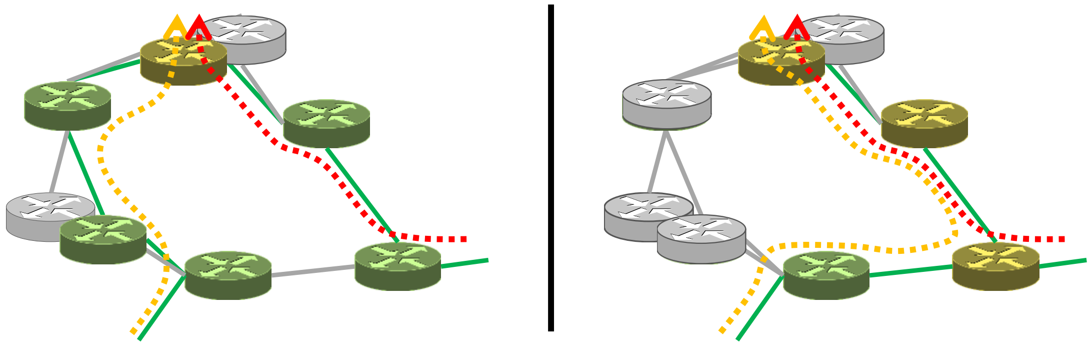
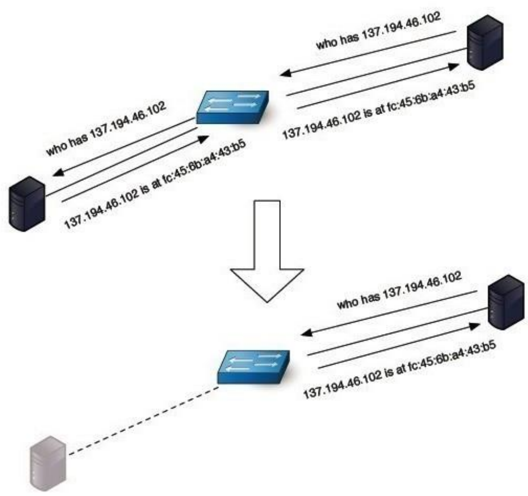


Figure 76:Energy-aware routing to reduce the number of active nodes at low traffic loads (Source: ECONET Project, 2010)

Most wireline networks are designed to be continuously and always available: only some devices can be turned off when they are not communicating, since when the entire device is shut down, it loses contact with the network (and cannot be woken when required). Standby modes then have to be explicitly supported with special techniques able to maintain the "network presence" when nodes or components are asleep. 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) 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[75].



[74] Such technology should be compliant with the latest version of the European Commission's Code of Conduct on Energy Consumption of Broadband Equipment.

[75] For more information, see http://www.ecma-international.org/memento/TC38-TG4-M.htm

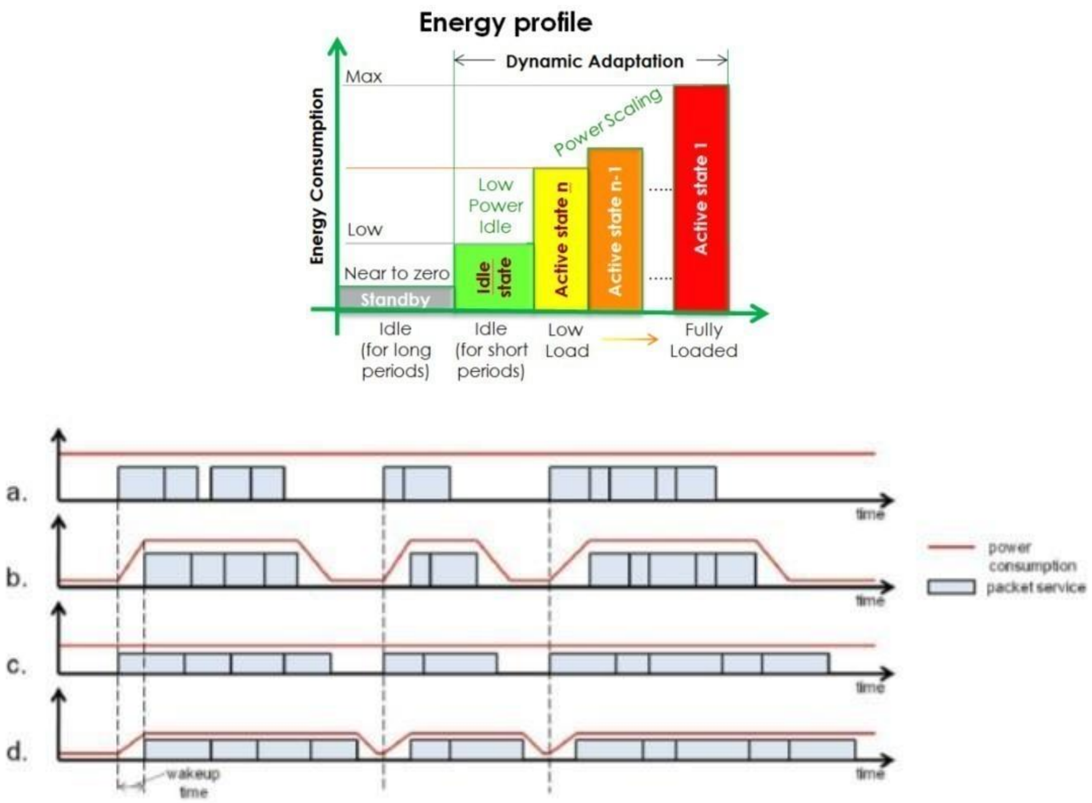
Figure 77: External proxying (Source: Rossi et al., 2010)

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.

Use 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 disc, NIC) according to the amount of 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.



Packet service times and power consumptions in the following cases: (a) no power-aware optimizations, (b) only idle logic, (c) only performance scaling, (d) performance scaling and idle logic.

Figure 78: Dynamic adaptation approaches to reduce the energy consumption of network devices (Source: Davoli, 2013 (top) and ECONET Project, 2010 (bottom))

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).

Take 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 the IP packets the routers transfer (Zhang, 2010).
- The energy-efficiency of IP packet forwarding also depends on the frequency with which 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, videoconferencing, distributed gaming) which requires a large bandwidth.

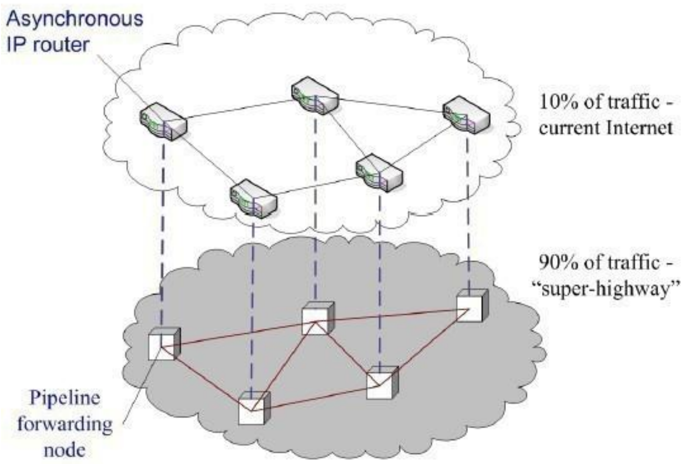


Figure 79:Pipeline forwarding architecture (Source: Zhang, 2010)

- 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 allows significant reduction of inter-cell interference (EARTH, 2012a).

Provide 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) 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).
- A sorry server returns the alternative response to inform that services cannot be provided for some reason (such as traffic congestion), which allows the shifting of 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).

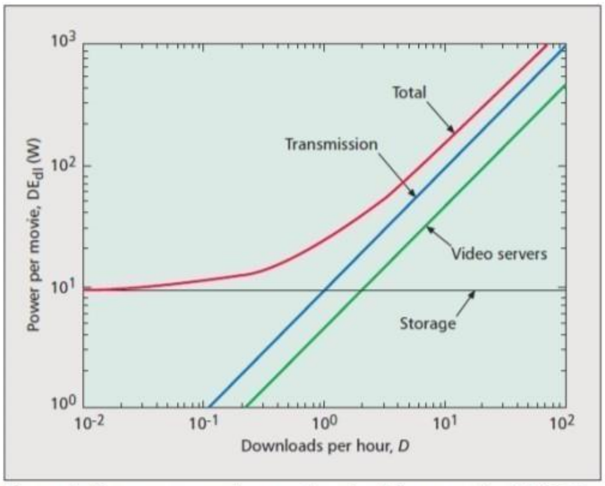


Figure 6. *Power consumption per download for a standard definition 2 hour video that has 20 copies replicated in data centers [10].*

Figure 80:The effect of content downloading frequency on overall energy consumption (Source: Hinton, 2011)

- Using cache servers can reduce bandwidth usage, so it can achieve energy savings corresponding to the reduction if the copy of the contents exists in this server.

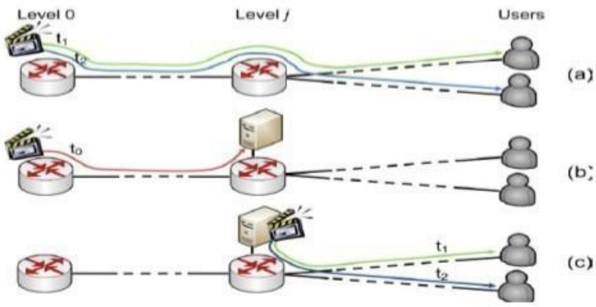


Figure 5 – Traditional content distribution (a) and content caching approach (b) (c).

Figure 81:Cache servers approach for content distribution (Source: TREND Project, 2013)

- Using shared services for delay-tolerant applications (e.g. emailing, web browsing, video or audio downloading) allows for many users to share the bandwidth provided without noticing any degradation in speed.

Distributing broadcast content in advance can shift the peak of 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 section presents the main practices that should be followed when managing networks, but techniques should be adapted to the characteristics of the network:

Table 46: Applicability of best practices aiming at improving the energy management of existing telecommunication networks

Technique	Network	Network	End users' requirements	Actor

	segment	technology		
Measure the energy consumption	From core to access network	All types of technology	All types of end users	Network operators
Use smart standby functions	From core to access network	All types of technology	Inappropriate for users requiring connection stability or a very short resumption time	Network operators
Use dynamic power scaling opportunities	From core to access network	All types of technology	All types of end users	Network operators
Take advantage of dynamic scheduling transmission	From core to access network	All types of technology	Inappropriate for users requiring fast transmission rates	Network operators
Provide energy-aware services	From core to access network	All types of technology	Inappropriate for users requiring high Quality of Services	Network operators and ICT services 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 of network operators in terms of network management (human resources, qualifications, tools, etc.).

The implementation of the energy-aware practices defined above may require the recruitment of additional staff (with specific qualifications), the purchase of 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 47: 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
Use smart standby functions	Staff in charge of the network management system	- Selecting equipment with standby function - Investing in software to better manage the network	Reduction of energy costs (up to 40%)
Use dynamic power scaling opportunities	Staff in charge of the network management system	- Selecting equipment with power scaling function - Investing in software to better manage the network	Reduction of energy costs (up to 40%)
Take 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%)
Provide 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 the energy consumption of networks is 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[76] 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 the event that 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 submeters installed and connected to 2 700 telecommunication sites which account for 53% of Telecom Italia usage (TIM, 2016).

Vodafone has deployed submeters and smart meters across more than 50 000 base stations and 60% of its technology centres (Vodafone, 2015).

4.2.10 Reference literature

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4.3 Improving risk management for electromagnetic fields through assessment and transparency of data

SUMMARY OVERVIEW:					
Electromagnetic fields (EMFs) 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 life cycle 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	Emissions to air	Water use & consumption	**Noise and EMF emissions**	Landscape and biodiversity
Environmental performance indicators					
• The percentage of sites assessed by measurement for compliance with EMF limits • The percentage of sites regularly or continuously monitored (also with software) for compliance with EMF limits					
Cross references					
Prerequisites	NA				
Related BEMPS	• 2.2 Making the best use of an environmental management system • 4.2 Improving the energy management of existing networks • 4.6 Reducing the environmental impacts when building or renovating telecommunication networks				
Benchmarks of Excellence	• None defined.				

4.3.1 Description

Electromagnetic fields (EMFs) 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.

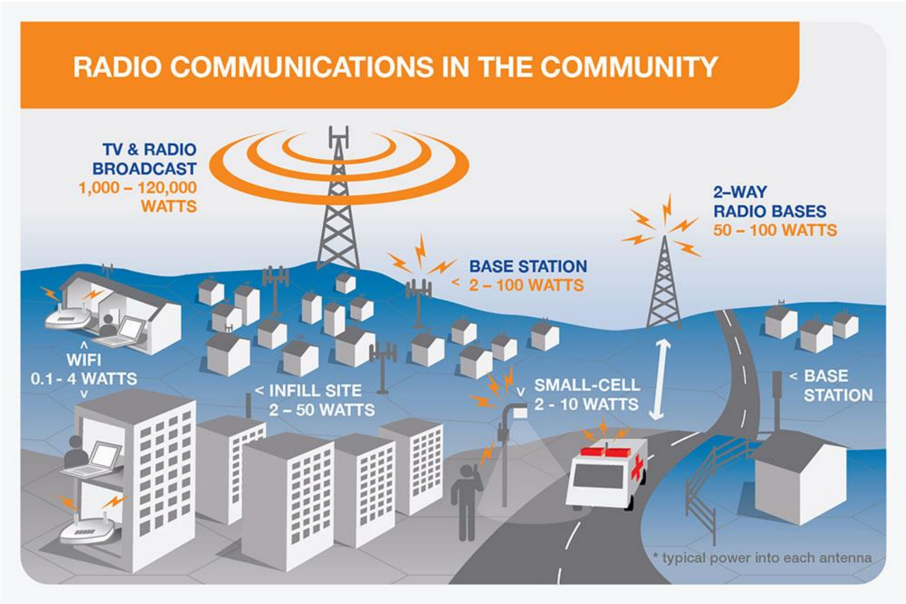

Figure 82:Typical radio and wireless communications in the community (Source: ITU, 2014)

It is best practice for telecommunication providers to do the following:

- **Improve risk management for electromagnetic fields through assessment and transparency of data**

  At every stage of the life cycle of wireless transmitters or receivers (networks antennas, end-user devices, etc.), actions should be implemented to make information on compliance with EMF exposure limits available 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.

Industry guidance has been published, for instance the ITU technical report on Electromagnetic field (EMF) considerations in smart sustainable cities (ITU, 2014) with ideas for the effective design and careful deployment of wireless networks and short-range devices which are vital to ensuring electromagnetic field (EMF) compliance and maximum efficiency for ICTs.

4.3.2 Achieved environmental benefits

The main benefit linked to a more detailed assessment and increased transparency regarding EMF exposure is improved risk management from telecommunication operators. This helps reduce risks for health and the environment by proving that EMF exposure stays 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 indicator can be monitored

- the percentage of sites assessed by measurement for compliance with EMF limits.

Direct measurement, especially at remote sites, can be difficult to carry out. Alternatively, the following indicator can be used:

- the percentage of sites regularly or continuously monitored (also with software) for compliance with EMF limits.

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 the general public can actually result in higher levels of concern among these people (Wiedemann et al., 2013).

4.3.5 Operational data

Improve 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 that are 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 also have to ensure that all relevant staff has an adequate awareness of EMF issues (especially staff which are likely to handle the concerns of the public, including employees answering phones and in 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).

The ITU has discussed reference values and best practices, e.g. on specific absorption rate (SAR). SAR is the unit of measurement for the amount of radiofrequency (RF) energy absorbed by the body when, for example, using a mobile phone, wireless device or walking close to radio communication transmitting antennas. SAR is measured in units of watts per kilogram (W/kg). The SAR is determined at the highest certified power level in laboratory conditions. See for instance Telecom Italia (2012) for operator-developed best practice on SAR limits enforcement.

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: • HERMES (Human Exposure and Radiation Monitoring to Electromagnetic Sources), which started in 2002 in partnership with the National Technical University of Athens and the Aristotle University of Thessaloniki; • PEDION24 (pedion means "field" in Greek, and 24 means 24-hour monitoring), which started in 2006 in partnership with the two previous universities and the University of the Aegean and the University of Piraeus. These programmes have 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 a mobile monitoring station, which measures and records the electromagnetic radiation levels in the environment, expanding the application field. 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: ▪ 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); ▪ 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-minute 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. 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 EMFs and on the local context (existence of associations against EMF exposure, media coverage of EMF issues, visibility of antennas, etc.).

Table 48: Applicability of the best practice aiming at managing electromagnetic field issues within telecommunication networks

Technique	Network segment	Network technology	End users' requirements	Actor
Improve risk management for electromagnetic fields through	Access networks	Wireless networks	All types of publics	Network operators

assessment and transparency of data				

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 relations 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 49: Economics data related to managing electromagnetic fields issues within telecommunication networks

Technique	Operating costs	Investment costs	Return
Improve risk management for electromagnetic fields through assessment and transparency of data	- Increased communication activities - 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 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 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 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 volts per metre and percentage of recommended threshold) can either come from an on-site 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 on 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 in 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 requires electricity and specific environmental conditions to properly function. Telecommunication operators have the opportunity when selecting and deploying such materials within their networks to improve energy efficiency by selecting and configuring appropriate equipment. It is best practice to:

- **select and deploy the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks (more energy-efficient technology, power management features, etc.);**
- **deploy integrated and multi-standard solutions, instead of multiple single-standard systems running in parallel and not properly configured;**
- **select and deploy the most energy-efficient cooling systems in base stations (e.g. passive cooling, simple fans, heat exchangers) and central offices (e.g. hot aisle / cold aisle blanking plates, hot air containment, air ducting);**
- **select and deploy the most energy-efficient UPS (e.g. highly efficient UPS, modular UPS) in base stations and central offices;**
- **design telecommunication sites which maximise 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 pieces of hardware equipment needed) 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity

Environmental performance indicators

- Percentage of broadband equipment meeting the Broadband Code of Conduct requirements in terms of energy consumption and energy-enabling features
- Percentage of equipment able to deliver dynamic management
- Share of base stations with multi-standard solutions where applicable
- Share of sites with a Remote Radio Head or Active Antenna System
- Share of sites equipped with hardware compliant with the ETSI standard
- Share of sites with non-mechanical cooling
- The temperature is set at the maximum allowable according to the equipment on site (Y/N)
- Average UPS System Efficiency
- Average COP of cooling systems

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 • 4.2 Improving the energy management of existing networks • 4.5 Installing and upgrading telecommunication networks • 4.6 Reducing the environmental impacts when building or renovating telecommunication networks
Benchmarks of Excellence	• 100% of new installed broadband equipment meets the requirements of the EU Code of Conduct for broadband equipment in terms of energy consumption • Energy efficiency of power/energy stations is 96% or higher • Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems

4.4.1 Description

Telecommunication and ICT systems require electricity for different functions:

- running ICT equipment (servers, transmitters, receivers, etc.);
- operating 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.

Like any electrical equipment, ICT equipment requires a power supply and produces waste heat while running. Furthermore, the need for cooling and energy losses related to the power infrastructure (power distribution unit, UPS, building transformers) increase with the number of pieces 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 the network elements are connected and what the dependencies are 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.

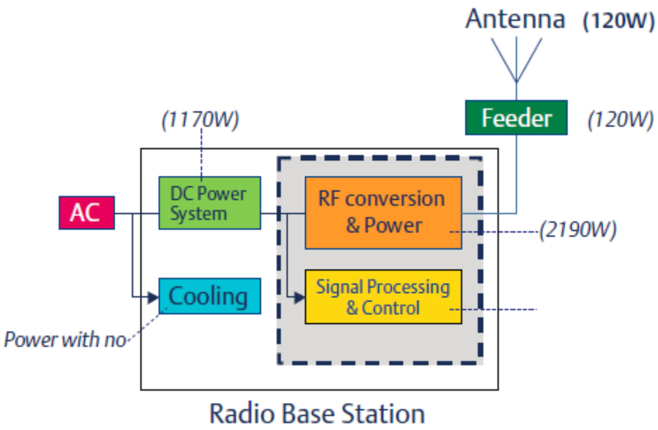


Figure 83:Radio base station block diagram (with associated power losses) (Source: Emerson, 2008)

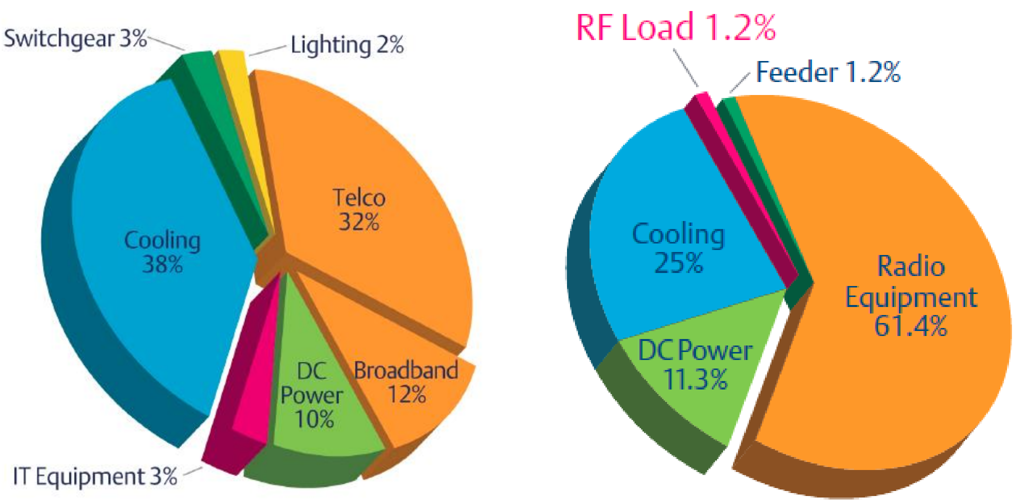


Figure 84:Energy consumption per function in central offices (left) and in base stations (right) (Source: Emerson, 2008)

This chapter develops techniques that can be implemented in order to improve the energy efficiency of network equipment such 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 PCs, telephones and fax machines) and customer premises equipment (including routers, modems or adapters) is developed under Section 2.3 on the Procurement of sustainable ICT products and services. A summary of the relevant criteria in terms of energy efficiency for such equipment is given below.

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 Energy Star or follow the EU Green Public Procurement Criteria for Office IT equipment or Imaging Equipment

It is best practice to do the following:

- **Opt for selecting and deploying 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), or with power management features.

- **Opt for deploying integrated and multi-standard solutions.**

  Multi-standard equipment offers an opportunity for reducing the number of different equipment generations on the same site, e.g. a base station.

  Integrated solutions ensure an optimisation of the installed site, with only required elements and proper configurations (in terms of cooling and power supply for example).

- **Opt for selecting and deploying the most energy-efficient cooling systems.**

  Telecommunication sites, such as base stations or central offices, are made of an aggregation of different ICT components that may require cooling.

  In base stations, the use of passive cooling, simple fans, heat exchangers and advanced controls can help reduce active cooling.

  In central offices, techniques similar to 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 containment, air ducting, etc.

- **Opt for selecting and deploying the most energy-efficient UPS.**

  Uninterruptible Power Systems are sources of energy losses due to electricity conversion. To avoid such effects, highly 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 evolves.

- **Opt for designing telecommunication sites which maximise energy-efficiency.**

  After purchasing energy-efficient hardware, choosing an appropriate solution design 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 pieces of hardware equipment needed (see 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;
- reduction of (indirect) CO_2 and other atmospheric pollutant (NOx, SOx, particles, etc.) emissions, 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).

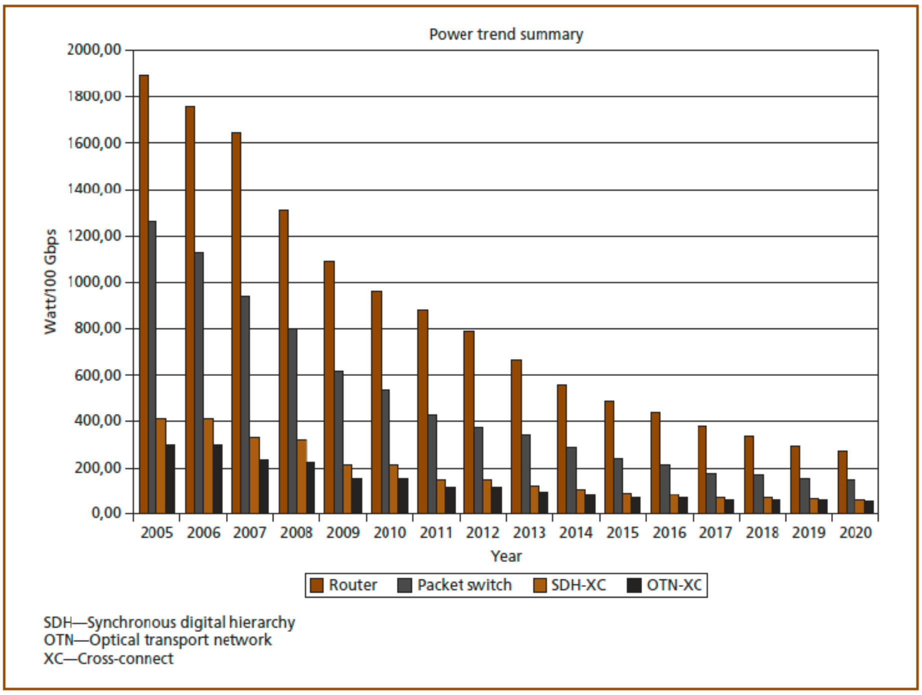


Figure 85:Energy improvement of core networks (Source: The Institute for Energy Efficiency, 2013)

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).

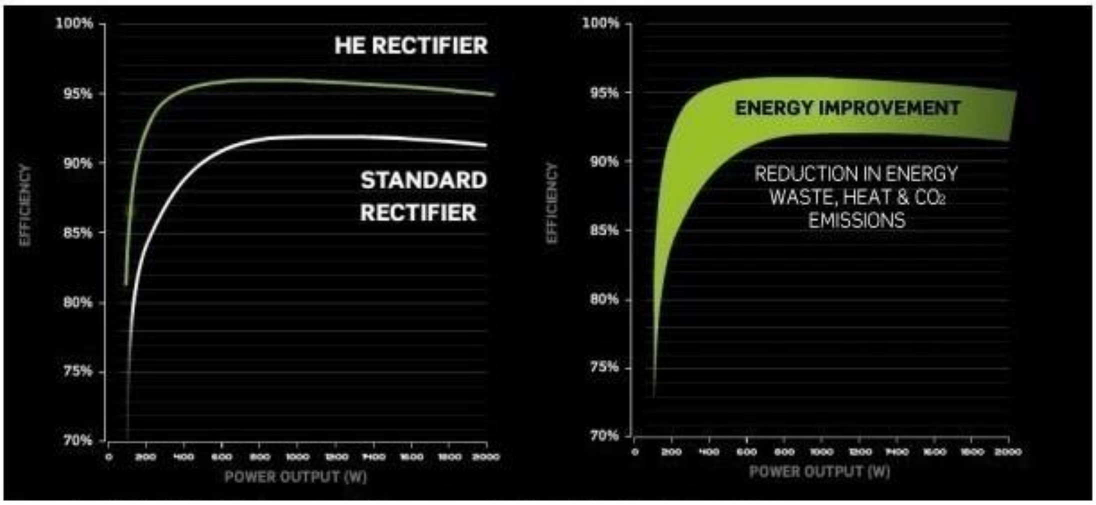


Figure 86: High efficiency (96%) rectifier compared with 92% efficient rectifier (Source: Eltek, 2012)

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 consumption and energy-enabling features;
- **percentage of equipment able to deliver dynamic management;**
- **share of sites with multi-standard solutions where applicable;**
- **share of sites with a Remote Radio Head or Active Antenna System;**
- **share of sites equipped with hardware compliant with the ETSI standard;**
- **share of sites with non-mechanical cooling;**
- **the temperature is set at the maximum allowable according to the equipment on site (Y/N)**

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)):

- **Average power / energy station energy efficiency** which can be used to monitor the power efficiency of transceiver systems (EARTH, 2012b): $\mathbf{PE = P_{RFout} / P_{DC}}$ where P_{RFout} refers to the output power of the transceiver system and P_{DC} to the total supply power. For a UPS 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 the energy consumption of network equipment (e.g. switches, routers) 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 the addition or changing of a large number of network components (e.g. cables and fibres, transceivers, power amplifiers), which means:

- **increasing the consumption of raw materials** (e.g. rare earths, plastics, glass, metals), **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 Section 4.6 on Reducing the environmental impacts when building or renovating telecommunication networks.

Increasing the energy efficiency of the network can lead to a 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

Selection and deployment of the most energy-efficient ICT equipment (radio, telecommunication, broadband and IT devices) in telecommunication networks.

Radio equipment (power amplifiers, Radio Frequency transceivers and antennas, etc.) in wireless networks

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.

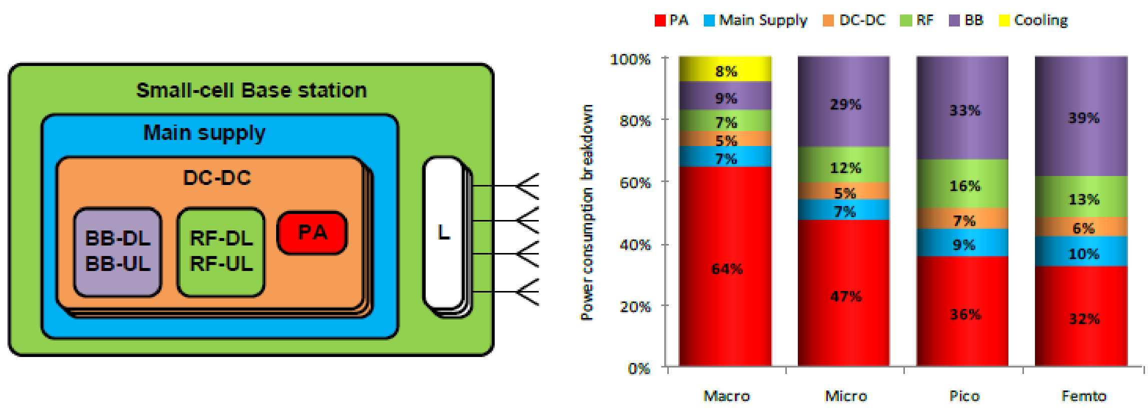


Figure 87:Simplified block diagram of a small-cell base station (left) and the base station power consumption breakdown for different cell sizes (right) (Source: EARTH, 2012e)

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 a 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 the 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 Converters (optimised for mixed signal filtering, synchronisation and data conversion);
- baseband processors (optimised for various diversified signal processing tasks, such as MIMO-OFDM[77] processing, channel estimation, equalisation, etc.);
- channel error correction processors (optimised for various FEC[78] 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[79] 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);
- cable service provider equipment (I-CMTS, M-CMTS);
- powerline service provider equipment.

Replacing components should also include energy-efficiency-enabling features, such as the following:

- Low power idle mode, as recommended by the EU Broadband Equipment Code of Conduct[80]. The idle mode consists of rapidly turning off subcomponents when no activities are performed.
- Sleep mode, which is characterised by higher energy savings but a longer 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.

[77] Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM).
[78] Forward Error Correction (FEC).
[79] Complementary metal–oxide–semiconductor (CMOS).
[80] 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

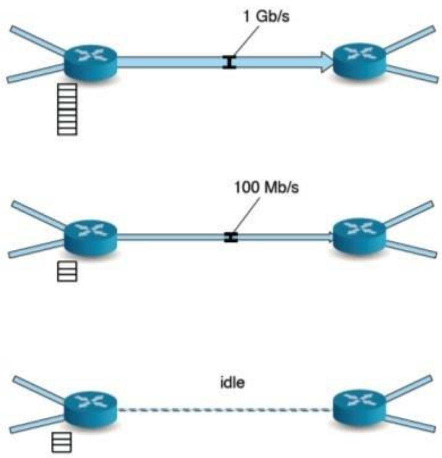


Figure 88:Adaptive Link Rate strategies: the rate of 1 Gb/s link can be reduced to 100 Mb/s or the link can be made idle to save energy (Source: Rossi et al., 2010)

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, etc., for wireless networks). Since each technology shares common auxiliary infrastructure such as a cooling system, security, battery backup and backhaul, significant energy savings can be realised. Energy savings of about 40% can be obtained (Ericsson, 2014). Such solutions are deployed through specific equipment and software.

Integrated solutions ensure the 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)

Selection and deployment of the most energy-efficient cooling systems.

Efficient cooling technologies can also be applied in order to decrease the 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 regions with a hot climate. 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 in the CELTIC-plus project OPERA-net2 showed that liquid-cooled energy consumption was nine times lower than an air-cooled solution. It enables a 45% cooling capacity increase, a 75% heat density upgrade and a 40% cooling volume reduction on the device level. Zhang P. et al. (2013) observed a 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 reuse of heat for other applications (Celtic-Plus, 2015).

In central offices, techniques similar to 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 containment, air ducting, etc.

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. When the system is functioning normally, power enters the facility and flows through the UPS. UPS performance definitions are available in EN 62040-3 (UN-ECE, 2011) and the EU Code of Conduct for UPS provides further information.

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).

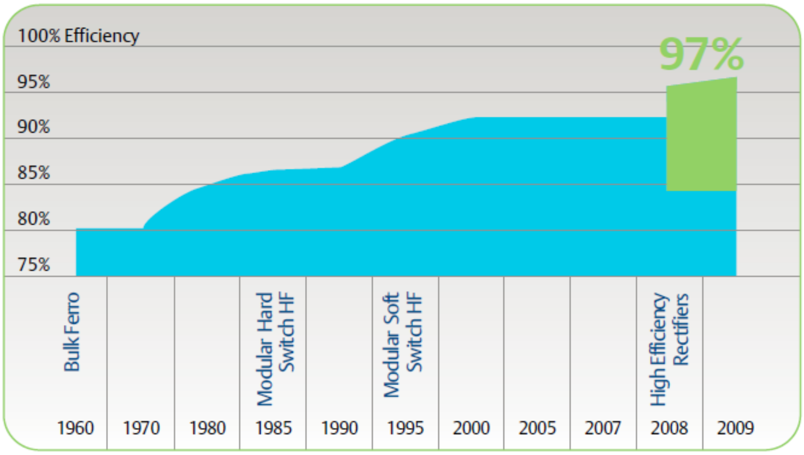


Figure 89:Telecom rectifier efficiency trend (Source: Emerson, 2010)

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 (230 V AC to 48 V DC converters) 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).

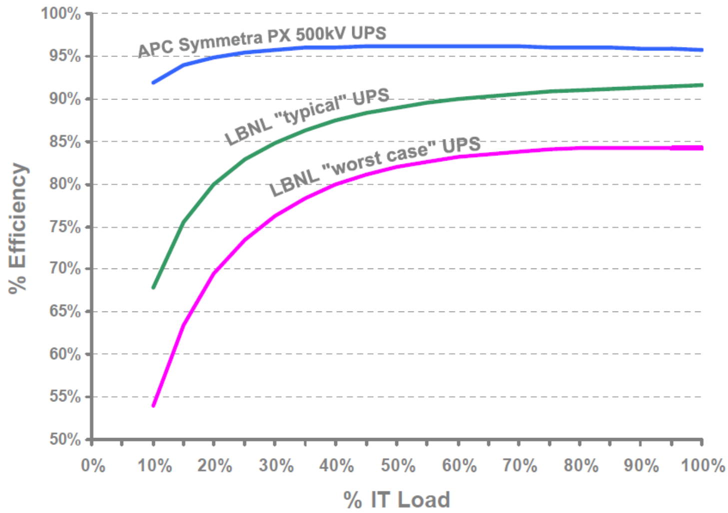


Figure 90:Comparison of efficiencies of a recently introduced high-efficiency UPS to UPS efficiency data published by Lawrence Berkley National Labs (Source: Rasmussen, 2011)

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 a 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.

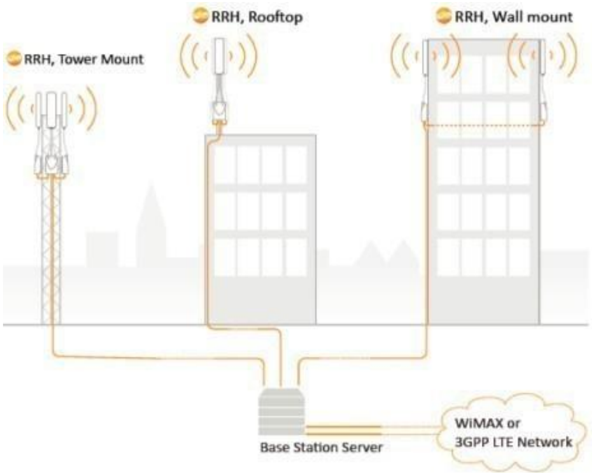
Privilege design of telecommunication sites maximising energy efficiency.

Migrating distributed functions to a central server in wireline networks

Mobile networks dissipate a high proportion of their power at customer premises (especially for FTTH – fibre-to-the-home - 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.



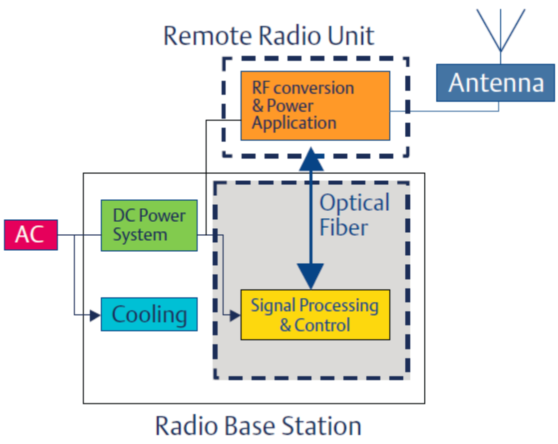


Figure 91:Example of Remote Radio Heads (left) (Source: Altera, 2009) and diagram (right) (Source: Emerson, 2008)

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 working directly from 400 V 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-unit UPS.

Their different technological design results in different levels of functionality (ability of a UPS system to supply the loads uninterrupted) and reliability (continuous UPS uptime duration between critical failures), as shown in the figure 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 92:Comparison of the functionality (first table) and reliability (second table) of different UPS solution designs (Source: Gutor, 2015)

Use software enabling energy savings.

Installation of software and networking functions and virtualisation carry important opportunities for the reduction of energy consumption. For instance, software can reduce the amount 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 leads 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 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, connection 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 the correct topology of the power supply systems;
- select UPS systems compliant with the EU Code of Conduct for UPS (JRC, 2012) or Energy Star (both of which specify minimum efficiency requirements for UPS).

Table 50: 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 networks	All types of technology	All types of end users	Network operators and technology providers
Deploy integrated and multi-standard solutions	Access networks	Mobile networks	All types of end users	Network operators and installers
Select and deploy more energy-efficient cooling systems	From core to access networks	All types of technology	All types of end users	Network operators, technology providers, and installers

Select and deploy more energy-efficient UPS	From core to access networks	All types of technology	All types of end users	Network operators, technology providers, and installers
Design more energy-efficient telecommunication sites	Access networks	All types of technology	All types of end users	Network operators and installers
Use software enabling energy savings	From core to access networks	All types of technology	All types of end users	Network operators

4.4.7 Economics

Using higher-efficiency power supplies will directly lower a data centre's power bills and indirectly reduce cooling system costs 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 figure below.

UPS Configuration	Relative Solution Costs: Single Feed Loads	Relative Solution Costs: Dual Feed Loads
Single Unit	100 %	120 %
Cascade	180 %	200 %
Parallel Redundant	180 %	200 %
Dual Units	200 %	220 %

Figure 93:Relative cost of various UPS solution designs (Source: 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 investment **(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 in transportation costs and reduces labour requirements, and avoids the need for a crane during installation.
- The **environmental responsibility** and image of operators is another driver 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 the elimination of the energy required to environmentally control battery rooms, thereby reducing non-productive related energy consumption (Verizon, 2013).

Deutsche Telekom[81] operates its own fixed-line and mobile communications networks in Europe and the United States. The company deployed a programme to improve the energy consumption of its network, by:

- migrating over to new technologies and consistently removing technology no longer needed;
- optimising energy supply and conversion (e.g. by improving power converters);
- using more energy-efficient technology for lighting, monitoring and, above all, cooling facilities.

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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 unplugged and that the power and cooling supply are not oversized and are 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 or full broadband equipment on wireline sites) to optimise network sites (decommissioning unused equipment, replacing obsolete equipment, properly configuring cooling systems, etc.); • put in place a decommissioning plan 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 life cycle 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	Emissions to air	Water use & consumption	Noise and EMF emissions	Landscape and biodiversity	
Environmental performance indicators						
• Mobile Network data Energy Efficiency ($EE_{MN,DV}$) • Mobile Network coverage Energy Efficiency ($EE_{MN,CoA}$) • Wireline network efficiency (ICT energy use / total energy use of the network) • Quantity of unused or inefficient equipment decommissioned and removed from base station sites each year						
Cross references						
Prerequisites	• The installation of new equipment when upgrading existing network sites means having selected and purchased suitable ICT, cooling and UPS equipment.					
Related BEMPS	• 4.2 Improving the energy management of existing networks • 4.4 Selecting and deploying more energy-efficient telecommunication network equipment • 4.6 Reducing the environmental impacts when building or renovating telecommunication networks					
Benchmarks of Excellence	• A plan and a management process for optimising all existing network sites have been defined (to remove unused and obsolete inefficient equipment, to properly configure cooling systems, etc.)					

4.5.1 Description

Wireless and wireline networks are made up of numerous, diverse and diffuse 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 often results in 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 the installation of new equipment: specific equipment or multi-standard equipment. Telecommunication operators usually use their existing sites to also install 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.

Although rapid replacement with the latest equipment will improve the overall network energy efficiency, it also causes significant off-site environmental impacts such as:

- resources and energy consumption from ICT equipment manufacturing;
- fuel consumption and air pollution from transportation;
- hazardous pollution related to WEEE management.

Besides, during network rollout, site cleaning may be not properly carried out, due to a lack of time from the installation team. When the new equipment is not properly installed and no old (unused/inefficient) equipment is decommissioned, an increased energy consumption can be observed.

Indirectly, energy consumption from the 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 do the following:

- **Take advantage of technology transition (e.g. deploying 4G technology in existing base stations or full broadband equipment on wireline sites) to optimise network sites.**

  Telecommunication operators regularly perform a transition from one old generation to a new one. This provides a unique opportunity for having direct access to base network sites (e.g. base stations) and to improve their 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 adapt them to the needs of the new ICT equipment design.

- **Put in place a decommissioning plan** to ensure that all efforts are coordinated and in particular to coordinate the external companies that may be involved. Having in place an adequate management process focused on upgrading base station sites to integrate the practices described will help achieve optimal levels of performance.

This BEMP focuses on the installation and upgrading of telecommunication network equipment, both in wireless and wireline networks, and covering not only ICT equipment, but also ancillary equipment such as cooling. The other BEMPs in this chapter cover specific aspects to be used in this BEMP:

- 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 on 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, etc.)

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 of 10% up to 30%. (Spagnuolo, 2015).

The deployment of single base station solutions that can support different generations simultaneously offers the possibility to reduce the overall power consumption by up to 50% compared to a situation with diverse generations of equipment, and in the 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 station. 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).

For wireline networks, similar indicators have not yet been developed. A proxy for their energy efficiency can be used as follows: **ICT energy use / total energy use of the network**.

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:

- **quantity of unused or inefficient equipment decommissioned and removed from base station sites each year.**

4.5.4 Cross-media effects

The installation of new equipment in telecommunication networks for energy efficiency purposes 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 pollution).

LCA may help define when replacing older equipment provides greater environmental benefits than repairing and extending the use of this equipment.

4.5.5 Operational data

Take advantage of technology transition (e.g. deploying 4G on existing base stations) to optimise network sites.

The transition from one technology generation to another, dictated by business purposes, offers a unique opportunity for having direct access to the different sites constituting a widespread 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 also install 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 has less of an environmental impact. With this approach, transportation is mutualised and no additional environmental impact is observed (related to fuel consumption and air consumption). However, such changes at telecommunication base station 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 pieces of telecommunications equipment can be decommissioned.

During network rollout and before installing new equipment, decommissioning unused equipment appears to be particularly relevant, as is designing an appropriate 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 the 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 minimise its inner temperature.
- The limiting factor is usually back-up batteries (if required), since temperatures above 25 °C reduce battery lifetime: in hot 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 a 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 with installation teams on the importance of carrying out such actions, and deploying a training programme if necessary;
- utilisation 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 an internal audit on the occasion of a site's installation;
- reviewing the action plan, the objectives and the governance if necessary (on account 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 as 30% of energy operating costs of telecommunication sites. For its 12 000 telecommunication sites that represents 45-55 GWh/year or EUR 5 000 000/year compared to a regular compressor cooling solution.

4.5.8 Driving force for implementation

Energy-efficient equipment not only saves 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 costs 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[82] (Sweden) has been deploying a modernisation programme 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;
    - utilisation 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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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: • **plan capacity and forecast demand ahead of building or renovation;** • **co-locate ICT infrastructures, in order to limit the number of different infrastructures;** • **locate network infrastructures (fixed-line, antennas, buildings, etc.) close to existing access roads and outside conservation areas;** • **install noise-reducing solutions, such as barriers, absorptive material or mufflers.**

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

Relevant life cycle 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	Emissions to air	Water use & consumption	**Noise and EMF emissions**	**Landscape and biodiversity**

Environmental performance indicators
• Percentage of sites shared with other operators (%) (wherever feasible, e.g. legally) • Existing infrastructure is used when building new wireline networks (Y/N)

Cross references	
Prerequisites	The implementation of such techniques will depend on the characteristics of the environment around the network (urban vs rural area, species living in the area, etc.).
Related BEMPS	• 2.3 Procurement of sustainable ICT products and services • 2.5 Use of renewable and low-carbon energy • 4.3 Improving risk management for electromagnetic fields through assessment and transparency of data • 4.4 Selecting and deploying more energy-efficient telecommunication network equipment
Benchmark of excellence	• At least 30% of sites are shared with other operators (wherever feasible, e.g. legally)

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, in both urban and 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 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 result in complaints and reputational issues.

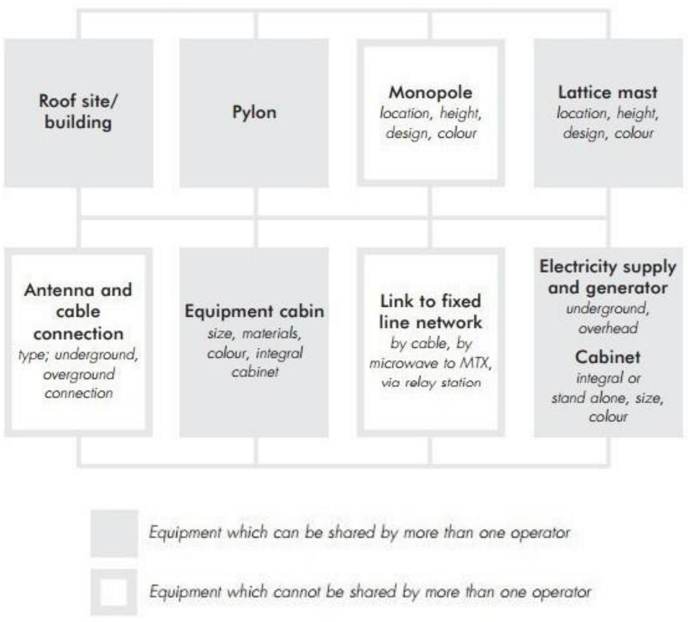

Figure 94: Required mobile telecommunications radio base station equipment (Source: Scottish Natural Heritage, 2002)

Noise is another major concern for telecommunication service providers (the Environmental Noise Directive[83] applies to EU sites and includes in particular obligations to monitor noise levels). 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 foot 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.

[83] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

It is best practice to do the following:

- **Plan capacity and forecast demand** when preparing for building or renovating networks, in order to anticipate and reduce environmental impacts.
- Co-locate ICT infrastructures.

  This technique aims at limiting the number of infrastructures, mainly to limit the impact of fixed and mobile networks on the landscape.

- Locate network equipment close to existing access roads and out of conservation areas (for rural settings).

  Environmental criteria should be taken into account when selecting the location of new network infrastructures (fixed-line, antennas, buildings, etc.), as should 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). This has to be counterbalanced by the demand for network coverage, in particular in low-density rural areas.

- Install noise-reducing solutions (for urban settings in particular). 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

Better planning and siting of ICT infrastructures can decrease both the visual and environmental impact. If building an additional structure is not necessary, an operator can install an antenna on an existing tower or building, thereby avoiding building a new structure. If it is necessary 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 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 (%) - wherever feasible, e.g. legally;
- existing infrastructure is used when building new wireline networks (Y/N).

4.6.4 Cross-media effects

Installing noise reduction equipment means using additional equipment, thereby triggering new waste both during the initial installation of the equipment, and for maintenance purposes.

Co-location 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 infrastructures 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 the following:

- **Co-location 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 customers' signal, usually each provider would build its own tower (Nagle, 2012). Co-location aims at avoiding building multiple towers close to each other, by placing several antennas on a single tower. Site-sharing now seems to have 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 outside 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 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 blocks, for instance, can have a NRC of 0.35 (Hammett & Edison, 2015). Barriers should be solid (> 2 kilograms per square metre) 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 posts, or cementitious wood panels. An earthen berm can be used alone or in conjunction with a wall (Sound Solutions, 2015).

In several countries, network operators have worked together to define good practices regarding the impact of their equipment on the 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. Although 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 "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 the following:

- Located within an area dedicated to a 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 the existence of topographical features and natural vegetation, flora and fauna, the impact on the 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 the 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) allows the operator to position the project in a sensitivity category, from very sensitive in red to less sensitive in green on the graph below.

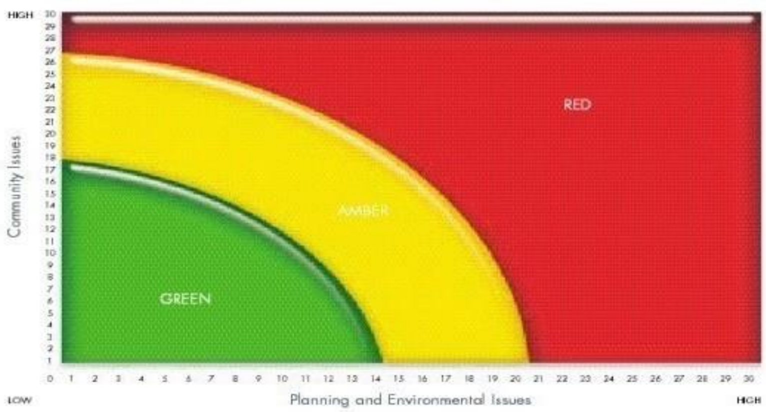

Figure 95:Traffic Light Rating Model for Public Consultation (Source: Mobile Operators Association et al., 2013)

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 in 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 the 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 the following:
• Practices regarding new antennas:
  ○ universality: operators apply the set of practices everywhere in the country;
  ○ viewpoint: operators look at each potential siting through the eyes of the pedestrian, resident and lessor;
  ○ tailored approach: new antennas respect the appearance of buildings, infrastructures and landscapes;
  ○ simplicity: operators make the design of new antennas lighter.
• Practices regarding new antennas on buildings:
  ○ continuity: new antennas shall look like they are part of the building on which they were installed.
• Practices for new antennas on towers/pylons:
  ○ last-resort: operators only build new pylons on last-resort;
  ○ siting: operators take into account the integration in the landscape when deciding where to build pylons.
• Forbidden practices:
  ○ operators shall not install antennas and cables on facades if these are visible from the street;
  ○ operators shall not install antennas on roofs without designing these to match the design of the building;
  ○ operators shall not use supports legs for antennas if these are visible;
  ○ 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

Co-location on a single tower might not always be the appropriate solution to environmental issues. Among the issues that can result from co-location are the following:

- Coverage problems: the antenna may be poorly located or not high enough to provide 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, owned by one operator and leased to another) can lead to disputes, hence making the management of the tower more complicated. (Nagle, 2012)

In some jurisdictions, co-location may not be legally feasible. Local/national authorities may not authorise it due to concerns about collusion (oligopolistic behaviour).

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 over 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 concerns. The size and location of the infrastructure will also often determine which processes must be followed. Smaller towers and antennas are not always subject to specific authorisations (in this 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. historical districts).

Table 51: Applicability of best practices aiming at reducing the environmental impacts when building or renovating telecommunication networks

Technique	Network segment	Operation	Actor
Co-location 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**. **Co-location** implies that fewer 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 52: Economics data related to reducing the environmental impacts when building or renovating telecommunication networks

Technique	Operating costs	Investment costs	Return
Co-location of ICT infrastructures	/	May require stronger or taller structures	Reduction of complaints and regulatory issues, and better image 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 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 the 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. co-location 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 the end of 2015 for the AMEA region.

4.6.10 Reference literature

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5 Improving the energy and environmental performance in other sectors ("Greening by ICT")

5.1 Introduction / scope

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 1.3 Environmental relevance of the sector). This chapter focuses on the most relevant opportunities for the Telecommunications and ICT Services sector to contribute to improving the environmental performance of other sectors.

5.2 Greening by ICT

SUMMARY OVERVIEW:

Across all sectors, four main change levers for reducing GHG emissions and improving environmental performance in general through ICT are available:

- **digitalisation and dematerialisation;**
- **data collection and communication;**
- **system integration;**
- **process, activity, and functional optimisation.**

These solutions are closely related to one another and complementary. They apply at different life cycle stages: while developing the services or products, between the development phase and the utilisation phase, and at the user's site.

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 deploy such solutions into their operations and business (by specifically designing the solution according to the client's needs, by providing training and communication, etc.);**
- **deploy these solutions internally, if relevant.**

Sectors					
Power	**Transport**	**Manufacturing**	**Service and consumption**	**Agriculture**	**Buildings**
Environmental performance indicators					
• GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions • Number of innovative dematerialisation solutions proposed to clients • Share of products and services (in terms of turnover) delivered digitally to the client					

Cross references	
Prerequisites	• Behaviour shift to allow these practices to really replace current habits (printing documents received by email, attending meetings in person, etc.)
Related BEMPS	• 2.7 Minimising data traffic demand through green software
Benchmarks of Excellence	• None defined

5.2.1 Description

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. This BEMP focuses on the most relevant opportunities for the Telecommunications and ICT Services sector to contribute to improving the environmental performance of other sectors.

Key examples of solutions that Telecommunications and ICT Services providers are already providing to bring environmental benefits to other sectors include: Intelligent Transportation Systems (Ericsson Network Society Lab, 2014), Smart Grid technologies, building management systems (European Commission, 2015).

Based on such initiatives, four main change levers for reducing GHG emissions and improving environmental performance in general were identified by the Global e-Sustainability Initiative (GeSI) in the SMART report (GeSI, 2012) and further developed in the SMARTer report (GeSI, 2015):

- **A. Digitalisation and dematerialisation** allow substitution and elimination of products or processes consuming huge amounts of energy and resources (transport, printed documents, etc.).
- **B. Data collection and communication** 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.).
- **C. System integration** helps to manage the use of resources, by facilitating the use of low-carbon energy and reducing energy consumption at the system level (building, company, grid, etc.).
- **D. Process, activity, and functional optimisation** improve efficiency through simulation, automation, redesign or control of process activity and services.

These solutions are closely related to one another and complementary. A further description of these is provided in the subsections below.

These solutions apply at different life cycle stages:

- while developing the service or products, the principles of digitalisation and dematerialisation 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 life cycle 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 resource consumption at an upstream stage);
- at the user's site, smart meters allow 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.

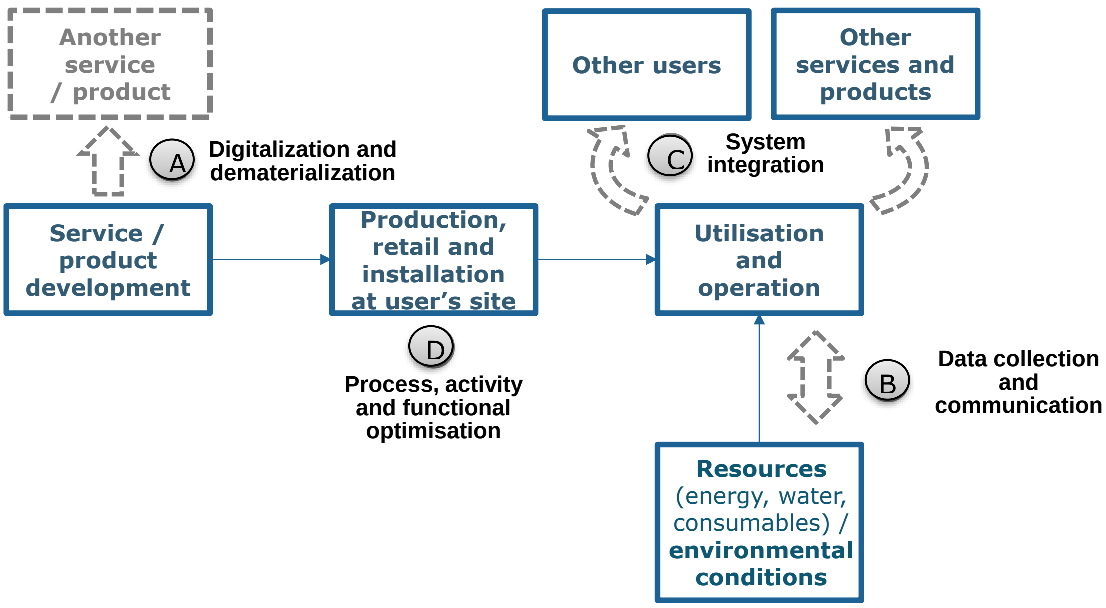

Figure 96: ICT levers for contributing to environmental benefits in other sectors

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 deploy such solutions into their operations and business (by specifically designing the solution according to the client's needs, by providing training and communication, etc.);**
- **deploy these solutions internally, if relevant.**

To develop, commercialise and deploy such solutions require business development based on strategic positioning: environmental benefits can respond to clients' expectations. The present BEMP does not explain how to create or sell such solutions, but how to develop the main principles behind them and it describes solutions already implemented in companies from other sectors.

This BEMP aims to inspire Telecommunications and ICT Services companies to develop and deploy new solutions, but it also aims to provide evidence of the environmental benefits of such solutions. Compared to the BEMPs in the three other chapters, this one is framed at a more general level and intends to show in which broad areas green ICT companies have contributed the most to reduce the impacts of other sectors.

The subsections below provide further details on the four main levers corresponding to "greening by ICT". These are also mirrored in the BEMP sections further below.

A. Digitisation and dematerialisation.

The principles of digitalisation and dematerialisation cover a large range of ongoing business developments, such as miniaturisation of products, servicing, and reducing material use. In this subsection, we refer to content switching from physical carriers to digital and online files and services. For instance, in some circumstances, music CDs have been replaced by MP3 files and digital payments.

The notion of digitalisation and dematerialisation is not new. The advent of the personal computer in the early eighties started the dematerialisation process with typed words leading to a reduction of physical books, newspapers and magazines. The rise of other smart devices (tablets, smartphones and e-readers) led to a new wave of digitalisation and dematerialisation.

The ICT sector itself has greatly impacted these technologies. ICT solutions are central to the dematerialisation of a large variety of products and services, but they also generate significant environmental impacts, as developed in the previous sections of the report. In addition, ICT companies can use the solutions they offer to other sectors.

A non-exhaustive list of digitalisation and dematerialisation solutions that have been developed by ICT services providers is presented below:

- **Developing audio- and video-conferencing applications to reduce the need for business travel.** Global audio- and video-conferencing are also implemented in organisations to improve internal communication.
- **Developing ICT solutions to encourage telecommuting.** The development of ICT solutions such as groupware, virtual private networks, and audio- and video-conferencing to offer 'virtual offices' allows staff to work remotely (typically from home) and reduces the need to commute to work.
- **Developing e-commerce to reduce retail's carbon footprint.** The development of solutions for online shopping offers customers the ability to order products via the Internet. This may reduce the emissions from transportation, but the main benefit is that it helps retailers reduce their carbon footprint and reduces the need for shops.
- **Developing e-paper and paperless procedures and archives 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 archives.
- **Developing online media to reduce the use of materials.** The dematerialisation of products such as CDs, DVDs and books into digital and/or online content or files reduces the use of materials through the electronic delivery of music, games, books and movies.

B. Data collection and communication.

Existing systems' efficiency can be improved by collecting data with smart sensors. Smart sensors are devices that convert physical parameters into electrical signals and gather data for remote reporting. An example of smart sensors are smart meters, a type of sensor used to record electric energy consumption. Data can then be analysed and communicated through software in real time to users.

Real-time information requires the integration of complex physical systems such as the electrical grid with networked sensors and with software for data analytics. The great amount of data collected needs to be aggregated, 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.

IC 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 grids and telecommunication networks, roads, pipes, etc. They have to cover a large scope of the operations at site or company level to ensure global performance analysis.

By improving the efficiency of operations, these types of ICT solutions help companies reduce their environmental impacts by reducing consumption of resources (energy, water, materials).

Presented below is a non-exhaustive list of data collection systems solutions that have been developed by ICT services providers:

- **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 reduce the peak demand for electricity and the load on the distribution system during certain times of the day. Communication through mobile devices about different pricing for electricity during different times of the day allows consumers and enterprises to adjust the 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** assist in analysing water consumption and leaks, and give greater control over water use.
- **Smart farming** is relevant in the agricultural sector, to adapt the amount of fertiliser, pesticide and water required for cultivation. Monitors can analyse weather conditions. Data can be collected remotely or on site.

C. System integration / smart cities.

With growing urbanisation, the increase of mobility and broader access to Internet, cities need to improve their efficiency and transform into smart cities. In smart cities for example, technology providers offer technical solutions to contribute to the integration of infrastructures and services in an urban environment.

The availability of smart solutions for smart cities has risen rapidly and ICT technology providers have developed smart solutions in different sectors, leading to more and more integrated infrastructures: energy grid, transport infrastructure 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 into 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 company level to improve the management of their own infrastructures. The use of system integration solutions helps organisations reduce their environmental impact by giving information to optimise the use of fossil fuel resources.

Presented below is a non-exhaustive list of system integration solutions that have been developed by ICT services providers:

- **Integration of renewables on- or off-grid.** The replacement of fossil fuel by electricity from carbon-free energy sources such as solar power or wind power. ICT allows a higher degree of integration of renewables into the grid and a more effective use of these. Renewable energy can also be used off the grid using energy storage in applications such as isolated telecom towers.
- **Integration of electric vehicles.** The development of ICT that promotes the use of electric vehicles or sustainable biofuels.

- **Fleet and traffic management.** 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.** Computer-based control systems installed in a building controlling and monitoring the building's mechanical and electrical equipment, e.g. HVAC.

These different solutions are interconnected and can rely on data collection solutions (refer to section on Data collection and communication).

D. Process, activity, and functional optimisation.

These cover 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.

Presented below is a 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. NB: This partially overlaps with fleet management as described in the previous section, but at vehicle level.
- **Optimisation of variable-speed motor systems and automation of industrial processes** allow machines to detect the strain under which they are working and adjust output accordingly instead of working less efficiently at constant speed. A process automation system is used to automatically control industrial processes.
- **Minimisation of packaging, use of eco-friendly material and design of products for easy and effective dismantlement** reduce the total materials required for a product and lowers a product's footprint by using design software.
- **Reduction of inventory** helps retailers optimise their inventory and reduces the amount of inventory needed.
- **Building design.** The design of energy-efficient buildings.
- **Food supply chain optimisation** makes 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 processes.

5.2.2 Achieved environmental benefits

The use of ICT solutions can help reduce energy consumption and resource 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 the power grid. They help reduce energy consumption and associated **GHG emissions**. (European Commission, 2015) (GeSI, 2015). ICT solutions also help integrate renewable energy into the grid, which supports GHG emissions reduction.
- **Transport:** ICT has already demonstrated that it can provide **significant fuel savings** by optimising driving and logistics and through fleet management systems. It indirectly reduces **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 digitalisation, dematerialisation and optimisation 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 help increase yields (GeSI, 2015). ICT solutions help to adapt and monitor water needs and therefore reduce overall **water consumption**. Soil monitoring solutions also help adapt the level of fertiliser and pesticides needed and indirectly help **preserve 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 reduces **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.

The different levers identified have specific environmental benefits:

A. Digitalisation and dematerialisation 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 shops 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 Gt CO_2eq worldwide. It also reduces the demand for lighting, cooling or heating office buildings or shops and reduces the need for office and shop space.

E-commerce, e-paper and online media reduce the use of raw material needed to produce or sell products and the need for storage and transportation. These reductions indirectly lead to CO_2 abatement which can reach 0.17 Gt CO_2eq (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).

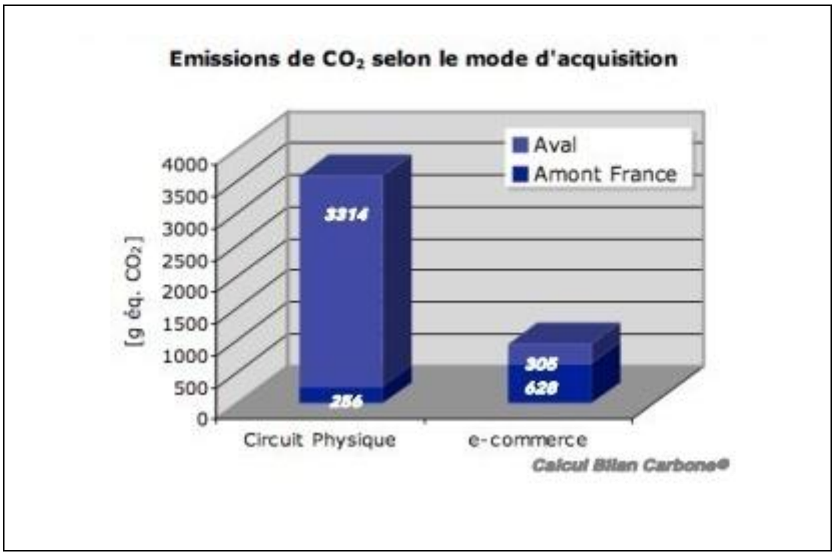

Figure 97:CO_2 emissions in traditional retail (left) compared to e-commerce (right) (Source: Fevad, 2009)

As mentioned in the introduction of this chapter, the degree of environmental benefits depends on many factors and in particular on the extent of rebound effects.

B. Data collection and communication

Data collection systems can result in one main environmental benefit which is the **reduction of resource consumption**. Depending on the sector and companies' activities, it can help reduce:

- energy consumption (electricity, fuel, etc.);
- water consumption;
- consumables consumption (fertilisers, etc.).

Indirect environmental benefits are linked to the reduction of associated GHG emissions.

Other environmental benefits are the reduction of resource consumption or of the use of chemicals such as pesticides, thus preserving water, soils and biodiversity.

Examples are given below for specific solutions:

- **Energy demand management and time-of-day pricing**

The management of electricity demand and reduction of peak load help reduce the need for other sources of energy-intensive power such as coal-fired power.

Smart meters on the grid achieve the CO_2 abatement shown below.

	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 98:Carbon emissions abatement from connected energy (t CO_2eq/year) (Source: 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 reduce fuel consumption, air pollutant emissions and noise emissions.

Eco-driving can reduce fuel consumption by about 15% (Smartdrive, 2012).

Eco-driving achieves the CO_2 abatement shown below.

	UK	Germany	Spain	France	USA	Europe
Eco-driving	24,000	19,000	16,000	17,000	108,000	252,000

Figure 99: Carbon emissions abatement from eco-driving (t CO_2eq/year) (Source: GeSI Mobile carbon impact, 2015)

- **Smart water**

Smart water management through data collection allows water consumption reduction by preventing leaks and better allocating water in the network.

Indirect environmental benefits include the reduction of production and distribution emissions due to lower water consumption.

Smart water management can have specific environmental benefits in the agricultural sector. Sensors can measure moisture and prevent unnecessary irrigation and soil erosion, therefore preserving water, soils and biodiversity.

- **Smart farming**

Soil monitoring prevents surface and groundwater pollution by adjusting the quantities of fertiliser and pesticides used for farming accurately to the plants' needs. It helps avoid spreading unnecessary volumes of fertiliser and pesticides which would not have been absorbed by plants, and which would have ended 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 fertilisers and pesticides and the use of associated raw materials, such as phosphate.

Smart farming or connected agriculture achieves the CO_2 abatement shown below:

	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 100: Carbon emissions abatement from connected agriculture (t CO_2eq/year) (Source: GeSI Mobile carbon impact, 2015)

C. The main environmental benefit of system integration solutions 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, etc.).

- **Integration of renewables**

The integration of renewables increases the use of carbon-free energy and reduces GHG emissions associated with carbon-intensive power. It also reduces the need for nuclear power plants, which can be critical in countries where nuclear power production is being phased out and would be replaced by fossil-fuel-fired plants.

- **Integration of EVs, intelligent traffic management, and fleet management and telematics**

It reduces the need for fuel consumption and reduces associated CO_2 and other atmospheric pollutant (NOx, SOx, particles, etc.) emissions.

EV connection achieves the carbon emissions abatement shown below:

	UK	Germany	Spain	France	USA	Europe
Electric vehicle connection	840	1,000	650	3,000	1,000	11,000

Figure 101: Carbon emissions abatement from EV (t CO_2eq/year) (Source: GeSI Mobile carbon impact, 2015)

- **Fleet and traffic management**

It reduces fuel consumption and reduces associated CO_2 and other atmospheric pollutant (NOx, SOx, particles, etc.) emissions.

Fleet vehicle management and smart logistics achieve the carbon emissions abatement shown below.

	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 102: Carbon emissions abatement from fleet vehicle management and smart logistics (t CO_2eq/year) (Source: GeSI Mobile carbon impact, 2015)

- **Building management system**

This allows energy consumption to be reduced through more efficient use of ventilation, lighting, etc. It indirectly helps reduce GHG emissions due to energy consumption.

Connected buildings achieve the carbon emissions abatement shown below.

	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 103: Carbon emissions abatement from connected buildings (t CO_2eq/year) (Source: GeSI Mobile carbon impact, 2015)

D. Functional optimisation and modelling

The use of functional optimisation and modelling software help organisations reduce their environmental impact by:

- **reducing energy consumption** needed in the production process through the anticipation of quantities produced or the adjustment of production systems;
- indirectly reducing CO_2 and atmospheric pollutant (NOx, SOx, particles, etc.) emissions, due to the decreased use of fossil-fuel-based energy;
- **reducing the use of resources** and materials through eco-design or optimisation of the quantity produced;
- **reducing end-of-life impacts** through the design of easily disassembled products.

There are other specific environmental benefits:

- **Optimisation of truck route planning and logistics network**

This offers significant savings in terms of truck utilisation and fuel use through route optimisation. It reduces indirect environmental impacts related to transportation: CO_2 emissions, other air pollutant (NO_X, O_3, etc.) emissions, noise, etc.

- **Optimisation of variable-speed motor systems and automation of industrial processes**

Load capacity affects the ability of machines to perform at 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 processes achieves the carbon emissions abatement shown below.

	UK	Germany	Spain	France	USA	Europe
Automation in industrial processes	37,000	92,000	20,000	7,000	324,000	319,000

Figure 104: Carbon emissions abatement from automation in industrial process (t CO2eq/year) (Source: GeSI Mobile carbon impact, 2015)

- **Minimisation of packaging** through design software helps reduce the amount of resources needed. It indirectly reduces the amount of waste generated.
- **Reduction of inventory** lowers emissions by reducing logistical and transportation emissions. It also reduces the 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 t CO_2eq (GeSI, 2012).
- **Food supply chain optimisation** helps reduce GHG from agricultural production through adoption of less polluting agronomic techniques (regarding soils, water resources and atmosphere) and increasing energy efficiency and the use of renewable energy. It also increases farms' resiliency to extreme weather and climate variability through weather forecast analysis and climate change adaptation solutions.

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 environmental performance improvement 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[84] GHG emissions throughout their value chain to measure the environmental impacts of the use of their products and services. The scope 3 indirect emissions measure CO_2 abatement from business travel reduction through the use of videoconferencing systems, and from a reduction in employees commuting 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 innovative dematerialisation solutions proposed to clients.
- Share of products and services delivered digitally to the client (in terms of turnover).

5.2.4 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. They 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 the energy price drops, manufacturers can use cheaper energy services 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 increased demand for goods and services.
    - Embodied energy: equipment used to improve energy efficiency requires energy to be manufactured, installed, and ultimately removed and processed as waste.

[84] The GHG Protocol Corporate Standard classifies a company's GHG emissions into three 'scopes'. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.

    - 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 (WEEE).

In addition, there are cross-media effects specific to each lever:

A. The main adverse effect of "digitalisation and dematerialisation" solutions is **the increased use of ICT devices**, with the related environmental impacts. The broad use of information solutions and digital devices increases the capacity of users to access information and therefore the time users will spend using them. An 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 digitalisation and dematerialisation is more energy-efficient, data centres also need to be more energy-efficient.

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 time for private travelling during the day, compared to the situation when 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 this would have been unnecessary while working at the office. Besides, heating houses is usually less efficient than heating offices because in houses typically only one person occupies the whole building/flat.
    - 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 leading to an increase in traffic.
- Teleconferencing solutions facilitate the organisation of meetings. Only some teleconference meetings would have been face-to-face meetings with commuting. The organisation of teleconferencing meetings 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 needs 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 a corresponding increase in energy use from server space and screen use.

B. The direct rebound effect of **data collection and communication** 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.

C. The use of ICT **system integration** can imply an increase of the overall energy consumed. The integration of technologies into grids and networks can have different impacts on the environment depending on the energy sources used. The integration of electric vehicles increases the use of electricity. The environmental impacts are different if the electricity is produced with energy-intensive fossil fuels or with carbon-free energy.

It can increase the use of renewable energy sources using raw materials, which can have different impacts on the environment (see BEMP 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 the following:

- Biofuel sources, 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's health and the environment. Nuclear hazardous waste, if not well managed, can also impact biodiversity and surface and groundwater quality.

D. Process efficiency and optimisation also leads to the deployment of new hardware.

5.2.5 Operational data

The section below collects a series of concrete examples for the various levers explored in the above description with an estimate of the concrete benefits in each case.

A. Digitisation and dematerialisation.

- **Developing audio- and video-conferencing applications to reduce the need for business travel**

With audio- and video-conferencing systems, ICT services providers help companies to implement global collaborative tools. The implementation of such a system enables employees to interconnect in a large network and to connect with their clients.

Audio- and video-conferencing systems should be installed on every site and each employee should 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 videoconferencing instead of a 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 videoconferencing. By using conferencing solutions internally, every year BT avoids around 717 000 face-to-face meetings, representing 53 000 tonnes of CO_2 and EUR 210 million in travel costs (GeSI, 2012).

- **Developing ICT solutions to encourage telecommuting**

Audio- and video-conferencing systems encourage employees to telecommute and therefore reduce their need to commute to work. Other ICT solutions give employees the 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 videoconferencing 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’s carbon footprint**

Digitalisation transforms companies’ business by switching from physical shops to an online platform, and by creating new online services such as rental of cars and accommodation.

The development of online shopping helps reduce the environmental impacts of retail companies:

- by reducing the infrastructures required, with the centralisation of products in storehouses, instead of multiple and different physical stores;
- by reducing customers commuting to shops and therefore companies’ scope 3 emissions.

The scope 3 emissions also depend on the optimisation of logistics and transportation. Different ICT solutions are applied to ensure an efficient delivery process:

- collect data on real-time traffic, create alerts and install applications for intermodal transportation and eco-driving to adapt driving (see Section 5.2.1);
- use an intelligent traffic management system to remotely monitor and control automobile traffic (see Section 5.2.1);
- 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 5.2.1);

- use truck-route-efficiency software to determine which route requires the lowest amount of fuel for a particular trip (see Section 5.2.1).

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 transactions on its website have displaced emissions equivalent to 4 million tonnes 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. They encourage the substitution of printed material such as newspapers, magazines, catalogues, brochures, directories, office documents, invoices and application forms with digital forms.

Digitalisation has to be global and used both for internal and external processes and communication to have a positive environmental impact. The implementation of a digitalisation process is 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 signature procedures and dematerialised archive services.

The company Esker developed an invoice automation solution helping companies decrease their paper consumption. It was deployed in the office of CAPSA, one of its clients. 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 EUR 96 000 a year between 2007 and 2012. In addition to money savings, 39 000 trees have been saved from being cut down and CO_2 emissions have been reduced by 10 500 tonnes (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 forms of consumption emerged with digitalisation and dematerialisation of the economy. The dematerialisation of products impacts many sectors: music, film, 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.

B. Data collection and communication.

- **Energy demand management and time-of-day pricing**

In the energy sector, data collection systems are deployed through the installation of smart meters on the grid. Companies went from one meter collecting information on a monthly basis to smart meters taking readings every 15 minutes which quickly leads to millions of data points for every meter installed.

This generates a vast amount of information on the grid and provides 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 generate data volume and complexity.

To manage the use of this information and obtain 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 advanced analytics using a combination of information such as: data on customers, consumption, physical grid dynamic behaviour, generation capacity, energy commodity markets and weather. Analysis gives a better understanding of customer segmentation and behaviour and of the influence of pricing 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 savings for customers and a reduced generation capacity for energy providers which reduces 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 allow a 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 optimise the load on the distribution system, reducing the overall energy consumption.

To make the most of the data available, ICT services providers provide 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 of devices such as air conditioners and water heaters and to enable consumers to check their energy consumption online. Consumers can authorise their appliances being turned 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 bill. Some consumers saved up to 40% (IBM, 2016).

- **Real-time traffic alerts, applications for intermodal transportation and eco-driving**

Data collection systems are used in the transport sector. Data is collected through a 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 the 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 in the cost of the insurance policy. Over 6 000 clients adopted this eco-driving application between the end of 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 are important for water operators and for industrial operators using water-intensive processes. Smart meters are installed on pipelines and adapted software analyses water consumption and leaks to improve water supply processes.

These types of solutions give operators or industrial users greater control over water use and allow for water consumption reduction through management of water balance data, and optimisation of the discharge of water, and real-time information. Real-time information also helps identify 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 in 2013 worked 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 historical maintenance data from sluices, pumping stations, locks and dams. The Digital Delta management system addresses different environmental aspects:

- monitoring of weather events to prevent impacts from natural disasters on agriculture fields, buildings and infrastructures;
- identification of leaks to manage maintenance and reduce water losses;
- monitoring of the quality of drinking water, ensuring the health and safety of the Dutch population.

The system uses virtualisation and deep analytics to provide a 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, and development of a 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 the cost of water management by 20% to 30%. By optimising the data sharing, it also reduces the scientific research and development time needed for information sharing, thus reducing the associated cost.

- **Smart farming**

Producers use more and more high-tech equipment to monitor soil conditions and livestock. Data collection systems are used in the agricultural sector to monitor soil conditions. Soil-moisture-sensing technology has been used for several decades and is widely used.

Data collection systems are used in the agricultural sector to adapt the amount of water, fertiliser 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 nitrates or soil pH.

Data collection can be done with remote sensing through satellite information collection on: weather forecasts and soil moisture, groundwater and terrestrial water storage, evapotranspiration, etc. All this information helps determine the right level of water, fertiliser 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 body temperature, animal activity, pulse and GPS position can be analysed. This information helps farmers adapt nutrition and anticipate 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 point D. below).

C. System integration.

- **Integration of renewables on- or off-grid**

The growing utilisation of renewable energy sources, mainly wind and solar, provides variable energy output depending on the time of the day, location, season, weather, etc. Integrating these renewables into the existing electric grid increases the need for smart grid management services. A **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 replace 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 the renewables integration challenge (GridTalk, 2013):

- Reactive compensation solutions: reactive technology mitigates some of the impacts of varying renewable energy output on power systems. Fast-compensating dynamic statistic compensators provide support and help renewable energy plants meet interconnection requirements.
- Volt/VAR optimisation: variable output from renewable energy generation impacts supply voltage levels for utility customers and affects power quality. Volt/VAR optimisation (VVO) is a process of optimally managing voltage levels and reactive power to achieve more efficient grid operation by reducing system losses, peak demand or energy consumption or a combination of the three. During the process, voltage control devices at a substation and on the circuit can be used to shrink the voltage drop from the substation to the end of the line and reduce the service voltage to customers while maintaining the voltage within defined limits. The efficiency gains are realised primarily from a reduction in the system voltage. This results in less energy being consumed by end-use equipment served by the distribution system (PowerGrid, 2015). This solution also uses sensing which gives utilities greater visibility into how renewable distribution impacts the grid to better manage the effects.
- Energy storage: this is an essential part of integration of renewable energy. It tackles issues such as rapid variations in output from renewable energy generation. It helps smooth variations by aligning actual output from renewable energy plants to scheduled output and storing electricity for use when demand is high and renewable energy generation output is low.

Such solutions help remove barriers to the use of renewable energy sources and accelerate their deployment on national grids and reduce the environmental impacts of electricity generation.

- **Integration of electric vehicles**

The growing market for Electric Vehicles (EVs) creates 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 being developed to promote the use of electric vehicles and allow integration on the grid. ICT solutions can cover:

- subscriber management;
- analytics, reporting system for on- and off-peak charge and dashboards;
- optimisation and load control;
- charge calculation.

- **Fleet and traffic management**

ICT services providers develop software management systems enabling more efficient management of the fleet and traffic. ICT services providers create dashboards to monitor fleet vehicles more efficiently.

For instance, in 2013, Michelin, a French tyre manufacturer, launched Effifuel, a fleet management solution (Michelin, 2014). The objectives of fleet management are to optimise the vehicle use 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 traceable vehicle data.

Effifuel is implemented in two main steps. The first step consists of the fleet audit. A fuel analyst collects the data and talks to 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 for eco-driving. Effifuel's solution provides digital tools to follow consumption 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 has helped save 1.5 litres per 100 kilometres for hauliers. If the entire European road haulage industry were to achieve the same fuel savings over one year, Michelin estimated that the use of Effifuel could save more than 3 billion litres of fuel. It will avoid 9 million tonnes of CO_2 emissions. Michelin estimates that its solution allows a saving of more than EUR 1 300 per truck per year. If the 2.5 million long-haul lorries in Europe used Effifuel, it would represent more than EUR 3 billion in savings.

- **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- or off-grid part).

The ICT sector delivers 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 start-up in smart energy solutions, developed for SRL CELMAC - Cellino Group (a group specialised in metals for the automotive industry) a 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 the system responds immediately. GL-RD lighting point control can also monitor the operating status of machinery (e.g. 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 has helped saving 210 kWh/year. The annual energy consumption has been reduced by 76%. It has also helped avoid 111 t CO_2eq per year. The payback time is estimated to be less than 2.5 years (Geolumen, 2015).

Another example for building management systems is the solution developed by Qarnot Computing. The company offers a cloud HPC (high-performance computing) service and has created two technologies: Q.ware software distribution platform and Q.rad digital heater:

- Q.ware distribution platform is a cloud service that 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 is a connected electric radiator embedding high-performance processors as a heat source. The heat produced by workload processing provides free and efficient heating.

Over the past 2 years, Qarnot has deployed more than 350 Q.rads (first generation) installed in the Paris region and is operating more than 5 000 cores. Qarnot's solution reduces the 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 and heaters for 120 g/kWh. For instance, computation work of more than 4 days and 6 hours represents 160 g of CO_2 saved (Qarnot Computing, 2016).

D. Process activity and functional optimisation.

- **Optimisation of truck route planning and logistics network**

Transport planning and logistics management software provides a strategic, operational and real-time planning functionality for large and complex transport and distribution networks.

Transport management software solutions are capable of planning thousands of movements in seconds and modelling complex operational rules and constraints. This type of software provides powerful algorithms modelling different types of data: 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 schedules based on real-time or forward planning. The real-time planning uses GPS location and transport orders' status to automatically update schedules. Forward schedules are optimised using vehicle routing and distribution scheduling systems which assign daily forecasts 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 networks 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 optimise variable-speed motor systems and automation of processes. Such software is 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 speed adjusted as required.

Motors consume most of the energy produced in industrial processes and controlling and adapting speed can realise up to 70% energy savings. The use of motor-controlling solutions helps 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, and easy and effective dismantlement. It is mainly used by industrial operators in the conception of their products and processes.

Modelling and design software helps lower the product footprint by: reducing the use of resources and 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 life cycle management. This platform helps capture products' handprints. **Handprinting** is the evaluation of a product's environmental impact beyond its footprint, based on a life cycle approach. Footprint focuses on negative consequences on the environment, whereas handprint also considers beneficial changes. There are two ways to create a handprint:

- preventing/reducing footprints that would have occurred;
- creating positive benefits that 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 and energy inputs to vehicle manufacture that 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 of the vehicle's lifetime 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 of this eco-design tool can enable sectors such as the global automotive sector to create handprints which are in 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 and profit margin and to reduce environmental impacts. Stocking control is at the core of an inventory management system which allows the control of the 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 optimise inventory at each level of the supply chain.

This modelling solution enables manufacturers to create their own 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 cutting CO_2 emissions.

- **Building design and voltage optimisation**

Modelling and design software is used in building conception. Such software is used before construction and allows companies to forecast the environmental impact of materials used and the energy efficiency.

For instance, Dassault Systèmes has developed 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 covers 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 has a major impact on the ability of farmers, consumers and buyers to trace the food they buy and sell. In the same way as for optimisation of manufacturers' supply chain, ICT software can optimise processes and reduce food waste at all stages.

Tracking systems give real-time tracking of food at production, storage and transportation stages. Real-time information helps farmers match demand and optimise the supply chain. The adjustment of production and demand allows the reduction of food waste at its source.

5.2.6 Applicability

The above-mentioned 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, airways, pipelines and terminals. Transport covers 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 businesses or final consumers. It may involve transport, distribution and sale of goods or services from producer to consumer.
- **Agriculture and land use**: this refers to the cultivation of plants or livestock. The agricultural sector is confronted with major challenges with a growing population and reduced natural resources. Increasing and more prosperous populations must be fed and issues such as water shortage and soil fertility decline must be taken into account (Stienen, Bruinsma, & Neuman, 2007).
- **Buildings**: this includes the process of constructing a building or infrastructure and building management systems.

Figure 105 gives examples of solutions that can be implemented in the six above economic end-use sectors through the four levers of change enabled by ICT services.

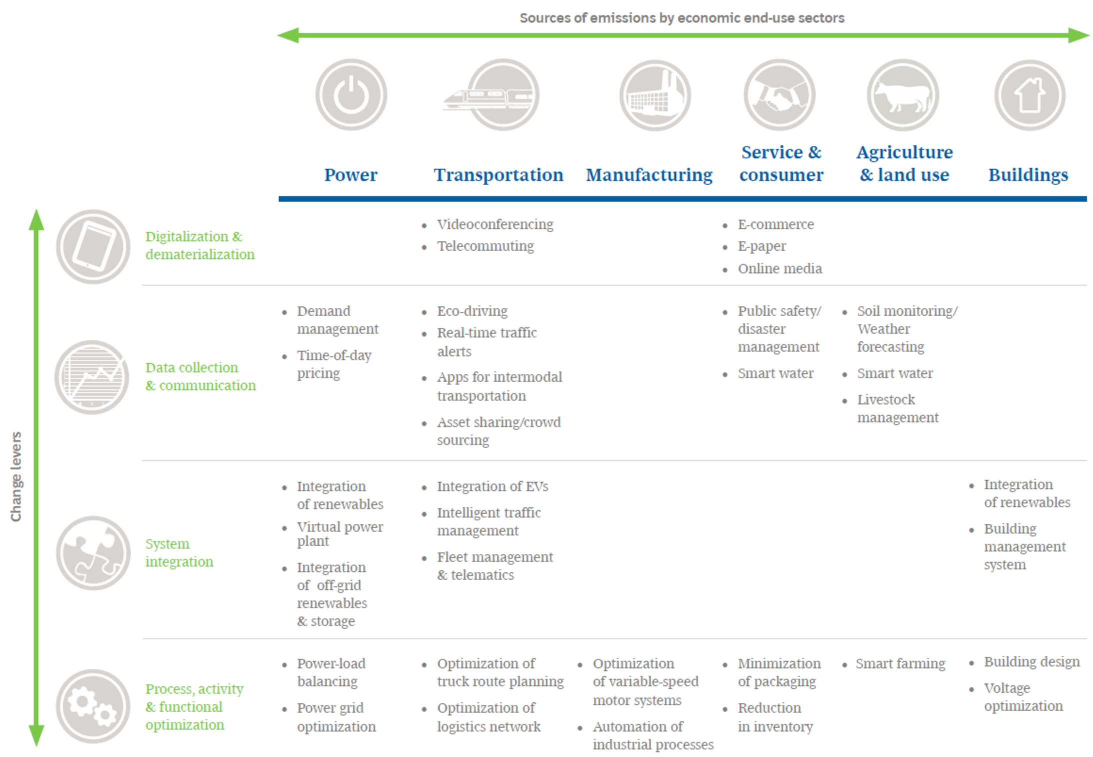

Figure 105: Example of ICT solutions enabling carbon savings (Source: GeSI, 2012)

Additionally, different levers have different constraints in terms of applicability:

A. Digitalisation and dematerialisation.

These solutions are relevant in any organisation that uses significant amounts of paper or that has a 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 lives, there can be significant reluctance to adopt new technologies and to change their behaviour. Teleworking creates new challenges to employers too as its application needs them to change working procedures.

B. Data collection and communication.

- **Energy 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 whether the local electricity system 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 services providers need to develop tailor-made applications for specific customers' needs. A high level of technical skills is required.

For users, 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 worthy of consideration.

Eco-driving applications require on-board smartphones 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 they are to be implemented on. Therefore, they can require a large amount of ICT equipment.

Smart water systems are used in the public sector or by private operators on the city's network and by the private sector for companies with 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 highly dependent on the geographical area and its impact on the 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 agricultural sector to collect data on soils and livestock. It requires training for farmers to encourage them to use this type of ICT solution and change traditional work habits.

C. System integration.

Any ICT services provider can develop system integration software and applications. The development of such solutions requires a high level of technical skills and the development of 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 is highly dependent on the ability of the network to handle intermittent generation and new transmission.

D. Process, activity, and functional optimisation

The development of such ICT solutions requires a good knowledge of markets' maturity and clients' needs. In some sectors, 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 brought about by adopting such technologies.

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 are necessary in order to optimise utilisation.

5.2.7 Economics

ICT services providers invest in R&D to develop new solutions to assist their clients, relying on a highly skilled workforce. The development of specific applications can require a high level of upstream investment in developing new tailor-made systems and analytical software, which are highly dependent on the clients' needs and context.

Certain technologies do not have a positive Net Present Value when deployed on a small scale (such as building management systems for homeowners). Some technologies may have too long a payback period for private adoption.

If not sustained by standardisation and regulation, ICT solutions could deliver reduced benefit and suffer early obsolescence.

Below are some examples relating to the different subsections:

B. The roll-out of smart meters requires 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 reaches around EUR 145 (The Telegraph, 2015).

D. Endeco Technologies Ltd developed a power-load balancing technology. In the 5 years following commercialisation, sales of the product were forecast to reach a total of EUR 124.8 million and a profit of EUR 28.8 million with a ROI of 1:17.5 over 5 years (European Commission, 2015).

5.2.8 Driving force for implementation

In the context of global objectives for energy transition, climate change mitigation and resource scarcity, organisations in all sectors have strategic objectives to improve their environmental performance and efficiency, creating new demand for services to reduce energy and resource consumption. The implementation of ICT solutions addresses the concerns of client organisations by:

- improving **resource efficiency** for materials, energy, water, etc.;
- **reducing costs** through energy savings and the reduction of material use;
- improving **operational efficiency** including for human resources;
- demonstrating **environmental commitment** to stakeholders.

Specific needs in the client sectors might imply particular requirements, for instance the following:

B. The agricultural sector faces new challenges on sustainable yield and organic farming development, which creates a need for data collection and analysis systems.

C. The transformation of the energy sector and transition to carbon-free energy sources such as renewable energy sources, as well as growing markets for EVs, increase the need for integration systems.

D. The automation of processes and functions improves clients' competitiveness by introducing tailor-made innovation and reducing resource consumption.

5.2.9 Reference organisations

Several companies already report their scope 3 GHG emissions (e.g. Proximus, see Proximus, 2015). Apart from the companies already referenced the Operational data section, the following companies are reference organisations in the following subsections:

A. Digitalisation and dematerialisation.

- 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).

B. Data collection and communication.

Smart Energy UK and Europe gave the following awards to ICT technologies[85] in 2016:

- 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.

C. System integration.

- BlaBlaCar, a French company leading in ridesharing platforms, developed a service to optimise car occupancy. The platform gives users access to real-time information on cars available for a lift. The platform reduces the number of empty seats on the roads with an occupancy rate of 2.8 people per car compared to an average of 1.6 in Europe.

D. Process, activity, and functional optimisation.

- Endeco Technologies Ltd is a pioneering, award-winning company recognised as the technology leader in smart grid energy aggregation (European Commission, 2015).

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[85] For more information, see: http://www.smuksummit.com/awards/2016-awards/

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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 into four chapters:

- Cross-cutting measures (in light grey in Figure 106), 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 in Figure 106), which refer to practices specific to data centre operators or server owners (and their suppliers).
- Telecommunications-network-related measures (in dark grey in Figure 106), which refer to practices specific to telecommunication operators (and their suppliers).
- Greening by ICT measures (in darkest grey in Figure 106), which refer to solutions developed by software developers and telecommunication service providers, and which are to some extent applicable for the Telecommunications and ICT Services sector.

However, these chapters are not set in stone and completely separate:

- 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 introductory table of each BEMP ("related BEMPS") and developed within the description section.

Most of the BEMPs are only applicable to specific life cycle stages: service development, planning and designing, selection and procurement, installation and upgrades, operation and management, or end-of-life management. Figure 109 shows that there is at least one BEMP applicable for each life cycle stage of any ICT asset (data centre, telecommunication network and end-user device). The introductory table of each BEMP specifies to which ICT asset and life cycle stage the BEMP is applicable.

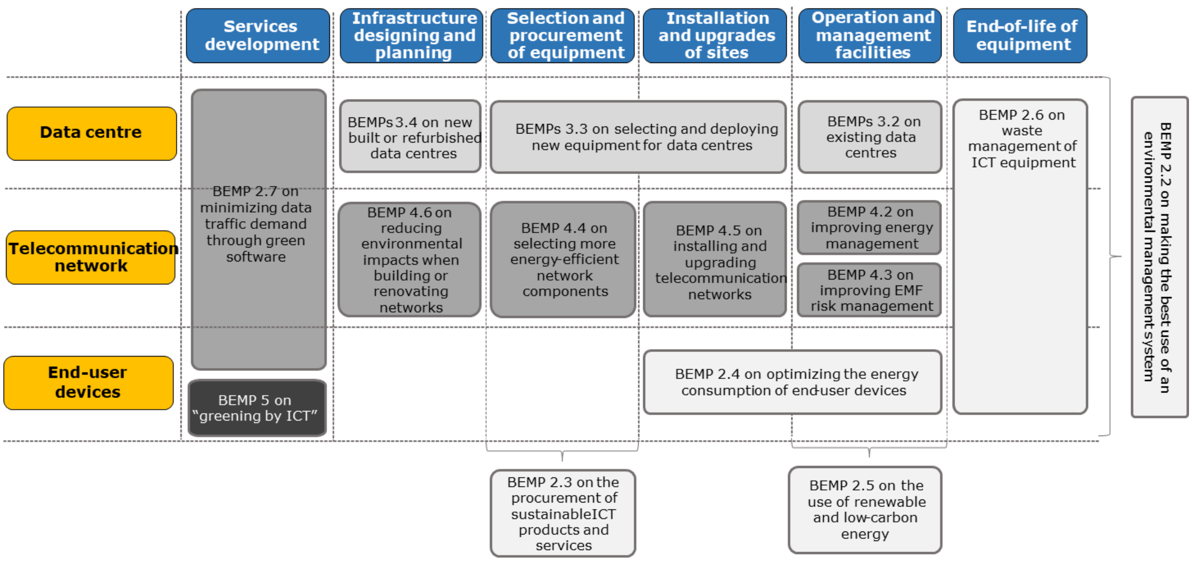

Figure 106: Overview of the BEMPs' applicability

6.2 Applicability to SMEs

The purpose of this section is to facilitate the use of this document by small and medium-sized enterprises (SMEs). As described in Chapter 1, the Telecommunications and ICT Services sector is made up of a large majority of micro-sized firms, with 93% of the total number of companies in the sector employing less than 10 people in the 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 are web portal, data processing or hosting companies (NACE code 63). If the telecommunications sector is also mainly made up of SMEs according to Eurostat (Eurostat, 2012b), this data fails 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, for example, to telecommunications network development or management may be of more direct relevance to large telecommunications 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 54 characterises all the BEMPs described in this document in relation to four aspects: target group, cost, applicability and achieved environmental benefit, using a user-friendly colour-coded "traffic light" assessment, given in Table 53.

Table 53: 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	Fully applicable
Environmental benefit	Low	Significant	High

Table 54: 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. benefit	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 organisations 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 the energy consumption of end-user devices	All companies				SMEs rely more on organisational solutions than on technical and standardised solutions, even if such solutions are affordable.

BEMP	Target group	Cost	Appl. to SMEs	Env. benefit	Comments
2.5 Use of renewable and low-carbon 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 may not be applicable for companies that share offices in an urban environment (most of the IT services companies).
2.6 Resource efficiency of ICT equipment through waste prevention, reuse and recycling	All companies				LCA services or training can cost a significant amount of money. Actions towards products sold to customers are more applicable to the telecommunication sector, with a majority of large firms.
2.7 Minimising data traffic demand through green software	All companies				Small companies may not have the resources to develop their own software, but can procure more energy-efficient software.
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 structures. The tools are mainly for large data centres because of heavy upfront investments.
3.2.3 Define and implement a data management and storage policy	Server owners				These practices can be implemented by most data 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 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 cooled air, and reviewing humidity settings can be done in most data centres, irrespective 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 environmentally friendly 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 new build or refurbishment of data centres					
3.4.2 Planning of new data centres	Data centre operators				Building a data centre according to a modular architecture is particularly relevant for big data centres.
3.4.3 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 decentralised system (servers placed in the rooms that they directly heat).
3.4.4 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 the aspect

BEMP	Target group	Cost	Appl. to SMEs	Env. benefit	Comments
					and structure of the new-build data centre and can be costly to implement.
3.4.5 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.
3.4.6 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 energy 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 Service requirements and by choosing relevant network technologies.
4.3 Improving risk management for electromagnetic fields through assessment 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 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 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 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 companies. Local authority planning policies can limit the capacity of operators to develop their network in specific areas.
5 Improving the energy and environmental performance in other sectors ("greening by ICT")					
5.2 Greening by ICT	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 pressures of the Telecommunications and ICT Services sector are its energy consumption and direct and indirect emissions of greenhouse gases (GHG). As shown in Figure 110, most of the 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, tackled 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 deal 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 different to the other ones as they refer to the minimisation of the environmental impacts of other sectors. On the one hand, the deployment of such solutions generates an increased 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, resource consumption, etc.

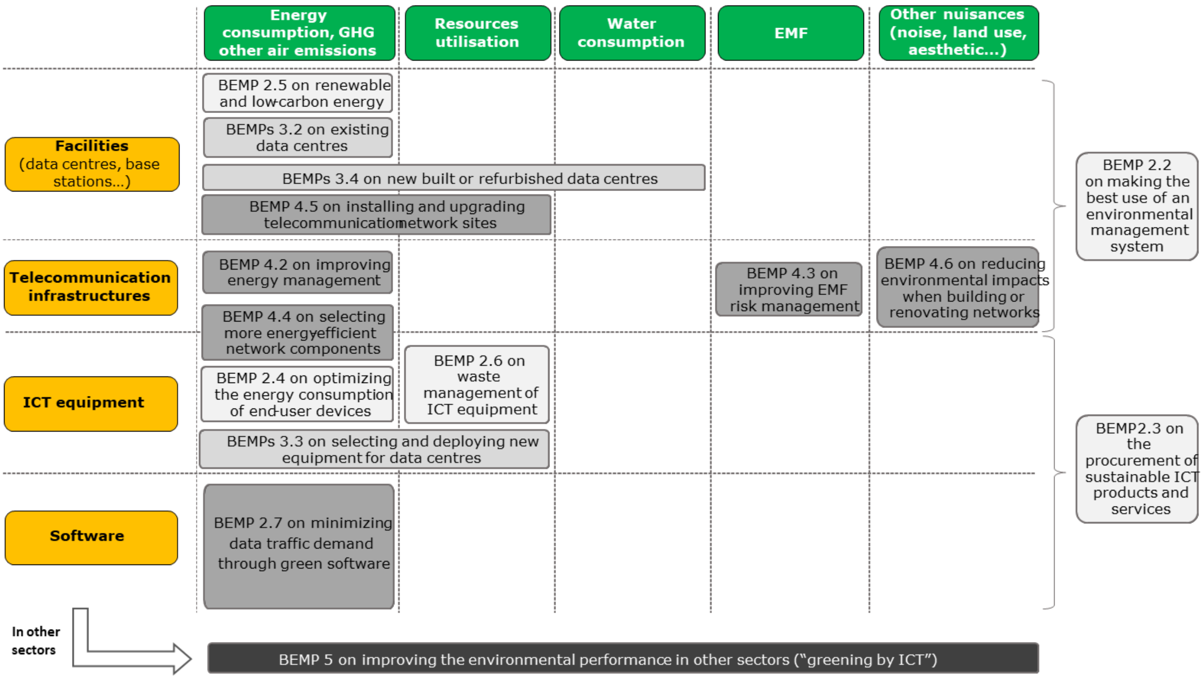

Figure 107: Overview of the main environmental aspects and impacts addressed by the BEMPs

7 Conclusions

The following table lists the key environmental performance indicators for each identified BEMP along with the conditions of applicability and Benchmarks of Excellence where feasible and meaningful.

BEMPs		Key environmental performance indicators	Benchmarks of Excellence
Cross-cutting BEMPs			
2.2	Making the best use of an environmental management system	• Implementation of an asset management system, e.g. certified with ISO 55001 (Y/N) • Share of operations with an advanced environmental management system implemented (% of facilities/operations), e.g. EMAS-verified, ISO-14001-certified • Share of 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 • Use of energy efficiency indicators (Y/N) • WEEE generation (in kg or tonnes) per unit of turnover (€) • Use of water efficiency indicators (Y/N) • Total carbon emissions (in t CO_2eq) for scopes 1 and 2 • Total carbon emissions compensated (in t CO_2eq) • Carbon emissions (in t CO_2eq) for scopes 1 and 2 per unit of turnover (€)	• The company has a global and integrated asset management system e.g. certified with ISO 55001 • 100% of operations implement an advanced environmental management system, e.g. EMAS-verified or ISO-14001-certified • 100% of operations measure and monitor their energy use and water consumption as well as waste management • The company has achieved carbon neutrality (scopes 1 and 2), including through the use of renewable energy and carbon compensation, after having pursued all efforts to improve energy efficiency
2.3	Procurement of sustainable ICT products 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 Star, TCO-certified etc.) • Use of total cost of ownership as a criterion in calls for tenders (Y/N) • Share of equipment purchased by the company complying with internationally recognised 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 weight given to environmental criteria in calls for tenders • Share of suppliers that have an environmental management system or energy management	• All ICT equipment purchased by the company is labelled with the ISO Type I ecolabel (e.g. EU Ecolabel, Blue Angel) (if available) or Energy Star label, or EU Green Public Procurement criteria (if available) are applied in its procurement. • All broadband equipment purchased by the company meets the criteria in the EU Code of Conduct on broadband equipment

BEMPs	Key environmental performance indicators	Benchmarks of Excellence
	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 end users	• 100% of packaging purchased by the company is made from recycled material or was awarded the Forest Stewardship Council label • 10% of the bid weighting is dedicated to environmental performance when purchasing ICT equipment • 100% of products and services provided by the company has related environmental information available to end users • Use of total cost of ownership as a criterion in calls for tenders
2.4 Optimising the energy consumption of end-user devices	• Energy use of offices (kWh) per unit of turnover or number of workstations or employees working on site (excluding HVAC and lighting if possible) • Share of end-user ICT devices having been configured on installation at optimal power management • Share of end-user ICT devices audited on power management at an appropriate frequency (e.g. yearly, only once during the lifetime of the product) • Share of staff trained at least once on energy savings	• All end-user ICT devices are configured on installation at optimal power management • All end-user ICT devices have been audited on power management at least once during their lifetime • All staff have been trained at least once on energy savings
2.5 Use of renewable and low-carbon energy	• 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 (%) • Renewable Energy factor (REF) according to EN 50600-4-3 • Carbon Usage Effectiveness (CUE) = CO_2eq emissions from the energy consumption of the facility (kg CO_2eq) / total ICT energy consumption (kWh) • Carbon content of the energy used = CO_2eq. emissions from the energy consumption of the facility (kg CO_2eq) / total energy consumption (kWh)	• 100% of electricity used is from renewable energy sources (either purchased or produced on site)
2.6 Resource efficiency of ICT equipment through waste prevention, reuse and recycling	• Share of facilities or sites with a certified zero waste management system or with a certified asset management system (% of facilities/sites) • Average service life of ICT equipment to be calculated for different product groups (e.g. servers, routes, end-user devices) • Share of ICT waste generated from own operations recovered for reuse or refurbishment or sent for recycling • Share of WEEE or ICT waste generated from clients recovered for reuse or refurbishment, or sent for recycling	• 100% of facilities have a certified zero waste management system or a certified asset management system • 90% of own ICT equipment recovered for reuse or refurbishment or sent for recycling • 30% of ICT equipment from clients taken back and recovered for reuse or refurbishment or sent for recycling (for ICT companies providing

BEMPs	Key environmental performance indicators	Benchmarks of Excellence
	• ICT waste sent to landfill	equipment to customers) • Zero ICT waste sent to landfill
2.7 Minimising data traffic demand through green software	• 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/TR 50600-99-1 regarding the development and deployment of new IT services • Amount of data transferred in relation to software utilisation (bit / web page view or bit / min of mobile application use) • Share of newly acquired software for which the energy performance has been used as a selection criterion within procurement (%) • Share of newly developed software for which the energy performance has been used as a development criterion (%) • Share of demand-adaptive designed software • Share of existing software which has been refactored or which has undergone code reviews towards higher energy efficiency (%) • Share of software for which the energy performance has been assessed or monitored (%) • Share of software for which a LCA has been carried out • Share of software developers (staff) trained on energy efficient software (%)	• All data centres have implemented the best practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding the development and deployment of new IT services. • All staff (software developers) trained on energy-efficient software. • At least one project for minimising data traffic demand through green software was implemented during the year
Data centres BEMPs		
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)	• KPI_{DCEM} Global KPI for Data Centre according to the ETSI standard • 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/TR 50600-99-1 • Share of ICT, cooling or power equipment with specific metering equipment (for measuring 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	• The KPI_{DCP} for existing data centres is equal to or lower than 1.5 • All data centres have an energy management system certified according to ISO 50001 or integrated in EMAS, or complying with the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1
3.2.3 Define and implement a data management and storage	• Energy use (kWh) per rack • Average storage disc space utilisation (%) • Average server utilisation (%) • Share of servers virtualised (%)	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding data management and storage, and

BEMPs		Key environmental performance indicators	Benchmarks of Excellence
	policy	• Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data management and storage, and management of existing ICT equipment and services (%)	management of existing ICT equipment and services
3.2.4	Improve airflow management and design	• Air flow efficiency (fan power in kWh / fan airflow in m^3/hour) • Return Temperature Index (identification of air recirculation) • Flow performance of the air handler • Thermal performance of the air handler • Rack cooling index (difference between allowable intake temperature and the one recommended by the ASHRAE) • Share of racks installed with a hot aisle / cold aisle configuration (with containment) • Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 0600-99-1 regarding airflow management and design	• 100% of new racks are installed with a hot aisle / cold aisle configuration (with containment) • All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding airflow management and design, and installation of ICT equipment to optimise airflow management
3.2.5	Improve cooling management	• 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 (%) • Carbon Usage Effectiveness (CUE) • Water Use Efficiency (WUE) • Share of data centres that have implemented the expected minimum 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/TR 50600-99-1 regarding cooling management	• Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems • All data centres have implemented the expected minimum 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/TR 50600-99-1 regarding cooling management
3.2.6	Review and adjust temperature and humidity settings	• Airflow Efficiency (fan power in kWh / airflow in m^3/hour) • Return Temperature Index (RTI) • Share of data centres that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding temperature and humidity settings	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding temperature and humidity settings

BEMPs	Key environmental performance indicators	Benchmarks of Excellence
BEMPs related to selecting and deploying new equipment for data centres		
3.3.2 Selection and deployment of environmentally friendly equipment for data centres	• Design PUE (dPUE) • Share of ICT products or services purchased by the company complying with specific environmental criteria (e.g. EU Ecolabel, Energy Star, sourced renewable energy) • 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 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)	• All new data centre ICT equipment is labelled with the ISO Type I ecolabel (e.g. EU Ecolabel, Blue Angel, etc.) (if available) or Energy Star label • All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding the selection and deployment of new ICT equipment / of cooling systems / of new power equipment / of other data centre equipment. • UPS meet the requirements of the Code of Conduct for UPS • Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems
BEMPs related to new build or refurbishment of data centres		
3.4.2 Planning of new data centres	• Energy use of the data centre per floor area (kWh/m²) • Design PUE (dPUE) • 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/FTR 50600-99-1 regarding Utilisation, management and planning of new build or refurbishment of data centres	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding utilisation, management and planning of new build and refurbishment of data centres
3.4.3 Reuse of data centre waste heat	• Energy Reuse Factor (ERF) • Energy Reuse Effectiveness (ERE) • Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding reuse of data centre waste heat	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding reuse of data centre waste heat
3.4.4 Design of the data centre building and	• Share of sites that have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1	• All data centres have implemented the expected minimum practices in the EU Code of Conduct

BEMPs	Key environmental performance indicators	Benchmarks of Excellence
physical layout	regarding data centre building physical layout	on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding data centre building physical layout
3.4.5 Selecting the geographical location of the new data centre	• 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding data centre geographical location	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected and optional practices of CLC/TR 50600-99-1 regarding data centre geographical location
3.4.6 Use of alternative sources of water	• 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 expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the Expected Practices of CLC/TR 50600-99-1 regarding water sources	• All data centres have implemented the expected minimum practices in the EU Code of Conduct on Data Centre Energy Efficiency or the expected practices of CLC/TR 50600-99-1 regarding water sources
Telecommunication networks BEMPs		
4.2 Improving the energy management of existing networks	• Average energy consumption per customer or subscriber (in kWh / customer or subscriber) • Mobile/Fixed Network coverage Energy Efficiency (the area covered by the network / the energy consumption) (in m^2/J) • Mobile/Fixed Network data Energy Efficiency (the data volume delivered / the energy consumption) (in bit/J) • Share of network energy usage 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 %)	• 50% of the network energy usage is monitored in real-time at telecommunication sites level (base stations and/or fixed-network nodes), or above • An energy management system is in place for telecommunication networks
4.3 Improving risk management for electromagnetic fields through assessment and transparency of data	• Percentage of sites assessed by measurement for compliance with EMF limits • Percentage of sites regularly or continuously monitored (also with a software) for compliance with EMF limits	• None defined

BEMPs	Key environmental performance indicators	Benchmarks of Excellence
4.4 Selecting and deploying more energy-efficient telecommunication network equipment	• Percentage of broadband equipment meeting the Broadband Code of Conduct requirements in terms of energy consumption and energy-enabling features • Percentage of equipment able to deliver dynamic management • Share of base stations with multi-standard solutions where applicable • Share of sites with a Remote Radio Head or Active Antenna System • Share of sites equipped with hardware compliant with the ETSI standard • Share of sites with non-mechanical cooling • The temperature is set at the maximum allowable according to the equipment on site (Y/N) • Average UPS System Efficiency • Average COP of cooling systems	• 100% of new installed broadband equipment meets the requirements of the EU Code of Conduct for broadband equipment in terms of energy consumption • Energy efficiency of power/energy stations is 96% or higher • Equipment with a COP of 7 or higher is selected for water chillers, and 4 or higher for Direct Expansion (DX) cooling systems
4.5 Installing and upgrading telecommunication networks	• Mobile Network data Energy Efficiency (EEMN,DV) • Mobile Network coverage Energy Efficiency (EEMN,CoA) • Wireline network efficiency (ICT energy use / total energy use of the network) • Quantity of unused or inefficient equipment decommissioned and removed from base station sites each year	• A plan and a management process for optimising all existing network sites have been defined (to remove unused and inefficient equipment, to properly configure cooling systems, etc.)
4.6 Reducing the environmental impacts when building or renovating telecommunication networks	• Percentage of sites shared with other operators (wherever feasible, e.g. legally) (in %) • Existing infrastructure is used when building new wireline networks (Y/N)	• At least 30% of sites are shared with other operators (wherever feasible, e.g. legally)
Greening by ICT BEMPs		
5.2 Improving the energy and environmental performance in other sectors	• GHG emissions based on the Greenhouse Gas Protocol, scope 3 emissions • Number of innovative dematerialisation solutions proposed to clients • Share of products and services (in terms of turnover) delivered digitally to the client	• None defined

List of abbreviations and definitions

AC	Alternative Current
ADEME	Agence De l'Environnement et de la Maîtrise de l'Energie (French environment and energy agency)
ASIP	Application-Specific Instruction Processor
BAT	Best Available Technique
BEMP	Best Environmental Management Practice
BREF	Best Available Technique Reference Document
BSC	Base Station Controller
BT	British Telecom
BTS	Base Transceiver Station
CAPEX	Capital Expenditure
CF	Compress and Forward
CHP	Combined Heat and Power
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 (Data Centre energy Productivity)
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
EC	European Commission
EDGE	Enhanced Data for GSM Evolution
EEE	Electronic and Electrical Equipment
EMAS	EU Eco-Management and Audit Scheme
EMF	Electromagnetic Fields
EPA	Environmental Protection Agency (U.S.A. ; US-EPA)
EPEAT	Electronic Product Environmental Assessment Tool
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric vehicle
FTTH	Fibre To The Home
FTTN	Fibre To The Node
GeSI	Global e-Sustainability Initiative
GHG	Greenhouse Gas
GHz	Gigahertz
GIFAM	Groupement Interprofessionnel des Fabricants d'Appareils d'Equipement Ménager (France)
GPRS	Global Packet Radio Service
GSM	Global System for Mobile communication
GSMA	Global System for Mobile communication Association (Groupe Spécial Mobile)
HFC	Hybrid Fibre Coaxial
HPC	High-Performance Computing
Hz	Hertz
ICNIRP	International Commission on Non-Ionising Radiation Protection
ICT	Information and Communications Technology
IEA	International Energy Agency
IED	Industrial Emissions Directive
IP	Internet Protocol
IREC	Institut de Recherche Economique Contemporaine

IT	Information Technology
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 (Statistical Classification of Economic Activities in the European Community)[86]
NIC	Network Interface Card
NRDC	Natural Resources Defense Council (U.S.A.)
NREL	National Renewable Energy Laboratory (U.S.A.)
NTT	Nippon Telegraph and Telephone Corporation
OLT	Optical Line Terminal
ONU	Optical Network Unit
OPEX	Operational Expenditure
ORC	Organic Rankine Cycle
OSS	Operational Support Systems
PA	Power Amplifier
PON	Passive Optical Network
PtP	Point-to-Point optical
PUE	Power Usage Effectiveness
QoS	Quality of Service
RBS	Remote Broadband Service
RF	Radio Frequency
ROI	Return On Investment
SAR	Specific Absorption Rate

[86] https://ec.europa.eu/competition/mergers/cases/index/nace_all.html

SCF	Store-Carry-and-Forward
SiNAD	Signal to Noise and Distortion
SPUE	Server Power Usage Effectiveness
SRD	Sectoral Reference Document
SSD	Solid State Drive
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

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