Best Environmental Management Practice in the Telecommunications and ICT Services Sector

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

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<td>AC</td>
<td>Alternative Current</td>
</tr>
<tr>
<td>AC</td>
<td>Air conditioning</td>
</tr>
<tr>
<td>ADEME</td>
<td>Agence De l’Environnement et de la Maitrise de l’Energie</td>
</tr>
<tr>
<td>ASIP</td>
<td>Application Specific Instruction Processor’s</td>
</tr>
<tr>
<td>BAT</td>
<td>Best Available Technique</td>
</tr>
<tr>
<td>BEMP</td>
<td>Best Environmental Management Practices</td>
</tr>
<tr>
<td>BIOS</td>
<td>Basic Input Output System</td>
</tr>
<tr>
<td>BREF</td>
<td>Best Technique Reference Document</td>
</tr>
<tr>
<td>BSC</td>
<td>Base Station Controller</td>
</tr>
<tr>
<td>BSS</td>
<td>Business Support Systems</td>
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<tr>
<td>BT</td>
<td>British Telecom</td>
</tr>
<tr>
<td>BTS</td>
<td>Base Transceiver Station</td>
</tr>
<tr>
<td>CAPEX</td>
<td>Capital Expenditure</td>
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<tr>
<td>CF</td>
<td>Compress and Forward</td>
</tr>
<tr>
<td>CHP</td>
<td>Combined Heat Power</td>
</tr>
<tr>
<td>CO</td>
<td>Central Office</td>
</tr>
<tr>
<td>CO2</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CoMP</td>
<td>Coordinated Multi-Point</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CRAC</td>
<td>Computer Room Air Conditioners</td>
</tr>
<tr>
<td>CRAH</td>
<td>Computer Room Air Handlers</td>
</tr>
<tr>
<td>CUE</td>
<td>Carbon Usage Effectiveness</td>
</tr>
<tr>
<td>DAS</td>
<td>Distributed Antenna System</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>DCeP</td>
<td>Data centre Energy Efficiency</td>
</tr>
<tr>
<td>DCiE</td>
<td>Data centre Infrastructure Efficiency</td>
</tr>
<tr>
<td>DEMS</td>
<td>Data centre Management System</td>
</tr>
<tr>
<td>DF</td>
<td>Decoded and Forward</td>
</tr>
<tr>
<td>DMIMO</td>
<td>Distributed Multiple-Input Multiple-Output</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
</tr>
<tr>
<td>DSLAM</td>
<td>Digital Subscriber Line Access Multiplexer</td>
</tr>
<tr>
<td>DTX</td>
<td>Discontinuous Transmission</td>
</tr>
<tr>
<td>EARTH</td>
<td>Energy Aware Radio and neTwork technologies</td>
</tr>
<tr>
<td>EbUA</td>
<td>Energy per bit and Unit Area</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EDGE</td>
<td>Enhanced Data for GSM Evolution</td>
</tr>
<tr>
<td>EEE</td>
<td>Electronic and Electrical Equipment</td>
</tr>
<tr>
<td>ELV</td>
<td>Exposure Limits Value</td>
</tr>
<tr>
<td>EMAS</td>
<td>European Management and Audit Scheme</td>
</tr>
<tr>
<td>EMF</td>
<td>Electromagnetic Fields</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>EPEAT</td>
<td>Electronic Product Environmental Assessment Tool</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FTTN</td>
<td>Fibre To The Node</td>
</tr>
<tr>
<td>GEC</td>
<td>Green Energy Coefficient</td>
</tr>
<tr>
<td>GeSI</td>
<td>Global e-Sustainability Initiative</td>
</tr>
</tbody>
</table>
GHG  Green House Gas
GHZ  Giga Hertz
GIFAM  Groupement Interprofessionnel des Fabricants d'Appareils d'Equipement Ménager
GPON  Gigabit Passive Optical Network
GPRS  Global Packet Radio Service
GSM  Global System for Mobile communication
GSM  Global System for Mobile Association
HFC  Hybrid Fibre Coaxial
Hz  Hertz
ICNIRP  International Commission on Non-Ionising Radiation Protection
ICT  Information and Communications Technologies
IEA  International Environment Agency
IED  Industrial Emissions Directive
IMS  IP Multimedia System
IP  Internet Protocol
IREC  Institut de Recherche Economique Contemporaine
IT  Information Technologies
ITU  International Telecommunication Union
JRC  Joint Research Centre
kWh  Kilo Watt Hour
LCA  Life Cycle Assessment
LPI  Low Power Idle
MIMO  Multiple-Input Multiple-Output
MSC  Mobile Switching Centre
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWh</td>
<td>Mega Watt Hour</td>
</tr>
<tr>
<td>NACE</td>
<td>Nomenclature Statistique des Activités Economiques dans la Communauté Européenne</td>
</tr>
<tr>
<td>NIC</td>
<td>Network Interface Card</td>
</tr>
<tr>
<td>NRDC</td>
<td>Natural Resources Defense Council</td>
</tr>
<tr>
<td>NREL</td>
<td>National Renewable Energy Laboratory</td>
</tr>
<tr>
<td>NTT</td>
<td>Nippon Telegraph and Telephone Corporation</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency Division Multiple Access</td>
</tr>
<tr>
<td>OLT</td>
<td>Optical Line Terminal</td>
</tr>
<tr>
<td>ONU</td>
<td>Optical Network Unit</td>
</tr>
<tr>
<td>OPEX</td>
<td>Operational Expenditure</td>
</tr>
<tr>
<td>ORC</td>
<td>Organism Rankine Cycle</td>
</tr>
<tr>
<td>OSS</td>
<td>Operational Support Systems</td>
</tr>
<tr>
<td>OXC</td>
<td>Optical Cross-Connects</td>
</tr>
<tr>
<td>PA</td>
<td>Power Amplifier</td>
</tr>
<tr>
<td>PBB</td>
<td>Polybromobiphenyls</td>
</tr>
<tr>
<td>PBDE</td>
<td>Polybromodiphenylethers</td>
</tr>
<tr>
<td>PON</td>
<td>Passive Optical Network</td>
</tr>
<tr>
<td>PPE</td>
<td>Power to Performance Effectiveness</td>
</tr>
<tr>
<td>PtP</td>
<td>Point-to-Point optical</td>
</tr>
<tr>
<td>PUE</td>
<td>Power Usage Effectiveness</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality-of-Services</td>
</tr>
<tr>
<td>RAT</td>
<td>Radio Access Technology</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>ROADM</td>
<td>Reconfigurable Optical Add-Drop Multiplexers</td>
</tr>
</tbody>
</table>
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROI</td>
<td>Return On Investment</td>
</tr>
<tr>
<td>SCF</td>
<td>Store-Carry-and-Forward</td>
</tr>
<tr>
<td>SINAD</td>
<td>Signal to Noise and Distortion</td>
</tr>
<tr>
<td>SNR</td>
<td>Sub Network Router</td>
</tr>
<tr>
<td>SPUE</td>
<td>Server Power Usage Effectiveness</td>
</tr>
<tr>
<td>SRD</td>
<td>Sectorial Reference Document</td>
</tr>
<tr>
<td>SSD</td>
<td>Solid State Discs</td>
</tr>
<tr>
<td>TDM</td>
<td>Time Division Multiplexing</td>
</tr>
<tr>
<td>TWG</td>
<td>Technical Working Group</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunications System</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VDSL</td>
<td>Very high bit-rate Digital Subscriber Line</td>
</tr>
<tr>
<td>WEEE</td>
<td>Waste Electrical and Electronics Equipment</td>
</tr>
<tr>
<td>Wh</td>
<td>Watt hour</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
</tr>
<tr>
<td>WUE</td>
<td>Water Usage Effectiveness</td>
</tr>
</tbody>
</table>
Introduction

Preface

This background report provides an overview of techniques that may be considered Best Environmental Management Practices (BEMPs) in the telecommunications and ICT services sector. The document was developed by Ernst and Young and Associés under a contract with the European Commission's Joint Research Centre (JRC) on the basis of desk research, interviews with experts and site visits. This background report is intended to provide a preliminary basis for further discussions between the JRC and technical experts via the forum of a Technical Working Group (TWG). **The contents of this report therefore represent early findings that will be further developed through discussions with the TWG, according to a structured process 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.**

The final findings will be presented in a best practice report produced by the JRC and used for the development of an EMAS Sectoral Reference Document (SRD), as illustrated below.

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

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. To support this aim, and according to the provisions of Art. 46 of the EMAS Regulation (EC No. 1221/2009), the European Commission is producing SRDs to provide information and guidance on BEMPs in several priority sectors, including the telecommunications and ICT services sector.

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

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of information included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Brief technical description of the BEMP including some background and details on how it is implemented.</td>
</tr>
<tr>
<td>Achieved environmental benefits</td>
<td>Main potential environmental <em>benefits</em> to be gained through implementing the BEMP.</td>
</tr>
<tr>
<td>Environmental indicators</td>
<td>Indicators and/or metrics used to monitor the implementation of the BEMP and its environmental benefits.</td>
</tr>
<tr>
<td>Cross-media effects</td>
<td>Potential <em>negative</em> impacts on other environmental pressures arising as side effects of implementing the BEMP.</td>
</tr>
<tr>
<td>Operational data</td>
<td>Operational data that can help understand the implementation of a BEMP, including any issues experienced. This includes actual and plant-specific performance data where possible.</td>
</tr>
<tr>
<td>Applicability</td>
<td>Indication of the type of plants or processes in which the technique may or may not be applied, as well as constraints to implementation in certain cases.</td>
</tr>
<tr>
<td>Economics</td>
<td>Information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, etc.).</td>
</tr>
<tr>
<td>Driving force for implementation</td>
<td>Factors that have driven or stimulated the implementation of the technique to date.</td>
</tr>
<tr>
<td>Reference organisations</td>
<td>Examples of organisations that have successfully implemented the BEMP.</td>
</tr>
</tbody>
</table>
Sector-specific Environmental Performance Indicators and Benchmarks of Excellence are also derived from the BEMPs. These aim to provide organisations with guidance on appropriate metrics and levels of ambition when implementing the BEMPs described.

- Environmental Performance Indicators represent the metrics that are employed by organisations in the sector to monitor either the implementation of the BEMPs described or, when possible, directly their environmental performance.

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

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

Role and purpose of this document

The present background report provides a basis to be used by the JRC and Technical Working Group for the elaboration of the "JRC Scientific and Policy Report on Best Environmental Management Practice in the Telecommunications and ICT services Sector", or simply "Best Practice Report", containing the technical basis for the Sectoral Reference Document (SRD).

Companies from the telecommunications and ICT services sector interested in implementing best practice in the improvement of environmental performance are recommended to refer instead to the final Best Practice Report that will be available online² as soon as it is finalised and published.

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

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

- **Telecommunications**: the transmission of voice, data, text, sound and video using electrical signals (both analogue and digital) using wires or cables (wired / fixed) or electro-magnetic waves (wireless / mobile).

- **Professional use of information and communication technology (ICT) equipment and infrastructure**: the design, construction, operation, maintenance, upgrading and dismantling of information and telecommunication infrastructure and networks at local, regional and international level. This includes data processing, hosting and related activities (e.g. data centres);

- **Broadcasting**: the distribution of audio, video and/or data content to a dispersed audience (i.e. radio and television) via any electronic mass communications medium such as over-the-air; via satellite; via a cable network or via the Internet.

- **Software development and publishing**: the development (e.g. designing, programming, modifying, documenting, testing and bug fixing) and publishing of software products (e.g. operating systems, search engines, applications, databases, web pages, video games, etc.).

- **ICT consultancy**: planning, designing, installing, maintaining and upgrading ICT systems that integrate computer hardware, software and communication technologies and other professional and technical ICT-related activities.

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

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

- Only certain sub-categories of publishing activities (NACE Code 58):
  - 58.21 Publishing of computer games
  - 58.29 Other software publishing

- All the sub-categories of telecommunications activities (NACE Code 61):
  - 61.1 Wired telecommunications activities
  - 61.2 Wireless telecommunications activities
  - 61.3 Satellite telecommunications activities
  - 61.9 Other telecommunications activities

- All the sub-categories of computer programming, consultancy and related activities (NACE Code 61):
  - 62.01 Computer programming activities
  - 62.02 Computer consultancy activities

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Best Environmental Management Practice in the Telecommunications and ICT Services Sector

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

Other activities from the NACE J section are partially included in the scope of the present SRD, because of their increasing digitalisation:
- Publishing of books, newspapers, journals etc. (NACE Code 58.1) via Internet
- Motion picture, video and television programme production, sound recording and music publishing activities (NACE Code 59)
- Broadcasting via Internet (NACE Code 60)
- News agency activities (NACE Code 63.91)
- Other information service activities n.e.c. (NACE Code 63.99)

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

Activities from other NACE code sections and which are directly connected to the previous Information and Telecommunication activities are also included in the scope because of their similarities:
- Reproduction of software (NACE Code 18.20)
- Installation of mainframe and similar computers (NACE Code 33.20)
- Activities of call centres (NACE Code 82.20)

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

The Telecommunications and ICT Services sector covers only a specific part of the value chain, since some activities are covered by other SRDs:
- ICT manufacturing industries (NACE Code 26.A, 26.2, 26.3 and 26.8), ICT trade industries (NACE Code 46.5) and recycling, reuse and repair of ICT equipment (NACE Code 95.1) are covered by the SRD for the Electrical and Electronic Equipment Manufacturing Sector
- ICT retail trade (NACE Code 47.1 and 47.4) is already included in the reference document on BEMP in the retail trade sector
The best environmental management practices (BEMPs) related to mobility (business travel and employee commuting) and tertiary offices are already developed in the reference document on BEMP in the Public Administration Sector. No specific BEMP related to the Telecommunications and ICT Services buildings and transportation was identified.

Due to these exclusions and inclusions of economic sectors and business activities, the scope of the BEMPs for the Telecommunications and ICT Services sector focuses on the following elements which are inter-linked:

- Data centres (servers, cooling equipment, power systems, etc.)
- Desktop infrastructure (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.)
This document covers the core business activities of organisations in the Telecommunications and ICT Services sector. The manufacturing, retail and recycling of ICT equipment are not included in this study as they are covered in other SRDs. The management of offices and general company transport are also not included as these are common for all types of organisations and not specific to organisations in the Telecommunications and ICT Services sector. The study distinguishes between:

- BEMPs that minimise the environmental impacts of organisations in the Telecommunications and ICT Services sector (direct aspects);
- BEMPs that organisations in the Telecommunications and ICT Services sector can implement in order to minimise environmental impacts of other sectors beyond the Telecommunications and ICT Services sector (indirect aspects).

The scope of the Telecommunications and ICT Services sector as well as the associated direct and indirect environmental aspects are illustrated in Figure 4.

![Figure 4: Overview of the scope of the environmental pressures of the Telecommunications and ICT Services sector](image)

**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:

- Subchapter 1.1 regarding general information on the sector (Telecommunications and ICT Services uses, turnover and employment)
- Subchapter 1.2 regarding environmental issues (direct and indirect aspects, environmental pressures)
- Subchapter 1.3 regarding initiatives for sustainability.

The main content of this document are the best environmental management practices (BEMPs). Chapter 2 provides an overview of all BEMPs considered in this study. The BEMPs are described in Chapters 3 to 9. Reflecting the overview above, the following BEMPs have been identified for the Telecommunications and ICT Services sector:

- BEMPs to improve the energy efficiency of networks (Chapter 3)
• BEMPs to improve the energy efficiency of data centres (Chapter 4)
• BEMPs to improve the energy efficiency of ICT equipment (Chapter 5)
• Cross-cutting measures for reducing energy consumption and reducing carbon footprint (Chapter 6)
• BEMPs related to WEEE management (Chapter 7)
• BEMPs related to the pressures of telecommunication and broadcast infrastructures (Chapter 8)
• BEMPs related to improving the environmental performance in other sectors (Chapter 9)
1 General information about the Telecommunications and ICT Services sector

1.1 General information

1.1.1 Turnover and employment

Based on this study’s scope definition, the relevant NACE codes and Eurostat database it was estimated that:

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

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

Figure 5: Evolution of the number of Telecommunication and ICT Services companies, turnover and employees (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

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

6 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

7 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).
62) (Eurostat, 2012a). If telecommunications services (NACE Code 61) represented only 5% of the total number of Telecommunications and ICT Services companies, they employed 23% of the employees of the sector and generated 44% of its global turnover.

Table 2: Turnover and employment statistics per NACE Code (Source: (Eurostat, 2012a))

<table>
<thead>
<tr>
<th>Companies</th>
<th>Turnover</th>
<th>Employees</th>
<th>Turnover</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>58.21 Publishing of computer games</td>
<td>1 257</td>
<td>0,2%</td>
<td>3,56</td>
<td>0,4%</td>
</tr>
<tr>
<td>58.29 Other software publishing</td>
<td>18 072</td>
<td>2,4%</td>
<td>19,75</td>
<td>2,2%</td>
</tr>
<tr>
<td>61.10 Wired telecommunications activities</td>
<td>11 000</td>
<td>1,5%</td>
<td>155,41</td>
<td>17,1%</td>
</tr>
<tr>
<td>61.20 Wireless telecommunications activities</td>
<td>6 027</td>
<td>0,8%</td>
<td>133,82</td>
<td>14,7%</td>
</tr>
<tr>
<td>61.30 Satellite telecommunications activities</td>
<td>800</td>
<td>0,1%</td>
<td>9,07</td>
<td>1,0%</td>
</tr>
<tr>
<td>61.90 Other telecommunications activities</td>
<td>25 190</td>
<td>3,4%</td>
<td>104,63</td>
<td>11,5%</td>
</tr>
<tr>
<td>62.01 Computer programming activities</td>
<td>230 850</td>
<td>30,8%</td>
<td>152,46</td>
<td>16,8%</td>
</tr>
<tr>
<td>62.02 Computer consultancy activities</td>
<td>230 644</td>
<td>30,7%</td>
<td>161,39</td>
<td>17,8%</td>
</tr>
<tr>
<td>62.03 Computer facilities management activities</td>
<td>20 000</td>
<td>2,7%</td>
<td>33</td>
<td>3,6%</td>
</tr>
<tr>
<td>62.09 Other information technology and computer service activities</td>
<td>87 500</td>
<td>11,7%</td>
<td>73</td>
<td>8,0%</td>
</tr>
<tr>
<td>63.11 Data processing, hosting and related activities</td>
<td>73 101</td>
<td>9,7%</td>
<td>42,09</td>
<td>4,6%</td>
</tr>
<tr>
<td>63.12 Web portals</td>
<td>20 010</td>
<td>2,7%</td>
<td>7,83</td>
<td>0,9%</td>
</tr>
<tr>
<td>63.99 Other information service activities n.e.c.</td>
<td>26 000</td>
<td>3,5%</td>
<td>12,1</td>
<td>1,3%</td>
</tr>
<tr>
<td>Total</td>
<td>750 451</td>
<td>100%</td>
<td>908,11</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Eurostat database (2012)

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

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

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

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

- The United Kingdom, Sweden, the Netherlands and Luxembourg were the countries where the Telecommunications and ICT Services providers represented in 2012 the largest share of the total non-financial companies (more than 5%);
- Ireland, Luxembourg, the United Kingdom and Sweden were the countries where the turnover generated by the Telecommunications and ICT Services
represented the largest share of the global non-financial business turnover (more than 4%);  
- Sweden, Luxembourg, Denmark, Finland and France were the countries where the Telecommunications and ICT Services providers employed the most people (more than 4.5% of the total number of employees in the non-financial business sector).

Table 3: Turnover and employment statistics per country aggregated for the Telecommunications and ICT Services sector (Source: (Eurostat, 2012a))

<table>
<thead>
<tr>
<th>Entreprises</th>
<th>Turnover</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>21,856</td>
<td>27,558.3</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>6,582</td>
<td>3,127.7</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>5,963</td>
<td>5,717.2</td>
</tr>
<tr>
<td>Denmark</td>
<td>11,318</td>
<td>14,901.6</td>
</tr>
<tr>
<td>Germany</td>
<td>73,557</td>
<td>173,172.7</td>
</tr>
<tr>
<td>Estonia</td>
<td>2,502</td>
<td>11,146.9</td>
</tr>
<tr>
<td>Ireland</td>
<td>3,368</td>
<td>19,354</td>
</tr>
<tr>
<td>Greece</td>
<td>6,835</td>
<td>7,948.7</td>
</tr>
<tr>
<td>Spain</td>
<td>10,083</td>
<td>39,914.5</td>
</tr>
<tr>
<td>France</td>
<td>91,459</td>
<td>142,850.4</td>
</tr>
<tr>
<td>Croatia</td>
<td>4,018</td>
<td>2,704.5</td>
</tr>
<tr>
<td>Italy</td>
<td>82,021</td>
<td>89,011.7</td>
</tr>
<tr>
<td>Cyprus</td>
<td>680</td>
<td>989.8</td>
</tr>
<tr>
<td>Latvia</td>
<td>3,530</td>
<td>1,353.3</td>
</tr>
<tr>
<td>Lithuania</td>
<td>2,142</td>
<td>1,332.2</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>1,594</td>
<td>7,631.2</td>
</tr>
<tr>
<td>Hungary</td>
<td>24,887</td>
<td>7,644.2</td>
</tr>
<tr>
<td>Malta</td>
<td>32</td>
<td>NA</td>
</tr>
<tr>
<td>Netherlands</td>
<td>47,516</td>
<td>19,004.9</td>
</tr>
<tr>
<td>Austria</td>
<td>14,089</td>
<td>15,587.2</td>
</tr>
<tr>
<td>Poland</td>
<td>54,306</td>
<td>20,661.1</td>
</tr>
<tr>
<td>Portugal</td>
<td>10,133</td>
<td>10,176.8</td>
</tr>
<tr>
<td>Romania</td>
<td>13,558</td>
<td>7,166.7</td>
</tr>
<tr>
<td>Slovenia</td>
<td>4,938</td>
<td>2,371.1</td>
</tr>
<tr>
<td>Slovakia</td>
<td>9,816</td>
<td>4,786.2</td>
</tr>
<tr>
<td>Finland</td>
<td>6,719</td>
<td>12,088.2</td>
</tr>
<tr>
<td>Sweden</td>
<td>40,353</td>
<td>36,120.1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>131,457</td>
<td>177,340.5</td>
</tr>
<tr>
<td>European Union 28</td>
<td>734,270</td>
<td>843,365</td>
</tr>
</tbody>
</table>

Source: Eurostat 2012

NB: The total numbers of this table are different from those in Table 2 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%.
1.2 Environmental issues of the telecommunication and ICT services sector

1.2.1 Direct and indirect aspects

According to EMAS Regulation (EC 1221/2009), an 'environmental aspect' is an element of an organisation's activities, products or services that has or can incur an impact on the environment, both the natural environment and people. Environmental impacts arise from pressures generated by environmental aspects, such as the emission of greenhouse gases or air pollution (Table 4). Environmental aspects may be classified accordingly:

- Direct environmental aspects are 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 are elements of an organisation’s activities, products or services over which the organisation does not have full management control, and thus cannot influence directly.

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

![Figure 4: Overview of the scope of the environmental pressures of the Telecommunications and ICT Services sector](image-url)

The environmental pressures of Telecommunications and ICT Services sector can be divided between:

- Consumption of energy, and other consumables to a lesser extent (water and chemicals);
- Production of Waste Electrical and Electronic Equipment (WEEE), air emissions, wastewater and waste heat.
Publishing software, providing broadcast services, managing data centres, running desktop infrastructure (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, transportation and other operations (e.g. paper consumption), are general activities that are of high relevance for most sectors and which are studied through the Sectoral Reference Document on BEMP in the Public Administration Sector. Table 4 lists the main environmental aspects and associated environmental pressures arising from Telecommunications and ICT Services.

The major indirect environmental aspects are associated with the production and consumption of ICT equipment and services. The different steps of the ICT equipment supply chain (raw material supply, manufacturing, wholesale and retail, Waste Electrical and Electronic Equipment) are studied in other references documents (electrical and electronic equipment (EEE) manufacturing sector and retail trade sector). The second order or indirect impacts this reference document focused on result from the use of applications and ICT services, e.g.:

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

This section provides a brief overview of environmental aspects that are important for the services covered in this document.

**Table 4: Main environmental aspects and environmental pressures related to the Telecommunications and ICT Services sector**

<table>
<thead>
<tr>
<th>Service / Activity</th>
<th>Main environmental aspects</th>
<th>Main environmental pressures</th>
</tr>
</thead>
</table>
| 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  
| Desktop infrastructure | - ICT equipment (computers, peripheral devices, etc.)  
| | - Software | - Energy consumption  
| |                                             | - Generation of WEEE  
| |                                             | - GHG emissions from electricity production  
| Telecommunication infrastructure and networks | - Buildings (central offices, base stations, etc.)  
| | - Nodes (antennas, satellites, routers, etc.) | - Energy consumption  
| | - Links (cables, fibres, landlines, etc.)  
| | - Terminals (phones, computers, modems, etc.)  
| | - Software (processors, controls, etc.) | - Generation of WEEE  
| |                                             | - Electromagnetic waves generation  
| |                                             | - GHG emissions from electricity production  
| |                                             | - Changes to the landscape and habitats  

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

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, desktop infrastructure include peripherals (printers, copiers, etc.), telecommunication networks use terminals (phone, modems, etc.) and broadcasting uses antennas. The use of ICT equipment implies similar direct environmental pressures: electricity consumption and waste of electrical and electronic equipment (WEEE) mainly. Indirect environmental pressures, such as the emission of Greenhouse Gas Emissions (GHG) and the other emissions to soil, water and air can be derived from these directs impacts.

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. Software can be used to monitor and control ICT and other electric and electronic equipment and therefore plays an important part in determining the energy consumption of Telecommunications and ICT Services.

Heating, Ventilation and Air-Conditioning (HVAC)
ICT equipment consumes electricity that often results in excess heat. In order to maintaining a suitable working environment and insuring the integrity of hardware the excess heat has to be removed. Due to the density of hardware and a higher sensitivity of equipment to temperature and humidity, data centres are particularly concerned with ventilation and air conditioning, but also 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 can lead 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.

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

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

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

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

**Wirelines**

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

### 1.2.2 Environmental pressures

**Greenhouse gases emissions and energy consumption**

The main environmental pressure of the Telecommunications and ICT Services sector is its energy consumption and direct and indirect emission of greenhouse gases (GHG). Various studies have estimated the contribution of ICTs (excluding manufacturing and broadcasting) to climate change at between 2% and 2.5% of total global CO₂ emissions (ITU, 2009) (Gartner, 2009). This ICT footprint is expected to increase significantly over the next few years according to several studies (Corcoran, 2013) (GeSI, 2012). The greenhouse gases emissions reported by the companies of the ICT sector (NACE codes 61, 62 & 63) are far lower, with only 0.2% of the total emissions at the EU-28 level.

A quantitative analysis of the different estimates of the ICT’s sector energy consumption in Europe revealed that the ICT sector (excluding manufacturing and broadcasting) was directly responsible for the consumption of 214 TWh of electricity in 2011 (Öko Institute, 2013). This represented 7.7% of the total consumption in EU-27, and resulted in 88.3 million tonnes of CO₂e. These figures are expected to increase to 259 TWh in 2020 or 8.1% of the total consumption of electricity in the EU.

While the use of fixed ICT products at home and at the office represented 2/3 of the total electricity consumption of the sector in 2011, this will decrease both in absolute and relative terms due to the increased use of mobile phones and the energy efficiency improvements of ICT equipment. A significant growth of electricity consumption is expected for data centres and telecommunication networks (35% and 150%, respectively), because of increased use of the internet and cloud services.
Figure 6: Comparison of the ICT-related electricity consumption in EU-27 in 2011 & 2020, excluding ICT manufacturing and broadcasting. Source: (Öko Institute, 2013).

Raw material consumption and WEEE production

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

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

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8 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.

9 650,871 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).
In EU-28, most of the wasted IT and telecommunication equipment is collected from households (89.5% according to Eurostat, 2012c). The majority of this waste is treated in the Member State where it was collected (83.5%), and 73.2% is recycled or reused (Eurostat, 2012c). According to the European Commission, only one third of e-waste in the EU was reported as appropriately treated (European Commission, 2009). The other two thirds were sent to landfills and potentially to sub-standard 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, explaining that a significant number of illegal shipments of e-waste are notified to the Commission each year.

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

Electromagnetic radiation
Exposure to non-ionising electromagnetic fields is growing, due to the deliberate use of radio waves and microwaves for telecommunication and broadcasting, and due to indirect production (by the electricity supply grid for example). This is a cause of concerns for citizens and organisations. Exposure limits have been set up in the EU, on the basis of the guidelines of the International Commission on Non-Ionising Radiation Protection (ICNIRP). While absorption of electromagnetic field energy 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). However, according to the WHO, the current level of knowledge

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

11 Levels of absorption of electromagnetic radiations depend on the transmission frequency and the distance from the source (transmitting antenna, mobile phones, etc.).
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 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 landscape, both in urban and in 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 to biodiversity may be more significant when creating long distance fibre optic cables, and access roads to transmission towers and other fixed infrastructure. In both contexts, the acceptance of the infrastructure by stakeholders (including inhabitants and local authorities) can vary considerably. A low acceptance by local stakeholders can be damaging for the network operators and result in complaints and reputational issues.

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 noise.

1.3 Initiatives for a sustainable Telecommunication and ICT Services sector

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

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

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


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

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

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

1.3.2 ISO 14000 family of standards

The ISO 14000 family addresses various aspects of environmental management. It provides practical tools for companies and organisations looking to identify and control their environmental impact and constantly improve their environmental performance. ISO 14001:2015 and ISO 14004:2015 focus on environmental management systems. The other standards in the family focus on specific environmental aspects such as life cycle analysis, communication and auditing.\(^\text{14}\)

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.

Though it is difficult to conclude as to how common environmental management is in practice, reports of the larger firms show that many of these recognize the importance of applying such schemes, declaring how wide ISO certification is in their facilities and often publishing certification under environmental sections of websites. From the companies reviewed, some reported on having at least one of the above mentioned environmental management schemes in place, some having both.

\(^\text{14}\) See [http://www.iso.org/iso/iso14000](http://www.iso.org/iso/iso14000)
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2 Overview of the BEMP of the telecommunications and ICT services sector

2.1 List of Best Environmental Management Practices

A best environmental management practice, BEMP, is defined in the EMAS regulation as "the most effective way to implement the environmental management system by organisations in a relevant sector and that can result in best environmental performance under given economic and technical conditions".

The environmental performance of described practices has been evaluated in technical detail along with economic considerations. For this purpose, detailed technical information and data were collected and collated, which is summarised and technically described in this document. The structure of the technical descriptions of the different practices is similar to the Best Available Techniques Reference Documents (BREFs) according to Article 13 of the Industrial Emissions Directive (formerly the IPPC Directive): description, achieved environmental benefits, appropriate environmental indicator, cross-media effects, operational data, applicability, economics, driving force for implementation, reference companies and reference literature.

In the description, all management possibilities are described: design and installation, selection and procurement of the equipment, operation and management, renovation and upgrades, and end-of-life management. The potential readers of the document are designers, owners and operators of data centres, telecommunications networks, broadcasting infrastructures, desktop architectures and software publishing. The BEMPs in Chapter 3 to 8 are focused on direct aspects of the Telecommunications and ICT Services sector: Chapter 3 to 6 focus on energy consumption in particular, Chapter 7 on waste production and management and Chapter 8 on BEMPs related to impacts on landscapes and electromagnetic radiations. BEMPs related to indirect aspects are described in Chapter 9.

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<th>Summary</th>
<th>ICT components</th>
<th>Relevant life stages</th>
<th>Main environmental benefits</th>
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<tbody>
<tr>
<td>Reengineering wired networks for introducing more energy-efficient technologies</td>
<td>Increasing the use of optical transmission (installing optical bypassing in core networks, using fibre in wired access networks), reducing the number of active electrical and electronic equipment (powering-down unused devices, transitioning to PON technology) and replacing existing devices by new more-energy-efficient ones can allow significant energy savings within core and wireline networks.</td>
<td>Telecom-munication network</td>
<td>Design and installation – Renovation and upgrades (selection and procurement of the equipment)</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Designing and managing an energy-aware wireless network architecture</td>
<td>The first step to save energy in wireless networks is to install more efficient base stations (with more energy-efficient power amplifiers, transceivers or antennas), then to design and adaptive and heterogeneous networks (optimal mix of cell sizes, relay nodes, etc.) and to manage it in an energy-efficient manner (cooperation between base stations, multi-connection mutualisation...).</td>
<td>Telecom-munication network</td>
<td>Design and Installation Operation and management, (Renovation and upgrades – Selection and procurement of the equipment)</td>
<td>Energy consumption</td>
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<tr>
<td>Dynamic traffic optimisation</td>
<td>Dynamic rerouting (nodes and links switch off, traffic redistribution, etc.)</td>
<td>Telecom-munication and Operation</td>
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<td>BEMP to improve the energy performance and minimising the environmental impacts of data centres</td>
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<tr>
<td>Better locating and planning data centres</td>
<td>Environmental conditions (temperature and humidity rate, land use, etc.) and surroundings (type of energy supply, possibility for heat reuse, etc.) should be parameters driven the choice for locating a new data centre.</td>
<td>Data centre</td>
<td>Design and installation (renovation and upgrades)</td>
<td>Energy consumption (landscape and biodiversity)</td>
</tr>
<tr>
<td>Optimising data centre utilisation and management</td>
<td>Software utilisation directly influences the energy consumption of hardware and their need for cooling. Data centre energy efficiency may be improved by developing or purchasing energy-efficient software, consolidating the use of servers through virtualisation and improving data management and storage.</td>
<td>Data centre (Software publishing)</td>
<td>Operation and management (Renovation and upgrades – End-of-life management)</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Airflow and settings management and reuse of heat</td>
<td>An energy-efficient airflow management relies on separating hot airflows from cold airflows (hot aisle / cold aisle layout, airflows containment, equipment segregation, etc.), on adjusting air parameters (temperature, humidity, etc.) and on reusing waste heat.</td>
<td>Data centre</td>
<td>Design and installation Operation and management</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Efficient cooling technologies and systems</td>
<td>When designing a data centre cooling system, the most energy-efficient technologies (such as free cooling and water cooling) should be selected and then deployed by using the most appropriate equipment and settings (variable fans, chilled water with an increased temperature, etc.).</td>
<td>Data centre</td>
<td>Selection and procurement of the equipment (Renovation and upgrades)</td>
<td>Energy consumption (Air emissions – Water use and consumption)</td>
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<tr>
<th>BEMP to improve the energy performance and minimising the environmental impacts of ICT equipment</th>
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<tr>
<td>Procurement for sustainable equipment</td>
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<tr>
<td>Improving the energy efficiency of ICT equipment</td>
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<tr>
<th>Cross-cutting measures for minimising energy consumption and the carbon footprint in the telecommunications and ICT services sector</th>
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<td>Use of alternative energy</td>
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*November 2015*
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

<table>
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<tr>
<th>BEMP related to raw material consumption and waste management</th>
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<td>Improving waste prevention</td>
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<td>Improving WEEE collection, recycling and recovery</td>
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<tr>
<th>BEMP related to other environmental impacts of telecommunication and broadcast infrastructures</th>
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<td>Reducing the effects of ICT infrastructures on landscape</td>
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<tr>
<td>Reducing noise and electromagnetic radiations emissions from telecommunication and broadcast networks</td>
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<table>
<thead>
<tr>
<th>BEMP related to improving the energy and environmental performance in other sectors</th>
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<tbody>
<tr>
<td>Provide services to improve the environmental performance of client activities</td>
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</tbody>
</table>
Telecommunication companies can offer services upstream to ICT devices purchase and use and services after the use of the equipment to ensure a proper end-of-life management.

| Provide services to help reducing other sectors’ environmental impacts | ICT technologies are used throughout many sectors and transform companies’ activities. The use of ICT technologies helps companies reduce their environmental footprint by dematerializing, collecting data and optimising processes. | Software publishing, ICT equipment (Telecommunication network – Broadcasting) | Operation and management (Design and installation) | Energy consumption, water use & consumption (Waste production – Air emissions) | electromagnetic radiations |
3  BEMP to improve the energy performance of telecommunication networks

3.1  Introduction / scope

There are several ways to reduce the energy consumption of telecommunications networks. This topic focuses on the network configuration of the different items forming the telecommunications and ICT networks: servers, base stations, landlines, satellites, antennas, routers, computers, etc. The energy performance of specific network equipment is covered in Chapter 5 BEMP to improve the energy performance and minimising the environmental impacts of ICT equipment.

A distinction can be made between different parts of the telecommunications network:

1. The customer / end-user device such as a telephone or a Local Area Network (LAN) that connects computers and other devices in a residence or building.
2. The access network which connects the customer / end-user to their immediate service provider.
3. The metro network which connects a number of access networks with the core network.
4. The core network which connects local providers to each other (and the internet).

![Figure 8: An overview of telecommunication networks (Iannone, 2012)](image)

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.

The approach to reducing energy consumption consists of three steps (Matthews, et al., 2010):

1. **Identifying the energy consumption hierarchy**: which network elements consume the most power and where are they located in the network (an example for a radio base station is given below)
2. **Map the chain of energy dependency**: how are the network elements connected and what are the dependencies with regard to operation and energy consumption

3. **Prioritise the initiatives or options for reducing energy consumption**: which actions or set of actions will result in the greatest reductions of energy consumption

![Diagram of Radio Base Station block diagram](Figure 9)

**Figure 9**: Radio Base Station block diagram (with associated power losses) and energy consumption per function (Emerson, 2008)

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 with 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 (see Figure 10). 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.

![Diagram of energy dependencies of a base transceiver station (BTS)](Figure 10)

**Figure 10**: Example of energy dependencies of a base transceiver station (BTS) (Source: Matthews, et al., 2010)

The following chapters intend to describe the BEMPs that improve the energy performance of telecommunications and ICT networks by focusing on:
1. network architecture:
   a. Reengineering wired networks and introducing more energy-efficient technologies
   b. Implementing an energy-aware network management system
   c. Dynamic traffic optimisation through green routing and radio resource management

2. power distribution / energy monitoring and management
   a. This BEMP is described in subchapter 6.4 (Energy monitoring and management), related to cross-cutting measures for reducing energy consumption and GHG emissions

3. ICT equipment (selecting energy efficient equipment)
   a. This BEMP is addressed in subchapter 5.2 (Procurement for sustainable ICT equipment)

4. cooling / thermal management
   a. This BEMP is related to the measures implemented in data centres (see subchapter 4.4 Efficient cooling technologies and systems.)
### 3.2 Reengineering wired networks for introducing more energy-efficient technologies

#### SUMMARY OVERVIEW:
Increasing the use of optical transmission; reducing the number of active ICT equipment; and, replacing existing devices with new more energy-efficient ones can allow significant energy savings within core and wireline networks.

<table>
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<th>ICT components</th>
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<td>Data centre</td>
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<th>Relevant lifecycle stages</th>
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<td>Design and installation</td>
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<th>Main environmental benefits</th>
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<tr>
<td>Energy consumption</td>
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</table>

- Power consumption per customer or subscriber
- Energy consumed per bit of data transferred
- % of access network using FTTN / PtP / PON technology
- % of broadband equipment meeting the Code of Conduct requirements

#### Environmental indicators

- Benchmark of excellence
  Implementation of Next Generation Networks (NGNs)

#### Cross references

- Prerequisites: Techniques should be adapted to the characteristics of the network, depending on:
  - the segment of the network concerned by the upgrade
  - the technology currently used in the network
  - end-users’ requirements
  - population density

- Related BEMPS
  - 3.3: Designing and managing an energy-aware wireless network architecture
  - 3.4: Dynamic traffic optimisation through green routing and radio resource management
  - 4.4: Efficient cooling technologies
  - 6.3: Reducing energy losses due to electricity conversion
3.2.1 Description

For telecommunication providers, networks can be divided into three network domains:

- **The core network**, which refers to the backbone infrastructure that interconnects large network nodes (cities for example) and spans nationwide. In order to insure high speed, high capacity and scalability of the core network, optical technologies are widely used to support the basic physical infrastructure (Zhang, 2010). Energy consumption of the core network occurs both from switching between the optical layer and the electronic layer (consumption due to IP routers, Digital and Optical Cross Connects, etc.) and from transporting data (consumption due to transmitters, pre-amplifiers, transponders, etc.).

- **The metro network**, which typically covers metropolitan areas and provides interfaces between the core network and dispersed access networks. It provides direct Internet connectivity to residential subscribers. Different networking technologies have been deployed in different metropolitan areas across the world (Zhang, 2010), such as Metro Ethernet (based on the use of edge routers, broadband network gateways and Ethernet switches), Metro WDM ring (where Optical Add-Drop Multiplexers add and drop optical signals) or SONET ring architectures (an add-drop multiplexer is used to aggregate low-bite-rate traffic to high-bandwidth pipes of core networks).

- **The access network**, which connects the telecom Central Office or Exchanger with end-users. It comprises the larger part of the telecom network and can be deployed through diversified techniques (Baliga J. e., 2011):
  - Digital Subscriber Line (DSL) is provided through copper cables used for fixed-line telephone service and needs a modem at each customer home;
  - Hybrid Fibre Coaxial (HFC) networks, where radio frequency material is transmitted through optical fibre before being converted into an electrical signal distributed to customers through coaxial cables (coupled to electrical amplifiers);
- Passive Optical Network (PON) is made of optical fibres, each one feeding one or more clusters of customers through a passive splitter, and optical network units at customers’ home for receiving the signal;

- Fibre To The Node (FTTN) uses an optical fibre from a network to a Digital Subscriber Line Access Multiplexer (DSLAM) located in a street cabinet, and then high-speed copper cables for feeding the customer premise;

- Point-to-Point optical (PtP) uses a dedicated fibre between each customer and the terminal unit and optical media converters at customers’ home to convert the optical signal into an electrical signal.

![Diagram of access network technologies](image)

**Figure 12: Overview of the main access network technologies (source: [Baliga J. e., 2011])**

*NB: WiMAX and UMTS refer to wireless access networks which are described in the following chapter.*

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.
On the contrary to wireless access networks, few attention used to be paid to energy consumption since there is no problem of interference (which can be caused by excessive base station transmission power), nor 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.

Energy consumption in networks mainly depends on the use of optical transmission, components’ energy efficiency and access rate. The different practices that can be implemented rely on:

- **Increasing the use of optical transmission** by:
  - Reducing the copper cable loop of the access network, through the replacement of large DSLAMs of DSL networks with smaller remote DSLAM units closer to customers for instance;
  - Installing an optical bypass at the core network level. In such a configuration, traffic not intended for the IP node remains in the optical layer and does not pass through the IT router. The capacity of the router is reduced and the associated power consumption as well. Furthermore energy losses related to optical / electronic / optical conversions are also reduced.

- **Reducing the number of active equipment** by
  - Powering-down, removing and decommissioning unused line circuit packs and other network components;
  - Using passive equipment. For example, PON technology saves energy at the network access level because it only requires passive equipment in the outside plant, contrary to FTTN and VDSL technology which uses active equipment (Baliga J. e., 2011).

- **Replacing existing network equipment** with more energy-efficient equipment by:
  - Using devices with a different technology (LSI microfabrication, optical node, multi-core CPU, advanced power-amplifier, etc.);
  - Purchasing devices that use the same technology as the existing but with reduced energy requirements (e.g. meeting the European Commission’s Broadband Equipment Code of Conduct).

Some energy efficiency approaches that are also relevant for telecommunication networks are treated under other BEMPS:
• BEMP to improve the energy performance and minimising the environmental impacts of data centres (Chapter 0)

• BEMP to improve the energy performance and minimising the environmental impacts of ICT equipment (Chapter 5)

• BEMPs specific to air-conditioning units are covered under Efficient cooling technologies and systems (subchapter 4.4)

• BEMPs specific to rectifiers and power supply units are covered under Reducing energy losses due to electricity conversion (subchapter 6.3)

Techniques for reducing the energy consumption of the static or fixed part of the network (by reducing power leakages) are described in subchapter 3.3: Designing and managing an energy-aware wireless network.

Dynamic techniques for reducing energy consumption are described in subchapter 3.4: Dynamic traffic optimisation through energy-efficient routing and radio resource management. Such practices reduce the variable part of the energy consumed by devices due to their system activity and changes in clock rates. Two main approaches can be implemented:

• reducing the overall data traffic (by using suitable Quality of Service (QoS) requirements, for example); and

• continuously optimising the activity of every device at the network level (dynamic power scaling, smart standby, proxy use, etc.).

3.2.2 Achieved environmental benefits

The BEMPs described above directly reduce energy consumption:

• The transition from backbone data networks using IP routing to optical technologies (Wavelength-Division Multiplexing, Optical Transport Networks (OTN), etc.) can significantly reduce energy use at the core network level, as shown on the figure below.

![Figure 14: Energy savings due to the introduction of optical paths within backbone networks (ECONET Project, 2010)](image)

• The EU TREND FP7 project (Towards Real Energy-efficient Network Design) estimated energy savings related to optical bypassing to be up to 50%.
Figure 15: Energy savings related to optical bypass implementation (Source: Baliga et al., 2009)

- Increasing optical transmission through the network access can also reduce overall energy consumption, with the implementation of:
  - Fibre-to-the-Node technology (FTTN), since replacing large DSLAMs of an existing DSL network with smaller remote DSLAM units closer to customers can save up to 20% of energy use per customer (Bhaumik S, 2011) due to a reduced transmission through copper cables and an increased transmission through optical fibre.
  - Point-to-Point technology: quantitative data about environmental benefit.

- PON technology saves energy because it only requires passive equipment in the outside plant, contrary to FTTN and VDSL technology which uses active equipment (Baliga J. e., 2011). Some results are shown below.

Figure 16: Power reductions realized by transitioning to a PON network, Source: (Matthews, et al., 2010)

Another category of techniques refers to the replacement of existing network components (e.g. network terminations, transceivers, antennas, etc.), which also leads to significant direct energy savings. Kilper et al. (Hinton, 2011) estimated the annual improvement in energy efficiency of the metro and core network equipment to be about 10 to 20%.
3.2.3 Appropriate environmental performance indicators

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

1. The power consumed by the customer premises equipment (e.g: the modem, the Optical Network Unit, the optical Media Converter, etc.) is referred to as $P_{CPE}$;
2. The power consumed by the remote node or base station (if there is one), which is shared by $N_{RN}$ customers or subscribers, is called $P_{RN}$;
3. The power consumed by the terminal unit (located in the local exchange or the central office), which is shared by $N_{TU}$ customers or subscribers, is named $P_{TU}$.

Since, $P_a$ can be expressed in the form\(^{15}\):

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

This metric, which is suitable to perform comparisons between network solutions, can be easily monitored by network operators since they know the power consumption and the number of subscribers. 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.

\(^{15}\) Baliga et al. (2011) considered that the equipment at the customer premise or in the remote node is cooled naturally by the surrounding environment, while the equipment at the terminal unit requires an external power supply and a cooling system (counting for 50% of the power consumed by the equipment only).
Another indicator used by Baliga et al. (2008) for defining the efficiency of an access network is the energy consumed per bit of data transferred. This metric can equivalently be described as the average network power (P) in relation to the average data rate (R). It is expressed in [W/bps]. The figure below shows that it decreases rapidly as the average access rate increases, since at low bit rates the energy consumption is mainly due to the fixed power consumption of the equipment at the customer premise.

In order to facilitate energy savings by changing equipment, energy efficiency metrics have been defined at the component level.

For example, the power efficiency of transceiver systems can be monitored by using the following metric (EARTH, 2012b)

\[ PE = \frac{P_{\text{RFout}}}{P_{\text{DC}}} \]

Where \( P_{\text{RFout}} \) refers to the output power of the transceiver system and \( P_{\text{DC}} \) to the total supply power.
However information about energy consumption of network equipment (e.g. switches, routers, etc.) is rarely available with the correct level of granularity (for example, only a single value for energy consumption is given, typically at maximum load).

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

- The percentage of wired access network (in length) using energy-efficient technologies, as FTTN, PtP or PON networks;
- The percentage of broadband equipment meeting the Broadband Code of Conduct requirements in terms of energy consumptions and energy-enabling features.

### 3.2.4 Cross-media effects

If changing from an existing network technology to a more efficient one is expected to lead to significant energy savings (as shown in section 3.2.2), it also induces adding or changing a large number of network components (e.g. cables and fibres, transceivers, power amplifiers, etc.). As for migrating to new generations of more energy-efficient equipment, transitioning to a new network technology will:

- Require new ICT equipment, which means increasing the consumption of raw materials (e.g. rare earths, plastics, glass, metals, etc.), and embodied energy;
- Generate waste of electronic and electrical equipment (WEEE), including hazardous waste 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 subchapter 8.2: Reducing the effects of ICT infrastructure on landscapes.

### 3.2.5 Operational data

**Transitioning to an optical network access**

Energy consumption of wired access networks is mainly dependant on the user-requested access-rate and on the loop length of non-optical cables. Replacing large DSLAMs with smaller remote DSLAM units closer to customers has been shown to reduce energy consumption (Bhaumik, Chuck, Narlikar, & Wilfong, 2011). This approach, called Fibre-to-the-Node (FTTN), allows transitioning from an existing all-copper network from the central office to the customers’ premises into a fibre-copper network with remote DSLAM units. Wireline technologies able to provide a fibre-to-the-home connexion generate even more significant energy savings.
Information about how to manage a change of wireline access technology

When speaking of wireless networks, backhaul (i.e. the links to the core network) or metro networks should be entirely optical in order to optimise the energy efficiency of the entire network.

Reducing the number of active network equipment

Further energy efficiency improvements can be obtained by using passive equipment through optical networks, which is the case for Passive Optical Networks (PON), such as GPON (Gigabit Passive Optical Networks) or Bi-PON (Bit-Interleaved Passive Optical Network).

Another solution for reducing energy consumption relies on powering-down, removing and decommissioning unused line circuit packs and other network components.

More information about how to implement such solution

Installing optical bypass in core networks

In core networks with high bandwidths, optical equipment requires less energy per bit of data transferred, compared to electronic equipment. Typical IP nodes represent a large share in the total power consumption of networks, and especially in core networks (up to 60%).

At IP nodes, optical cross-connects (OXC) are usually used to convert optical data streams into electronic data. The adoption of pure optical node leads to further energy savings from both conversions between optical and electronic signals and processing operations of electronic equipment.

Transparency refers to the direct optical transmission of data from source to destination using a lightpath: data traffic is optically switched at the intermediate

nodes and is processed electronically at the destination nodes. This technique can be implemented through the installation of optical bypass such as all-optical cross-connects (OXC) or reconfigurable optical add-drop multiplexers (ROADM) in order to bypass the IP node. Traffic not intended for the IP node remains in the optical layer and does not pass through the IP router. The capacity of the router is reduced and the associated power consumption as well. Energy losses related to optical / electronic / optical (O/E/O) conversions are also reduced. This solution, which should be considered at the network design stage, allows for significant energy savings (Zhang, Energy Efficiency in Telecom Optical Networks, 2010).

![Figure 5. Traffic flow (grey dashed line) in a node with SDH/SONET and WDM layers: a) all traffic is passed up through the lower layers and processed by the IP router; b) traffic is processed by the SDH/SONET switch, bypassing the IP router; c) Traffic is switched by the optical cross-connect, bypassing both the SDH/SONET and IP layers. Lower layers are progressively more energy efficient.](image)

**Figure 21: Illustration of optical bypassing in core network (Hinton, 2011)**

This solution, however, has a scarce aggregation capability, resulting in a large underutilisation of the transmission capacities. The implementation of translucent circuit switching allows the grooming of different traffic demands in the same lightpath. On the one hand, this solution requires fewer O/E/O conversions and to electronically process a small fraction of the total traffic. On the other hand, the number of devices used all along the network can be reduced, and also their related energy consumption.

The EU TREND FP7 project showed that Translucent IP-over-WDM (TI-IPoWDM) is more energy efficient than IP-over-SDH (IPoSDH) which bypasses IP nodes through digital cross connects or than Transparent IP-over-WDM (Tp-IPoWDM) which does not aggregate traffic. Moreover, the most energy efficient architecture of TI-IPoWDM results to be dependent on the connectivity index and geographical extension of the network.

### Installing more efficient ICT devices within networks

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, such as (ITU, 2010):

- LSI Micro-Fabrication (components have a reduced driving voltage);
- Multi-Core CPU (CPUs are controlled adequately according the load);
Clock gating (CPUs are activated only there is work to be done);
Etc.

Power consumption targets are regularly defined through the European Commission’s Code of Conduct on Energy Consumption of Broadband Equipment. The Code defines power targets per broadband port for:
- DSL network equipment (ADSL2 and VDSL2),
- Optical Line Terminations (PON and PtP),
- Interfaces (with narrowband network equipment),
- Cable equipment (I-CMTS, M-CMTS).

Replacing components should also include energy efficiency enabling features, such as:
- **Low power idle mode**, as recommended by the Broadband Equipment Code of Conduct. The idle mode consists of rapidly turning off subcomponents when no activities are performed.
- **Sleep mode**, which is characterized by higher energy savings but larger wake-up time, compared to idle mode. As sleep mode is not compatible with many Internet protocols (many of them assume that devices are always available). In order to avoid losing connectivity, a network proxy can be used (see subchapter 3.4: Dynamic traffic optimisation through energy-efficient routing and radio resource management).
- **Adaptive Link Rate (ALR) technology**, which allows for temporary reduction of bandwidth during low traffic periods (can be quickly restored to higher bandwidths when needed). By offering more operating modes (compared to a situation with only an idle and a working mode) this technology creates an opportunity for energy savings.

![Figure 22: Adaptive Link Rate strategies, (Rossi et al, 2010)](image)

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3.2.6 Applicability
Only a few telecommunication operators or Internet access providers own wireline networks and can engineer changes within these networks.

More information about network management and operation among European countries (relationship with State and Territory governments, local regulations, etc.)

This chapter describes the main practices which should be followed when reengineering telecommunication networks, but techniques should be adapted to the characteristics of the network:

- Depending on the segment of the network concerned by the upgrade (core, metro or access network);
- In relation to the technology currently used in the network (DSL, PON, etc.);
- In function of end-users’ requirements (video demand, connexion stability, workload capacity, etc.);
- According to the user population density, since the different types of network technologies described into this chapter (VDSL, FTTN, etc.) provide access rates depending on the maximum distance of end-users from the remote node (e.g. PON and PtP are able to service very low population densities at their maximum access rate).

3.2.7 Economics
When transitioning from an all-copper network access to a Fibre-to-the-Node network (Bhaumik, Chuck, Narlikar, & Wilfong, 2011), investment costs were estimated to be as 4.50 € per metre for laying fibre and 1,500 € per remote DSLAM unit.

More information about how it costs to transit from one access technology to another, or to install an optical bypass and another energy-efficient devices

3.2.8 Driving force for implementation
Cost savings are considered to be the main driver for implementing best environmental management practices related to energy-efficient technologies in 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.
Another major driver is the improved performance brought by the new technology installed.

3.2.9 Reference organisations

The Belgian telecommunication company, Proximus\(^\text{18}\), migrated to a high-tech broadband network, by removing or consolidating older data networks, traditional telephone exchanges and copper networks (more than 50% reduction of total technical space).

To be developed

3.2.10 Chapter references


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\(^{18}\) See Proximus 2014 CSR report (http://annualreport.proximus.com/node/21)


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### 3.3 Designing and managing an energy-aware wireless network

**SUMMARY OVERVIEW:**
The first step to save energy in wireless networks is to install more efficient base stations, then to design adaptive and heterogeneous networks and to manage it in an energy-efficient manner.

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- Power consumption per customer or subscriber
- Energy consumed per bit of data transferred
- Power consumption per area
- Energy per bit and Unit Area
- % of base stations with energy efficient equipment (adaptive PA, ASIP, etc.)
- % of Het Net (in areas / customers)

**Environmental indicators**

**Benchmarks of excellence**

To be developed

**Cross references**

**Prerequisites**

Techniques should be adapted to:
- The radio access technology used within the network
- The base station coverage
- The interference management constraints
- The terminal capabilities
- The forecast in capacity demand and population density
- The electro-magnetic emission limits

**Related BEMPS**

- 3.2: Reengineering wired networks for introducing more energy-efficient technologies
- 3.4: Dynamic traffic optimisation through green routing and radio resource management
- 4.4: Efficient cooling technologies
- 6.3: Reducing energy losses due to electricity conversion
3.3.1 Description

Technologies used in wireless networks can primarily be divided between:

- **Cellular mobile systems**, such as GSM (Global System for Mobile communications), EDGE (Enhanced Data rates for GSM Evolution), GPRS (Global Packet Radio Service), UMTS (Universal Mobile Telecommunications System) or 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 WiMAX (Worldwide Interoperability for Microwave Access) or WiFi (Wireless Local Area Network (WLAN)), where each home uses a modem to connect to a base station remotely located and connected to the metropolitan and edge network through fibre or point-to-point wireless backhaul.

Different generations of radio-access have succeeded (from 1G to 4G), with an increase in peak data rates, diversified contents and overall capacities. A synthesis of the different technologies currently used in the European Union is presented in the figure below.

**Figure 24: Main legacy radio-access technologies** (Source: WiSOA "Data rates for Wireless Technologies\(^\text{19}\))

Even if the major concerns about planning access networks are performance and reliability, energy-awareness has always been an important topic when designing mobile networks due to its characteristics:

- Most mobile devices and wireless sensors have a low duty cycle (i.e. operating through short periods of intense performance and long idle intervals in alternation) and require an optimised radio interface, because of their limited processing capacity and autonomy.

- Wireless communications transmission scheduling has been developed for preventing collisions and interferences which both represent a waste of channel bandwidth and energy.

However, the exponential growth in end-users’ demand (more subscribers, higher data rates, new video services, etc.) requires changes in wireless access networks, in

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\(^{19}\) Available at: [http://fr.slideshare.net/hossamfadeel48/multi-standard-multiband-receivers-for-wireless-applications](http://fr.slideshare.net/hossamfadeel48/multi-standard-multiband-receivers-for-wireless-applications)
order to both further increase performance (coverage, capacity, etc.) and energy savings.

Energy-efficiency and performance improvements in wireless networks can be obtained through:

- **Energy-aware network planning** (by changing the network architecture), which relies on more diversified and adaptable architecture in terms of capacity and coverage (network densification and base stations’ coordination and cooperation);
- **Energy-aware management** (by adapting the network configuration to the demand), which intends to dynamically adapt the data traffic path to the evolution of end users demand (coverage and capacity optimisation) in order to minimise overall energy consumption of network components (reduction of active equipment functioning, reduction of transmission distances, etc.);
- Installation of more energy-efficient components (by changing technology).

The following best environmental management practices are described in this section (principally issued from the EU EARTH FP7 Project\(^{20}\)):

- **Installing more energy-efficient components in base stations**, with a focus on power amplifiers, Radio Frequency transceivers and antennas;
- **Designing an optimal mix of cell sizes** with macro cell inter-site distance optimisation and small-cell\(^{21}\) deployment in areas where mobile demand is high (city centres, airports, large offices, etc.);
- **Developing relay nodes schemes** that reduce path loss (due to a shorter transmission range) and potentially generate less interference (due to a lower transmission power);
- **Enabling cooperation** (through a cross-layer design or by using multiple antennas for example), where each node acts as both an information source.

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\(^{20}\) The Energy Aware Radio and network technologies (EARTH) project aimed to address the global environmental challenge by investigating and proposing effective mechanisms to drastically reduce energy wastage and improve energy efficiency of mobile broadband (MBB) communication systems with 50% without compromising users’ perceived quality of service (QoS) and system capacity.

\(^{21}\) In wireless telecommunication, geographical areas covered by a transmitter are called cells. Small-cells (micro-cell, pico-cell, and femto-cell) need less power to transmit the data traffic compared with that of macro-cell, so it can save energy.

\(^{22}\) Available at: [http://qulsar.com/Applications/Telcommunications_and_Networks/HetNets.html](http://qulsar.com/Applications/Telcommunications_and_Networks/HetNets.html)
and a relay, in order to adapt packet transmission scheduling and resource allocation;

- **Taking advantage of multi-connection technologies**, which provide mutualisation possibilities.

These techniques consider energy consumption at network level, both in a static and a dynamic view since network architecture deployment strategies and network management strategies are intimately linked. They do not focus on data consolidation and traffic optimisation (described in subchapter 3.4), nor on core or wireline networks studied in the previous subchapter 3.2.

### 3.3.2 Achieved environmental benefits

The EU EARTH FP7 project (EARTH, 2012d) measured and published energy savings related to the implementation of the different wireless network best environmental management practices:

- Heterogeneous networks (a mix between macro and small-size cells) can provide up to 10% energy savings in high-traffic scenarios above 150 Mbit/s/km², compared to a macro only deployment (even 20% of the energy can be saved in hotspot scenarios);
- Multi-Radio Access Technology (RAT) can lead to 5% energy savings;
- Relays need 5-10% less energy per bit than macro only deployments in case of low offset power scenario (with higher energy savings in case of a two-hop scheme, compared to a multi-cast scheme);
- Multiple antennas can enable energy savings (e.g. through base station cooperation) but are not energy efficiency measures themselves;
- Coordination or cooperation between base stations can save 15 to 25% of energy per bit especially in heavily loaded systems.
- Quantitative data about environmental benefits requested for using energy efficient components in base stations (adaptive and more efficient power amplifiers, CMOS technology for RF transceivers, Remote Radio Heads and Active Antenna Systems).

### 3.3.3 Appropriate environmental performance indicators

The average power consumption of Radio Base Station equipment ($P_{\text{equipment}}$ in [W]) has been defined by the ETSI as the sum of power consumption of central parts ($P_C$) and remote parts ($P_{\text{RRH}}$) of the base station. Each power consumption is defined as the weighted average of power consumed at three different load levels: at busy hours ($P_{BH}$ for a $t_{BH}$ duration), medium ($P_{med}$ for $t_{med}$ duration) and low ($P_{low}$ for a $t_{low}$ duration) loads.

$$P_{\text{equipment}} [W] = P_C + P_{\text{RRH}}$$

$$= P_{BH} \cdot \frac{t_{BH}}{t_{BH} + t_{med} + t_{low}} + P_{med} \cdot \frac{t_{med}}{t_{BH} + t_{med} + t_{low}} + P_{low} \cdot \frac{t_{low}}{t_{BH} + t_{med} + t_{low}}$$

The energy performance indicators defined in the previous chapter can be used to set up or to monitor the best environmental management practices related to the design and management of networks. **The power consumption per customer** (or subscriber) and **the energy consumed per bit of data transferred** are useful when comparing network architecture alternatives.

Another indicator specific to wireless communication has been defined in order to compare networks of different cell sizes (and different mixes of cell sizes). **The power consumption per area** is defined as the network average power usage (equivalent to
the total energy consumption of the network) divided by the coverage area of the network (A) and is expressed in the unit [W/m²]. This indicator is more relevant at low traffic loads, when the network is coverage-limited rather than capacity-limited (EARTH, 2012a).

A complementary metric can be derived from the previous ones: the Energy per bit and Unit Area (EbUA), measured in [bit/J/km²]. This provides a figure on the bit delivery energy efficiency for a specific area (Lorincz, 2013).

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

- The percentage of base stations with energy-efficient equipment (as adaptive Power Amplifier, ASIP, etc.);
- The percentage of the network (in areas or customers) designed as an heterogeneous network.

### 3.3.4 Cross-media effects

Deploying a heterogeneous wireless network often relies on adding new micro cells to an existing macro cell scheme, in order to boost system capacity (in very dense areas) with only a moderate increase of power consumption per area. Densifying the network results in increasing the number of base stations, with more electronic and electric equipment, more antennas and more electromagnetic radiation. This may lead to the following non-desired effects on the environment:

- An increased consumption of raw materials (e.g. rare earths, plastics, glass, metals, etc.) and embodied energy;
- An increased production of hazardous waste (related to the waste of electronic and electrical equipment), which can lead to water and soil pollution, if not treated properly;
- An increased deterioration of urban environment due to additional antennas;
- An increased exposure of inhabitants to electromagnetic radiation.

Similar effects, in terms of raw material consumption and production of WEEE, can be observed when replacing specific base stations equipment.
3.3.5 Operational data

Improvements on the network level are achieved by establishing advanced base station deployment concepts and by introducing novel network management schemes.

Using energy efficient components in base stations

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.

![Simplified block diagram of a small-cell base station](image)

Figure 26: Simplified block diagram of a small-cell base station (on the left) and the base station power consumption breakdown for different cell-sizes (on the right), (EARTH, 2012e)

Replacing existing power amplifiers with higher efficient ones can reduce the power consumption of wireless networks at high loads. But if the power amplifier only operates on high DC power supply independently of the traffic load, then power is wasted at lower traffic loads. In order to enable further energy saving practices and component deactivation features, adaptive power amplifiers should be chosen. It allows operating point adjustment (to be able to optimise the power efficiency for low, medium and high traffic loads).

The energy efficiency of a small-cell baseband processor is increased by using an Application Specific Instruction Processor’s (ASIP) platform rather than a Field-programmable Gate Array’s platform (EARTH, 2012e). Four categories of ASIPs for energy-efficient signal processing can be considered according to the EARTH project:

- Digital front-end processors and Analogue-Digital Convertors (optimised for mixed signal filtering, synchronization and data conversion);
- Baseband processors (optimised for various diversified signal processing tasks, such as MIMO-OFDM processing, channel estimation, equalization, etc.);
- Channel error correction processors (optimised for various FEC 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 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).
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 27: Remote Radio Heads example (on the left - source (Altera, 2009)) and diagram (source: (Emerson, 2008))**

Power consumption targets are regularly defined through the European Commission’s Code of Conduct of the on Energy Consumption of Broadband Equipment. The Code defines power targets per broadband port for wireless network equipment (Wifi access point) and base stations (WiMAX, GSM/EDGE, WCDMA/HSDPA and LTE).

**Designing an optimal mix of cell sizes**

First of all, the distance between base stations should be adjusted to reduce overall energy consumption. The EU FP7 EARTH project (EARTH, 2012a) found that in dense urban areas a distance of 500 m is optimum.

The entire network can be separated into two parts: a dense traffic zone and a sparse traffic zone. The network being deployed can be energy-efficiently optimised by adaptively adjusting the cell size based on the spatial traffic distribution. The deployment of traffic zones with different cell sizes can save energy compared to a uniform deployment (by shortening the transmission range and decreasing path loss) without reducing the Quality of Service (EARTH, 2012d).

The higher the throughput requirements, the more micro-cells should be used for yielding optimal area power consumption. The EARTH project (EARTH, 2012c) demonstrated that:

- Up to 70 Mbit/s/km² the conventional macro-cell scenario is the best;
- For traffic density between 70 Mbit/s/km² and 100 Mbit/s/km² one micro-cell per macro site is the optimum deployment;
- At very high densities (above 150 Mbit/s/km²) implementing five or more micro-cells per macro site can save energy.
Further energy savings can be achieved when deploying both macro- and micro-cells in a heterogeneous network (Lorincz, 2013) because of reducing transmission distance. In such a design, macro-cells establish the overlay cellular networks (large coverage and low data rates), and small-cells are placed inside the macro site where mobile demand is high (city centres, airports, large offices, etc.). Small cells (i.e. micro-cells, pico-cells and femto-cells) need less power to transmit the data traffic compared with that of a macro-cell. Small cells can be used to off-load macro-cell traffic in areas where densities are beyond 250 Mbit/s/km² (EARTH, 2012d). Small cells should be installed at the cell edge where the macro-cell signal is most impacted by path loss and neighbour cell interference.

Base station components should be adapted to the size of the cell. Nevertheless micro-, pico- and femto-cells offer a larger flexibility in the choice of components due to lower power transceivers and less specific applications. Compact base transceiver stations may be used in order to implement such a small cell design: they do not require ground shelters and cooling equipment, and they consume less energy.

**Developing relay nodes schemes**

Relays can pick up signals transmitted from a base station and resend an amplified signal to the end-user receiver. Relays do not have a wired connection, but can increase the capacity of the cell or its coverage.
Relays nodes have significantly lower transmit power compared to macro base stations, but also consume less power. Similarly to a small cell scheme deployment, energy savings due to relay nodes implementation are more important in high load conditions (when relays node are actually needed to provide the required capacity), than in low traffic conditions due to their static energy consumption.

However, energy savings can only be achieved when the distance between the source and the destination is long enough. When deployed in a cellular system, the position and the number of deployed relay nodes have significant impacts on the system’s energy efficiency performance (EARTH, 2012d).

Different deployment scenarios of relay nodes can be implemented, as shown in the figure below.

Energy savings are mainly due to the improvement in capacity offered by both schemes, but also due to a lower power transmission. With a multi-hop scheme the overall transmitted power is lower than with a multicast cooperative scheme because of a transmission in two separate steps step (only low power is transmitted to the receiver). Not only the power use at the transmitter level can be reduced, but also the level of interference decreases with a multi-hop scheme (EARTH, 2012c).

Hybrid relaying techniques can further increase multi-hop relay schemes, by allowing the relay to dynamically switch between two schemes\(^\text{23}\) in order to adapt to the current channel status as well as the decoding status at the relay:

- **Decoded-and-Forward (DF)**, where the relay node decodes the received message and forwards the re-encoded message (benefiting from the transmitters’ diversity);
- **Compress-and-Forward (CF)**, where the relay node quantizes its observation, compresses the quantization index and forwards the compressed information (benefiting from the receivers’ diversity).

\(^{23}\) A classic relay is called Amplify-and-Forward (AF), where the relay node simply amplifies what it has received and forwards it.
For mixed indoor and outdoor network deployments, macro-cells complemented by additional relays for indoor coverage have been studied. Simulations show that a scenario with 5 relays per outdoor macro-cell provides sufficient coverage rate with lower energy consumption per area.

**Enabling cooperation between base stations**

Cooperation between base stations, also known as Coordinated Multi-Point (CoMP) communication, is a network management practice. It involves communication between neighbouring base stations (maximum 3 different base stations to be energy-efficient) in order to increase network capacity and to uniform user rate distribution within the cell.

Exploiting cooperative diversity and interference coordination between base stations can optimise transmission characteristics (e.g. rates, distances, etc.) in an energy-efficient way (Feng, 2013). The cooperation can be implemented in the data plane by processing algorithms (e.g. adaptive packet scheduling, joint processing, coordinated beamforming, etc.) or in the control plane by coordinating the allocated resources for the users.

One approach can be to allow a base station to share available frequency/bandwidth with neighbouring cells. This technique, called fractional frequency reuse planning, decreases the interference and increases energy efficiency.

Network configurations can be adapted to the daily variation of traffic, for example to low traffic hours in highly populated areas where the network is dimension for peak capacity. Then, dynamic traffic schemes can be used to adaptively switch on/off cells, standby components or use more or less resource blocks for example (see subchapter 3.4 for more information).

The CoMP system can be considered as a distributed antenna or distributed multiple-input multiple-output (DMIMO) system when backhaul links between each base station and cooperative processing are considered as ideal.

With the Smart Antenna Technology (or MIMO), a smart signal processing algorithm can control the direction of signals (reception or transmission) and reduce the interference of other signals of each antenna of an array. Such technology can support higher data rates under the same transmit power amount (e.g. Distributed Antenna Systems (DASs) can enlarge the available network coverage), and can achieve energy savings in wireless networks.

MIMO muting refers to turning off one or several base station transceivers, at night for instance. It does not completely switch off the whole base station, but deactivates some of the transceivers when traffic is low (cell coverage is maintained since the base station is kept operational).
Using multi-connection technologies

Different radio access technologies (RATs) are available (e.g. GSM, UMTS, HSPA, LTE, etc.) and often deployed in the same area or even at the same site. Energy saving techniques in Multi-RAT deployment relies on optimising the traffic distribution among RATs. Multi-RAT management can assign high traffic loads to the most suitable and most energy-efficient RAT and increase both available bandwidth and energy efficiency. The number of active base stations can then be reduced and dynamically adapted to the actual traffic demands of the network (see subchapter 3.4 for more information).

Further energy savings can be observed by co-locating different RATs within the same site:
- Fixed power consumption components can be shared among the different RATs;
- Other power consumption, related to cooling for instance, can be reduced due to the use of newer and bigger systems (e.g. economies of scale, technological advancement, etc.).

Orthogonal Frequency Division Multiple Access (OFDMA) systems, where different sets of orthogonal subcarriers are allocated to users with high Sub-Netowork Router (SNR) can increase system capacity. Energy consumption may be integrated into optimal resource allocation algorithms in order to improve the network energy efficiency (Feng, 2013).

### 3.3.6 Applicability

Only a few telecommunication operators or Internet access providers own wireless networks and can engineer changes within these networks.

More information about network management and operation among European countries (relationship with State and Territory governments, local regulations, etc.) is required.

This chapter presents the main practices which should be followed when designing or managing a wireless network, but techniques should be adapted to:
- The radio access technology used within the network (GSM, UMTS, HSPA, LTE, etc.);
- The base station coverage (i.e. the cell size);
- The interference management constraints;
- The terminal capabilities;
- The forecast in capacity demand (video demand, workload capacity, etc.);
- The user population density (urban / sub-urban / rural areas);
- The electro-magnetic emission limits (related to EMF regulation).

Most of these practices can be implemented both when installing a new wireless network and when upgrading an existing one (either replacing a few components or changing technology).

### 3.3.7 Economics

Relevant economic data is needed.
3.3.8 Driving force for implementation
The design and management of energy-aware wireless networks relies mainly on the use of models and applications to optimise energy savings. This usually includes assessing the economic feasibility of the practices suggested. Design and management schemes should be optimised regarding both energy savings and overall costs.

To be developed

3.3.9 Reference organisations
Small cells are being deployed across Europe, in particular by telecommunication operators as Vodafone UK, T-Mobile UK or Orange France (JDSU, 2013)

Moreover, Vodafone and O2 agreed in the UK to collapse their cell sites into one network to optimise energy consumption (JDSU, 2013).

To be developed

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### 3.4 Dynamic traffic optimisation through energy-efficient routing and radio resource management

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#### Relevant lifecycle stages

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

#### Main environmental benefits

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**Environmental indicators**

- Power consumption per customer or subscriber
- Energy consumed per bit of data transferred
- Power consumption per area
- Energy per bit and Unit Area
- % of nodes or links switched-off at low traffic loads
- % of network (in length or traffic) using dynamic traffic optimisation

**Benchmarks of excellence**

**To be developed**

**Cross references**

**Prerequisites**

- Techniques should be adapted to the characteristics of the network, depending on:
  - the segment of the network concerned by the upgrade
  - the technology currently used in the network
  - end-users’ requirements

**Related BEMPS**

- 3.2: Reengineering wired networks for introducing more energy-efficient technologies
- 3.3: Designing and managing an energy-aware wireless network architecture
3.4.1 Description
The energy consumption of modern telecommunications equipment is 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.);
- Due to low energy efficiency of some components at lower loads (e.g. rectifiers).

Due to end-user demand variability, traffic loads on telecommunication networks vary significantly over time and space, as shown in the figure below. There are long periods each day in which the average load of the network can be 5 or 10 times smaller than the peak values during the busy peak hours (EARTH, 2012d). A large part of the daily network energy consumption is thus spent for providing the full system capacity, even when the actual traffic demand is much lower.

![Figure 33: Example of traffic flow composition in a backbone network (ZIB report, 2014)](image)

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 this case). In a given design and with existing network components, effective energy-aware managing strategies consist in:

- Switching 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;
- Optimising data routing and transmission characteristics (e.g. changing of traffic path, adjusting transmission bandwidth and coverage, aggregating packet information, etc.) to dynamically reach the maximum energy-efficient potential of the network (while insuring a sufficient Quality of Service);
- Reducing the demand at peak loads by using Quality of Service (QoS) protocols (e.g. filters, sorry servers, cache server, etc.), in order to reduce the overall capacity of the network.

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, etc.) and the network design and management scheme (e.g. cell size, existence of relay nodes or bypasses, etc.). The two previous
subchapters 3.2 (Reengineering wired networks for introducing more energy-efficient technologies) and 3.3 (Designing and managing an energy-aware wireless network dealt with best environmental management practices related to these topics.

This subchapter focuses on techniques whose implementation differs across the different segments of the network:

- Radio-Resource Management refers to techniques for wireless networks (dynamic bandwidth management, cell breathing, etc.);
- Green routing can be implemented through wireline networks (proxying, dynamic power scaling, packet forwarding, etc.);
- Demand management through Quality of Service protocols (latency, filtering, etc.) can primarily set up at access network level.

### 3.4.2 Achieved environmental benefits

The EU FP7 EARTH project (EARTH, 2012d) examined energy savings related to the implementation of different energy-efficient routing and transmission techniques identified above:

- Dynamic sectorisation of macro base stations, where some base stations are in sleep mode during low-traffic hours, while cell size is increased) can lead to 13 – 30% of energy savings at network level;
- Turning off the appropriate base stations in an heterogeneous network at low loads traffic is able to provide from 25 to 40% of energy savings at network level;
- An effective dynamic bandwidth management can save about 25% of energy consumption at network level (21% in dense and urban areas and 29% in a suburban area (EARTH, 2010);
- Dynamic scheduling allows short sleep periods that can be utilised by Multicast Broadcast Single Frequency Network (MBSFN) which provides from 20 to 30% of energy savings per bit or by Cell Discontinuous Transmission (DTX) which can save up to 45% energy when combined with power control;
- Delay constraints allow to reduce the transmit power by adaptively scheduling the data packets at the “best” time within the delay of the QoS requirements and provide up to 20% of energy savings per bit of data transferred;
- Effects of sorry servers and filtering blocs in terms of energy savings
- Effects of efficient broadcast distribution (CDN, catch servers, shared services, scheduled distribution…) in terms of energy savings
- Dynamic allocation of users to the best available Radio Access Technology (through vertical handovers) can lead to 10% in energy savings;

In wireless networks, such savings are mainly due to the reduction in power consumption of power amplifiers and radio frequency transceivers (EARTH, 2012e):

- Applying sleeping modes for small-size cells can lead to 80% power reduction in pico-cell power amplifiers and 94% in macro-cell power amplifiers;
- Adapting the power amplifier operating points to the reduced power level can save up to 55% energy consumption in pico-cell power amplifiers and up to 35% in macro-cell power amplifiers;
- Power scaling can improve radio frequency transceiver energy efficiency by 35%;
• Adapting operation to channel conditions (SiNAD adaptation and duty-cycling) can provide 30% energy savings in small-cell transceivers consumption;

3.4.3 **Appropriate environmental performance indicators**

The energy performance metrics defined in the two previous subchapters (3.2 and 3.3) can be used for the best environmental management practices related to energy-efficient routing, adaptive transmission and Quality of Service management:

- **The energy consumed per bit of data transferred** is an appropriate indicator when comparing energy consumed by networks at a given traffic load. For example, it can be used for comparing at low load traffic smart sleeping techniques with a situation where all components are in active mode.

- **The power consumption per customer** (or subscriber) can be particularly useful when studying energy-efficient routing or Quality of Service managing techniques. In such cases, the number of customers is fixed, but data traffic can be reduced, reorganised (aggregated for example) or redirected in order to reduce energy consumption.

- **The power consumption per area** is principally used for wireless network access, so that it can provide energy consumption cells with different sizes (as it can be observed when implementing the cell breathing technique).

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

- The percentage of nodes or links (in length) that are switched-off at low traffic loads;
- The percentage of the network (in length or traffic) using dynamic traffic optimisation (dynamic scheduling, dynamic bandwidth management...).

3.4.4 **Cross-media effects**

Developing the techniques described before requires processing applications, transmitting protocols or monitoring performance (e.g. energy consumption, data traffic loads, etc.) which can add to network power consumption.

Moreover, if certain types of technology are implemented without an efficient control, this can degrade the network performance and require extra network resources, and thereby consume more energy.

3.4.5 **Operational data**

**Smart standby of network components and interfaces**

An effective energy-aware network management consists in switching off as many devices and links as possible, while respecting the connectivity and Quality of Service (QoS) constraints. Idle network elements can be selectively switched off at low traffic loads, such as at night. As shutting down network elements can affect the overall performance of the network (e.g. congestion, extra-delay, etc.), it has to be carefully evaluated under connectivity and QoS constraints.

Due to a redundancy in core networks, some of the network nodes can be put in standby mode when they are not used as a source or destination of traffic, and they are also not essential as transfer nodes (Zhang, 2010). As nodes can only be put to sleep when totally unused, energy-aware traffic engineering and routing should be used. When the traffic falls below a given threshold, residual traffic can be rerouted...
through few “active” nodes, so that the others can be put in standby mode\textsuperscript{24}. 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).

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Energy-aware routing to reduce the number of active nodes at low traffic loads (Source: (ECONET Project, 2010))}
\end{figure}

Most wireline networks are designed to be continuously and always available: only some devices can be turned off when it is not communicating, since when the entire device is shut down, it loses contact with the network (and cannot be awake when required). Standby modes then have to be explicitly supported with special techniques able to maintain the “network presence” when nodes or components are at sleep. A “proxy” (i.e. a computer that maintains full network connectivity) can maintain a continuous network presence while a network node is in a sleeping mode operation and consumes less energy (ITU, 2010). The proxy responds to small control traffic (e.g. responding to requests, sending periodic network presence messages, etc.) instead of the network node which is woken up when further processing is required.

\textsuperscript{24} Such technology should be compliant with the latest version of the European Commission’s Code of Conduct on Energy Consumption of Broadband Equipment.
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.

**Dynamic power scaling**

Power scaling can dynamically reduce the working rate of processing engines or link interfaces:

- Adaptive Link Rate and Dynamic Voltage Scaling can respectively control link speeds and the driving voltage of devices (e.g. CPU, hard disk, NIC, etc.) according to the amount of the traffic to be processed. Traffic routes can be distributed so that each node treats minimum traffic, and sets link rates or voltage at the adequate level.

- With Low Power Idle (LPI), links or processing engines enter low power states when not sending or processing packets, but can quickly switch to a high power state when needed.
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).

**Dynamic scheduling transmission**

Dynamic scheduling transmission can control the amount and the timing of packet transmission through core network routers in an energy-efficient way (by avoiding output waits at each node):

- The size of IP packets impacts the energy consumption of routers in core networks. Energy-aware packet forwarding can lower energy consumption by increasing the size of IP packets the routers transfer where (Zhang, 2010).
- The energy-efficiency of IP packet forwarding depends also on the frequency that packets are forwarded from node to node. Pipeline forwarding uses predefined schedules for IP packets to be switched and forwarded periodically (every time cycle). This results in the creation of a synchronous virtual pipe where periodic switching prevents delays due to resource contention and loss.

**Figure 36: Dynamic adaptation approaches to reduce energy consumption of network devices. Source: Davoli, 2013 (top) and (ECONET Project, 2010).**
resulting in congestion, by insuring transmission availability of each node for forwarding the packets of each flow (Zhang, 2010). This pipeline forwarding parallel network can be used for carrying traffic requiring a deterministic service (e.g. phone calls, video on demand, video conferencing, distributed gaming, etc.) which require large bandwidth.

**Figure 37: 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 (see the previous sub chapter 3.3 related to energy-aware design and management of wireless networks) can be reduced, while the power amplifier is operating close to its most efficient operation point. Further energy savings in base stations can be observed at off-peak traffic hours by implementing bandwidth adaptation at system level. Neighbouring cells can coordinate their bandwidth configuration through a reuse scheme that allow significant reduction of inter-cell interference (EARTH, 2012a).

**Dynamic sectorisation of base stations (cell-size breathing)**

Dynamic sectorisation aims at switching off certain base stations at off-peak hours, by increasing the coverage of other base stations (EARTH, 2012a). This technique can particularly be implemented in urban areas, where macro base stations are relatively close to each other and capacity can be limited by interference in peak hours. At lower traffic load, when interference is lower, some extra loss on the radio links can be tolerated and macro base stations can switch to fewer but larger sectors.

This technique which constantly changes the range of the geographical area covered by a transmitter (function of data rates and traffic demand) is also called cell-size breathing.
Providing energy-aware services

The diversity of the Quality of Services (QoS) requirements for different applications may be used for energy savings:

- Delay-tolerant traffic should be identified (e.g. email, file downloading, offline processing, etc.) since such data traffic loads can be more easily served by a dynamic scheduling transmission scheme and provide energy savings (see above). This technique can be implemented through Store-Carry-and-Forward (SCF) transmission: the data flow related to the delay-tolerant application is transmitted to a mobile relay which carries the data close to the base station, before transmitting the data to the base station (Feng, 2013).

- Sorry server returns the alternative response to inform that services cannot be provided for some reason (such as traffic congestion), which allows to shift peak traffic demand (ITU, 2010).

- Filtering blocks unnecessary data to be transmitted, and can save energy associated with this data transmission (ITU, 2010).

Server networks can be designed and managed in an energy-aware way (ITU, 2010):

- Using an optimised Contents Delivery Network (CDN) for delivering web contents via the Internet can save energy since optimised CDN can access a closer server than the original one (if the same content is available, which is more likely when the content is more popular);
Using cache servers can reduce bandwidth usage, so it can achieve energy saving corresponding to the reduction if the copy of the contents exists in this server;

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

Distributing broadcast content in advance can peak-shift the traffic and reduce the maximal transmission capacity needed, so it reduces the number of active devices and saves energy.

**3.4.6 Applicability**

This subchapter presented the main practices which should be followed when managing networks, but techniques should be adapted to the characteristics of the network:

- Depending on the segment of the network concerned by the upgrade (core, metro or access network);
In relation to the technology currently used in the network (e.g. DSL, PON, WiMAX, GSM, etc.);

In function of end-users’ requirements (e.g. video demand, connexion stability, workload capacity, etc.).

More information about the type of company targeted (SMEs?)

3.4.7 Economics

Relevant economic data is needed.

3.4.8 Driving force for implementation

Dynamic traffic optimisation mainly focuses on the performance of the network and on the Quality of Service. On the one hand, the techniques described before must take into account these two 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 proceed to energy savings (sorry servers, filters, etc.).

Beyond these parameters, the operational costs savings resulting from the implementation of such techniques is an important driver.

3.4.9 Reference organisations

Alcatel-Lucent announced that a new feature of their software (called dynamic power save) can bring up to 27% power consumption reduction for base stations deployed by China Mobile (Feng, 2013).

To be developed

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4 BEMP to improve the energy performance and minimising the environmental impacts of data centres

4.1 Introduction / scope
A data centre is a physical room or building that houses computer, server and networking systems and components. It is typically used by organisations for remote storage, processing and distribution of large amounts of data. A data centre is typically made of:

- A physical building, including security, location and maintenance;
- Power equipment, with uninterruptible power supplies (UPS), power distribution units and cabling, backup generators and others;
- A cooling system, consisting of a cooling plant, pipes, pumps and fans, etc.;
- IT equipment, which refers to IT hardware installed into racks;
- An operating system, that to say software installed on the IT equipment.

There were an estimated 509,147 data centres (all types) in the world in 2011, representing 286 million m² of data centre space. This number is expected to grow up significantly by years and until 2018 (IDC, 2013).

The Joint Research Centre (JRC, 2012) has estimated total annual energy consumption of data centres in Western Europe as 56 TWh (or 2%) of the total electricity consumption per year. In 2012, this was projected to increase to 104 TWh (or 4%) per year by 2020. The large consumption of energy is due to the need for permanent storage of data (24/24 availability, back-up generators, etc.) and the need for cooling of the servers to maintain optimal operating temperatures. Cooling technology can be responsible for up to 50% of total energy consumption in server rooms, and may require large volumes of freshwater and refrigerants.

Data centres have traditionally been designed with large tolerances for operational and capacity changes with possible future expansion in mind (JRC, 2012). The over-dimensioning of data centres leads to inefficiencies: redundant power and cooling systems, IT equipment with a low average utilization, etc. Nowadays, data centres owners and operators have incentives (energy costs for example) and tools (including energy-efficient equipment) for designing new high energy performance data centres, and improving the energy efficiency of existing ones.

Figure 41: Example of data centre architecture. Source: Schneider Electric – Reference Design 23 – Performance-Optimized 1MW E-Class data centre.
The following sections intend to describe four BEMPs that allow an overall improvement of data centres energy and environmental performances:

1. Better locating and planning data centres;
2. Optimizing data centre utilisation;
3. Efficient cooling technologies and systems;
4. Air flow management and design, and heat reuse.

Figure 42: Overview of the elements and BEMPs of data centres to improve the energy and environmental performance
4.2 Better locating and planning data centres

**SUMMARY OVERVIEW:**
Environmental conditions (temperature and humidity rate, land use, etc.) and surroundings (type of energy supply, possibility for heat reuse, etc.) should be parameters driven the choice for locating a new data centre. A modular architecture should be defined in order to avoid extra energy consumption related to over-sizing.

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4.2.1 Description

The planning sequence should establish the location site and design requirements of the data centre’s equipment and physical infrastructure (e.g. power, cooling, building, security, etc.). It can be divided into 4 main steps: establishing key project parameters (capacity, costs, etc.), developing system concept (location, technologies, etc.), incorporating user preferences an constraints (in terms of design) and determining implementation requirements (regulations to follow, procurement rules, installation guidelines, etc.).

![Figure 43: System planning of data centre projects. Source: (Rasmussen, 2013).](image)

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

Energy efficiency goal for the data centre infrastructure system should be one the key parameters defined initially (with criticality, capacity, growth plan, density and budget) by consulting key stakeholders (finance executive, CEO, key IT executive, IT operations manager, etc.) (Rasmussen, 2013).

Then, these key parameters, including energy efficiency, can be used for developing the physical infrastructure system concepts for the data centre, including:

- Environmental criteria for site selection:
  - Land availability – avoiding natural and agricultural land;
  - Climate and ambient temperature (influence on the performance of side-economiser cooling systems an on the inside temperature);
  - Proximity to threats and natural disasters (e.g. flooding)
  - Proximity to renewable energy, cooling resources and heat reuse possibilities (offices, swimming-pool, etc.)
  - Proximity to telecommunications network and other public infrastructure (e.g. roads)

- Equipment technologies of the data centre, and especially powering, cooling and air-managing systems, since this equipment consumes important amount
of energy in a data centre. Moreover, such equipment must be carefully adapted to the expected powering and cooling needs of IT equipment that will be installed.

At this stage, user preferences (can be changed or adjusted after consideration of cost and consequences) and constraints (obstacle that cannot be overcome) should be integrated into the design process (within the framework of the system concept already chosen). Involving IT operations, network engineers or facilities engineers is important to ensure the compatibility of the design with users’ practices, since energy efficiency of equipment relies greatly on the utilisation mode. This is particularly true when speaking of energy efficiency, since relevant environmental management practices can be implemented when operating and managing different systems:

- Air-flow management (see chapter 4.5), including humidity and temperature settings;
- Energy monitoring and management of the data centre (see chapter 6.4);
- WEEE management (see chapter 7.3).

Finally, implementation requirements should be set up. It corresponds to a set of rules that can be divided between standard requirements (special regulatory compliance, compatibility of subsystems, safety, etc.) and project requirements, where user specific details are defined (human and equipment resources, special procurement, deadlines, etc.) (Rasmussen, 2013). Best environmental managing practices can be implemented within this step:

- Procurement related to the purchasing of energy-efficient equipment, as for IT devices (see chapter 5), cooling plants and air conditioners (see subchapter 4.4), fans and humidifiers (see subchapter 4.5) or power plants (see subchapter 6.3) can be implemented to selected more-efficient models within equipment technologies already chosen.
- Equipment installation guidelines, in order to ensure the efficiency of the equipment that will be purchased, and which has to be installed properly in order to show optimised energy consumption performances.

After the planning sequence, the design of the data centre can be completed, in order to lead to project engineering specifications able to be used for building the data centre (Rasmussen, 2013):

- Detailed component lists
- Exact floor plan of racks (including power and cooling equipment)
- Detailed installation instructions
- Detailed project schedule

The physical layout of the data centre thus defined may also influence 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.

From a global perspective, most of the practices that can be implemented all along the planning sequence are described in the following section which defines:

- How to define energy-efficiency goals?

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26 Some following chapters demonstrate that important energy-savings can be made when choosing more energy-efficient technologies (in particular, see chapter 4.4 related to efficient cooling technologies and chapter 6.3 related to energy-efficient power systems).
o See BEMP 6.4 related to energy monitoring and management.

- How to select carbon-efficient technologies?
  o See BEMP 4.4 related to efficient cooling technologies and systems and BEMP 6.2 related to energy losses reduction.

- How to implement procurement for more environmental-friendly devices?
  o See BEMP 5.2 related to energy-efficient IT equipment and BEMP 7.2 related to WEEE prevention and lifecycle.

- How to manage a data centre from an energy-efficient perspective?
  o See BEMP 4.5 related to air-flow management and design, and waste heat reuse, and BEMP 6.3 related to energy monitoring and management

Then, this section focuses on the following best environmental management practices:

- Selecting an optimal location from an environmental perspective;
- Avoiding oversizing the data centre.
- Building a data centre on a practical modular architecture (i.e. able to accommodate variations in room size and shape), in order to facilitate future upgrades toward more efficient systems (Rasmussen N., 2014).

Three main sections of the EU Code of Conduct on Data Centres (JRC, 2015) refer to better planning data centres, as summarized in the table below.


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</table>

4.2.2 Achieved environmental benefits

Better site-selection and planning of data centres leads to:
- significant energy savings and cooling refrigerants (potential GHG and ozone depletion) due to a reduced need for cooling;
- reduced GHG emissions from reduced energy consumption and the use of available renewable energy resources;
- less impact of natural habitats and wildlife (avoids urban sprawl and soil sealing).

Avoiding oversizing the data centre and building a data centre on a practical modular architecture will:
- reduce energy and material consumption as less space is needed;
- lower the land footprint of the facility (soil sealing).

4.2.3 Appropriate environmental performance indicators

The major metrics for defining energy-efficiency goals, and then to monitor results are:
- **Power Usage Efficiency (PUE)**, which is defined as the ratio of the total power to run the data centre facility to the total power drawn by all IT equipment.
- The **Data Centre Infrastructure Efficiency (DCiE)**, which is defined as the inverse of the PUE.
- **Land footprint** (m²).
- **Availability of free cooling (in hours)**.
- **Solar insolation** (kWh/m²/day), which is the solar power available at a defined location over a period of time (a day in this case).
- **Share of renewable energy in the local energy mix (%)**.
4.2.4 Cross-media effects

The selection of a site function of its potential in terms of energy efficiency could lead to the choice of a site in a remote area. The employees would have to travel further and there might be more transmission losses.

While avoiding oversizing, a data centre may be built too small from the start. Then, it will be more expensive and less efficient than if it was designed to be the right size.

4.2.5 Operational data

Better locating the data centre

When deciding where to build a new data centre, the following parameters may reduce its environmental footprint, especially in terms of energy consumption (Sustainability Victoria, 2010):

- The ambient outdoor temperature: an area with a low ambient external temperature (Western, Central and Northern Europe for example) may allow the deployment of free or economised cooling concepts;
- The ambient outdoor humidity: an area with a low ambient humidity rate not require the use of dehumidifiers when using free cooling and may improve the efficiency of evaporative cooling;
- The availability of other cooling sources such as a river or a lake without conservation restrictions;
- The potential re-use of waste heat, with the presence of an adjoining building able to utilise the high level of waste heat produced by the data centre (for heating office or industrial space, swimming pools, etc.);
- The proximity to a power generating plant, in order to reduce transmission losses;
- The availability of renewable energy sources, which means optimal environmental conditions (solar exposure, wind potential, etc.) and the possibility to connect locally produced electricity to the network;
- The absence of noise, aesthetic or conservative constraints that can be written in local planning documents.

Moreover, further parameters should be taken into account when designing the architecture of the building. Especially unwanted heat transfers should be avoided, through:

- An appropriate insulation of the building (in order to isolate hot from cold areas in the building);
- A minimization of the solar heating of cooled areas by providing shade (with a green roof for example) or increasing the reflectivity of the building;
- An installation of mechanical and electrical power supplies, such as UPS units, outside the cooled areas.
Designing modular data centres to avoid oversizing

Data centre over-sizing is one of the largest drivers of electrical waste and occurred when the design value of the power and cooling equipment exceeds the IT load (Rasmussen, 2011). This situation can be observed when:

- IT systems are initially oversized due to overestimates of current and future loads and necessary computing capacity, and to redundancies added by multiple stakeholders (owners, process engineers, electrical engineers, HVAC engineers, etc.) whose intention is to secure their own activities (E-Server, 2009). Then the power and cooling systems is sized for too large a load.

- The power and cooling systems are sized for a future larger load. Not only the expected IT load is usually about 90% of total capacity, but the IT load is being deployed over time, and initial loads are often below 20% of total capacity (E-Server, 2009). Then, power and cooling equipment, which remains the same, is initially largely oversized, and slightly gains use over time.

The power supply required is often over estimated. While data centre are commonly estimated to need an electrical grid connection to support a 2.7 kW/m² (or more) IT equipment density, it was demonstrated by benchmark that average values in practice were around 0.27 kW/m² (E-Server, 2009).
The first solution is to optimise computer equipment redundancy, in accordance with resilience and reliability, and energy consumption. An overall assessment of power and IT failure risks for the business should be performed, so as the consolidation of such equipment.

Another solution to avoid extra energy consumption related to oversizing is to continuously adapt power and cooling equipment to IT load. In many actual data centres the extra cost associated with installing such equipment later is significant, then powering and cooling equipment are often completely installed up-front. Designing a data centre with a modular architecture can facilitate continuous changes in equipment. It can be deployed according to the following principles (Rasmussen, 2011):

- The data centre should be provided in pre-engineered modular building blocks;
- The main input switchgear, main power distribution panels, and the standby generator(s) should be deployed up-front (and then meet ultimate design capacity);
- The installation of UPS, battery system, power distribution units, bypass switchgear, and rack power distribution wiring can be phased, and should be able to use the cable distribution primarily installed (in order to reduce wiring, drilling, and cutting);
- The cooling system can be upgraded and extended according to specific needs, by using blade systems in cooled racks for example and using the existing airflow design.
- Special site preparation such as raised floors would be reduced.

![Figure 46: Mitigation of the oversized power capacity over the lifetime of a data centre through modularity (Source: (Rasmussen, 2011))](image)

### 4.2.6 Applicability

Locating a data centre according to its energy-efficiency potential, and building it according to a modular architecture is particularly relevant for big data centres (since costs savings can overcome the constraints resulting in building a data centre remotely) and for activities whose future needs in terms of IT loads are expected to be much higher than the actual needs, or that are currently uncertain.

More information about categories of companies targeted (SMEs?)
4.2.7 Economics

Integrating modular power and cooling technologies can result in TCO savings of 30% compared to a typical oversized data centre operating today (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 47**: Major CAPEX (top) and OPEX (down) cost savings related to the implementation of a modular architecture (Torell, 2014)
Similar data about the benefits of better locating a data centre

4.2.8 Driving force for implementation

Integrating energy-efficiency parameter within the selection of the data centre location should be positive in terms of operating cost savings since the performance of the cooling system should be increased. 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 could not be the lowest on the site selected for its highest energy-efficiency potential. Moreover regulations vary according territories and do not allow the same possibilities in terms of building a data centre (town planning constraints, incentives for renewable sources, etc.).

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

On the contrary, reducing computer equipment redundancy can slightly reduce the resilience and reliability of such equipment, and by consequence of the whole data centre. An accurate assessment of the minimum redundancy necessary should avoid facing oversized risks.

4.2.9 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).

To be developed

4.2.10 Chapter references


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4.3 Optimizing data centre utilisation and management

**SUMMARY OVERVIEW:**
Software utilisation directly influences the energy consumption of hardware and their need for cooling. Data centre energy efficiency may be improved by developing or purchasing energy-efficient software, consolidating the use of servers through virtualisation and improving data management and storage.

**ICT components**

<table>
<thead>
<tr>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
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</table>

**Relevant lifecycle stages**

<table>
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<tr>
<th>Design and installation</th>
<th>Selection and procurement of the equipment</th>
<th>Operation and management</th>
<th>Renovation and upgrades</th>
<th>End-of-life management</th>
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</table>

**Main environmental benefits**

<table>
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<tr>
<th>Energy consumption</th>
<th>Waste production</th>
<th>Air emissions</th>
<th>Water use &amp; consumption</th>
<th>Noise and electromagnetic radiations</th>
<th>Landscape and biodiversity</th>
</tr>
</thead>
</table>

**Environmental indicators**

- Power to Performance Effectiveness (PPE)
- Server PUE (SPUE)
- Server Compute Efficiency (ScE)
- Deployed Hardware Utilisation Ratio (DH-UR)
- Deployed Hardware Utilization Efficiency (DH-UE)
- IT Equipment Energy Utilization (ITEU)
- Disk space utilisation (%)  
- Server utilisation (%)  
- % of practices from the Code of Conduct for Data Centres implemented (parts 4.2, 4.3 & 4.4)

**Benchmarks of excellence**

Implementing practices of the EU Code of Conduct for Data Centres (parts 4.2, 4.3 and 4.4) with a value of 2 or more.

**Cross references**

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<th>Prerequisites</th>
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<th>Related BEMPS</th>
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</table>
- 3.2: Reengineering wired networks for introducing more energy-efficient technologies
- 5.2: Procurement for energy-efficient equipment and installation
4.3.1 Description

A typical data centre is primarily composed of the following IT equipment:
- Servers, used for running IT operations;
- Data storage equipment (Hard Disk Drive, Solid State Drive, etc.);
- Information security elements (e.g. firewalls);
- Network equipment (service provider, switches, cables, etc.).

![Figure 48: Example of a typical network implementation with top of racks switches](Source: ASHRAE TC9.9 - Data Center Networking Equipment – Issues and Best Practices)

IT systems traditionally consume about 50% of the data centre energy power. Servers and storage drives are power supplied in order to run drives (about 16% of the electricity consumption), PCI cards (about 9%), processors (about 19%), memory (about 6%) and chip sets (about 7%); another 7% of electricity is consumed by fans and about 35% is lost due to AC/DC and DC/AC conversions (Source: Intel and EXP Critical Facilities, quoted in the Green Grid, 2007 – The Green Grid opportunity, Decreasing data centre and other IT energy usage patterns).

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 choice of an energy-efficient technology of access network segment refers to a best environmental management practice defined in the previous part of this report (see section 3.2: Reengineering wired networks for introducing more energy-efficient technologies), while the selection of energy-efficient IT hardware is developed in the following part of this report (see section 5.2: Procurement for energy-efficient equipment and installation).

The techniques described below aim at reducing the number of servers and storage hardware powered within the data centre and optimising the performance of all hardware regarding to their energy consumption. These practices deal with the

operation of applications, databases and services run onto servers, and with the data stored onto drives.

Three main sections of the EU Code of Conduct on Data Centres\(^{29}\) refer to practices related to data centres’ IT equipment.

**Table 6: Energy Efficiency Practices concerning data centre IT Equipment (source: EU Code of Conduct for Data Centres - Version 6.1.1 (JRC, 2015))**

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<td>Reduce hot / cold standby equipment</td>
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<td>4.2.4</td>
<td>Select efficient software</td>
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<td>Incentives to develop efficient software</td>
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<td>Eliminate traditional ZN hardware clusters</td>
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<th>4.3</th>
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<td>4.3.7</td>
<td>Control of system energy use</td>
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<td>4.3.8</td>
<td>Audit of existing IT equipment environmental requirements</td>
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<table>
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<th>4.4</th>
<th>Data management</th>
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<td>Data management policy</td>
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<td>Separate user logical data storage areas by retention and protection policy</td>
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<td>Separate physical data storage areas by protection and performances requirements</td>
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<td>4.4.4</td>
<td>Select lower power storage devices</td>
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<td>4.4.5</td>
<td>Reduce total data volume</td>
</tr>
<tr>
<td>4.4.6</td>
<td>Reduce total storage volume</td>
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</table>

The first 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)\(^{30}\).

The second lever consists in improving data management and storage, since a significant part of the data being stored is either unnecessary, duplicated or does not require rapid access. Reducing both the total volume of data stored and the total storage volume reduce the number of storage hardware used.

The third option is to consolidate the use of servers into order to reduce the number of highly resilient and reliable hardware powered. 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 or the analysis of IT reported data (server and network utilisation for example). Then, the relevant IT services can be alternatively by consolidated, virtualised\(^{31}\), archived, decommissioned or removed, according to their current state of use.


\(^{30}\) 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.

\(^{31}\) Virtualisation (running multiple independent virtual operating systems on a single physical computer) allows the same amount of processing to occur on fewer servers by increasing server
4.3.2 Achieved environmental benefits

Reducing the numbers of IT equipment powered and optimising the use of servers’ sleeping modes directly reduce the electricity consumption of IT equipment. Such energy savings can be explained by a reduction in the power supply of each IT component (memory, drives, processors, chip set, or fans), but also by a more efficient architecture.

As any electrical equipment, IT equipment requires power supply and produces waste heat while running. Need for cooling and energy losses related to the power infrastructure (power distribution unit, UPS, building transformers) increase with the number of active hardware. Consolidating IT equipment will indirectly reduce the electricity consumption related to cooling (more BEMPs related energy-efficient cooling are available in the sections 4.4 and 4.5) and the over-consumption due to power supply (see section 6.3 for more information).

- 1 Wh of energy saved at the server level results in roughly 1.9 Wh of data centre-level energy savings (Energy Star, 2011).

Such indirect effects can also be observed when developing energy-efficient software since software systems do not consume energy directly but affect hardware utilisation rate and lead to indirect electricity consumption.

Combined energy savings (that to say both direct and indirect effects) potential offered by the different techniques developed in this chapter can be estimated to be:

- **Energy-efficient storage** performance depends mainly on the quantity of data to be stored (and on the number of files), but energy savings up to 50% can be reached at the storage equipment level (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;

utilization, reducing required server power and consequently the size of the necessary cooling equipment.

32 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).
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

- 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.

Quantitative benefits related to automated tiering, energy-efficient storage equipment (SSD) or MAID (Massive Array of Idle Disks)

- On the order of 40%-80% for virtualisation projects (Energy Star, 2011; (PrimeEnergyIT, 2013)), depending on the degree of virtualisation (hardware partitioning, full or para virtualisation container virtualisation, etc.), on the degree to which new applications and features are implemented, and on the specificity of the system.

Figure 50: Reduction in servers’ energy demand by virtualisation. Source: Case study from the PrimeEnergyIT project (PrimeEnergyIT, 2011).

Quantitative benefits related to other consolidation solutions (decommissioning of unused servers, N+1 clustering, downsizing the portfolio application, combining applications onto fewer servers)

4.3.3 Appropriate environmental performance indicators

Regarding energy efficiency, a first category of indicators can be defined at different levels as a ratio between data workload and energy consumption (NRDC, 2014):

- **Power to Performance Effectiveness** (PPE) measures the data centre performance per kW, in order to monitor projects aiming at raising servers’ utilisation rate.

- **Server PUE** (SPUE) is a declension of the PUE, since it refers to the ratio between total server input power and its useful power (power consumed by IT equipment: processors, memory, I/O cards, etc.).
• **Useful work** corresponds to a number of work units (e.g. transactions, URLs, etc.) per energy consumed (kWh).

Besides these indicators relevant for monitoring energy savings, a set of indicators can be defined in order to follow consolidation and other IT optimisation projects (Smart City, 2014):

**Server Compute Efficiency** (ScE) has been defined by the Green Grid as the percentage of servers doing “useful work” (meaning the servers having active primary services). ScE can be aggregated at the data centre level (average of the ScE values from all servers during the same time period), in order to determine the **Data Center Compute Efficiency** (DCcE). Monitoring the efficiency of compute resources allows identifying areas of inefficiency (The Green Grid, The Green Grid Data Center Compute Efficiency Metric: DCcE – White Paper #34 from the Green Grid, 2010).

**Deployed Hardware Utilisation Ratio** (DH-UR) refers to an indicator measuring the power drained by idle servers or storage equipment (amount of power waste). It has been defined by the Uptime Institute (Uptime institute, 2007) as the number of servers running live applications divided by the total number of servers deployed, or as the number of terabytes containing frequently accessed data divided by the total number of terabytes of the storage system.

A similar indicator was defined for assessing the power efficiency of operating servers and storage systems with the **Deployed Hardware Utilization Efficiency** (DH-UE) which is for servers the minimum number of servers necessary to handle peak load divided by the total number of servers deployed (Uptime institute, 2007).

**IT Equipment Energy Utilization** (ITEU) aims at measuring the efficient operation of IT equipment since this is the ratio between the total energy consumption of IT equipment (actual in kWh) and the total rated energy consumption of IT equipment (rated in kWh). This indicator can be used for improving utilisation ratio through consolidation and reduction of the number of equipment in operation (Green IT Promotion Council, 2012).

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

- The storage disks space utilisation (%);
- The servers’ utilisation (%);
- The share of practices from the Code of Conduct for Data Centres (parts 4.2, 4.3 & 4.4) implemented (%).

### 4.3.4 Cross-media effects

The first major unexpected effect on environment related to the implementation of the techniques described above can result in expansions and upgrades often associated with consolidation projects. Such evolutions can change direct energy consumption due to an enlargement of the IT equipment park and more energy-consuming hardware.

The second effect results in the use of applications to implement techniques such as virtualisation, automatically management, and so on. These applications occupy system resources for their execution and reduce the effects of these practices on lowering server utilisation rate. At intensive traffic, virtualised servers consume more energy than physical ones (Wen et. al., 2010).
Another side-effect of virtualisation can occur because of the facility and speed of implementing new virtual servers. Then the number of virtual-server can increase quickly and lead to an increased power demand.

4.3.5 Operational data
According to the different techniques identified in section 4.3.1., the corresponding details for implementation and operational data are given.

Energy-efficient data storage management
One of the most visible storage inefficiencies is low disk-space utilisation, with utilisation rates of 20% frequently observed in organisations, while a 60 or 70% utilisation rate should be a minimum (Hitachi et. al., 2013). Several causes can be identified: data duplication, inability to remove obsolete data, limited consolidation of resources, etc.

A data-reduction technology aims at reducing storage consumption by removing data waste and redundancy (Hitachi et. al., 2013):

- **Deduplication** intends to reduce redundancies that consume disk space unnecessarily and require more storage devices. Deduplication software find and eliminate unnecessary copies by retaining unique files or data blocks and providing pointers to duplicates. Such software should perform automated operations, without impacting the performance of the storage system and in a maximum efficient way\(^{33}\). Storage capacity savings from deduplication can be up to 90% (Hitachi, 2013), except for primary and archive storage where a 35% maximum saving can be reached (PrimeEnergyIT, 2011).

- **Data compression** can reduce the amount of data stored. Data compression should be performed on rarely accessed files (since compressing and decompressing the data consume energy), on uncompressed formats (e.g., JPEG, MPEG or MP3 are already compressed) and before encryption (Energy Star, 2011). Between 15 and 40% of storage capacity can be saved by compressing data, depending on initial state (PrimeEnergyIT, 2011).

- **Tiering storage** - also referred to as Information Lifecycle Management or Hierarchical Storage Management - refers to the dynamically storage of data according to the relative demand for that data:
  - Low-priority data (rarely used, such as archival or “cold” data) can be stored on higher latency storage equipment that uses less energy;
  - High-priority data (to be expected in immediate demand) can be stored on low latency storage equipment that consumes more energy (Energy Star, 2011).

Applications called automated tiering have been developed in order to perform such work automatically (Hitachi, 2013).

A storage capacity planning and monitoring solution may facilitate the identification of inefficiencies and enables the implementation of the techniques described above.

Storage virtualisation refers to different techniques of mapping from physical location to virtual location. Storage virtualisation does not provide directly energy savings, since it does not allow reduction in dataset size or does not ensure the utilisation of

\(^{33}\) E.g.: not wasting a large amount of the capacity in order to perform deduplication.
energy efficient servers (SNIA, 2012). However, storage virtualisation is needed for using some energy-efficient technologies, such as:

- **Thin provisioning** enables more efficient disk space utilisation by centrally allocating space only as applications require the space (and not before there is data to store). Such technology avoids over-allocation of storage capacities based on anticipated storage requirements implemented because applications would suffer performance issues if storage capacities were exceeded. Space utilisation savings from thin provisioning have been estimated at between 20 to 50% (PrimeEnergyIT, 2011).

- **Snapshots** refer to a form of deduplication that creates temporary “copies” of data that only include data changes, instead of using additional space for complete copies of live data (Energy Star, 2011).

- **RAID** (or redundant array of independent disks) combines multiple disk drive components into a single logical unit and require less capacity than for mirroring (SNIA, 2012). While mirroring (or RAID 1) doubles storage consumption by creating a duplicate copy of each storage disc for back-up, RAID 5 requires only one extra redundant disc in a RAID set to prevent data loss from a single disc failure (RAID 6 can survive two discs failure).

Other techniques may be used for reducing energy consumption related to storage activities:

- Selecting energy efficient storage equipment, such as **Solid-State Discs** (SSD). SSD intend to offer the highest Input/Output Operations Per Second (IOPS) and to support high-performance application requirements (Hitachi, 2013). The majority of SSD use flash memory which consumes less energy than DRAM, since it does not consume energy at rest-state (SNIA, 2012).

- 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).

**Servers’ consolidation**

Performing an audit the IT services and analysing IT reported data (when useful indicators are monitored, as server and network utilisation for example) is an essential preliminary step before implementing a consolidating strategy. The inventory should focus on (Uddin and Rahman, 2010):

- Identifying server resources (type of processors, memory size, network type, local storage, operating system, etc.);

- Categorising server resources (network infrastructure servers, application servers, web servers, database servers, etc.);

- Categorising application resources (custom applications, mission critical applications, support to business applications, etc.),

- Allocating computing resources required by these different workloads.

Such work may allow the identification of:

- IT services which do not achieve high utilisation of their hardware. Such IT services may be consolidated, through the use of resource sharing technologies improving the use of physical resources.

- IT services which are not used on a regular basis, and which can be virtualised or archived, and be brought online or on low power media.
IT services with a low business value and servers with no use still running - comatose servers typically represent about 10 to 30 % of servers (Energy Star, 2011). They may be decommissioned or removed to locations with a lower reliability or resilience level (and which use less energy).

These techniques enable the use of fewer servers or at least fewer highly-performant servers, thus decreasing electricity consumption and waste heat (PrimeEnergyIT, 2013).

Decommissioning of unused servers requires the definition of baseline utilisation, so that unused servers can then be identified; for example, if a server received only network activity from the backup server, domain controller and antivirus server, it can be considered as unused (Energy Star, 2011). Then examining CPU utilisation of each server through a Data Centre Infrastructure Management (DCIM) may allow identifying unused servers. Before removing definitively unused servers, they can be turned off for a limited time, in case a user came out for requiring the server to be turned on again.

Server consolidation refers to techniques that intend to reduce the total number of used servers by concentrating applications on fewer devices.

- **Combining applications** onto a single server (and onto a single operating system process) can consolidate two or three lightly used servers into a single one (Energy Star, 2011).
- **N+1 server clustering** technology requires only one backup server per cluster of server, while a system usually needs one backup server for each primary working server (Energy Star, 2011). If an application fails on one server, the application is automatically and instantly activated on another server within the cluster.
- **Downsizing the application portfolio**, by uninstalling redundant applications that are underutilised (Energy Star, 2011).
- **Virtualisation** refers to a method for running multiple independent virtual operating systems on a single device (US Department of Energy, 2011). It allows consolidation of applications from different operating systems and/or servers and reduction of the required number of physical servers by an increase of their utilisation rate. Consolidation factors through virtualisation can be of at least 10 to 20 (PrimeEnergyIT, 2011). Moreover idle power consumption of virtualised server is closed to zero and much lower than physical server idle consumption (Kommeri et. al., 2012) and energy consumption can be minimised at a given traffic load by launching the optimal number of virtual machines (Wen et. al., 2010).

Before implementing virtualisation, servers with specific restrictions (from a privacy, security or regulatory order) or with very high-level service requirements should be put away and servers with similar workloads should be grouped (Energy Star, 2011). Workloads with complementary characteristics should be combined (with applications run during business hours and others during peak off hours for example) up to the targeted utilisation level, as 50% or higher for many areas (PrimeEnergyIT, 2011). At the same time, required storage capacities, processor resources and cooling capacities should be adapted to the new architecture (Energy Star, 2011). Different technologies for server virtualisation may be chosen: hardware partitioning, which creates different instances of operating systems in the same physical device, virtualisation based on an underlying operating system or application virtualisation.
4.3.6 Applicability

Even if virtualisation is more frequently used in bigger data centres, this technique can also be implemented in smaller server rooms.

PrimeEnergyIT project (PrimeEnergyIT, 2011) identified several side effects of virtualisation, which can lead to difficulties while implementing such technique:

- Creation of hotspots within the server room, by changing load density and location;
- Lower stability of the system, because of changes dynamically operated by several operators without a centralised coordination;
- Creation of complex interdependencies between power, cooling and space capabilities, and difficult provisioning.

Consolidation of both storage devices and servers should avoid datasets or applications with security and privacy requirements or highly variable in terms of storage or workload capacities.

4.3.7 Economics

According to the Uptime Institute, decommissioning a single rack server can annually save 440€ in energy, 440€ in operating system licenses, and 1,320€ in hardware maintenance costs (Energy Star, 2011).

![Figure 51: Cost savings from decommissioning idle servers. Source: (Uptime Institute, 2014).](image)

The Uptime Institute annually organises a Server Roundup contest where participants have to decommission the higher number of existing servers. The 2013 winners were:

- Barclay’s, which decommissioned 9 124 servers, resulting in savings of $4.5M in power costs and €1M in legacy hardware maintenance costs.
- Sun Life Financial, which decommissioned 441 servers, resulting in savings of 88,000€ in power costs.

Specifically, the judicious use of a small amount of solid-state can “take the performance strain” as needed and. For example, it can involve the use of fewer high-
performance HDD spindles, which then leads to OPEX and CAPEX savings and less of a need for active management.

**Economic data related to virtualisation and energy-efficient data storage management**
(costs of software, avoided costs...)

### 4.3.8 Driving force for implementation

As shown on the paragraph above, consolidation leads to cost savings from lower power consumption, less cooling, less maintenance and fewer operating system licences. Consolidation also leads to reduction of IT equipment numbers and space requirements. Benefits from consolidation largely exceed costs related to software purchasing. Economics represent the major reason for implementing consolidation.

Virtualisation techniques offer a number of advantages for the data centre management (Energy Star, 2011), by:
- improving flexibility;
- reducing downtime, because of a higher availability and disaster recovery solutions (Energy Star, 2011);
- enabling faster deployments (PrimeEnergyIT, 2013) due to an optimisation of the test and development phase (reuse of pre-configured systems, standardised environments, etc.).

### 4.3.9 Reference organisations

Intel (Green Software)
Oracle (Green Software)

To be developed

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4.4 Efficient cooling technologies and systems

**SUMMARY OVERVIEW:**
When designing a data centre cooling system, the most energy-efficient technologies (such as free cooling and water cooling) should be selected and then deployed by using the most appropriate equipment and settings (variable fans, chilled water with an increased temperature, etc.).

### ICT components

<table>
<thead>
<tr>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
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### Relevant lifecycle stages

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

### Main environmental benefits

- **Energy consumption**
- **Waste production**
- **Air emissions**
- **Water use & consumption**
- **Noise and electromagnetic radiations**
- **Landscape and biodiversity**

### Environmental indicators

- Energy efficiency of cooling systems = average cooling system power (kW) / average cooling load (kW)
- Power Usage Efficiency (PUE) = total power to run the data centre facility / total power drawn by all IT equipment.
- Data Centre Infrastructure Efficiency (DCIE) = 1 / PUE
- Water Usage Effectiveness (WUE) = annual site water consumption / IT equipment consumption of energy
- % of practices from the Code of Conduct for Data Centres implemented (parts 5.2, 5.4 & 5.5)
- Free cooling utilisation (number of hours fluid-side economisers are used over a year)

### Benchmarks of excellence

Implementing practices of the EU Code of Conduct for Data Centres (parts 5.2, 5.4 and 5.5) with a value of 2 or more.

### Cross references

**Prerequisites**

**Related BEMPS**

- 4.2: Better locating and planning data centres
- 4.3: Optimizing data centre utilisation and management
- 4.5: Airflow management and design, and heat reuse
4.4.1 Description

Cooling is needed to ensure the right operating conditions for ICT equipment to perform reliably – some IT equipment can only function in a particular range of temperature and humidity (efficient humidity and temperature settings are described in section 4.5). 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.

![Diagram of cooling system](image)

Figure 52: Simplified chiller schematic - Simplify cooling (Source: (BCS, 2010))

Sizing the necessary cooling system of a data centre depends on the environment where is located the data centre (section 4.2), on the efficiency of IT equipment used in the data centre (section 4.3 and 4.4) and on the airflow management performance (section 4.5).

After implementing solutions for reducing the total cooling requirements for data centres (described in the previous BEMPs of this report part), a focus on cooling plant can be made. 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).

![Energy consumption chart](image)

Figure 53: The breakdown of energy consumption in a typical data centre (Source: Fujitsu [http://www.sustainability-perspectives.com/article/practical-methods-for-improving-ict-sustainability/])
Three main sections of the EU Code of Conduct on Data Centres\textsuperscript{34} refer to cooling technologies and systems.

**Table 7: Energy Efficiency Practices concerning data centre cooling technologies and systems (source: EU Code of Conduct for Data Centres - Version 6.1.1 (JRC, 2015))**

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<td>5.5.5 Do not control humidity at CRAC / CRAH unit</td>
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<td>5.5.6 Cooling unit sizing and selection</td>
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</tbody>
</table>

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

The first step when designing an energy efficiency cooling system relies on the selection of the more appropriate technology.

Free cooling designs use cool ambient conditions in order to remove heat from the compressor (Tschudi, 2013):

- Direct air free cooling uses external fresh air to cool the facility (after being filtered) if the indoor air quality must meet specific humidity and temperature requirements;
- Indirect air free cooling uses an air-to-air heat exchanger in order to remove heat produced by IT equipment to the atmosphere;
- Indirect water free cooling uses cooling coils (cooling towers, dry coolers, etc.) to cool chilled water by using external ambient conditions.

If ambient conditions do not allow the use of free cooling concepts all the time (depending on the difference between the outdoor and indoor temperature), and backup mechanical cooling or compressor should be used otherwise. These are called ‘economised cooling systems’, which use ‘free cooling’ a part of the year. Cooling designs should allow the use of ‘free cooling’ as much as possible.

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.

When building a new data centre or renovating an older one, and after selecting the main technology, the cooling system should be conceived in a way of optimising energy efficiency:

- At a cooling plant level, by:
  - Selecting chillers with high Coefficient Of Performance (COP);
  - Installing the cooling plant in a modular arrangement allowing the shutting down of unused cooling equipment;
  - Creating a thermal storage, where chilled water is used for later use.
- At a computer room air conditioner or handler level, by:
o Selecting cooling units sized to the IT equipment and shutting down unnecessary cooling equipment;
o Installing fans with variable speed control in order to facilitate airflow and temperature management;
o Installing a centralised humidity control (through the humidity of fresh air coming into the building) instead of humidifiers controlled at computer room level.

4.4.2 Achieved environmental benefits

Improving the energy efficiency of the cooling system is expected to primarily reduce direct energy consumption of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply35.

- 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 minimize the load on the primary cooling system or entirely stop the need for the chiller or compressor.

- Quantitative data about energy savings due to water source cooling or direct liquid cooling

Besides energy savings, efficient cooling technologies and systems can also reduce other environmental pressures:

- Direct water consumption, related to the use of evaporative cooled chillers which use the evaporation of water as a heat rejection mechanism. Freshwater usage is a concern (particularly in dry areas) and the amount of sediment in a given volume increases as vapor is removed, requiring separation and disposal of this "blowdown." Some data centres have implemented techniques for using non-utility water sources cooling or other non-potable purposes: rainwater, wastewater or seawater have already been used. Quantitative data are missing

- Direct greenhouse gases emissions, via refrigerator gases leakages from condensers. The use of synthetic chlorofluorocarbon (CFC) refrigerant gases in cooling plants resulted in significant impacts to the ozone layer. These gases were substituted by hydrofluorocarbons (HFC) which are now being targeted for replacement due to their high contribution to global warming. Free cooling concepts lead to the non-utilisation of refrigerants with a large Global Warming-Potential (e.g. R410A has a GWP of 1.725). Quantitative data are missing

4.4.3 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).

35 Energy production and transmission generates huge pressure on environment: greenhouse gases emission (related to fossil-fuel burning), water consumption (for running steam-turbine of fossil-fuel and nuclear plant), natural resources consumption (fossil fuels, wood, etc.) or landscape disturbance (plants, electrical lines, etc.).
The most common metric used to measure the efficiency of cooling systems is the **coefficient of performance** or COP (sometimes CP): \[ \text{average cooling load (kW)} / \text{average cooling system power (kW)} \] (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.

Moreover, specific indicators that are usually followed by data centre operators, give a good overview of the energy-efficiency of the cooling system since cooling energy represents an important part of energy consumed in data centres. The **Power Usage Efficiency (PUE)**\(^{36}\) 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 **Data Centre Infrastructure Efficiency (DCiE)** is defined as the inverse of the PUE.

![Figure 55: Definition of the Power Usage Efficiency (PUE) of a data centre (Source: (Rasmussen, 2011))](image)

Following the same approach, The Green Grid Association developed similar indicators relevant for measuring and comparing environmental performance of data centres:

- The **Carbon Usage Effectiveness (CUE)** is the total CO\(_2\) emissions caused by the data centre consumption of energy / IT equipment consumption of energy;\(^{37}\)
- The **Water Usage Effectiveness (WUE)** is the annual site water consumption (humidification and water consumption for cooling) / IT equipment consumption of energy.\(^{38}\)

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

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\(^{36}\) The PUE is an end-user metric developed by the *The Green Grid Association*. For more information, see: http://www.thegreengrid.org/~/media/WhitePapers/WP49-PUE%20A%20Comprehensive%20Examination%20of%20the%20Metric_v6.pdf?lang=en


\(^{38}\) For more information about the WUE: http://www.thegreengrid.org/~/media/WhitePapers/WUE
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- Free cooling utilisation, which is the number of hours of utilisation of the fluid-side economiser over a year (h);
- The share of practices from the Code of Conduct for Data Centres (parts 5.2, 5.4 & 5.5) implemented (%).

4.4.4 Cross-media effects

Energy consumption and second-order environmental pressures (water consumption and GHG emissions) are intimately linked through the different measures described into this section.

- If ambient outdoor air is non-appropriate (e.g. in case of moist climate, forest fire, etc.) when a direct air-side economiser is functioning, that can lead to an indoor air contamination or humidification / drying and affect IT equipment. Humidifiers can be used for maintaining an optimal humidity range but consume energy.
- Evaporative cooled chillers allow huge energy savings (see section 4.5.1.), but require water. The National Renewable Energy Laboratory estimates that on-site evaporative cooling consumes 7.6 M litres per MW year.39

If the renovation of an existing data centre reduces direct energy consumption, replacing equipment could lead to:

- Acquiring new electrical and electronic equipment, which means increasing the consumption of raw materials (rare earths, plastics, glass, metals, etc.), and embodied energy;
- Generation of more waste of electronic and electrical equipment, including hazardous waste which can lead to water and soil pollution, if not treated properly.

For each technique, all the environmental benefits and pressures must be identified and quantified, in order to allow a global view on environmental performance.

4.4.5 Operational data

According to the different techniques identified in section 4.5.1., the corresponding details for implementation and operational data are given.

Centralised air handling

In a centralised air handling system, cooling is made by blowing air over a cooling coil filled with chilled water typically supplied by a chilled water plant (i.e. chiller).

A specifically-designed central air handler system is much more efficient than a multiple distributed unit system (Computer Room Air Conditioners) since:

- it uses larger motors and fans, more energy-efficient than smaller ones;
- it is more suitable for the use of Variable Speed Drives (or VSDs) on fans, improving the fans efficiency when under loaded;
- it allows redundancy to be implemented in a manner that increases normal operating system efficiency;
- it prevents simultaneous humidifying and dehumidifying by using centralised controls;
- it facilitates air management (see section 4.5.) and free cooling (installation of an air-side economiser).

39 More information is available at: http://www.nrel.gov/docs/fy13osti/58902.pdf
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 outside-air lower temperature. The two main technologies are air economizers and fluid economizers.

Air economizers can provide "free" cooling by introducing the outside air for complete or partial cooling of the data room. When outside conditions are suitable for the use of air-economizers, the need for an air conditioning system is reduced or eliminated and energy used by compressors or cooling towers is saved. Such direct outside-air cooling may be supplemented by compressor-based cooling when free cooling cannot be provided (due to temperature or environmental conditions). In very cold conditions the incoming air may be mixed with some of the heated air extracted from the data centre.

Data centres require clean air with a specific relative humidity (the optimal relative humidity range is between 40 and 55 percent (Emerson, 2007)). Thus, outside air must be filtered before entering the data centre, and humidified if necessary:

- "Dry air" economisers can only be used in few geographic locations due to contamination and humidity issues: using humidifiers for correcting the humidity of the server room consumes important amount of energy and mitigates the energy savings from not chilling or compressing.
- "Evaporatively conditioned" air systems are effective for transforming the incoming air into the desired conditions before entering the data centre but present reliability issues (mildew concerns and high maintenance requirements).
The use of air-side economizers should be preceded with an engineering evaluation of the local climate and contamination conditions. They can be installed into rooftop air handlers or mixing boxes mounted on each CRAH unit.

Fluid economisers can be used in a wider range of climates since they allow a better control of humidity and contaminants and require less maintenance. In fact, outside air does not enter the data centre, and so does not require humidification and does not bring contaminants (gases, dust, pollen, etc.).

A fluid economiser system can be incorporated into a chilled water or glycol-based cooling system. Outside air is used to cool the fluid (water or glycol) in an open cooling tower or dry coolers, minimizing 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.
Indirect fluid economisers can be installed in two main configurations:

- While using a parallel configuration, the cooling loop is isolated from the chiller and provides the entire cooling load when outside conditions are suitable or is shut down (and the chiller takes over).
- With a series configuration, fluid economisers are able to share the load with the chiller or compressor. Then, they can be used at warmer conditions than parallel economisers and can provide free cooling during a longer time during the year.

**Using water source cooling**

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

Direct liquid cooling is far more efficient than air cooling: water has a significant higher heat capacity than air; water pumps are much more energy-efficient than air fans; and the separation of cool and warm flows is easier.

There are many variations of direct liquid cooling solutions. They all deliver liquid at or very near the point heat is generated (directly into IT equipment or at the row or rack level), rather than conditioning the server room. Two main approaches can be identified:

- Water cooled racks use chilled water coils integrated into the racks and coolant lines than can be installed underfloor.
- Liquid immersion cooling where IT components are immersed in sinks filled with a dielectric fluid cooled via a heat exchanger.

Such technologies are much more efficient than air-cooling system: they can serve higher heat densities and use warmer chilled water (13°-15°C compared to 6°-7°C (PG&E, 2012)). Since, 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).
4.4.6 Applicability

Free cooling can only be used when the temperature level of the return flow of the cooling system must be above the outside temperature. Then, the location of the data centre is a fundamental factor concerning the feasibility and the performance of the free cooling system, so is the temperature and humidity range of IT equipment. Few years ago free cooling was said best suited for climates with wet bulb temperatures lower than 13°C for 3,000 or more hours per year. Following the update of temperature and humidity ranges for data centres defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), free air-cooling is expected to be used all year in 99 percent of Europe (too hot areas in North-western Spain and in Sicily, and one too humid area in South-Western Ireland are excluded) (The Green Grid Association, 2011).

Alternative cooling systems such as liquid cooling or free-air cooling are most easily implemented in new data centres. Implementing such solutions in existing data centres requires investigations related to the geographical location and design of the data centre and to the existing data centre (type of cooling system). For example, an air-side economiser can only be installed if the data centre has access to an exterior wall or roof and moving from computer room air conditioners (CRACs) to a centralised air handling system may spare space in the server room since air handlers can be installed outside the data centre (on the roof for example). A year-round cooling load must be available – at least, it would improve the economic feasibility of the measures.

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

The costs of installing the cooling technologies described before depend on the size of the data centre (and so its cooling requirements), if the operation is a construction of a new data centre or the renovation of an older one, etc.

Technology providers have created models to evaluate the economic feasibility of implementing such solutions.

- Adding a fluid economiser (series configuration) and optimising parameter settings (variable fans, warmer water) increases the capital cost of the installation by 10%, but reduces the floor space occupation and the energy consumption (by 39%). Thus the total cost of ownership (TCO) is reduced by an average of 18% (Emerson, 2007).
- Adding an air-side economiser increases the capital cost of the installation by 13%, but reduces the floor space occupation and the energy consumption (by 42%). Thus the total cost of ownership (TCO) is reduced by an average of 22% (Emerson, 2007).

The PrimeEnergyIT Project supported by the Intelligent Energy Europe Programme (PrimeEnergyIT, 2012) produced case studies about implementing different free cooling solutions. This project concluded in most of the cases to amortisation period of 1 year when upgrading existing data centres with such technology.

Economic data about water source cooling and direct liquid cooling to be found

4.4.8 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 best environmental management practice related to cooling technology and systems. Implementing such solutions (free cooling, centralised air handling system, etc.) will result in electricity consumption savings, but also in the reduction of the floor space occupied by the conditioning system.

Another important driver can be the legislation, since it increasingly prohibits the removal of water for cooling purposes from surface waters.

Finally, the maintenance remains an important issue when selecting a new cooling technology, since some solutions may require specific conditions (high pressure, protection against fire, etc.) and additional equipment (filters, humidifiers, etc.).

4.4.9 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)

**To be developed**

### 4.4.10 Chapter references


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4.5 Air flow and settings management, and reuse of heat

**SUMMARY OVERVIEW:**
An energy-efficient airflow management relies on separating hot airflows from cold airflows (hot aisle / cold aisle layout, airflows containment, equipment segregation, etc.), on adjusting air parameters (temperature, humidity, etc.) and on reusing waste heat.

<table>
<thead>
<tr>
<th>ICT components</th>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
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| Main environmental benefits | Energy consumption | Waste production | Air emissions | Water use & consumption | Noise and electromagnetic radiations | Landscape and biodiversity |

- Energy Reuse Effectiveness (ERE)
- Airflow Efficiency (W/m3/hr)
- Return Temperature Index (RTI)
- Flow performance
- Thermal performance
- Rack Cooling Index (RCI)
- % of practices from the Code of Conduct for Data Centres implemented (parts 5.1, 5.3 & 5.6)

**Environmental indicators**

An RCI of 100% represents ideal conditions for the equipment; while an RCI < 90% is often considered to portray poor conditions (US Department of Energy, 2011).

Implementing practices of the EU Code of Conduct for Data Centres (parts 5.1, 5.3 and 5.6) with a value of 2 or more.

**Cross references**

| Prerequisites | 4.2: Better locating and planning data centres
|--------------|----------------------------------------------------------------------------------------------------------------------------------|
| Related BEMPS | 4.3: Optimizing data centre utilisation and management
|              | 4.4: Efficient cooling technologies and systems

**4.5.1 Description**
The reliability of electronics and electrical systems relies on environment conditions, such as temperature, humidity (to prevent electrostatic discharge and condensation inside servers) or cleanliness (to prevent contamination). The production of heat loads by data centre equipment and the influence of outdoor conditions (sunshine exposure, use of outdoor air for cooling, etc.) affect these parameters. In order to meet the equipment specifications, the inside air quality must be controlled: heated air should
be removed and cooled air brought, incoming air should be filtered and inside air humidity should be managed (by humidifying or dehumidifying).

The air flow and settings management intends to maintain the data centre operating environmental envelope and to optimize the functioning of cooling system, humidifiers and filters. It will depend:

- on the data centre architecture, including layout and arrangement (see BEMP 4.2: Better locating and planning data centres);
- on the existing IT equipment performance, and especially on the number and the utilisation rate of devices (see BEMP 4.3: Optimizing data centre utilisation and management through the operating system and virtualization of IT services);
- on the cooling system, and particularly the use of an air-side economiser or not (see BEMP 4.5: Efficient cooling technologies and systems).

Poor air flow management will reduce both the efficiency and capacity of cooling equipment, increase fans and humidifiers utilisation, and generate waste heat.

Three main sections of the EU Code of Conduct on Data Centres refer to air flow management and design.

Table 8: Energy Efficiency Practices concerning data centre airflow management and design (source: EU Code of Conduct for Data Centres - Version 6.1.1 (JRC, 2015))

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Airflow management for data centres includes the design of data centres and the configuration of equipment to minimise or eliminate the mixing of cooling air supplied and the hot air rejected from equipment. Airflow management aims to continuously

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supply only the necessary amount of cold air for removing the heat created by IT equipment: the entire volume of air has to circulate only one time through IT equipment and has to absorb heat.

The design of the data centre, and especially the arrangement of the IT equipment, will condition the success of airflow management:

- Configuring a hot and cold aisles layout ensures that hardware shares an air flow direction without mixing cold and hot air;
- 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 by;
- Avoiding airflow obstructions that can be created by cabling and other structures placed in the airflow paths (by using overhead cabling for example);
- Segregating IT equipment according to their environmental requirement (mainly humidity and temperature) is necessary to provide appropriate airflows to separate areas;
- Separating the data centre’s cooling system from the comfort cooling system. This avoids the cooling system set points to be dictated by non IT equipment.41

When IT equipment is operating, the volumes and parameters of supplied cooled air have to be adjusted (by installing and using real-time metering) 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;
- The intake air temperature of IT equipment should be reviewed and raised if possible;
- The working humidity range of IT equipment should be reviewed and widened if possible in order to reduce the demand for humidification and the humidifiers load (in accordance with recommended environmental conditions).
- Adiabatic humidifiers and evaporative cooling are efficient systems since they produce both cooling and humidity.

Heat produced by IT equipment can also 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.).

### 4.5.2 Achieved environmental benefits

Improving the energy efficiency related to airflow and setting management is expected to primarily reduce direct energy consumption of data centres (direct pressure), and by consequence mitigate indirect environmental pressures related to energy supply.42

42 Data Center Solutions has estimated the energy savings43 related to several of the previous best environmental management practices identified above:

41 The use of waste heat from the data centre can however be used to heat other spaces.

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

Blanking panel installation, which aims at improving air flow through the IT equipment and avoiding inefficient airflow around, can reduce energy consumption by 1-2%.

Floor plenum management intends to avoid air flow obstructions, and can reduce energy consumption by 1-6%.

Floor layout planning in a hot/cold aisles arrangement can reduce energy consumption by 5-15%.

Aisle containment systems increase the efficiency of the hot/cold aisles arrangement, and can drop energy consumption by 5-10%.

Raising server inlet temperature reduces energy consumption up to a certain point (due to a reduction of cooling need) then fan power increasing consumption gain the upper hand. Since, energy savings related to changes in inlet temperature will depend on the initial inlet temperature (how far from the optimal temperature) and on the equipment own characteristics (Moss & Bean, 2013).

A reduction of 10% in fan speed reduces that fan's use of electricity by approximately 25%. A 20% speed reduction yields electrical savings of roughly 45%.

Energy savings from widening humidity settings and optimising the volume of supplied cooled air: to be identified

Using adiabatic humidifiers can provide important energy savings, since this technology does not raise water temperature (comparing to alternative systems that boil water in a reservoir for instance) and provides cooling simultaneously. Among the adiabatic humidifiers, ultrasonic humidifiers are proven to reduce by 90-93% the energy consumption related to humidification and to require a lower water use (compared to electrode type humidifiers)\(^4\).

Implementing a solution of heat reuse reduces the waste of heat and the net energy consumption.

### 4.5.3 Appropriate environmental performance indicators

An indicator, derived from the PUE (Power Usage Effectiveness), offers a global overview of the data centre energy efficiency while taking account the heat reused:

**Energy Reuse Effectiveness** (ERE) is defined as the ratio between the total facility energy (kWh) minus the reuse energy (kWh), and the IT Equipment Power (kWh).

Specific metrics have been developed:

- **Air flow Efficiency** is defined by the Lawrence Berkeley National Laboratory as the total fan power (W) divided by the total fan air flow (m\(^3\)/hr). This metric measures how efficiently air is moved through the data centre (depending on fan system efficiency, low pressure drop design, etc.).

- **Return Temperature Index** (RTI) has been defined by the Lawrence Berkeley National Laboratory in two ways:
  - The ratio (in percentage) between the air handler temperature drop (C\(^°\)) and the IT equipment temperature rise (C\(^°\)), airflow weighted;

The ratio (in percentage) between the total airflow rate through the air-handler (m$^3$/h) and the total airflow rate through the IT-equipment (in m$^3$/h).

An RTI of 100% should be the target goal for an efficient air management system, since a RTI over 100% suggests recirculation of air (creation of “hot spots” which increase the return air temperature) and a RTI less than 100% indicates by-pass of air (the cold air does not contribute to cooling the electronic equipment and returns directly to the air handler).

- **Flow performance** is defined$^{45}$ as the air handler temperature drop ($^\circ$C) divided by the difference between the server outlet temperature and the discharge air temperature from the air handler ($^\circ$C). This metric indicates how much cooled air is really used to cool the IT equipment.

- **Thermal performance** is defined$^{46}$ as the IT equipment temperature rise ($^\circ$C) divided by the difference between the server outlet temperature and the discharge air temperature from the air handler ($^\circ$C). This metric indicates how much of the air used by the IT equipment really comes from the cooling system.

- **Rack Cooling Index** is defined by the ASHRAE as the difference between the allowable and recommended intake temperatures from the ASHRAE guidelines, with the RCI$_{HI}$ as a maximum and the RCI$_{LOW}$ as a minimum. The RCI measures how effectively equipment racks are cooled according to equipment intake temperature guide-lines established by ASHRAE.

### 4.5.4 Cross-media effects

Raising operational temperatures in a data centre for an energy efficiency purpose can only be done up to a certain point since (The Green Grid, 2013);

- **The server power utilisation increases** above a certain temperature (roughly 25 $^\circ$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 more important amount of air need at higher operating temperatures;

- **The exhaust air temperature can be inadequate** for operational working practices within hot aisles (the temperature can reach 50°C);

- **The relative server failure rate slightly increases** with temperature, and so the lifetime of the IT equipment reduces. At higher operating temperatures the IT equipment should be replaced more often, and the consumption related to manufacturing (raw materials, embodied energy, water, etc.) and the WEEE production would be more important.

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For each technique, all the environmental benefits and pressures must be identified and quantified, in order to allow a global view on environmental performance.

**4.5.5 Operational data**

According to the different techniques identified in section 4.5.1., the corresponding details for implementation and operational data are given.

**Implement cable management**

The distribution of cooling air can suffer from interferences under-floor (cable congestion in raised-floor plenums for example) or over-head. This can significantly reduce the airflow and promote the development of hotspots.

A cable management strategy aims at minimising air flow obstructions. It should target the entire cooling air flow path and insure a 60 cm clear height within raised floor. The following actions can be implemented: using overhead cabling, removing abandoned or inoperable cables, etc. (U.S. Department of Energy, 2011).

**Hot aisles / cold aisles arrangement**

This technique intends to optimise supply and return air configuration, by ensuring that cold and hot air do not mix. In such an arrangement, the IT equipment is laid out in parallel rows of racks with alternating cold (rack air intake side) and hot (rack air heat exhaust side) aisles between them. Racks are located in a perpendicular way to the aisles and IT equipment with non-standard exhaust directions must be addressed in some way (shrouds, ducts, etc.). An air flow, with the same direction and coming from the cold aisle, is passing through each rack and is exhausted into the hot aisle behind the rack, as shown on the figure below.
Both overhead and under-floor air distribution systems can be used in a hot aisle / cold aisle configuration (U.S. Department of Energy, 2011).

- With an overhead air distribution system, supply outlets should be used (instead of traditional office diffusers) and located in front of racks (above the cold aisle), while return grilles or open ducts can be used for air return.

- With an under-floor air distribution system, because the under-floor plenum is used as a duct, attention should be paid at avoiding obstructions (see the technique of cable management above), at preventing by-pass and negative pressure air flows (see the technique below), and at correctly guiding supply air flows (by installing well vented tiles).

In order to better control the volume of air supplied, the temperature monitoring should be located in front of the computer equipment and variable speed fans should be used (in order to be able to provide optimised air flow at part-load conditions).

**Aisle separation and containment**

The following techniques will help containing volumes of air with a different temperature and reducing the circulation of air around the servers (U.S. Department of Energy, 2011), and so reinforcing the energy efficiency of a hot aisle / cold aisle arrangement.

- Blanking panel should be installed on the intake side of the rack, where there are vacant equipment slots, in order to block off existing holes through the rack and to reduce air recirculation;

- Cover plates should cover floor or ceiling openings (grommets can be used for sealing cable openings) in order to avoid by-pass and negative pressure flows;

- Enclosing panels should be installed in a way to isolate cold aisles, hot aisles or both from the data centre room (see figure below), and to mitigate “short-circuiting” (the mixing of hot and cold air).
Since the supply air volume is dramatically reduced, fan speeds and cold supply can be reduced, and so as the energy consumption related to fans and chiller. Higher return temperatures extend the use of an air-side economiser and facilitate the use of the exhaust air as a heat source. Moreover, higher IT equipment densities are also better supported by this configuration.

Beyond the containment of hot and cold aisles, IT equipment should be segregated according to their environmental requirement. Such a configuration will allow providing appropriate air flows (in terms of humidity and temperature mainly) to separate areas in the data centre room. The comfort cooling system (providing cooling for offices or technical areas) should be separate from data centre’s cooling system: only IT equipment should define the set points of the cooling systems, in order to optimise cooling performances.

**Metering temperature and raising temperature set points**

The whole Heating, Ventilation and Air-Conditioning unit should use the server intake temperature as the set point temperature (and not the return air temperature entering the CRAC/CRAH for cooling). However thermal sensors should also be installed in other locations (supply and return temperature at CRAC/CRAH level, chilled water temperature, etc.) in order to evaluate the thermal performance of the cooling system. Wireless sensor network solutions have the advantage to be quickly deployed and easily adapted to IT equipment changes in the data centre. A centralised control system can avoid competition between the different units forming the cooling system.

The temperature set points should meet IT equipment needs, depending on heat produced and environmental requirements. The standardised operating environments for different types of equipment are set forth by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). These specifications give the optimal temperature and humidity set points for standard equipment, regarding its operational performances (reliability, energy consumption...). The last set of values published by the ASHRAE in 2011 is given on the figure below (class A1 refers to enterprise servers and some storage products, while class A2 refers to volume servers and workstations in an IT space, etc.). The 2011 specifications confirm the widening of recommended and allowable values given by the ASHRAE (compared to the 2004 and 2008 sets of values).

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47 The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) signed a memorandum of understanding in order to strive to harmonize international standards with the ASHRAE. We assumed that the operating environment parameters were similar.
Figure 65: ASHRAE environmental classes for data centres (ASHRAE, 2011)

Usually, facilities are overcooled, and the server intake IT equipment can be raised within the recommended or allowable temperature ranges. Such increase of inlet temperature should be performed gradually (careful metering of potential or existing hot spots) and take into account manufacturer specifications. These changes can reduce the capacity of the cooling system needed (and so the size and / or the number of units) and the energy consumption related to cooling supply and fan speed. The use of an air-side or a water-side economiser can be facilitated by increasing the number of potential hours of free cooling.

**Metering and widening humidity settings**

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

Further energy savings can be reached (PG&E, 2012) by:

- Switching from a standard humidifying system (most often integrated into a CRAC/CRAH unit) to an adiabatic humidifier or to an evaporative cooling system, which will be able to humidify and cool at the same time;
- Centralising the humidity control by using a centralised signal which will coordinate all the units in a same room to be in the same mode (humidification or dehumidification) and avoid competitions (one unit is dehumidifying and one other is humidifying).
Adjusting volumes and quality of supplied cooled air

Real-time metering should be installed throughout the data centre in order to monitor IT equipment power usage and intake temperature, and pressures at different locations of the data centre room: racks (by-pass air flow and recirculation air flow percentage), raised-floors (pressure differentials within plenums) and CRAC/CRAH (air flow supply). With such measurements fan speed can be adjusted (if multiple speeds fans are used), in order to produce a slight oversupply of air compared to the IT equipment flow demand, in order to minimise heated air recirculation (JRC, 2015).

The air quality inside the data centre and in the surrounding areas should also be monitored to identify particulates or gaseous contaminations (due to industries, forest fires, etc.) which could damage IT equipment. A mitigation strategy may involve filtration, which increases the fan power required.

Heat reuse

Heat produced by IT equipment can also be reused, by installing a heat recovery system. A heat exchanger may be used for removing heat from the data centre and for heating water which can be then sent to buildings which need to be warmed (offices, industrial buildings, swimming pools, etc.).

![Figure 66: Heat recovery system implemented into an Intel data centre (source: http://www.intel.com/content/dam/doc/performance-brief/intel-it-data-center-heat-recovery-helps-create-green-facility-brief.pdf)](image)

4.5.6 Applicability

Implementing a cable management strategy, designing a hot aisle / cold aisle layout or establishing containments and separations are energy saving solutions that can be adopted in a majority of data centres (Energy Star). However, retrofitting an existing data centre layout may have significant costs and designing an appropriate airflow management may require a professional expertise.
Raising set point temperature or widening humidity range of servers can only be done within the operational specification given by the server manufacturer and within acceptable working conditions (depending on containments and separations implemented). Increasing the intake air temperature of servers will have more impact on the energy consumption of data centres using air-side economisers (more hours of free-cooling are available) or variable speed fans (a reduced speed fan for CRACs can be used) (Energy Star).

Ultrasonic humidifiers should only be used with de-ionized water (Energy Star).

### 4.5.7 Economics

PG&E estimated hot aisle / cold aisle retrofits to have a ROI greater than two years, whereas aisles containments are supposed to have a ROI inferior to two years (Energy Star).

Similar information for other techniques (cable management, metering temperature...) to be found

Intel developed a heat recovery system into a data centre (the heat is used inside the same building), with an estimated ROI of 1.7 months. Projects aiming at reusing the heat produced by the data centre in another location may show a much longer ROI.

### 4.5.8 Driving force for implementation

The main driving forces for implementing an air flow management system are (PG&E, 2012):

- costs reductions, due to energy savings (operating costs) and reduction in cooling capacity (in case of first investment);
- higher rack density capacities;
- heat related processing interruptions or failures reduction.

To be developed

### 4.5.9 Reference organisations

Qarnot Consulting (heat reuse)
Dalkia (heat reuse)
ATOS (heat reuse)
IBM (heat reuse)

To be developed

### 4.5.10 Chapter references


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5 BEMP to improve the energy performance and minimising the environmental impacts of ICT equipment

5.1 Introduction / scope
This section focuses on ICT equipment, devices and peripherals used by telecommunication and IT companies, such as:

- Data centre equipment (servers, cooling equipment, uninterruptible power supplies, etc.)
- Network equipment (antennas, switching systems, etc.)
- Personal computers (desktop and laptop);
- Mobile devices (smartphones, mobile, tablets, etc.);
- Other peripherals (monitors, scanners, copiers, fax machines, etc.).

Such ICT equipment is intensively used in the Telecommunications and ICT Services sector, but is also widely used in other sectors. In the European Union, 17 TWh are annually consumed by ICT equipment used in offices (business and administration) (Öko Institute, 2013).

Energy efficiency measures related to ICT equipment used at home (TVs, home routers, set top boxes, games consoles, etc.) are not included in the scope of this BEMP. A BEMP related to the selection of routers and set-top boxes that are supplied by telecommunication and broadcasting companies is described in the section 9, due to its influence on other sectors energy consumption.

Energy consumption of ICT equipment depends on two main factors:

- Energy requirements, or the energy required to run the equipment;
- Usage pattern, or the way the equipment is used (duration, activity, load, etc.).

The total energy consumption of ICT equipment in a company is a function of:

- the number of ICT equipment turned on;
- the type of ICT equipment, since laptops have on average a lower power consumption than desktops (Menezes A. e., 2014), LCD monitors require less energy than CRT monitors (Brat, 2006), the larger the screen is, the higher the power consumption is, etc.;
- the energy performance of the ICT equipment, the energy performance of ICT equipment is continuously increasing (Aebischer and Hilty, 2014) and depend on product ranges and individual models;
- use patterns, or the amount of time the devices are on modes active, low or off.

Two main categories of measures may be implemented in order to improve the sustainability of ICT equipment and will be developed in the following detailed BEMP:

1. Using more sustainable ICT equipment: procurement of energy efficient models and more environmentally-friendly equipment, replacement of desktop computers with laptops, installation of switches that enables or disables the power supply,

2. Changing how ICT equipment is used: installation of software solutions, training of teams, implementation of standby and switch off processes, etc.), which is harder to implement and requires more time.
Other techniques related to server virtualisation and consolidation or data management are described in the section focusing on data centres (section 4.3).

## 5.2 Procurement for sustainable ICT equipment

### SUMMARY OVERVIEW:
Assessing the needs and purchasing ICT equipment in a way of prioritising the use of labelled, mobile, shared, multifunction and appropriately sized equipment to reach energy saving.

<table>
<thead>
<tr>
<th>ICT components</th>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant lifecycle stages</td>
<td>Design and installation</td>
<td>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>Main environmental benefits</td>
<td>Energy consumption</td>
<td>Waste production</td>
<td>Air emissions</td>
<td>Water use &amp; consumption</td>
<td>Noise and electromagnetic radiations</td>
</tr>
</tbody>
</table>

### Environmental indicators
Computers, multifunction devices:
- Power consumption in different mode usage: idle, sleep, active mode
- Share of ecolabelled products
- Amount of chemicals and hazardous substances used

### Benchmarks of excellence
- All ICT equipment is ecolabelled (e.g. Energy Star, EU Ecolabel, Blue Angel, etc.) (if available) or EU Green Public Procurement criteria (if available) is applied in procurement,

### Cross references

#### Prerequisites
- Technical skills on ICT equipment, more particularly on data centres equipment such as cooling system and hardware components, to verify technical specifications
- Inventory of the existing ICT equipment installed

#### Related BEMPS
- 5.3: Improving the energy efficiency of desktop architecture
- 7.2: Improving waste prevention
- 7.3: Improving WEEE collection, recycling and recovery

### 5.2.1 Description
One of the most effective measures to improve energy efficiency is to use energy efficient ICT equipment. The degree of sharing and of multifunctionality (e.g. personal vs. shared printers, multifunctional devices vs. multi unifunctional devices, etc.), equipment model (e.g. desktop vs. notebook, CRT monitor vs. LCD monitor, etc.), component hardware (e.g. high-end Graphics Processing Units or video cards), and software applications affect the baseline amount of power that IT equipment consume. The degree of sharing and of multifunctionality of equipment used relate to the number of equipment needed to be effective.
ICT equipment energy consumption can be managed at different stages. It can be considered at the procurement level, upstream to the use of the equipment and during the use of the equipment. The BEMP on improving the energy efficiency of desktop equipment in use is covered in section 5.3.

The definition of a sustainable procurement policy is the first step to achieve energy-efficiency in ICT equipment. On the one hand, the appropriate selection and installation of IT devices can provide significant long term energy and cost savings, and investing in new equipment instead of older ones may benefit from a short return on investment. On the other hand, purchasing new equipment (even with energy efficiency and functionality gains) reduces the product life and increases the production of Waste of Electrical and Electronic Equipment (WEEE). BEMP on WEEE management are addressed in Chapter 7.

Green procurement is a challenge in organisations and constitutes a key role between suppliers and buyers (European Commission, 2011).

The energy efficiency criteria can be considered at each level of the procurement policy:

- **Process preparation**: it covers the assessment of the existing fleet of ICT equipment and of the needs compared to the different equipment and new technologies available on the market. There are several opportunities for reducing energy consumption from an existing fleet of equipment. An audit of existing IT equipment can help identify:
  - unused equipment which can be completely decommissioned or removed;
  - idle equipment which can be powered down / put on standby or removed;
  - IT equipment with restrictive intake temperature which may be replaced with newer equipment or placed in an appropriate area (segregated from other equipment).
- **Call for tender**: it can include required environmental criteria to meet.
- **Bid evaluation**: environmental criteria must be checked.

The assessment of the needs, the usages and the market allows the selection of appropriate equipment such as:

- **Mobile devices** (laptops, tablets, mobile phones) rather than desktop computers and fixed landline phones. Such devices consume less energy due to a more-energy-efficient architecture, allowing for longer periods of operation disconnected from the electrical network.
- **Computers with appropriately sized options** that meet the needs of the users. For example “mini computers” can be purchased if performance needs are relatively basics (email, word processing, web browsing, etc.) and no intensive application is required (such as high-definition video, important modelling capacities, etc.). Highly performant components, such as disk drives, graphic cards or central processing units require more energy for running, and the larger the size of a monitor, the more energy it consumes.
- **Data centres IT equipment**: cooling system consisting of a cooling plant, pipes, pumps and fans and hardware equipment, servers, installed into racks.
- **Multifunction devices** to replace several devices such as printers, copiers, scanners and fax machines. A multifunction device can consume 50% less energy than the four devices with each their specific function (Project Buy smart +, 2012).
- **More energy-efficient technologies**, since LCD monitors consume less energy than CRT monitors, ink jet printers are far more energy efficient than
laser printers, multi-core CPU computers may save energy, Solid-State Discs use less energy than DRAM, etc.

- **Ecolabelled products** (Energy Star\textsuperscript{49}, Blue Angel\textsuperscript{50}, TCO\textsuperscript{51}, EPEAT\textsuperscript{52}, etc.), with minimum energy performance standards and functionality that allows energy management (standby modes, automatic brightness control, etc.).

The second stage is the supplier selection. Once the needs are identified, the tender process can integrate energy efficiency criteria. The selection of the equipment also relies on a life cycle costing analysis to determine the return on investment. During the bid evaluation, criteria and threshold can be defined to ensure that the selection is based on environmental criteria.

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

**Table 9: Types of equipment by ecolabels**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Energy Star</th>
<th>Blue Angel</th>
<th>TCO</th>
<th>EPEAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCs</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Notebook computers</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Monitors</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Multifunctional devices</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Servers</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The selection criteria for energy-efficient IT equipment can be more specific for data centres’ equipment such as servers and hardware components (processor, throttle drive, etc.). 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 AC/DC converting system.

\textsuperscript{49} ENERGY STAR is a widespread label which only addresses the energy efficiency rating of specific computer hardware (computers, displays, imaging equipment, UPS and servers). For more information, see: http://www.eu-energystar.org/

\textsuperscript{50} Blue Angel (Blauer Engel) is a German environmental label which is declined for different type of services and products, including ICT equipment. For more information, see: https://www.blauer-engel.de/en/

\textsuperscript{51} TCO is a Swedish label including environmental and ergonomic criteria and which focus on office computer equipment. Its climate section asks for an energy consumption compliant with the currently available Energy Star standard. http://tcodevelopment.com/

\textsuperscript{52} EPEAT is an American environmental label that can be used for assessing computers and other electronics. For more information, see: http://www.epeat.net/
5.2.2 Achieved environmental benefits

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

The positive impact of Energy label programmes on energy consumption is difficult to evaluate since the technologies evolve rapidly and the market has known significant growth. However, energy label programs certainly accelerated the adoption of energy-efficient equipment.

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

The use of labelled equipment reduces other environmental pressures. It reduces direct greenhouse gases emissions. In 2012, the US EPA estimates that Energy Star products prevent more than 150 million metric tons of greenhouse gas emissions annually. Office equipment represents a great share of total GHG emissions avoided.

![Figure 67: Total Greenhouse gas emissions avoided per type of equipment (Energy Star, 2012)](image)

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

Some ecolabels, such as EPEAT, integrate other environmental criteria other than energy-efficiency. Criteria on the reduction of the use of hazardous substances and chemicals are included which results in other environmental benefits.

The purchase of ICT equipment containing less toxic materials and fewer substances result in the reduction of WEEE generated and hazardous substances generated. It will also allow the reduction of the amount of natural resources needed for the manufacturing of the product.

In a report on environmental benefits of 2010 EPEAT purchasing (EPEAT, 2011) categories and estimates the different environmental benefits as follow:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>9 million megawatt hours</td>
</tr>
<tr>
<td>Primary Materials</td>
<td>16 million metric tons</td>
</tr>
<tr>
<td>Air Emissions (including greenhouse gases)</td>
<td>36 billion kg</td>
</tr>
<tr>
<td>Greenhouse Gas Emissions</td>
<td>1.6 million MTCE*</td>
</tr>
<tr>
<td>Water Emissions</td>
<td>77 million kg</td>
</tr>
<tr>
<td>Toxic Materials (incl Hg)</td>
<td>1,156 metric tons</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>31,992 metric tons</td>
</tr>
<tr>
<td>Hazardous Waste</td>
<td>59,525 metric tons</td>
</tr>
</tbody>
</table>

*Figure 68: Estimated Environmental Benefits from 2010 Worldwide EPEAT Purchasing*

**5.2.3 Appropriate environmental performance indicators**

In the framework of the procurement policy for ICT equipment companies can assess the energy performance of the existing or prospected ITC equipment. Companies can measure the consumption of equipment in different modes: off mode, sleep mode, idle state, active state and the overall energy consumption. The measurement required specific data on how equipment are used, standards values and approaches can be used:
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

Figure 69: Work day computer energy consumption equation (Dell, Dell client Energy savings calculator, 2015)

\[
E_{WORKDAY} = E_{PROD} + E_{MAXPERF} + E_{LUNCH} + E_{BREAK}
\]

Where:
- \( E_{WORKDAY} \) = Total energy consumed during typical work day
- \( E_{PROD} \) = Total energy consumed during productivity applications
- \( E_{MAXPERF} \) = Total energy consumed running max performance applications
- \( E_{LUNCH} \) = Total energy consumed over lunch period
- \( E_{BREAK} \) = Total energy consumed during breaks

Other relevant environmental performance indicators focus on the follow-up of ecolabelled products:
- Share of ecolabelled products
- Follow-up of the level reached on eco labels scales

To measure the level of energy efficiency to reach to comply with Energy Star requirements, Energy Star developed the following methodology. Energy consumption of ICT equipment is based on the usage mode. 4 usage modes are commonly used each associated with a level of consumption:
- Off mode: lower power state that persists as long as the appliance is connected to the electricity supply;
- Sleep mode: low power state when a computer enters automatically or manually after a period of inactivity;
- Idle state: activity is limited to basic applications;
- Active state: when the computer is carrying out useful work and according to loads.

Energy consumption of energy-efficient equipment can be characterised by its Typical Energy Consumption (TEC). The calculation of the TEC is based on the measurement of the power consumption of each usage mode.

Another useful performance indicator to evaluate the energy efficiency of devices is the estimation of CO2 emissions avoided.

Other environmental criteria can also be considered through the follow-up of the amount of chemical and hazardous substances used in the equipment.

5.2.4 Cross-media effects
The procurement of more sustainable ICT equipment will create cross-media effects which shall be avoided or reduced as much as possible.

<table>
<thead>
<tr>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours per Day running Office Applications</td>
</tr>
<tr>
<td>Hours per day running High Performance Applications</td>
</tr>
<tr>
<td>Number of Work days per year</td>
</tr>
<tr>
<td>Electricity Cost ($/kWh)</td>
</tr>
</tbody>
</table>
The switch to more energy efficient devices will ultimately generate WEEE. The waste created shall be monitored and proper end-life management implemented. Programs of refurbishment, donation or recycling can be considered.

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

The use of more energy efficient product also implies the use of more powerful devices. The purchase of energy efficient devices will lead to more modern equipment and technologies using more complex components. But because they are faster and more powerful, they can be using more energy at the end (Carbon Trust, 2006).

5.2.5 Operational data
This section covers operational data and implementation techniques at each procurement levels introduced in section 5.2.1.

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.

Defining the actual needs for new equipment is a crucial step to avoid all unnecessary purchases and cross-media effects. Renewing ICT equipment and workstations should not be proceeded systematically but consider different criteria. It should be based on the age and use patterns of the equipment. The needs of the users should also be evaluated.

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

- the usage mode
- annual usage
- power draw
- device annual electricity consumption
Figure 71: Calculation of overall device consumption (Peric, Medojevic, & Petrovic, 2014)

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

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

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

**Using ecolabelled equipment as a reference for more sustainable ICT equipment**

The next step after the evaluation of the existing equipment is to benchmark the existing technologies on the market. The identification of energy-efficient products can be made by referring to the different ecolabels. The International Organisation for Standardisation (ISO) classified labels into three categories (Buy Smart +, 2012):

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

Energy labels such as Energy Star can be associated with the Type I labels. The Type I label is the most reliable from a procurement standpoint being based on an independent process of verification.
**EU Ecolabel**

**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 EU the energy labelling of office equipment through the EU Energy Star Programme (managed by the European Commission). 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 provides a database of labelled products.

**The Blue Angel** label is another internationally recognised environmental label created on the demand of the German Environment Ministry. Criteria take into account: recyclability, pollution mitigation during manufacturing, chemical emissions, noise and energy consumption reductions including during standby mode. The requirements to meet in terms of energy efficiency for workstations are based on the Energy Star programme. Contractor must meet all applicable Energy Star criteria and specify the admissible maximum value based on the Typical Energy Consumption equation (RAL, 2014)

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

The Buy Smart + report (2012) summarize the differences on the different eco label in the following table:

---

53 http://www.eu-energystar.org/
Life-cycle cost assessment

The procurement process can include a life cycle costing. This way the buyer does not only relies on the purchasing price but integrates the operating costs and disposal costs. These costs are evaluated over the expected useful lifetime of the product. For many products, costs occurring during the use and disposal are higher than purchasing cost. It is therefore relevant to integrate a life-cycle costing approach in the procurement process. The different costs may be treated by different departments. The procurement procedures will require the cooperation of different internal authorities.

Call for tender and bid evaluation

Once the needs and technical requirements have been identified, the call for tender can specify energy performance requirements. The technical specifications and minimum characteristics to pass the selection can be listed and bonus points may be assigned when the minimum threshold is surpassed.

The ecolabel criteria can be referred to and must be accurately correlated with contract objective. The buyer should ensure that the bid selection criteria must be communicated in full transparency.

5.2.6 Applicability

A green procurement policy to purchase more sustainable ICT equipment can be implemented in different sized companies. The availability of a great amount of information online on ecolabelled products gives the possibility to any company to benchmark energy-efficient products and integrate energy-efficient criteria in the bid evaluation.

However, the procurement of specific IT equipment especially in data centres requires internal resources with hands-on technical skills (PrimeEnergyIT, 2012). Therefore, the procurement department shall be supported by other services in order to retrieve specific information.
• technical skills on IT equipment, more particularly on data centre equipment such as cooling system and hardware components, to verify technical specifications;
• knowledge on the existing IT equipment installed.

For the integration of environmental concerns in the procurement process the company must set overall environmental and economic goals. The top management involvement and commitment will facilitate the development of a green procurement policy.

To ensure the success of the integration of energy-efficient criteria in the procurement process, long-term performance monitoring shall be put in place. The impact of the energy-efficient IT equipment purchased must be measured through performance indicators (refer to section 5.2.3). Bigger companies may be more able to establish a performance indicators dashboard and to monitor and track data having more human resources.

5.2.7 Economics

Ecolabelled IT devices are not particularly more expensive than other devices.

As specified in the previous section (5.2.6) a life cycle cost analyses 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>
<thead>
<tr>
<th>CAPEX</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT hardware purchase and installation</td>
<td>IT equipment energy costs</td>
</tr>
<tr>
<td>Software licenses and installation</td>
<td>IT equipment maintenance</td>
</tr>
<tr>
<td></td>
<td>Software operation and maintenance</td>
</tr>
<tr>
<td></td>
<td>IT operation</td>
</tr>
</tbody>
</table>

Figure 73: IT equipment CAPEX and OPEX (PrimeEnergyIT, 2012)

Energy Star provided a tool online to calculate the cost savings on a fleet of equipment. In the long-run, Energy Star qualified products can offer energy cost savings up to 75% (EPA, 2011).

EPA estimated energy cost savings and life-cycle cost savings for different equipment:

<table>
<thead>
<tr>
<th>Action</th>
<th>Annual Energy Cost Savings</th>
<th>Life-Cycle Energy Cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace 5,000 computers and monitors with ENERGY STAR qualified products and activate power management</td>
<td>US$290,210 (EUR 255,000)</td>
<td>US$663,428 (EUR 583,000)</td>
</tr>
</tbody>
</table>

Figure 74: Estimated energy cost savings and life-cycle energy cost savings (EPA, 2011)
5.2.8 Driving force for implementation

In relation to the economics factor mentioned in the previous section, energy cost savings and life-cycle cost savings are the main drivers force for implementing a green procurement policy. Integrating in the procurement process criteria for energy efficiency will ultimately result in electricity consumption savings.

The implementation of a green procurement policy will encourage the monitoring of energy savings data and will systematise the need assessment process and the benchmarking of products.

Another driver is the reduction the maintenance costs. Energy-efficient products have longer productive lifetime than less efficient products. It helps reducing the number of time product needs to be replaced.

Finally, the environmental benefits such as the reduction of CO2 emissions can support a global sustainable strategy and demonstrate the leadership of the company.

5.2.9 Reference organisations

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

- Telefonica (Spain)
- Telecom Italia
- Microsoft (US)
- Deutsche Telekom (Germany)

A benchmark helped identified companies using Energy Star certified equipment:

- Dassault Systèmes uses EU Energy Star certified ICT equipment
- EMC corporation uses Energy star certified storage systems
- IBM uses EU Energy Star ICT equipment

5.2.10 Chapter references


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5.3 Improving the energy efficiency of ICT equipment

SUMMARY OVERVIEW:
The first step for reducing energy consumption in an office is to assess the use of ICT devices, and to remove the unused ones, and then to increase the use of switch off and stand-by modes, organisational (training and communication) and technological (software and advanced plugged strips) solutions should be implemented.

<table>
<thead>
<tr>
<th>ICT components</th>
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<tbody>
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<td>Data centre</td>
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<tr>
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<td>Software publishing</td>
</tr>
<tr>
<td>Desktop architecture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevant lifecycle stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and installation</td>
</tr>
<tr>
<td>Selection and procurement of the equipment</td>
</tr>
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<td>Operation and management</td>
</tr>
<tr>
<td>Renovation and upgrades</td>
</tr>
<tr>
<td>End-of-life management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main environmental benefits</th>
</tr>
</thead>
<tbody>
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<td>Energy consumption</td>
</tr>
<tr>
<td>Waste production</td>
</tr>
<tr>
<td>Air emissions</td>
</tr>
<tr>
<td>Water use &amp; consumption</td>
</tr>
<tr>
<td>Noise and electromagnetic radiations</td>
</tr>
<tr>
<td>Landscape and biodiversity</td>
</tr>
</tbody>
</table>

Environmental indicators
- Total electricity consumption of ICT equipment
- Energy Efficiency: SEC = Energy used/products produced
- Power factor: (real power flowing to the load) / (apparent power in the circuit)
- Energy savings per employees
- Share of staff trained on energy savings

Benchmarks of excellence
- Energy consumption of ICT equipment is monitored throughout the company (Implemented benchmarking mechanisms (y/n))

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
- 4.3: Optimising data centre utilisation and management
- 5.2: Procurement for energy efficient IT equipment

5.3.1 Description
There are substantial opportunities to achieve energy and cost reductions from existing equipment by monitoring and managing their energy performance and adjusting their settings and optimising their use. This part focuses on the use of office IT equipment. All types of IT devices must be taken into account. Studies show that in the scope of office equipment, printers and copiers consume as much electricity as computers (Aebischer and Hilty, 2014).

The energy consumption of an IT device depends on its operating mode. It is recognised that electricity consumption of equipment in standby mode is important
and can be easily reduced and controlled. Servers, photocopiers, computers and screens are the largest energy consumers in ICT field regarding office equipment. Some devices, especially printers and fax machines, consume even more energy in standby mode. Other devices consume electricity even after being turned off. The power efficiency during non-active mode is topical issue:

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

The first step for reducing energy consumption in an office is to assess the use of IT devices, and to remove the unused ones, or at least to unplug or turn them off. The assessment of the existing equipment and needs method is developed in the previous section describing the BEMP on the procurement for energy efficient equipment and installation (5.2). After being purchased, energy-efficient devices should be installed and configured properly in order to allow energy savings. Such device rationalisation policy should be implemented in relation with IT services and through audits of the desktop architecture in order to power down all redundant equipment (ITU, 2012).

In order to get computers, monitors and other peripherals switched off outside working hours, and put in standby mode when not used during the day (during a meeting, at lunch, etc.), different solutions may be implemented:

- **Organisational solutions**, such as providing training and communication to staff members (through reminders, discussion sessions, etc.);
- **Technological solutions**, such as
  - Using advanced plugged strips, such as load-sensitive plug strips (e.g. when turning off a computer, related peripherals are also turned off) or occupancy-sensing strips (when the user is absent, equipment is automatically turned off in response);
  - Using software solutions which aim at reducing energy consumption of computers or telephones.

### 5.3.2 Achieved environmental benefits

The main environmental benefit induced by the monitoring of IT equipment is the **reduction of the annual energy consumption**. According to Webber et al (2006), power management can reduce 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 used of multifunction devices will also impact the energy consumption. Multifunction devices consume 50% less energy than the consumption of four separated devices (Buy Smart +, 2012).

Standby mode and switched off stage constitute the main area of improvement. In standby mode and even switched off some devices (computers, monitors, copiers) still consume energy. A study by the World Economic Forum, claimed that 18% of office workers never switch off their PC at night or during weekends and a further 13% leave it on some nights each week. These behaviours result in the generation of about 700,000 tonnes of CO₂ emissions (World Economic Forum, 2009).
Evening and weekends account for 75% of the week. Thus, 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).

The Ecodesign Directive entered into force in 2009. The objective is to ensure the lowest energy consumption possible in standby and off-mode for electronic devices. The main requirement was maximum 1 W power for passive standby and off-mode in 2010 and passed to maximum 0.5 W in 2013. The expected savings from this measure are 35 TWh/year by 2020.

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

### 5.3.3 Appropriate environmental performance indicators

The main environmental performance indicator regarding the power management of ICT equipment is the measurement of annual energy consumption over the years. The estimation of the electricity consumption in the use phase is basically calculated as below (Aebischer and Hilty, 2014):

\[
\text{Energy}(t) = \sum_{ijk} n_i(t) \times e_{ij}(t) \times u_{ijk}(t)
\]

with:
- \(n\): number of devices of type \(i\)
- \(e\): electric power load in functional state \(j\)
- \(u\): intensity of use by user \(k\)

The power management of IT equipment requires the analysis of consumption during different usage modes of a device. The main area of improvement is the energy consumption during standby-mode and off-mode, which therefore also need to be evaluated.

The power in the different states is declared for standard models but the uncertainty relies in the intensity of use of the device. It is based on the utilisation of the user and if the automatic power management settings have been changed. To facilitate the calculation of the energy consumption, it can be based on the average energy consumption and use time data. The Buy Smart + project (2012) indicates the average values for different IT equipment:

<table>
<thead>
<tr>
<th>Workstation computer</th>
<th>On</th>
<th>Standby</th>
<th>Off</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical power [W]</td>
<td>78.2</td>
<td>2.2</td>
<td>2.7</td>
<td>--</td>
</tr>
<tr>
<td>Use time [hours/year]</td>
<td>2,279</td>
<td>3,196</td>
<td>3,285</td>
<td>--</td>
</tr>
<tr>
<td>Energy consumption [kWh/year]</td>
<td>178</td>
<td>7</td>
<td>9</td>
<td>194</td>
</tr>
</tbody>
</table>

**Figure 75**: Average values for a computer equipped with a 3 GHz processor (Buy Smart +, 2012)
Figure 76: Average values for a laptop computer equipped with a 1.7 GHz processor (Buy Smart +, 2012)

<table>
<thead>
<tr>
<th>Laptop computer</th>
<th>On</th>
<th>Standby</th>
<th>Off</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical power [W]</td>
<td>32</td>
<td>3</td>
<td>1.5</td>
<td>--</td>
</tr>
<tr>
<td>Use time [hours/year]</td>
<td>2,613</td>
<td>2,995</td>
<td>3,153</td>
<td>--</td>
</tr>
<tr>
<td>Energy consumption [kWh/year]</td>
<td>84</td>
<td>9</td>
<td>5</td>
<td>98</td>
</tr>
</tbody>
</table>

Table 3: Average values for standard screens in 2009 [Energy Star]

Figure 77: Average values for standard screens based on Energy Star data (Buy Smart +, 2012)

<table>
<thead>
<tr>
<th>17” LCD screen (reasonably priced)</th>
<th>On</th>
<th>Standby</th>
<th>Off</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption [W]</td>
<td>25</td>
<td>1.2</td>
<td>1.2</td>
<td>--</td>
</tr>
<tr>
<td>Use time [hours/year]</td>
<td>2,586</td>
<td>3,789</td>
<td>2,375</td>
<td>--</td>
</tr>
<tr>
<td>Energy consumption [kWh/year]</td>
<td>52.2</td>
<td>4.3</td>
<td>3.6</td>
<td>60.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>17” CRT screen</th>
<th>On</th>
<th>Standby</th>
<th>Off</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption [W]</td>
<td>73</td>
<td>3</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>Use time [hours/year]</td>
<td>2,586</td>
<td>3,789</td>
<td>2,375</td>
<td>--</td>
</tr>
<tr>
<td>Energy consumption [kWh/year]</td>
<td>153.3</td>
<td>10.9</td>
<td>9</td>
<td>173.2</td>
</tr>
</tbody>
</table>

Table 4: Examples of average values of electrical power and electricity consumption of printers, in 2009 [Source: Energy Star]

Figure 78: Average values for electrical power and electricity consumption of printers based on Energy Star data (Buy Smart +, 2012)

To go further than the measurement of the energy consumption, the energy efficiency of the IT equipment can be measured. The European Directive 2005/32/EC defines energy efficiency as: ‘a ration between an output of performance, service, goods or energy, and an input of energy’. In the Reference Document on Best Available Techniques for Energy Efficiency (2009), the European Commission, describes the energy efficiency ratio as the amount of energy consumed per unit of product, referred to ‘Specific Energy Consumption’ (SEC). The SEC is calculated as follow:

SEC = Energy used/products produced

The performance of the IT equipment in terms of energy consumption can also be measured through power factor which assess the quality of the current. The power factor is defined as the ratio of the real power flowing to the load to the apparent
power in the circuit (Aebischer & Hilty, 2014). The power factor is a dimensionless number between -1 and 1.

In a more organisational and managerial point of view, other performance indicator can be put in place regarding staff involvement. Indicators such as Energy savings per employee can be tracked. The number of people trained on energy savings can also be tracked in order to measure the share of employees trained on the topic.

5.3.4 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). Energy efficiency is one of several environmental objectives to meet. Other objectives such as saving raw materials reduce GHG emissions should not be left out and be monitored in parallel to energy efficiency.

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

5.3.5 Operational data
The improvement of the energy efficiency of desktop equipment relies on power management. Power management refers to strategies used to reduce energy consumption of devices by focusing on the reduction of the consumption during non-active mode.

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

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

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

Organisational solutions
The implementation of organisational solutions relies on the change of behaviour and management practices. The commitment to reduce energy consumption must come from the top management. The top management can fix objectives to run the power management policy.
To support the top management and to help personalise the mission statement and the energy policy, ‘energy champions’ can be appointed (Carbon Trust, 2006). This champions network will help communicate the objectives and policy to the staff.

The implementation of the power management policy, a key step is to raise employees’ awareness (IT2Green, 2014). The objective is to encourage them to question their habits on the use of electronic devices at work:

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

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

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

Power management also focuses on the use of the right device for the task executed, the needs for each tasks shall be evaluated. The assessment of the needs are tackled in the previous section in the development of the BEMP on the procurement of energy efficient IT equipment (refer to section 5.2). The improvement of energy efficiency is related to space planning and understanding of common space and device utilization. Through the understanding of the use of the different types of devices, their number can be optimised. For instance, some workstations sometimes have their own single-user machines, printers, copiers, fax machines and scanners, whereas these types of equipment can be commonly used by over 60 people (NREL, Reducing plug and process loads for a large scale, low anergy office building: NREL’s research support facility, 2011). Better space planning and need evaluation can help optimising the overall number of devices needed and therefore the electricity consumption related to those devices especially while idle.

Centralisation of shared multifunction devices can be hindered by the will of employees to keep these devices private. Some people can object 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 efforts on educating staff.

To ensure the sustainable deployment of the power management, energy monitoring shall be considered. Data will help identify the highest consumption and allow for strategic and operational decisions (CEPIS, 2015).

**Technological solutions**

**Manually set up power management**

Manual power management can be set up to reduce energy consumption during non-active mode. The manual set up requires to physically turning to low power mode or switch off equipment. The manual power management relies more on education program of staff. Ongoing education program and reinforcement can help achieving great energy savings through power management (Bray, 2006).
Automatically set up power management solutions
In order to facilitate power management, automatic solutions can be developed. Automatic solutions can be more or less complex to set up.

The use of default modes for the switching to saving modes on computers or servers and for default printing can be easily set up. It must be integrated as the company policy to use these default modes.

Hardware power management can be done through the use of dedicated software. Software can influence the operating states of hardware by using power-saving modes. It can also influence the extent and the timing of power consumption through the distribution of the computing or memory load in network (Aebischer and Hilty, 2014). Theoretically, automatic power management reach 100% of devices by switching to low power mode when idle or by turning off devices.

Other solutions such as devices to plug to computers into the USB port can help reducing energy consumption by optimising power modes. For instance, the Ecobutton can be used to put a computer in the lowest power mode when not in use. The computer is suspended with a push of a button and reactivates with a click on the keyboard. The device can display a message showing the amount of energy saved during the time the computer was off (IREC, 2012).

Smart power strip is another type of device used to cut off power to peripherals when a computer is turned off to limit the electricity consumption during this mode. Computer shall be plugged into a socket and the peripherals into another socket. The device smart power strip will detect when the computer is turned off to turn off all the peripherals (IREC, 2012). For instance, TrickleStar is a smart power strip that can be especially used on small workstation set up on a PC and a monitor. There are different types of power strips that can be used on office IT equipment (NREL, Saving Energy through advanced power strips, 2013), (Energy Star, Deploy smart power strips, 2015):

- Remote switch power strip which can be turned off by the user via a remote switch. For the device to be efficient, the user must remember to turn off the power strip each time.
- Master-controlled power strip which when a primary device is turned off by the user, the power strip automatically turns off the controlled outlets where the peripheral devices are plugged in.
- Timer-equipped smart power strips: outlets that are controlled by programmable timers. Devices plugged to this type of smart power strip can be scheduled to automatically turn off at a designated time.
- Occupancy sensing smart power strips: outlets are controlled by a motion detector. Devices plugged can automatically turn off or on in response to physical presence. The user can define a period of time elapses.
- Current sensing power strips: can turn outlets off or on when a monitor plugged into the master outlet enters a low powered sleep mode or is turn off or on. It can be used in combination with monitor power management features.

5.3.6 Applicability
The implementation of power management depends on the leadership commitment to support overall energy savings objectives and environmental performance. It is also dependant on the implication of the staff to contribute to the power management measures. The implementation of a successful power management policy also requires the involvement of different services and functions within a company. The IT department, the procurement department must exchange information.
The applicability of the different techniques detailed in previous section 5.3.2 depends on the size of the company:

- Small to medium-sized companies rely more on employees to set 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 programs and communication. It is harder to reach a consistent high level of power management in a large organisation whereas smaller companies can more easily track “bad users” (Carbon Trust, 2006).

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

### 5.3.7 Economics

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

Regarding technical devices that can be used for power management, the Ecobutton costs around 17€ whereas a smart power strip costs between 25 and 30€ (IREC, 2012).

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

### 5.3.8 Driving force for implementation

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

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

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

### 5.3.9 Reference organisations

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

- BT (UK)
- Dassault Systèmes (France)
5.3.10 Chapter references


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Best Environmental Management Practice in the Telecommunications and ICT Services Sector


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6 Cross-cutting measures for minimising energy consumption and carbon footprint in the telecommunications and ICT services sector

6.1 Introduction / scope

This section focuses on other measures related to energy which can be implemented in every segment of the Telecommunications and ICT Services sector (data centres, telecommunication networks, desktop architecture, etc.).

Energy efficiency is a relevant topic for most telecommunications and ICT services providers: energy consumption costs money and is responsible for large quantities of greenhouse gases emissions.

Previous BEMPs described techniques which can be adopted in order to reduce the energy consumption of ICT equipment (servers, PCs and peripherals, etc.). The following techniques intend:

- To increase the use of alternative energies (section 6.2.);
- To reduce electricity losses due to electricity conversion (section 6.3);
- To improve the monitoring and management of electricity consumption (section 6.4).
6.2 Use of alternative energy

**SUMMARY OVERVIEW:**
Electricity generation from renewable sources significantly reduces the carbon footprint of electricity. On-site electricity generation systems using solar, wind, geothermal or biomass energy can be set up in order to supply ICT equipment with low-carbon electricity.

<table>
<thead>
<tr>
<th>ICT components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data centre</td>
</tr>
<tr>
<td>Telecommunication network</td>
</tr>
<tr>
<td>Broadcasting</td>
</tr>
<tr>
<td>Software publishing</td>
</tr>
<tr>
<td>Desktop architecture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevant lifecycle stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and installation</td>
</tr>
<tr>
<td>Selection and procurement of the equipment</td>
</tr>
<tr>
<td>Operation and management</td>
</tr>
<tr>
<td>Renovation and upgrades</td>
</tr>
<tr>
<td>End-of-life management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main environmental benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
</tr>
<tr>
<td>Waste production</td>
</tr>
<tr>
<td>Air emissions</td>
</tr>
<tr>
<td>Water use &amp; consumption</td>
</tr>
<tr>
<td>Noise and electromagnetic radiations</td>
</tr>
<tr>
<td>Landscape and biodiversity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Green Energy Coefficient (GEC)</td>
</tr>
<tr>
<td>• Share of electricity from renewable sources</td>
</tr>
<tr>
<td>• Carbon Usage Effectiveness (CUE)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benchmarks of excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 100% of energy used is from renewable sources (either sourced or produced on-site)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cross references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerequisites</td>
</tr>
<tr>
<td>• Depends on the geographical location of the data centre and its size</td>
</tr>
<tr>
<td>Related BEMPS</td>
</tr>
<tr>
<td>• 4.4: Efficient cooling technologies and systems</td>
</tr>
</tbody>
</table>

6.2.1 Description
While it is possible to increase the energy efficiency of data centre power and cooling systems (see section 4.4 on efficient cooling technologies and systems), additional improvements can be made by increasing the use of renewable energy sources (GENIC, 2014). Using renewable sources (solar, geothermal, wind, marine and hydro technologies) reduces significantly the carbon footprint of electricity production compared to burning fossil fuels, as shown on the graphs below.
Different techniques have been implemented, depending on the degree of involvement of the organisation in the production of electricity.

- **Purchasing third-party electricity from the grid** produced from renewable sources: this is the easiest way for companies to add renewable energy to their energy mix. This can be done by acquiring so-called “electricity tracking certificates”. Organisations can purchase certificates that guarantee that one MWh of electricity was produced with a certain set of characteristics (e.g. energy source and CO₂ emissions). The most common certificate in the EU is the Guarantee of Origin (GO) (RenewIT, 2014). Combined with a Power Purchase Agreement (PPA) of the same amount, ICT organisations can purchase electricity from renewable energies to power their infrastructures. This is the case of Microsoft who bought 22 MW of wind power to supply its data centre in Dublin (IDA-Ireland, 2012).

- **Producing own electricity, either on or off-site:**
  - **On-site generation**: The renewable energy source is produced on site, e.g. by building wind turbines or by setting up solar PVs on the roof (in urban areas) or around the facility (in rural areas).
  - **Off-site generation**: If on-site generation is not possible due to a lack of resources or of space, off-site generation can be established instead.
in a location where the conditions for renewable electricity production are more favourable. Similarly to on-site production, this requires a large upfront investment to build the necessary power generation capacities.

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

- Woody biomass can be burnt on-site to produce high-pressure steam that drives a turbine generator to make electricity (with an increased efficiency for Combined Heat and Power systems or CHP) which supply the site.

- Solar power requires significant sun exposure surfaces and has a significant cost. A very large installation of photovoltaic solar panels can be set up on roofs or on adjacent fields in order to produce a part or the entire amount of electricity needed for running ICT equipment in data centres, base stations, offices, etc.

- Wind power from on-site turbines can be used to provide electricity for office buildings, data centres and base stations.

- Geothermal cooling systems include an array of vertical holes drilled into the ground that house a piping system filled with water or refrigerant and serves as a heat exchanger for data centres.

The use of renewable energy is most developed with data centres, but base stations could also benefit from the use of renewables. As some remote European base stations are off-grid, network operators in these off-grid sites constantly rely on diesel powered generators to run these base stations, which is not only expensive (cost of diesel and maintenance), but also generates air pollution and CO2 emissions (Hasan, 2011). Renewable energy from solar panels and small wind turbines could offer a viable alternative to diesel. Renewable energy sources power 4.5% of the world’s off-grid base stations in 2014, up from just 0.11% in 2010 (NavigantResearch, 2010). Although the vast majority of off-grid base stations are located in developing countries, some are located in Europe. Nevertheless, if the business case is strong to adopt renewable energies in developing countries (especially solar PVs, which offer a rapid pay-off of the initial CAPEX), it is not yet the case in the European Union, where very few projects have been launched (see 6.2.9).

### 6.2.2 Achieved environmental benefits

Electricity from the grid is the main energy source of data centres and base stations. Diesel generators are often used either as a backup or a primary energy source – particularly when located in an area not connected – or with an unreliable connection - to the grid. As a consequence, a transition to renewable energy would:

- **Decrease CO2 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, 2014). A simultaneous rise of the share of electricity coming from renewables would have a massive impact on the CO2 emissions of these infrastructures. Regarding base stations, considering that around 410,000 base stations run on diesel power in 2014 worldwide, the replacement of diesel motors by solar panel or wind turbines would save up to 8.7 billion litres of diesel per year (Hasan, 2011) (Ike, 2014).

- **Decrease 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.

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

6.2.3 Appropriate environmental indicators

The purpose of adding renewables to the energy mix of ICT network infrastructures is to decrease both the use of fossil fuels and its environmental impact — particularly GHG emissions.

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

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

- **Green Energy Coefficient (GEC)** (JRC, 2014): is a metric that quantifies the portion of a facility’s energy that comes from green sources. GEC has a maximum value of 1.0, indicating that 100% of the total energy used by the data centre is green energy. GEC is computed as the green energy consumed by the data centre (measured in kilowatt-hours or kWh) divided by the total energy consumed by the data centre (kWh). For the purposes of GEC, “green energy” is defined as any form of renewable energy for which the data centre owns the rights to the green energy certificate or renewable energy certificate, as defined by a local/regional authority.

The consequence of the decision to use renewable energies should be a decrease in the CO₂ emissions of the data centre or base station. The CO₂ 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 efficiency) 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 (CO₂-eq.) from the energy consumption of the facility divided by the total ICT energy consumption; 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.

Examples of levels of CUE

6.2.4 Cross-media effects

If the environmental benefits from renewables are a largely shared consensus, the social acceptance of some renewables is yet to be demonstrated. This is mostly the case for wind power systems. Despite the better energy production to required space ratio than PV systems of the same capacity, wind turbines are accused of causing noise and visual pollution. Other effects include the impacts on wildlife, birds and bats in particular. Collision with blades has been identified by researchers as being responsible for the death of birds and bats. More recently, bats have been estimated to be the most at risk specie, due to internal haemorrhage caused by varying air
pressure around the turbine. As a consequence, wind turbines face multiple pressures from the design phase to the operation phase in many European countries.

### 6.2.5 Operational data

A more detailed presentation of the different types of renewable energies available to power data centres and base stations, as introduced in 6.2.1 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 a 4,500 m² installation is necessary in order to match a 1 MW power demand. In Europe, the average production time frame of a solar PV is 8 to 12 hours. The variability of production levels, depending on weather conditions (night, cloudy periods), requires solar PVs to be complemented by batteries or a diesel backup system. The investment in solar PV is high, but is compensated by lower maintenance costs compared to other energy systems.

- **Wind**: wind is a highly variable resource, often preventing it from being the primary energy source for data centres. In rural areas, where the construction of wind turbines is a less sensitive issue than in urban areas, large scale wind systems can be considered. In order to produce 1 MW of electricity, a 53 meter rotor diameter is necessary, in addition to a reliable backup system. Similarly to solar PVs, wind is a relatively mature technology with a good rate of return on investment. The electricity generation capacity of wind turbines is very broad, ranging from a few kW for micro wind turbines (for example installed on roofs in urban areas) to 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.

- **Free cooling**: free cooling is the use of outside air conditions to provide cooling to a data centre. A complete description of cooling systems is available under 4.6.

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

- **Solar thermal**: since ICT facilities primarily require electrical energy, solar thermal technologies need a conversion of this thermal energy to electrical energy using organic Rankine cycle (ORC) or turbine systems. To reach the temperatures needed for these systems to provide electrical energy, large ground space is needed. For a facility the only use of these technologies would be when a large amount of space is available, so the possibility of this technology will be focused in rural areas. According to the EU, 1.2% of the total heating and cooling energy demand will come from solar thermal in 2020 (GENiC, 2014).
• **Geothermal energy production**: geothermal energy generates continuous, clean, safe and reliable power. Geothermal energy is the thermal energy contained in the Earth. There are different ways of exploiting geothermal energy, from areas with the highest enthalpy that can use the steam to produce electricity in large power plants to areas with the lowest enthalpy to simply produce hot water. EU expects that geothermal represents the 0.3% of the electricity consumption in 2020 and 1.3% of heating and cooling consumption (GENiC, 2014).

• **Combined heat and power** (CHP), or tri-generation: CHP and tri-generation installations generate the most of these thermal energy productions since they produce heat, electricity, and, in the case of tri-generation, cold. To convert this thermal energy into electricity there are different type of technologies and systems such as turbines, stirling engines and organic rankine cycle (ORC) machines (GENiC, 2014).

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

Table 10: Examples of existing data centres renewable energy use (GENiC, 2014)

<table>
<thead>
<tr>
<th>Location</th>
<th>Size</th>
<th>Power Installation</th>
<th>Alternative Energy Type</th>
<th>Energy needs covered by renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valencia (Spain)</td>
<td>600 m², 294 racks</td>
<td>4,5 MW</td>
<td>Solar PV on roof</td>
<td>130 kW (3%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biomass boiler</td>
<td>100 kW (2%)</td>
</tr>
<tr>
<td>Pamplona (Spain)</td>
<td>100 m², 50 racks</td>
<td>1,5 MW</td>
<td>Solar PV on roof</td>
<td>22 kW (3%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free cooling</td>
<td>10-100 kW (1.5-15%)</td>
</tr>
<tr>
<td>Cork (Ireland)</td>
<td>80 m²</td>
<td>50 kW</td>
<td>Wind turbines on roof</td>
<td>4 kW (8%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biomass boiler</td>
<td>50 kW (100%)</td>
</tr>
<tr>
<td>Helsinki (Finland)</td>
<td>270 m²</td>
<td>600 kW</td>
<td>Wind turbines on roof</td>
<td>13.5 kW (2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biomass boiler</td>
<td>100 kW (17%)</td>
</tr>
<tr>
<td>Luxemburg</td>
<td>410 m²</td>
<td>275 kW</td>
<td>Wind turbines on roof</td>
<td>20 kW (7.5%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biomass boiler</td>
<td>100 kW (36%)</td>
</tr>
<tr>
<td>Brno (Czech Republic)</td>
<td>100 m²</td>
<td>150 kW</td>
<td>Biomass boiler</td>
<td>100 kW (67%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free cooling</td>
<td>19.5 kW (13%)</td>
</tr>
</tbody>
</table>

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

The inability of on-site 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).

6.2.6 Applicability

The applicability of the renewable energy sources presented in 6.2.5 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 2 shows the global yearly irradiation map, for solar PV installations
- Figure 3 shows the wind average speed, for wind turbines
- Figure 4 shows the biomass forest availability, an important factor for woody biomass boiler installations.
- Figure 5: geothermal heat density
- Figure 6: free cooling potential available hours.

For each resource, GENIC - a EU funded research programme aimed at reducing the energy consumption of data centre across Europe - distinguishes between three levels of abundance, namely above average, on average and below average (GENiC, 2014).
Figure 80: Irradiation map (GENiC, 2014)
Figure 81: Wind speed map (GENiC, 2014)

- Average Global Wind Speed level Classification:

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>AVERAGE WIND SPEED (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;= 6</td>
</tr>
<tr>
<td>2</td>
<td>(4.5 to 5.5)</td>
</tr>
<tr>
<td>3</td>
<td>&lt; 4.5</td>
</tr>
</tbody>
</table>

- Average above-ground forest living biomass level Classification:

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>BIOMASS RESOURCES (Tonnes/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;200</td>
</tr>
<tr>
<td>2</td>
<td>100 – 200</td>
</tr>
<tr>
<td>3</td>
<td>1 – 50</td>
</tr>
</tbody>
</table>
Figure 82: Biomass resource (GENiC, 2014)

Figure 83: Geothermal resource (RenewIT, 2014) (GENiC, 2014)

Figure 84: Average yearly number of free-cooling usage hours (GENiC, 2014)
Based on the above detailed climate characteristics, GENiC established the following merit order or renewable energy sources for each geographical zone (Mediterranean countries, Western Europe, Central and Eastern Europe, northern countries).

<table>
<thead>
<tr>
<th>Mediterranean countries (Spain, Portugal, South of France, Italy, Baltic Countries, Greece)</th>
<th>Western Europe (France, Belgium, Holland, Luxemburg, Germany)</th>
<th>Central and Eastern Europe (Poland, Austria, Czech Republic, Baltic Countries)</th>
<th>Northern Countries (Great Britain, Ireland, Denmark, Sweden, Norway, Finland)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global horizontal irradiation</td>
<td>1&lt;sup&gt;54&lt;/sup&gt;</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Average global wind speed</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Average biomass</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Average free cooling or economizer, average external air usage</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Average geothermal heat flow density</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 11: Merit order of renewable energy sources for each geographical zone (GENiC, 2014)

**Size/available surface area**

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

**Small data centres**

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

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

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<sup>54</sup> 1 = high recommendation; 2= medium recommendation; 3 = low recommendation
### Best Environmental Management Practice in the Telecommunications and ICT Services Sector

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<table>
<thead>
<tr>
<th>Type of DC</th>
<th>Description</th>
<th>Size (m²)</th>
<th>Number of servers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server closet</td>
<td>No external storage; typically use a common HVAC(^{55}) system; room within an office building; IT workload = 10 kW</td>
<td>&lt;18.6</td>
<td>1-2</td>
</tr>
<tr>
<td>Server room</td>
<td>No external storage; common HVAC with additional cooling capacity; IT workload = 10 kW</td>
<td>&lt;46.4</td>
<td>10-100</td>
</tr>
</tbody>
</table>

**Table 12: Typical characteristics of a small data centre (GENiC, 2014)**

**Urban data centres**

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

<table>
<thead>
<tr>
<th>Type of DC</th>
<th>Description</th>
<th>Size (m²)</th>
<th>Number of servers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localized data centre</td>
<td>Moderate external storage; dedicated HVAC system; a few CRAC(^{56}) units with fixed speed fans; IT workload = 30 kW</td>
<td>&lt;92.9</td>
<td>100-1000</td>
</tr>
<tr>
<td>Mid-tier data centre</td>
<td>Extensive external storage; under floor air distribution and CRAC units with variable speed fans; IT workload = 220 kW</td>
<td>&lt;464.5</td>
<td>1000-10.000</td>
</tr>
</tbody>
</table>

**Table 13: Typical characteristics of an urban data centre (GENiC, 2014)**

**Large data centres**

Due to their size, large data centres are built in isolated, often colder, locations (see BEMP in subchapter 4.2 Better locating and planning 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 practices centres manage to cover all of their needs.

<table>
<thead>
<tr>
<th>Type of DC</th>
<th>Description</th>
<th>Size (m²)</th>
<th>Number of servers</th>
</tr>
</thead>
</table>

---

\(^{55}\) HVAC = heating, ventilation and air conditionning  
\(^{56}\) CRAC = Computer Room Air Conditioner
### 6.2.7 Economics

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

- **Energy prices from fossil fuel sources are bound to experience a structural increase** in price in the years to come. As a consequence, it will make sense for ICT operators to add renewable energy capacities to their energy mix (GENiC, 2014).

- **Renewable energy sources are still maturing, which means that the price is structurally reducing while the reliability of the technologies is increasing.** Today, the main concern for ICT operators, apart from technical considerations like variability of electricity generation, is the capital expenditures of the installation of solar PVs, wind turbines or biomass boilers. The price of a solar PV module varied between 0.8 and 2.3€/Wp in the year 2011, and has been experiencing a structural downward trend ever since. It is estimated that around 2050, the cost of a solar PV system will be under 1.32€/Wp. In this price range and in countries with a good solar radiation level (over 1,400 Wh/kWp), the levelised energy cost would be significantly lower (9.52c€/kWh) than the current cost of conventional electricity sources. Biomass boilers have a broad price range, depending both on the technology and on the size of the project. Prices seem to range from 500 to 1,200€/kW for projects from 50 kW to 2 MW. Prices from wind turbines depend on the type of windfarm (onshore or offshore). It appears that onshore farms have a cost of 1,100€/kW to 1,390€/kW, which is expected to remain stable but with an increased capacity factor (40% today). Offshore turbines have higher prices (around 2,415€kW and experiencing a downward trend) along with higher capacity factors (50%) (RenewIT, 2014).

Similarly to renewable powered data centres, renewable powered off-grid base stations could offer long-term financial benefits to the operator. Below is the economic analysis of a South-African project for a solar powered base station. Although this case comes from a developing country, the economic rationale (high CAPEX compensated over time by lower OPEX) would be the same for operators in a European context.

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57 The levelised energy costs is the net present value of the unit-cost of electricity over the lifetime of a generating asset.
6.2.8 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 data centres and base stations involves an immediate major capital expenditure (CAPEX) investment to purchase and install, these are gradually decreasing. The operating expenditure (OPEX) for renewable energy sources such as wind, PV, hydro and geothermal energy can actually be lower than traditional energy sources once the CAPEX has been paid off. Government subsidies for renewable energy installation and guaranteed feed-in tariffs help reduce energy costs for ICT organisations.

- **Reputation:** corporate social responsibility and the desire to improve the image of the company can be driver for installing renewable energy technologies. Many ICT organisations have carbon targets and renewable energy is one of the main approaches to reducing CO₂ emissions.

- **Regulatory pressure:** The Telecommunications and ICT sector is not covered by the EU emissions trading scheme (EU ETS), but some countries have emission trading schemes that apply to ICT organisations. For example, the UK’s Carbon Reduction Commitment applies to public and private organisations with annual electricity consumption over 6000 MWh.

6.2.9 Reference organisations

- **Avalon Networks** is a German web hosting provider. 100% of its electricity is produced by renewable energy, with the following distribution (AvalonNetworks, 2015):
  - 80% is purchased from the electricity provider Naturstrom, which provides Avalon networks with **Guarantee of Origin certifications** for the purchased amounts.
  - 20% is **locally generated** electricity from a 4 kW **solar PV system**. The amount of electricity produced is documented daily and made available publicly online.

- **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).

- GreenQloud’s Iceland-based two data centres, used for cloud computing, are powered by a mix of hydropower and geothermal energy.
- In Norway, Green Mountain Data Centre and Fjord IT both power their data centres using hydropower. Fjord IT is a start-up which’s data centre reaches a PUE of 1.3, and planning on building a second one with a PUE of 1.05.

### Base stations

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

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### 6.3 Reducing energy losses due to electricity conversion

#### SUMMARY OVERVIEW:
Installing newer energy-efficient rectifiers and selecting ICT equipment functioning with DC current may reduce energy losses due to energy conversion.

<table>
<thead>
<tr>
<th>ICT components</th>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
</thead>
</table>

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

#### Main environmental benefits

<table>
<thead>
<tr>
<th>Energy consumption</th>
<th>Waste production</th>
<th>Air emissions</th>
<th>Water use &amp; consumption</th>
<th>Noise and electromagnetic radiations</th>
<th>Landscape and biodiversity</th>
</tr>
</thead>
</table>

#### Environmental indicators
- UPS Load Factor = UPS average load / UPS Load capacity
- UPS System Efficiency (%) = UPS output power (kW)/ UPS input power (kW)* 100

#### Benchmarks of excellence
- Minimum efficiency according to European Commission’s Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems (UPS)
- Energy Star
- UPS System Efficiency greater than 96%

#### Cross references
- **Prerequisites**
  - The selection process for newer UPS technologies varies depending on whether a new infrastructure is being planned or an existing one is being upgraded
  - The cost analysis of the adoption of DC power at an ICT infrastructure level is a major prerequisite, as the upfront cost of this not yet mature practice is high
- **Related BEMPS**
  - 2.3 Designing and managing an energy-aware wireless network architecture
  - 6.4 Energy monitoring and management

#### 6.3.1 Description
Telecommunication and ICT systems require electricity for different functions:
- Running ICT equipment (servers, transmitters, receivers, etc.);
- Functioning support equipment (in base stations, data centres, offices, etc.), such as cooling, ventilation or lightning systems;
- Transmitting electrical signals moving along power cables from node to node.

The typical power chain (and examples of energy inefficiency) of a data centre is shown on the figure below:
Uninterruptible Power Supply (UPS) systems often provide a large potential for energy savings. In order to protect the activity from power outages, ICT infrastructures require a backup power supply, which can take over when the primary energy supply is interrupted. **Usually, the backup power source takes the form of an uninterruptible power supply, UPS.** When the system is functioning normally, power enters the facility and flows through the UPS. The UPS charges and routes power to the racks. This operation nevertheless implies **significant power losses.** The average UPS has an efficiency of only about 92% (Fehrenbacher, 2009).

UPS systems provide uninterrupted DC power to ICT equipment through:

- Power plants (made of a float rectifier, a battery charger and a switching cubicle), which are used to rectify the AC input commercial supply to desired output DC power.
- Batteries, in order to stock electricity;
- Inverters, which are providing uninterrupted AC supply to equipment;
- Engine alternator sets, which are made of a diesel engine and an alternator, and may produce electricity.

Besides their primary function (providing short-term power in case of power source fail), UPSs also provide different features to correct utility power issues. Three main system topologies are available, depending on the application desired (PrimeEnergyIT, 2011):

- Passive standby, also called Voltage and Frequency Dependent (VFD), is solely capable of protecting the load from power disruptions (power failures, voltage dips, and surge voltages). In a normal electric supply situation the UPS has no interaction with the utility power. When the input supply is outside UPS design load tolerances, an inverter engages the energy storage mechanism to provide power to the load, bypassing utility electrical supply. This topology is more common in low-power applications.

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58 The European standard of 415/240 V has already considerably eliminated power distribution unit (PDU) transformers and their associated losses. Data centres that use transformer-based PDUs suffer an efficiency reduction of 2% to 15%. Apart from North America, most parts of the world have already adopted the 415/420V standard, so this issue is true mostly for the US (US Dpt of Energy, 2011).
- Line interactive, also called Voltage Independent (VI), is capable of protecting the load like a VFD UPS and in addition provides protection to the load by regulating frequency within optimal limits. In particular, it protects from under-voltage applied continuously to the input, or over-voltage applied continuously to the input. This topology is not commonly used above 5,000 VA.
- Double conversion, also called Voltage and Frequency Independent (VFI), is capable of protecting the load against adverse effects from voltage (like a VI) or frequency variations without depleting the stored energy source, as it continuously supplies total load power by regulating utility electricity before it reaches the load. This topology is rare for loads below 750 VA.

Each topology has its advantages and drawbacks. In the range 750 VA–5,000 VA line-interactive UPS tend to have longer operating lives and increased reliability with a lower total cost of ownership, while double conversion on-line UPS occupy less space and can regulate output frequency.

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).

The following solutions (also mentioned in the EU Code of Conduct for Data Centres (JRC, 2015)) can be implemented in order to increase the energy efficiency of power systems providing the energy used by data centres, base stations and other telecommunication and ICT equipment:

- **Selecting high efficiency Uninterruptible Power Systems** (or UPS), using rectifiers which can allow a reduction of energy losses due to electricity conversion.

![Figure 87: Telecom Rectifier Efficiency Trend. Source: (Emerson, 2010).](image)

- **Installing modular UPS**, where equipment sources of inefficiency (mainly switching units and batteries) can be easily changed if the electrical load of the facility evolve.
- Choosing an appropriate **UPS solution design** depending on the load requirements of an infrastructure.
• **Getting data centres to run on DC power** or reducing the number of conversions from AC to DC and DC to AC may reduce electricity losses. In most data centres, power is supplied from the grid as AC power and distributed throughout the data centre infrastructure as AC power. But most of the electrical components within the data centre as well as the batteries storing the backup power in the UPS system require DC power. As a result, the power must go through multiple conversions resulting in power loss and wasted energy (US Dept of Energy, 2011). Losses due to transforming vary depending on the load level. The highest efficiency is typically reached between 80 and 90% of the total load while for levels below 50% energy efficiency decreases significantly (PrimeEnergyIT, 2011).

![Diagram of DC power flow](image)

**Figure 88: Example of increased energy efficiency due to one less conversion. Source:** (Emerson, 2008).

• A better **monitoring of the energy consumption of telecommunication facilities** can help identify energy losses (see 6.4 on energy monitoring and management).

### 6.3.2 Achieved environmental benefits

The efficiency gains of using DC have both a direct benefit (fewer power conversions) and indirect benefit (less generation of heat).

There are several environmental benefits of reducing energy losses. As shown on the graph below, benefits of energy losses reductions are expected in the following domains:

- **Reduction of energy waste**, thanks to the reduction of large quantities of non-productive power consumed by the infrastructure;
- **Reduction of waste heat**, thanks to a better management of the activity of the servers and the reduction of electricity voltage conversions of UPS. In addition, the quantity of heat to be cooled by the air conditioner will decrease, thereby decreasing non-productive power consumption;
- **CO₂ emissions** are expected to decrease due to less power consumed.
It has been estimated that in the case of a large ICT company with power consumption for one year of 8.9 billion kWh, the associated emissions reach 7.1 million metric tonnes of CO₂. 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 CO₂ emissions (Eltek, 2012).

**Figure 89: 96% high efficiency rectifier compared with 92% efficient rectifier (Eltek, 2012)**

**Figure 90: Energy waste reduction from a high efficiency DC power system. Source: (Eltek, 2012)**

### 6.3.3 Appropriate environmental performance indicators

Two main indicators can help identify the level of performance of a telecommunication infrastructure, and the associated energy losses (Stanley, 2007):

- **UPS System Efficiency**

  As mentioned in 6.3.1, the several electricity conversions taking place in a UPS are an important source of energy loss. To measure the energy loss due to these conversions, one can compare the input power provided by the grid to the UPS with the output power that the UPS provides to the equipment. This can be done using the following formula:

  \[
  \text{UPS System Efficiency (\%)} = \frac{\text{UPS output power (kW)}}{\text{UPS input power (kW)}} \times 100
  \]
As explained with more details in 6.3.5, the industry average is around 90-92% while high efficiency UPS now reach up to 96%.

- **UPS load factor**

A major issue regarding energy inefficiency is the low level of average load of UPS, due to system over-sizing and redundancy factor. As explained in 6.3.5, when the equipment is doubled for redundancy, or when the equipment is operated well below its rated power, efficiency falls dramatically. This can be measured using the UPS load factor, calculated by dividing the UPS average load by the UPS load capacity (UPS Load Factor = UPS average load / UPS Load capacity). In this formula, the UPS average load is the load calculated in a data centre, while the load capacity is given in the technical datasheets of the equipment (US Dept of Energy, 2011).

**Examples of levels of UPS load factor**

### 6.3.4 Cross-media effects

The optimisation of existing telecommunication infrastructures can lead to the replacement of equipment that is still working. Replacing existing equipment implies:

- Demand for additional **resources to produce new equipment**,
- And the production of **WEEE**, if newer, more efficient equipment is installed.

### 6.3.5 Operational data

According to the different techniques identified in section 6.3.1., the corresponding details for implementation and operational data are given.

- Selecting **high efficiency Uninterruptible Power Systems**, using rectifiers which can allow a reduction of energy losses due to electricity conversion.

The European Commission’s *Best practices guidelines for the EU Code of Conduct on data centres* recommends that high efficiency UPS systems should be selected, of any technology including electronic or rotary to meet site requirements (JRC, 2015).

Telecommunications networks usually use DC power because of its safety and reliability, in addition to its compatibility with battery backup systems. AC electricity from the grid is transformed into DC electricity to operate the telecommunication equipment by rectifiers. This process involves power losses, which have nevertheless been reduced constantly over time, ever since the development of switch mode rectifier technology in the 1970s. Today’s typical 48V rectifiers achieve efficiencies of 90% to 91% and some best-in-class rectifiers can even reach 96% efficiency. 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 electrical power (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 maturing technology should be considered when selecting an UPS system (Pacific Gas and Electric Company, 2006).

- Installing **modular UPS**, where equipment sources of inefficiency (mainly switching units and batteries) can be easily changed if the electrical load of the facility evolves.

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 (JRC, 2015).

- Choosing an appropriate **UPS solution design** depending on the load requirements of an infrastructure.
Investing in the right UPS solution is a good way to reduce power losses and increase the reliability of the system to adapt to varying loads. The most common UPS is the single unit UPS. Newer systems include:

- Cascade/hot-standby UPS
- Parallel redundant UPS
- Dual units UPS.

Their different technological design result in different levels of functionality (ability of a UPS system to supply the loads uninterrupted) and reliability (continuous UPS up-time duration between critical failures), as shown on the tables below:

![Figure 92 Comparison of the functionality of different UPS solution designs (Gutor, 2015)](image)

![Figure 93 Comparison of the reliability of different UPS solution designs (Gutor, 2015)](image)

Moreover, getting data centres to run on DC power or reducing the number of conversions from AC to DC and DC to AC may reduce electricity losses due to conversions. However, this shift also comes at a significant deployment cost.

Power is typically delivered to a data centre as high voltage AC power; this is stepped down to lower voltage AC power for distribution to racks for server and other IT equipment use. Inside this IT equipment, power supplies convert the AC power to the DC power needed for digital electronics. For every Watt of energy used to power servers, up to 0.9 W can be lost through this series of power conversions (Ganesh, 2012). In addition, more power is needed to cool the conversion equipment.

To address these energy inefficiencies, DC power is becoming more common in data centres due to its greater efficiency (this trend applies mostly to new data centres). The efficiency gains of using DC have both a direct benefit (fewer power conversions) and indirect benefit (less generation of heat). This has not yet become a common practice and, therefore, could carry significantly higher first costs, but it has been tested at several facilities. Test results reveal about a 10% savings in energy for the entire data centre compared to even the most efficient AC configurations (Bigelow, 2014). Another study compared the benefits of adopting a 380V DC power distribution for an ICT facility to a traditional 480V AC power distribution system. The results showed that the facility using the DC power had a 7% reduction in energy consumption.
A better monitoring of the energy consumption of telecommunication facilities can help identify energy losses (see 6.4 on energy monitoring and management).

As most data centres are not subject of a sufficient monitoring of energy consumption, it is difficult for the operator to know how to reduce energy losses. For instance, because operators want to avoid power outage due to overload peaks, servers are usually under loaded. While server systems designers assume typical loads of 40-70%, many customers buy rather low configured systems and run them with low utilisations. Thus, the servers may well run idle at 20% of the maximum load of the power supply (E-Server Consortium, 2007). These energy losses due to insufficient monitoring can be addressed in several ways, described in more details in subchapter 6.4.

The list of operational measures above is not necessarily exhaustive.

Also, it would be interesting to know their merit order (i.e. which technology saves the most energy).

6.3.6 Applicability

The elements to take into consideration for the adoption of new, more efficient UPS systems vary depending on when a new infrastructure is being built or when upgrading an existing infrastructure. For new installations, the management team must (PrimeEnergyIT, 2011):

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

For the optimisation of existing infrastructures, the decision process includes the following steps (PrimeEnergyIT, 2011):

- Analyse the UPS technology and efficiency.
- Evaluate options and benefits of replacement of old equipment.
- Evaluate costs and benefits of redundancy.

Regarding the use of DC power to provide energy to a telecommunication infrastructure, the applicability of this practice will depend on its cost. Indeed it appears that the shift to DC powering comes at a significant deployment cost. As mentioned previously, this has not yet become a common practice and, therefore, could carry significantly higher first costs (Bigelow, What's happening in data center energy management, 2014).

6.3.7 Economics

Using higher efficiency power supplies will directly lower a data centre’s power bills and indirectly reduce cooling system cost and rack overheating issues.

It is estimated that, in most cases, a high efficiency power supply can pay-off within one year, even if the manufacturing costs for the newer equipment are doubled.
PG&E estimates that improving the energy efficiency by 10% through the purchase of newer equipment can trigger savings of €1,800 (for a 10kW rack) to €6,200 (for a 25kW rack), on the basis of a cost of electricity at €0.12/kWh. Similarly, selecting a 5% higher efficiency model of UPS can save over €34,000 per year in a 1,400 m² data centre, with no visible impact on the data centre’s operation beyond the energy savings (PG&E, 2012).

As presented in 6.3.2, it has been estimated that in the case of a large ICT company like with a yearly consumption of 8.9 billion kWh, an increase of power network efficiency by 6% would allow savings of 534 million kWh per year in electricity, worth €47 million per year (Eltek, 2012).

Regarding the design of UPS mentioned in 6.3.5, the costs associated with each technology vary. A relative solution cost of each technology is given in the table below:

![Figure 94 Relative cost of various UPS solution designs (Gutor, 2015)](image)

6.3.8 Driving force for implementation

Two main driving forces for the implementation of practices to tackle energy losses can be identified. First, as stated in 6.3.7, 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 environmental responsibility of operators is another driving reason for looking to high-efficiency technology to power telecommunications networks. As mentioned in 6.3.2, 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 CO2 emissions from telecommunication infrastructures.

6.3.9 Reference organisations

In several US and Europe-based facilities (Miami, Culpeper, Amsterdam), Verizon has adopted energy efficient UPS using efficient flywheels (see 6.3.5 for an explanation of its functioning). This allows eliminating the energy required to environmentally control battery rooms, thereby reducing non-productive related energy consumption (Verizon, 2013).

Google has long been a frontrunner in terms of data centre energy efficiency. A large part of these data centre’s very high PUE (slightly above 1.1) is due to the integration
of a high efficiency UPS. This specific design shifts the UPS and battery backup functions from the data centre into the server cabinet, providing the data centre with UPS efficiency of 99.9% (DataCenterKnowledge, 2009).

Example of ICT facility powered by DC power

6.3.10 Chapter references


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6.4 Energy monitoring and management

**SUMMARY OVERVIEW:**
Energy management relies on benchmarking, collecting data, analysing data and establishing a strategy aiming at implementing a systematic approach to improving energy efficiency and renewable energy use.

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<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
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<td>Relevant lifecycle stages</td>
<td>Design and installation</td>
<td>Selection and procurement of the equipment</td>
<td>Operation and management</td>
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<td>Main environmental benefits</td>
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<tr>
<td>Environmental indicators</td>
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<tr>
<td>Benchmarks of excellence</td>
<td>• 100 % of facilities are monitored</td>
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<tr>
<td>• Implemented benchmarking mechanisms (y/n)</td>
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<td>Cross references</td>
<td>Prerequisites</td>
<td>• Sufficient financial means to invest in technology-intensive monitoring tools</td>
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<tr>
<td>• Sufficient knowledge on the future development of the infrastructure (because ROI will take some time to materialise)</td>
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<tr>
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<td>• 5 Improve the energy performance and minimising the environmental impacts of ICT equipment</td>
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6.4.1 Description
Electricity is usually the major source of energy used by telecommunication and ICT services providers, far ahead transport fuel and heating. The causes of direct electricity consumption vary depending on the activities of the organisation (telecommunication, IT, broadcasting, etc.) and on the infrastructure included into its scope (data centres, networks, etc.).
Figure 95: 2014 estimated profile of energy (on the left) and electricity consumption (on the right) for some European telecommunication companies (based on the companies’ annual reports)

According to JRC, most data centres currently have little or no energy use or environmental measurement capability (JRC, 2015). Improving energy efficiency requires measures of power usage, in order to:

- identify current performances, for setting a baseline and comparing with other companies;
- calculate potential savings, for justifying new technologies investments and best practices implementation, and for defining goals;
- evaluate the results, for adapting the energy efficiency strategy and showing the improvements to management, government agencies or customers.

Energy management refers to a systematic approach to managing energy consumption including energy efficiency (reducing the amount of energy used) and renewable energy (switching to a low or zero carbon energy source). This should be integrated into wider management systems and have support at the top level of management and a dedicated staff resource. It must include a policy (action plan and regular reviews) and performance measurement. It must be embedded at all levels through internal and external communication plus staff training.

This BEMP explains how energy management can be implemented in practice and applies at the building level. It follows the principles of PDCA (Plan, Do, Check, Act) as per leading environmental management systems e.g. EMAS and ISO 14001. This is an iterative sequence which facilitates continuous improvement and allows those responsible to be proactive.

Figure 96: Sequence of key actions to implement an energy action plan. Source: SRD of BEMP for Tourism Sector.

This BEMP focuses on implementing parts of the PDCA cycle which are specific to energy management:
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

- Identify benchmarks and set goals
- Data collection and ongoing monitoring (in the “check” part of the cycle)
- Data analysis, target setting, establishing a strategy / action plan (in the “plan” part of the cycle)

Many companies have identified the need for metrics describing how efficiently power is transferred from the source of energy to the IT equipment. For example, the Green Grid Initiative has defined the PUE (Power Usage Effectiveness) and DCiE (Data Centre infrastructure Efficiency) metrics, which are widely used for reporting and comparing data centre energy efficiency (these metrics are described into the data centre section of this document).

Analysis metrics and tools have also to be set up in order to determine why the efficiency can be poor and to assist operators in selecting and making effective financial and environmental improvements. The installation of smart energy meters at the device plug (after all of the power conversion, switching and conditioning performed) enables to provide frequent readings of the energy consumption of IT equipment (servers, desktop infrastructures, etc.).

Such information allows the creation and implementation of an efficient energy policy at a site-level. This has to be deployed on the basis of clear objectives, appropriate governance (with a steering committee, a management system, etc.) and pertinent actions (investments, settings, trainings, etc.).

An exterior point of view may be obtained with the certification of the energy management system (according to the ISO 50001 standard for example) or energy performances audit. This can allow the improvement of the energy efficiency policy.

6.4.2 Achieved environmental benefits

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 infrastructures, which is much larger than the actual energy needed to perform the core service provided by a data centre. Indeed, the energy consumed is split between servers (which do directly useful work) and the power, cooling, and networking infrastructure that supports the correct functioning of servers. It is estimated that, in average, for every Watt of energy being consumed by servers, about 0.5 W is needed to cool them (Hancock, 2009). Another source of additional energy consumption is the powering of idle resources. In facilities without appropriate energy monitoring practices, servers consume almost as much energy when idle or lightly loaded, as when heavily loaded (Meisner, 2009). The problem is exacerbated by the fact that most data centres, being provisioned for peak rather than average load, are very lightly loaded on average—considerably less than 50% typically.

The consequence of this lack of appropriate energy monitoring is that, while a PUE of 1 would signal a 100% energy efficiency, the current industry average is 2, meaning that considerable inefficiencies exist (Vaid, 2010). Putting in place energy measurement tools can allow the identification of energy inefficiencies, and the adoption of processes to monitor energy use.

Second, this superfluous energy consumption means that the CO₂ emissions are largely inflated by indirect and unproductive equipment. Reducing energy consumption should lead to a strong reduction of CO₂ emissions by the ICT sector.
6.4.3 Appropriate environmental indicators

6.4.4 The key indicator here is the share of facilities where energy is monitored, and for which benchmarks have been set. This monitoring in turn can be based on a series of energy-related indicators described in other BEMPs of this report. Cross-media effects

Putting in place energy management and monitoring practices requires investing in additional IT equipment. In addition to the resources needed to produce this new equipment, the replacement of current data centre equipment by newer, smarter equipment means producing massive amounts of WEEE.

6.4.5 Operational data

Below is an overview of the energy management of telecommunication buildings and data centres. This shows the different levels on which energy management and monitoring needs to happen.

![Figure 97: Overview of the energy management of telecommunication buildings and data centres (Matsuda, 2012)](image)

The energy monitoring process starts with the development of measurement capacities. Several items can be measured, starting with the incoming energy consumption. This can be done by installing metering equipment capable of measuring the total energy use of the data centre including all power conditioning, distribution and cooling systems. Similar metering equipment can be installed to measures the IT energy consumption (total energy delivered to the IT system) and the supply air temperature and humidity for the IT equipment. These measurements can be done at various spots, including (CLP Power, 2013):

- Transformer, where the total facility power can be measured. Power Electricity travels through the service entrance and into a transformer, which feeds everything downstream: switchgear, UPS, lighting, CRAC/CRAHs, and, eventually, the IT equipment.
- Uninterruptible Power Supply (UPS), where the total IT load can be measured. Downstream from transformer, transfer switches, switchgear.
- Power Distribution Unit (PDU), where the total IT load can be measured (in a more comprehensive way than at UPS level). Different from a rack-based power units (where the IT equipment is actually powered), these floor mount units distribute power via circuit breakers to the cabinets and racks housing IT equipment (CLP Power, 2013).

The second step is **collecting the data measured**. This 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.

Finally, **energy data needs to be reported** to be of use in managing the energy efficiency of the facility. Similarly to the data collection process, data reporting can be done in the form of periodic written reports (that use the indicators listed in 6.4.3), or with an automated energy reporting console.

Analysing data allows the infrastructure management team to **set energy efficiency 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. As previously mentioned, the average industry PUE is estimated to be somewhere between 1.8 (Geet, 2014) and 2.2 (CLP Power, 2013). Below is an industry benchmark published by CLP:

![Figure 98: Benchmark of industry energy efficiency (CLP Power, 2013)](image)

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).

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), as presented in the “equipment” section of the figure above. Some of these emerging self-aware equipment include:

- Enterprise-class lower-power servers to reduce idle processor cores. These new generation servers use thermal controls such as variable-speed cooling fans monitored by tachometers, multiple temperature measurement locations within the system and continuous power monitoring that calculates and reports usage to compatible tools (Bigelow, 2014).
- Smart Power distribution units (PDUs) use intelligence to help organisations map energy draw. Networked PDUs offer real-time power monitoring and temperature or humidity sensing. Smart PDUs pay off in large data centres that require granular monitoring. Complementary management tools process data provided by PDUs to analyse power use and environmental conditions in the racks (Bigelow, 2014).

- Uninterruptable power supply (UPS). Modern UPS systems report readiness, battery status, load and other operating conditions to monitoring and management software. For large data centres, an emerging trend in UPS is the incremental ramping up of battery capacity as load increases. By matching the battery count to the load allows to reduce the energy wasted on charging extra batteries (Bigelow, 2014).

The main attribute of this type of equipment is that it creates a link between the equipment itself and a more or less centralised energy management system (DEMS, data centre energy management system, in the figure above) (Matsuda, 2012). Two major benefits of such a system can be highlighted. First, the real time interactions between the equipment and the DEMS allow a self-awareness of the system, which means that it can adapt its activity to a given context. For example, the most advanced data centres are equipped with tools allowing them to optimise electric power by varying the working servers in response to load fluctuations. That means that if the load requires only half of the servers in a data centre to operate in order to provide its service, the power consumption can be reduced by concentrating the activity in half of the servers while stopping the other, instead of supplying partly idle servers with power. In addition to this self-adjustment, the ICT equipment sends data on its operation to the data centre energy management system, which analyses the data automatically and in turn sends operation orders to the equipment. The data can be overviewed and analysed by management teams, for control purposes and in order to define an energy strategy for the facility. Second, this system allows for operators to benefit from an extensive data flow. This data flow in turn allows for a better benchmarking, data analysis, and ultimately decision making, as shown in the “operation know-how” of the figure above.

6.4.6 Applicability
Some technology intensive automated data management tools can be very costly, especially for smaller size structures. The tools are mainly for large size data centres because of heavy upfront investments.

Another constraint for the implementation of smart energy monitoring tools is the pay-off time. Data centres with large growth forecasts might plan to relocate in order to extend their activity. As the return on investment (ROI) takes a few years to materialise due to large upfront investments, these facilities will wait before they invest in monitoring tools.

6.4.7 Economics

Need for additional information on costs and returns of energy monitoring

The main interest economic benefit of energy monitoring is an increased profitability, due to lower energy costs combined with increased business levels. A decrease in energy consumption can deliver substantial cost savings over time. It is estimated that implementing energy practices in data centres, and consolidating applications onto fewer servers, could reduce data centre energy usage by 20% (Universal Electric Corporation, 2010). When taking into account the use of newer servers and best practices that include real time power monitoring, the improvement could reach 45%. If operators fully understand their power usage, they
can enter a load shifting strategy, meaning that they alternate between several data centres to follow less expensive electrical rates around the world, take advantage of lower rates at night or decrease air conditioning costs. In addition, better understanding its power usage can help a data centre manager to project growth more accurately, e.g. when to add more UPS, racks and servers etc. (Universal Electric Corporation, 2010).

In addition, by adopting energy monitoring practices, data centres can make room for additional business opportunities, thanks to a better understanding of their energy capacities. Without energy monitoring practices, staffs doesn’t know which devices and systems are generating the load and it is not clear where spare capacity exists in the data centre. By better monitoring the energy consumption and spare capacity, data centres can provide more service while decreasing the risk of power outage. Upgrading to the new generation of equipment, in addition to saving power and space, is essential for rolling out new revenue-generating services as well (Eltek, 2012).

6.4.8 Driving force for implementation

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

- **Cost reduction:**
  - Energy monitoring can reduce existing costs resulting from losses due to inaccurate or non-existent energy monitoring. As mentioned in 6.4.7, it has been estimated that implementing energy monitoring practices in data centres, with actions like the consolidation of applications onto fewer servers, could reduce data centre energy usage by 20% (Universal Electric Corporation, 2010).

- **Technological improvements:** As mentioned in 6.4.5 newer equipment allow for a more thorough energy monitoring. The Universal Electric Corporation estimated that the use of newer equipment in data centres could reduce the energy usage by 45%, compared to 20% using older equipment (Universal Electric Corporation, 2010).

- **Harmonisation of metrics:** The availability of key metrics (along with calculation processes, scope etc.) is a major improvement that will foster the development of energy monitoring practices. The research and harmonisation effort has been carried out by a multi-stakeholder’s taskforce (Global Taskforce on data centre energy efficiency (JRC, 2012)), meaning that operators can now focus on the implementation of the proposed metrics and calculation processes.

6.4.9 Reference organisations

The **Nippon Telegraph and Telephone Corporation (NTT)**, is a Japanese telecommunications company headquartered in Tokyo. NTT has launched a research program through the NTT Energy and Environment Systems Laboratories on energy management technologies for telecommunication facilities. This program aims at finding ways to achieve energy savings by implementing various energy controlling practices. NTT has conducted research and tested several practices. These practices include: "ICT equipment task allocation, which dynamically controls load allocation and network topology for air conditioning systems to operate efficiently; coordinated control of ICT equipment air conditioning to improve tracking capabilities to match the heat source allocation; power supply control, which stops supplying unnecessary electric power to standby devices; and a data centre energy management system, which integrates and collaboratively controls these technologies.” As presented in
6.4.5, this process means that a comprehensive energy monitoring system has been built, creating a steady data flow within the infrastructure.

European benchmark

6.4.10 Reference literature


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7 BEMP related to raw material consumption and waste management

7.1 Introduction / scope

The ICT sector has a significant role to play in reducing both the use of raw materials and the production of e-waste and hazardous materials of ICT equipment. Manufacturing and design of ICT equipment are excluded from the scope of this study (covered in the SRD for the Electrical and Electronic Equipment Manufacturing sector), only best practices on end-of-use management of equipment will be analysed.

Organisations in the telecommunications and ICT services sector also produce other types of waste (e.g. paper, packaging and food waste) that could be considered, but in this document only BEMPs related to the waste of electrical and electronic equipment (WEEE) as this is specific to the sector, are studied. For other general waste management BEMPs, see SRD on BEMP for Electrical and Electronic Equipment manufacturing sector. Manufacturing and design of ICT equipment are excluded from the scope of this study, only best practices on end-of-use management of equipment will be analysed.

Waste management in the ICT sector is a challenge because of the use of different metals and hazardous waste which are not easily recycled. These materials need to be properly treated at end-of-life to avoid damage on human health and the environment. The following table shows the important amount of rare metals used in different ICT components.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Use in ICT goods</th>
<th>Share of total going into ICT production, United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Wiring on circuit boards; housings</td>
<td>8% in electronic components</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Heat dissipation of conductors in electronics</td>
<td>50% in ICT components</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Nickle-Cadmium batteries</td>
<td>8% in batteries</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Rechargeable batteries for mobile devices; coatings for hard disk drives</td>
<td>5% in batteries (global)</td>
</tr>
<tr>
<td>Copper</td>
<td>Conductors in electronics</td>
<td>2% in electronic and electronic components</td>
</tr>
<tr>
<td>Gallium</td>
<td>Integrated circuits, optical electronics, LEDs</td>
<td>94% in ICT components</td>
</tr>
<tr>
<td>Germanium</td>
<td>Optical fibres, optical electronics, infrared systems</td>
<td>10% in optical fibres (global)</td>
</tr>
<tr>
<td>Gold</td>
<td>Solders, conductors and connectors</td>
<td>6% in electric and electronic components</td>
</tr>
<tr>
<td>Indium</td>
<td>LCDs, photovoltaic components</td>
<td>n.a.</td>
</tr>
<tr>
<td>Lithium</td>
<td>Rechargeable batteries for mobile devices</td>
<td>25% in batteries (global)</td>
</tr>
<tr>
<td>Nickel</td>
<td>Rechargeable batteries for mobile devices</td>
<td>10% in batteries</td>
</tr>
<tr>
<td>Palladium</td>
<td>Conductors in electronics</td>
<td>15% (global)</td>
</tr>
<tr>
<td>Plutonium</td>
<td>Hard disk drives, TFT LCDs, etc.</td>
<td>6% (global)</td>
</tr>
<tr>
<td>Silver</td>
<td>Wiring on circuit boards; miniature antennas in RFID chips</td>
<td>n.a.</td>
</tr>
<tr>
<td>Tantalum</td>
<td>Capacitors and conductors in embedded systems, PCs and mobile phones</td>
<td>60% in ICT components</td>
</tr>
<tr>
<td>Tin</td>
<td>Lead-free solders</td>
<td>24% in electric and electronic components</td>
</tr>
</tbody>
</table>

Figure 99: Overview of metals found in ICT equipment. Source: (OECD, 2010).

The term ‘waste’ is defined by the Directive 2008/98/EC on waste. It defines ‘waste’ as any substance or object the holder discards or intends or is required to discard; and ‘waste management’ as the collection, transport, recovery and disposal of waste, including the supervision of these operations and actions of dealers or brokers. This directive also defines the hierarchy of waste management. Priority should be given,
sequentially, to prevention, preparing for re-use, recycling, other recovery (e.g. energy recovery) and disposal.

![Waste Hierarchy Diagram]

**Figure 100: The waste hierarchy**

Each stage of waste management can be defined as followed:

- **Prevention**: measures taken before a substance, material or product has become a waste (e.g. improved preservation, monitoring, etc.)
- **Preparing for re-use**: all operations of checking, cleaning or repairing by which products become re-usable (e.g. cleaning and repairing operations).
- **Re-use**: any operation by which products or components that are not waste are used again for the same purpose for which they were conceived (e.g. re-use of computers, set-top boxes and Wi-Fi routers). This operation is not covered in the waste Directive but it is relevant for the waste management of the ICT sector.
- **Recycling**: waste is reprocessed into products or materials, which purpose is the same or other than the original product.
- **Recovery**: any operation which results is to replace other materials by waste serving for a useful purpose, or waste being prepared to fulfil a function (e.g. recovery of rare metals and batteries.)
- **Disposal**: any operation which is not recovery, even if the operation is associated with the recovery of energy.

This hierarchy should be applied to waste management to achieve the best overall environmental performance.

In response to the fast development and spreading of electronic equipment, regulatory measures have been decided at the European level to reduce the amount of WEEE generated. The Directive 2002/96/EC on waste electrical and electronic equipment (WEEE) aims, as a first priority, the prevention of waste electrical and electronic equipment and its reuse, recycling and other recovery formats. The revised Directive 2012/19/EU entered into force in 2012 and sets new collecting and recycling objectives.

One of the main concerns of the WEEE management is the content of hazardous substances in these wastes. The introduction of producer responsibility is the mean to encourage design techniques taking into account or facilitate repairing, reuse, dismantling, recycling and recovery. Retailers are involved directly in the life cycle of such equipment and in the management of WEEE, irrespective of the selling technique, including distance or electronic (online) selling. The role of retailers is
defined as distributor, as they supply the equipment to the customers who are going to use it. As distributor, the retailer is the responsible for ensuring that waste can be returned free of charge by the customer when supplying a new product. As producers, retailers can set up take-back systems from private households and they should set up systems to treat WEEE with the best available technique.

There are two areas where companies in the telecommunications and ICT services sector can improve WEEE management through waste reduction, reuse or recycling:

- WEEE management of ICT equipment used by telecommunications and ICT services companies (e.g. servers, network equipment, antennas, etc.)
- WEEE management of products sold or leased by telecommunication and broadcasting companies (e.g. mobile phones, set-top boxes and Wi-Fi routers).
7.2 Improving waste prevention

**SUMMARY OVERVIEW:**
Waste prevention aims to reduce the production of waste by extend ICT equipment life, which can be implemented through sustainable procurement policy and life cycle asset management.

<table>
<thead>
<tr>
<th>ICT components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data centre</td>
</tr>
<tr>
<td>Telecommunication network</td>
</tr>
<tr>
<td>Broadcasting</td>
</tr>
<tr>
<td>Software publishing</td>
</tr>
<tr>
<td>Desktop architecture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevant lifecycle stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and installation</td>
</tr>
<tr>
<td>Selection and procurement of the equipment</td>
</tr>
<tr>
<td>Operation and management</td>
</tr>
<tr>
<td>Renovation and upgrades</td>
</tr>
<tr>
<td>End-of-life management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main environmental benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
</tr>
<tr>
<td>Waste production</td>
</tr>
<tr>
<td>Air emissions</td>
</tr>
<tr>
<td>Water use &amp; consumption</td>
</tr>
<tr>
<td>Noise and electromagnetic radiations</td>
</tr>
<tr>
<td>Landscape and biodiversity</td>
</tr>
</tbody>
</table>

**Environmental indicators**
- Average product life
- Number of PCs and mobile phones per person

**Benchmarks of excellence**
- An asset management system is integrated in the organisation

**Cross references**

**Prerequisites**
- Compliance with the Directive 2012/19/EU on WEEE
- Access to a large range of information on equipment

**Related BEMPS**
- 5.2: Procurement of energy efficient ICT equipment
- 9.2: Services to help customers reduce their impact on the environment

**7.2.1 Description**
In order to address the challenge of reducing waste in the ICT sector, the primary concern is to improve waste prevention. Preventing waste means reducing the amount of waste that will be generated at the end of use of the equipment. It also includes the assessment of the content of hazardous waste and of their future impact on the environment.

With respect to waste prevention, the European Commission puts the emphasis on the following objectives:
- Foster durable, reusable and recyclable products
- Change current consumption patterns
- Waste prevention and decoupling objectives based on best available practices

The revised Directive 2012/19/EU on WEEE aims at preventing the generation of WEEE and improving their reuse and recycling. The European Directive RoHS restricts
the use of certain substances used in ICT devices: mercury, lead, cadmium, hexavalent chromium, polybromobiphenyls (PBB), and polybromodiphenylethers (PBDE). It aims at reducing the amount of hazardous waste emitted.

Companies can go beyond the regulation and implement solutions to improve waste management. Best practices on waste prevention cover the selection and procurement of future ICT equipment and the assessment of installed devices. It is related to an objective of extending product life. These best practices can be related and put into perspective with best practices detailed on ICT energy efficiency of ICT equipment (Chapter 5).

Waste prevention can also be based on different solutions:

- Procurement policy: contracting leasing service or maintenance contracts. Using Life Cycle Assessment tools such as ISO 14044 for Environmental management - Life cycle assessment.
- Asset management: ensuring the identification of all areas of optimisation, consolidation and aggregation to avoid unnecessary investments and additional waste creation. The audit of the equipment used is detailed in the section 5.2 on the procurement of energy efficient IT equipment.
- Ecodesign review to ensure the amount of materials needed.
- Offering services to extend life service of products.

Other services such as take-back programme of mobile phones and eco-rating scheme can be put in place to reduce the amount of waste generated from the use of ICT equipment. These types of services are tackled in the section 9.3 focusing on services to help customers reduce their environmental impact by using ICT equipment.

### 7.2.2 Achieved environmental benefits

A TNS SOFRES and GIFAM study 2011 (ADEME, 2012) showed that 40 to 50% of products 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 implementation of a waste management program would reduce this amount of products replaced.

ICT products require the use of a wide range of metals, plastics and other substances that are contained in electrical and electronic equipment. A mobile phone can contain over 40 substances (UNEP, 2009). The environmental impact of the primary metal production is significant, especially for precious and special metals. Great amounts of land are used for mining and energy is generated for the extraction of the metals. For example, to produce 1 tonne of gold, palladium or platinum, CO\(_2\) emissions of about 10,000 tonnes are emitted. The figure below shows the CO\(_2\) emissions related to the extraction of main EEE metals.
The improvement in the use of the resources used to produce ICT equipment helps decrease these CO$_2$ emissions and to preserve natural resources.

7.2.3 **Appropriate environmental performance indicators**

Different environmental performance indicators can be relevant to follow a waste prevention management policy.

Through the review of the life cycle assessment of the products, the different life stage of the product can be reviewed:

- Measurement of the useful life: the product is in use. A product can be reused and have a second useful life with a second user.
- Measurement of the holding period of a product: the product is no longer used but not disposed.
- Measurement of the life-span of a product.

Regarding the amount of resources used, indicators on the follow-up on the amount of metals used from one year to another is a good indicator to evaluate the environmental impact of the product:

- Total weight of plastic material
• Total weight of electronics;
• Number of plastic materials used;
• Presence of halogenated compounds in plastics and electronics
• Presence in integrated circuits

The related CO₂ emissions can also be tracked.

If services are offered to customer in order to extend the useful life of a product, it can be relevant to evaluate the performance of those services and their impact on useful life of a product.

7.2.4 Cross-media effects
The reduction of the amount of resources used for a product is not always possible. Some substances are irreplaceable to produce ICT equipment and their use is incompressible.

The improvement of the environmental performance of ICT products is dependent on the technologies available on the market and on the level on innovation for a product.

7.2.5 Operational data
The improvement of waste prevention requires the establishment of a waste prevention plan. According to the pre waste European project⁵⁹ there are different steps in the implementation of a waste prevention plan.

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.

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. SMART⁶⁰ specific objectives on waste flow and actions can be set.

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

The waste prevention plan can also be based on a SWOT⁶¹ analysis and implemented within a timeframe. Communication channels and partnerships shall be identified and developed to ensure the implementation of the waste prevention project.

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.

A waste prevention plan aims at reducing the amount of waste generated by products. The assessment of the situation helps understanding the composition of the products and their impact on the environment. This stage can be based on a life cycle assessment of the product (LCA). The LCA captures the environmental impacts of each phase in a product life cycle OECD 2010 Greener and smarter. It covers the overall value chain from “cradle to grave”. A product life cycle can be represented as showed in the following scheme:

⁵⁹ http://www.prewaste.eu/index.php?option=com_k2&view=item&id=481&Itemid=74
⁶⁰ Specific, Measurable, Achievable, Relevant, Time-bound objectives
⁶¹ Strengths, Weaknesses, Opportunities, Threats matrix analysis
The LCA step can help identify the amount of resources used and where to cut waste. ICT equipment contains dangerous substances which can be reduced.

An ecodesign process can be put in place to reduce the initial amount of resources used and to reduce final waste generated. Different strategies can be applied to design an ecodesigned electronic product (NTUA, 2007) and GeSI 2008 contribution:

- Develop a new concept: by integrating innovative strategies like immaterialization which is the replacement of a physical product with nonphysical product or service or dematerialization using fewer new raw materials.
- Make physical optimisation:
  - by increasing the reliability and enhance product functions;
  - by using fewer units to satisfy the same consumer needs;
  - by prolonging the useful life of a product and by making the product more adaptable by allowing continuous updating;
  - by optimising and integrating functions through multipurpose machines combining functions;
- Select the right material: the choice of the right material depends on the life cycle assessment. The materials chosen can be: recycled, recyclable, renewable, using less material, low energy content.
- Optimise the distribution process: optimisation of the packaging and elimination of unnecessary materials.

Ecodesign can help reduce the amount of hazardous materials used which is a topical issue in the ICT sector. Another important topic is the reduction of the material used for the packaging.

After reducing the amount of materials used at the designing stage, the environmental performance can be improved by increasing the service life of the product. Companies have low impact on the way consumers use their products but they can reduce the obsolescence.

There are different types of obsolescence (ADEME, 2012):
- Indirect: impossible to repair because of the lack of availability of components.
- Incompatibility: the software no longer matches the new operating system.
- Aesthetic: new products available on the market with a new design which makes old products obsolete.
- Operating: product programed to function for a determined number of cycles.
- Customer service: too long repair period making customers more willing to buy a new product than repair an old one.

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

From a service provider point of view, a data centre or network operator, these solutions can be integrated at the procurement level. The process for the integration of a green procurement policy taking into account environmental performance criteria is developed in the section 5.2. The procurement policy can integrate a review of the LCA analysis and the Ecodesign process of the manufacturers. Criteria based on LCA and ecodesign and the reduction of resources and materials can be integrated in the contract with a manufacturer.

Companies can also offer different services to customers 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 on usage conditions, developing functionalities to improve existing products, making easier the replacement of components.

Services providers can contract these kinds of services to extend shelf life of their ICT equipment and reduce the final total amount of WEEE they generate.

Waste prevention also focuses on the waste generated by a company itself and not only generated by the products a company sells. A company can assess the use of its resources. An asset management plan can be implemented to identify areas of optimisation in the use of the equipment. An audit can be led on the equipment used. This assessment will avoid unnecessary investments and additional waste generation. As detailed in the section 5.2 the green procurement policy shall integrate the review of the existing equipment.

### 7.2.6 Applicability

The stages of the LCA and of ecodesign are relevant for manufacturers at the conception of a product. However, service providers companies can review in partnerships with manufacturers the composition of the products to ensure that they use or that they will sell products with reduced environmental impact. This review must be integrated into the procurement policy. The integration of environmental criteria into the procurement policy is detailed in the section 5.2 on the procurement of energy efficient ICT equipment.
The development of these solutions requires the access to a wide range of information on the products which can be hard to obtain. They must be developed in partnerships with manufacturers and different services within a company.

7.2.7 Economics

The establishment of a green procurement policy and the review of the ecodesign and life cycle assessment require investing in human resources and skills.

Using LCA assessment for ICT product can also have economic benefits (OECD, 2010) by increasing control over internal efficiencies and over suppliers. The close monitoring of environmental performance allows better risk control over the supply chain. LCA-based indicators and ecodesign of products can help identify area with high turnover of resources or high rates of waste and pollution which can be considered to lower production costs for the final product or components.

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

7.2.8 Driving force for implementation

Waste prevention solutions are an opportunity to create a competitive advantage. As mentioned in the previous section, the development of new technologies and products through LCA and ecodesign and the development of new services to customers can improve a company’s market share and increase customer loyalty. Consequently, economic opportunities can be drivers for the implementation of waste prevention plan.

In the framework of an environmental strategy and of CO2 emissions and waste reduction objectives, waste prevention is a good way to achieve these objectives.

7.2.9 Reference organisations

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

- Alcatel Lucent: has developed a simplified LCA framework that evaluates eco-impact information for ICT products.
- SAP: Asset life cycle management.
- Belgacom: improved packaging of mobile phone SIM cards, namely the replacement of the ABS carrier and information booklet in paper, by an information card packed in polypropylene, which has led to waste savings of 9 tonnes.
- Telefonica:
  - develops equipment purchase policies for our operations that facilitate reuse and recycling at the end of its useful life.
  - support standards that reduce the generation of e-waste and improve the ecodesign of this kind of equipment for telecoms services.

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### 7.3 Improving WEEE collection, recycling and recovery

**SUMMARY OVERVIEW:**
Establishing collection and recovery (e.g. reuse, repairing, remanufacturing) channels can reduce the amount of waste sent to landfill and to ensure that it is recycled properly.

<table>
<thead>
<tr>
<th>ICT components</th>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Relevant lifecycle stages</th>
<th>Design and installation</th>
<th>Selection and procurement of the equipment</th>
<th>Operation and management</th>
<th>Renovation and upgrades</th>
<th>End-of-life management</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Main environmental benefits</th>
<th>Energy consumption</th>
<th>Waste production</th>
<th>Air emissions</th>
<th>Water use &amp; consumption</th>
<th>Noise and electromagnetic radiations</th>
<th>Landscape and biodiversity</th>
</tr>
</thead>
</table>

- Total WEEE generated
- Total WEEE recycled
- Total WEEE reused
- Percentage of equipment recovered
- Percentage of contaminated equipment removed
- Percentage of non-contaminated equipment recovered
- Follow-up of the improvement of ICT equipment life cycle
- The amount of assets losses, when the process is managed by a specialised recycling company
- Total hazardous substances avoided
- CO₂ emissions avoided

**Environmental indicators**

**Benchmarks of excellence**

- 100% or ICT equipment recovered and reused or recycled.

**Cross references**

**Prerequisites**
Need for the appropriate technologies, skills and channels for recycling, recovery, refurbishment and reuse.

**Related BEMPS**
- 7.2: improving waste prevention
- 9.2: services helping customers reducing their environmental impact
7.3.1 Description

The ICT sector is characterised by a rapid innovation cycles and a high turnover of hardware and software. The ICT sector is facing a fast growing electrical waste stream and therefore must consider collection and recycling of devices to reduce their impact.

WEEE is a complex mixture of materials and components that because of their hazardous content, and if not properly managed, can cause major environmental and health problems. The main concern for disposal is the metal and hazardous substances contained in WEEE. ICT devices contain significant amount of copper, lead and mercury which are not easily separated and recycled. The level of ICT hardware recycled is still low and the sector encounter a real challenge to improve waste collection and recycling.

European Directives have been put in place on specific waste to further the Directive 2012/19/EU entered into force in 2012 on collecting and recycling WEEE. In 2010, the EU Batteries Directive came into force with the objective to divert batteries away from landfill.

The techniques described in this part as best environmental practices refers to establishing collection and recovery (e.g. reuse, repairing, remanufacturing) channels, in order to reduce the amount of waste sent to landfill and to ensure that it is recycled properly.

Reuse, refurbishment or repair of ICT equipment is most desirable since this option increases the lifetime of the electronic product and higher resource efficiency. Therefore, the consumption of raw materials (rare earths, plastics, glass, metals, etc.) is prevented and less embodied energy is required.

Recycling of electronics allows for materials to be recovered (precious metals, ferrous metals, glass, plastics, etc.), and reduces the environmental impact associated with the extraction of raw materials (air emissions, effluent discharges, land disturbances, mine waste and tailings, and noise). Moreover, recycling e-waste ensures that hazardous and toxic substances are handled (cadmium, lead, mercury, arsenic, etc.) and avoids environmental impacts due to inappropriate processes (landfill or combustion).

One of the main techniques to allow proper environmental management of end-of-life products is the implementation of reverse supply chain. It includes:

- The promotion of longer product life and duration of use
- Take-back programmes:
  - between ICT manufacturers and companies in telecommunications and ICT services sector
  - between companies in the telecommunications and ICT services sector and their clients (e.g. mobile operations)
- Exchange and repair services
- Remanufacturing or refurbishing of products
- Long-term leasing contracts
- Donation programmes

These different solutions are tackled in other sections of this report, the section 7.2 on waste prevention and the section 9.3 and service to help customers reduce their environmental impact.
7.3.2 Achieved environmental benefits

End-of-life management have different environmental benefits. The main direct environmental benefit is the reduction of waste and hazardous waste generated. The establishment of channels of dismantling, recovery and recycling will reduce the total amount of waste generated. The reduction of waste generated will indirectly reduce the GHG emissions linked to the creation of waste. The following table shows the potential dangerous substances concentration in products generating e-waste. It also shows the annual global emissions related to each waste.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Relationship with E-waste</th>
<th>Typical E-waste concentration (mg/kg)*</th>
<th>Annual global emission in E-waste (tonne)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polybrominated diphenyl ethers (PBDEs)</td>
<td>Flame retardants, coolings units, transformers, insulation foam</td>
<td>1.4</td>
<td>291</td>
</tr>
<tr>
<td>Polybrominated Biphenyl (PBBr)</td>
<td>Product of combustion, low-temperature combustion</td>
<td>2.5</td>
<td>45</td>
</tr>
<tr>
<td>Chlorinated polystyrene (TC)</td>
<td>Product of combution, low-temperature combustion, inorganic plastic, ITO</td>
<td>3.6</td>
<td>60</td>
</tr>
<tr>
<td>Polyethylene terephthalate (PET)</td>
<td>Flame retardants, silicones (Evans et al., 2003))</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Polyvinylidene chloride (PVDC)</td>
<td>Doping material for Si, Silica, Silicate, ITO</td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>Flame retardants, plastic (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Flame retardants, plastic (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Gallium (Ga)</td>
<td>Flame retardants, plastic (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Indium (In)</td>
<td>Backlighting, LCD displays, plastic (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Batteries (Crane and Schoenung, 2009)), CRTs, batteries</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Lithium (Li)</td>
<td>Batteries (Crane and Schoenung, 2009))</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>Batteries (Crane and Schoenung, 2009))</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>Batteries (Crane and Schoenung, 2009))</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>Rectifiers (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td>Writing, switches (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>Solder (Crane and Schoenung, 2009))</td>
<td>1.7</td>
<td>34,000</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>CRT screens (PVDF, 2003)</td>
<td>1.7</td>
<td>34,000</td>
</tr>
</tbody>
</table>

Adapted from (e-waste, 2009).
* (Moore et al., 2007)
** Assuming a global e-waste production of 20 million tonnes per year.

Figure 104: Potential environmental contaminants arising from E-waste, (Robinson, 2009)

An ITU study shows the estimated GHG emissions avoided by using recycled content and materials:
### Table: GHG emissions from materials used in ICT equipment, ITU

<table>
<thead>
<tr>
<th>Material</th>
<th>Estimated GHG emissions(^{a, b}) (kg CO(_2).e) extraction/mfg stages (to produce 1 kg of material)</th>
<th>Material finished product form – typical recycled content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0% recycled content</td>
<td>100% recycled content</td>
</tr>
</tbody>
</table>
| 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%  
● Rolled sheet goods |
| Metal – stainless steel (electric furnace and argon-oxygen decarburization) | 6.8 | 1.8 | ● Typical (world) – 38%  
● Structural – 75%  
● Electrical/electronic – < 5% |
| Metal – copper (smelting/converting and electro-refining) | 3.33 | 0.55 | ● Typical (world) – 34% |
| 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\(^{10}\) | 6.1\(^{1}\) | |
| Plastic – acrylonitrile butadiene styrene (ABS) | 5.45\(^{9}\) | 3.9\(^{8}\) | |
| Plastic – polystyrene (PS)/styrene acrylonitrile (SAN) | 5.09\(^{9}\) | 3.9\(^{8}\) | |
| Plastic – polyethylene terephthalate (PET) | 4.09\(^{7}\) | * | |
| Plastic – polyethylene, low density (PE-LD) | 3.71\(^{3}\) | * | |
| Plastic – polypropylene (PP) | 3.51\(^{7}\) | * | |
| Plastic – polyhydroxy-alkanoates (PHA) ["bio plastic"] | 0.49\(^{1}\) | * | |

\(^{a}\) Under study/evaluation within plastics recycling industry  
\(^{b}\) NDA – no data available

---

The generation of e-waste generates hazardous substances which can be potentially sent to landfill. E-waste contaminants can then enter aquatic systems via leaching from dumpsites e-waste may have been deposited (Brett H. Robinson 2009). The
recycling and reuse of equipment will reduce the amount of waste sent to landfill and **reduce the impact on aquatic systems.**

When wastes are sent to dumpsites, their storage 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.**

7.3.3 **Appropriate environmental performance indicators**

Different indicators can be followed to monitor the environmental performance of recycling, recovery and reuse processes.

Main indicators to follow are indicators focusing on the amount of waste generated or avoided:

- Total WEEE generated;
- Total WEEE recycled;
- Total WEEE reused;
- Percentage of equipment recycled by types of materials;
- Percentage of contaminated equipment removed;
- Percentage of non-contaminated equipment recovered.

Other appropriate indicators are on the efficiency of the recycling and recovery processes:

- Follow-up of the improvement of ICT equipment life cycle;
- The amount of assets losses, when the process is managed by a specialised recycling company;
- Disassembly time: time to separate all plastic parts from electronics.

Finally, other indicators can be reported related to environmental impacts from the generation of WEEE:

- Total hazardous substances avoided;
- CO₂ emissions avoided.

7.3.4 **Cross-media effects**

Many companies must outsource the recycling process to specialised companies. Specific attention shall be kept on potential adverse effects linked to the outsourcing. ICT equipment often contains sensitive data. Therefore, when ICT equipment are disassembled and reused the company must ensure that data are safely removed. The company can check the security information management led by the recycling facility.

When products are refurbished to be reused, the refurbishment shall not alter the quality of products. If the refurbishment modifies the quality or functionalities of a product, the company shall communicate in full transparency to users within the company or to external customers.

Some refurbishment channels aims at sending equipment in other countries. Reused devices are often sent to developing countries that do not own necessary recycling infrastructures to properly manage end-of-life of electronic equipment. There is a potential risk that a reused product will not be properly disposed at its end-of-life.
7.3.5 Operational data

The improvement of waste management passes through the proper management of the end-of-life of products. The treatment of wastes can be outsourced to companies specialised in the process.

The treatment of ICT equipment represents different challenges:

- Maximise the recovery of valuable material resources such as rare metals.
- Dismantling and removing components.

Different steps can be followed while treating ICT equipment. Once equipment has become waste, reverse supply chain can be established to ensure the proper and environmentally sound management of WEEE. The concept of reverse supply chain is based on different subsequent steps (ITU, 2012):

The overall end-of-life management process of ICT equipment is showed in the following scheme:

![Figure 106: End of life management for ICT equipment, (ITU, 2012)](image)

Reverse logistic

During the first stage, handling and transportation of the equipment should be managed with care to avoid damaging that could reduce the potential for reuse and refurbishment. Waste will be transported from different locations to the warehouses where they will be stored. This first step also involves the inspection and cleaning of waste to prepare them for the next step.

Companies can subcontract the waste treatment to companies specialised in waste treatment.
Dismantling and segregation

The removal of components can be a difficult part of the dismantlement process because of dangerous substances contained in ICT equipment. Therefore, the first step of the dismantling is to remove dangerous components and substances. This operation should be well prepared to ensure that every necessary measure have been taken in terms of safety.

After the removal of problematic components, equipment can be further disassembled and sorted. The dismantling phase includes a manual or semi manual dismantling of products (UNEP, 2009). This operation can be significantly optimised and the process of dismantling components such as power supply, hard discs and disc drivers can be improved by using electric or pneumatic screwdrivers to accelerate the speed of dismantling. When the product can no longer be disassembled into separated parts, the different components must be sorted into various material streams such as: steel, aluminium, circuit boards, plastics. Each stream matches a specific recovery process.

Disassembly does not require high technological skills but worker shall be trained to safely carry out specific manual tasks.

Dismantling methods and objectives are different depending on the type of material. The UNEP report (UNEP, 2009) details some strategies to put in place as shown in the table below:

<table>
<thead>
<tr>
<th>Objectives</th>
<th>How to achieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>HZ+R</td>
<td>High collection rate</td>
</tr>
<tr>
<td>HZ</td>
<td>Removal of: Ink cartridges, PCB containing capacitors, Mercury-containing switches, batteries</td>
</tr>
<tr>
<td>R</td>
<td>Recovery of (valuable) components: PVBS, HD, reusable components</td>
</tr>
<tr>
<td>R</td>
<td>Recovery of material fractions: Ferrous, Non-ferrous (Al, Cu), Non-metals, Plastics, rubber, woods, Remaining fractions</td>
</tr>
<tr>
<td>R+HZ</td>
<td>Recovery of Material fractions</td>
</tr>
</tbody>
</table>

HZ = control over hazardous fractions; R = recovery of components or material

Figure 107: dismantling objectives and methodologies, (UNEP, 2009)

Refurbishment and repair

The stage of refurbishment depends on the type of components or product. The refurbishment consists in checking the functionality of the equipment through testing. Hardware is verified and then old data and software are removed. If hardware components are needed to complete the equipment they will be assembled.

After old digital data destruction, new software and required instructions sets may be installed. The goal is to ensure that the product fully meet the required functions.
The components or ICT products entering the refurbishment process and destined to be reused must be handled in a suitable manner to preserve their value.

Some components or products may still be altered but may be repairable.

The repair of ICT equipment requires specific skills. Companies in the ICT sector can refurbish and repair their ICT equipment to extend their life cycle but if they do not benefit from the internal skills needed for this process, specialised refurbishment companies shall be involved in the process.

**Reuse**

After refurbishment and repair, products shall be suitable to be sent back on the market and reused. Different selling channels can be considered whether on specialised second hand shops or on the Internet. This process will extend products useful life and overall life cycle.

**Recycling and recovery**

The dismantling of equipment allowed sorting by types materials which will be recycled and recovered.

Non-ferrous and ferrous materials are first separated. Non-ferrous materials are further separated into copper, aluminium, brass etc. Different techniques can be used such as optical sorting, density separation, eddy current separation and vibration separation.

Other material is then processed to separate for instance electric components such as circuit boards and site.

Each material will have a specific recycling and recovery process. Special attention should be put on batteries because of the variety of batteries used in ICT equipment. The composition of batteries will require different processes which increase the difficulty for recycling.

Metals are other complex materials to recycle. Large amounts of metals are used in the production of ICT equipment but some metals are used in small amount. The recovery of small amount of metals is not efficient and will not be possible. Recovery of metals can require many steps and specific equipment and control system.

The decision of which metals to recover depends on the cost efficiency. For instance, even though gold and silver are only present in small amount in ICT equipment, they will be recovered because of their high market value.

The same question on cost recovery is raised for the treatment of plastics components. Sometimes the cost of recovery exceeds the value of the recovered material and therefore is not beneficial. When plastic is sent to recovery, plastic components may need further cleaning and decontamination to remove substances such as paints, labels and imbedded metal pieces. To optimise the recycling process, plastics must be sorted by types of polymer. Polymer recognition can be a complex process but new technologies on recovery systems exist to sort the different types.

Consideration should be given to circular economy and cradle-to-cradle approaches. The goal is to create close loop where the waste generated from a process becomes an input for another. Waste can be seen as a mean to improve efficiency (ITU, Toolkit on environmental sustainabilitu for ICT sector, 2012).
End-of-life management

ICT equipment treatment process will generally be ensured facilities specialised in recovery and recycling. The waste producer company must ensure that the service provider handles the waste management process properly. This monitoring can be based on different information.

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

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

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

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

o Verify specific permits such as: storage permit, air emission permit, water permit, hazardous waste permit, etc;

o Ensure proper handling of transboundary movements;

7.3.6 Applicability
The efficiency of a reverse supply chain depends on the efficiency of each step previously detailed. Each step must help meet environmental needs and must be well interfaced with the next step. All steps are interdependent to make the whole process work.

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

The recycling and refurbishment processes also depend on the performance of the equipment, the level of technologies and labour available. The level of technologies and skills depends on the country and on geographical areas.

7.3.7 Economics
The development of techniques and channels to reuse products and avoid waste extend the life cycle of equipment. The reuse of equipment can generate new benefits when the equipment is put on the market again. When the equipment is reused internally it reduce the investment needed for the equipment and will help invest in other areas of the company.

The contract with recycling facilities can be negotiated and aligned with the exact needs of the company.

European countries have implemented taxes on waste sent to landfill. The reduction of the amount of waste a company sent to landfill by recycling and reusing products will lower this tax.
Figure 108: Comparison of landfill tax levels in European countries EUR per tonne in 2011, excluding VAT, (European Topic Centre on Sustainable Consumption, 2012)

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

7.3.9 Reference organisations
- Bouygues Telecom: Mobile phones are collected, sorted out, tested, and refurbished by Les Ateliers du Bocage. 300,000 mobiles have been recycled since 2010. Since 2012, more than 10 million euros have been paid back to customers for giving their old mobile phones in the framework of the take-back programme.
- Orange: the implementation of a take back programme of mobile phones.

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8 BEMP related to other environmental impacts of telecommunication and broadcast infrastructures

8.1 Introduction / scope

This chapter focuses on environmental pressures due to the building and operation of telecommunication and broadcast infrastructures, such as antennas, landlines, underground and underwater cables, etc. These infrastructures and equipment have external negative effects which could be considered.

In most countries, the construction of ICT infrastructures such as radio masts and towers is regulated by law, with texts relating to urban planning, environment or telecommunication. Nevertheless, ICT operators can go beyond this and take additional initiatives to prevent or reduce the negative impacts of their infrastructure.

The following sections describe practices that reduce the negative visual and environmental impacts of ICT infrastructure. Telecommunication infrastructures can be perceived as being visually intrusive in urban and natural landscapes. The construction of ICT infrastructure can also alter terrestrial and aquatic habitats. Potential impacts on biodiversity can be significant during construction and installation of linear infrastructure such as long distance fixed telephone line cables. These issues can be managed through the identification of the right location, the landscape integration and specific architectural design.

Noise can also be an issue for some types of ICT infrastructure (data centres, base stations) that use backup power generators and air conditioning.

Telecommunications and broadcast infrastructures are characterised by the transmission and reception of signals which do create electromagnetic fields (EMF). The electromagnetic spectrum used for telecommunication extends from 3 kHz to 300 GHz (i.e. radio frequency). The emission of electromagnetic radiation is a public and scientific concern. Exposure to Electromagnetic fields (EMF) has been increasing with the growth in the use of appliances of the telecommunications industry and of the transmitter masts used as radiotelephone base stations. In response to health concerns and the fast growing exposure, the EU passed a Directive on occupational exposure to EMFs in 2013. The Directive covers all known direct biophysical effects caused by EMF. It establishes exposure limits values (ELV) and requires different actions to respect these limits.
Guidelines were published by the independent scientific committee the International Commission on non-ionizing radiation Protection (ICNIRP) on maximum exposure levels. There was a publication in 1998 covering the frequency range up to 300 GHz (ICNIRP, 1998). In 2020, new guidelines for the frequency range 1 Hz to 100 kHz are to be published. In addition to the ICNIRP, the ITU (the UN agency for ICT), the IEC (International Electrotechnical Commission) and the Institute of Electrical and Electronics Engineers all have adopted standards regarding levels of EMF exposure.

The following table summarizes the basic restrictions set by the ICNIRP:
### Figure 110: Overview of ICNIRP restrictions (source: [ICNIRP, 2010])

<table>
<thead>
<tr>
<th>Exposure characteristic</th>
<th>Frequency range</th>
<th>Internal electric field (V m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Occupational exposure</td>
<td></td>
</tr>
<tr>
<td>CNS tissue of the head</td>
<td>1 - 10 Hz</td>
<td>0.5 / f</td>
</tr>
<tr>
<td></td>
<td>10 Hz - 25 Hz</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>25 Hz - 400 Hz</td>
<td>2 x 10⁻⁴ f</td>
</tr>
<tr>
<td></td>
<td>400 Hz - 3 kHz</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>3 kHz - 10 MHz</td>
<td>2.7 x 10⁻⁷ f</td>
</tr>
<tr>
<td>All tissues of head and body</td>
<td>1 Hz - 3 kHz</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>3 kHz - 10 MHz</td>
<td>2.7 x 10⁻⁷ f</td>
</tr>
<tr>
<td></td>
<td>General public exposure</td>
<td></td>
</tr>
<tr>
<td>CNS tissue of the head</td>
<td>1 - 10 Hz</td>
<td>0.1 / f</td>
</tr>
<tr>
<td></td>
<td>10 Hz - 25 Hz</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>25 Hz - 1000 Hz</td>
<td>4 x 10⁻⁶ f</td>
</tr>
<tr>
<td></td>
<td>1000 Hz - 3 kHz</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>3 kHz - 10 MHz</td>
<td>1.35 x 10⁻⁶ f</td>
</tr>
<tr>
<td>All tissues of head and body</td>
<td>1 Hz - 3 kHz</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>3 kHz - 10 MHz</td>
<td>1.35 x 10⁻⁶ f</td>
</tr>
</tbody>
</table>

**Notes:**
- f is the frequency in Hz
- All values are rms
- In the frequency range above 100 kHz, RF specific basic restrictions need to be considered additionally.
8.2 Reducing the effects of ICT infrastructure on landscapes

SUMMARY OVERVIEW:
In order to reduce the impact of new telecommunications infrastructure on fauna, flora, land-use and landscapes, they should be placed underground, close to road access, camouflaged or integrated in existing infrastructure.

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<th>Environmental indicators</th>
<th>Height (e.g. below a 12 meters threshold, no specific permission is required to build a mast in France)</th>
<th>Surface (e.g. below a 5 m² surface, no specific permission is required to build a mast in France)</th>
</tr>
</thead>
</table>

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<tr>
<th>Benchmarks of excellence</th>
<th>Develop and implement company guidelines or a code of conduct regarding the planning and installation of ICT infrastructures that causes minimal visual and environmental impact</th>
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<th>Cross references</th>
<th>Prerequisites</th>
<th>The potential negative impacts of colocation must be evaluated prior to agreeing to share a tower (risks of bad coverage, interferences etc.)</th>
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<th>Related BEMPS</th>
<th>NA</th>
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8.2.1 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 visual impact on the character and amenity of the local environment depending on the perception of the local community as well as the aesthetic value assigned to the scenery, both in urban and in rural contexts. The need to integrate ICT infrastructures in an urban context without defacing existing buildings is a real challenge for network operators. Installing antennas, electricity closets and air conditioning equipment on buildings which were not originally designed for this purpose requires putting in place specific processes to deal with the issues arising from the installation. In a rural context, terrestrial and aquatic habitats may be altered primarily during the construction of telecommunications infrastructure depending on the type of infrastructure component and proposed location. Potential impacts to
biodiversity may be more significant when creating long distance fibre optic cables, and access roads to transmission towers and other fixed infrastructure. In both contexts, the acceptance of the infrastructure by stakeholders (including inhabitants and local authorities) can vary considerably. A low acceptance by local stakeholders can be damaging for the network operators and result in complaints and reputational issues.

Figure 111: Mobile telecommunications radio base station equipment (Scottish Natural Heritage, 2002)

The following techniques have been deployed when planning and designing new infrastructures, or when renovating older ones, in order to minimize their effect on landscape, fauna and flora:

- To carry out a thorough consultation process with local stakeholders, to collect information on the acceptance of the siting and design of the planned installation;
- To minimize construction of additional towers through colocation in existing towers or existing structures such as buildings or power transmission towers;
- To locate new fixed-line infrastructure and facilities close to existing access roads and out of nature conservation areas, and to rehabilitate sites after construction works;
- To use measures such as surface mounting, concealment, colour co-ordination, camouflage and landscaping to hide at least the base of towers and ancillary structures, and to draw attention away from the facility.

8.2.2 Achieved environmental benefits

A better planning and siting of ICT infrastructures can decrease the both their visual and environmental impact. If building an additional structure is not inevitable, an operator can install an antenna on an existing tower or building, thereby avoiding building a new structures. If it is a necessity to build a new structure, thorough planning can decrease the need for heavy construction works, by siting the
structure close to a road and to the grid. This results in the following potential environmental benefits:

- A reduced impact on the fauna and flora around the infrastructure
- A reduced visual pollution of the landscape for inhabitants and tourists.

8.2.3 Appropriate environmental indicators
The following two indicators are used in a few countries when analysing the need for an ICT infrastructure to be delivered a specific permission to be built:

- **Height**: in a few countries, legislation refers to a height-threshold, which determines whether the planning and design of a telecommunication infrastructure needs to be analysed by public authorities. For instance, operators must require a permission to build a tower or a mast in France when its height exceeds 12 meters. A similar process exists in Denmark (GMSA, 2012).

- **Surface**: some countries’ legislations use the surface of a telecommunication infrastructure to determine whether or not it is visually impacting and hence requires permission from authorities (e.g. this is the case in France when the surface exceeds 5 m²) (GMSA, 2012).

8.2.4 Cross-media effects
Camouflage elements necessitate the use of additional resources, including paint, plastic and metals, during construction. In order to preserve the visual effect from camouflage techniques, these elements need to be maintained and dismantled when they no longer serve their purpose.

8.2.5 Operational data
As mentioned in 8.2.1, national and local legislation regulate the construction of ICT infrastructure in most countries. 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 constructing infrastructure. Telecom service providers can however decide to voluntarily adopt best practices when choosing location and installing ICT infrastructures.

The best practices to be adopted by operators can include:

- **Consultation with third parties**
A good practice implemented by some operators is to engage with stakeholders when planning a new piece of infrastructure. The identification of stakeholders is the first step of the process. Usually, local planning authorities and representatives of the local communities are the main counterparts. In that field, a thorough process was introduced by the Code of Best Practice on Mobile Network Development in England in 2013 (Mobile Operators Association et al., 2013). In addition to consulting the Planning Authority, mobile operators agreed to commit to proportionate community engagement, depending on the environmental and social sensitivity of the project. Operators anticipate the views and attitudes of local inhabitants, social and political representatives and the media. Regarding environmental issues, operators can analyse the type of properties close to the infrastructure, e.g. homes, schools and nurseries, hospitals, etc. The siting (topographical features, flora and fauna, impact on skyline, etc.) and appearance (height, shape, materials, colour, etc.) should also be subject to analysis.
Colocation of ICT infrastructures

The increase in the number of radio towers and base stations is a result of an increasing pressure on operators to provide coverage to customers everywhere. To transmit information in an area, an operator usually needs to build a tower or mast, on which an antenna is attached. Electric cables link the antenna to an electrical room or to the grid and to a radio room. As each provider needs its own antenna to transmit its customer’s signal, usually each provider would build its own tower (Nagle, 2012). Colocation aims at avoiding building multiple towers close to each other, by placing several antennas on a single tower. Site-sharing now seems to become the norm and network operators now share much of their network infrastructure via joint venture commercial arrangements (Mobile Operators Association et al., 2013).

Location close to existing access roads and out of conservation areas

In order to be built, a relay antenna needs to be accessible by road, and in order to operate, it needs to be connected to the grid (or to rely on its own power supply system, see 6.2) (FFTélécoms, 2004). To minimize 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), other cannot (e.g. national parks with a large surface require a mobile coverage). In such cases, operators must be extra careful regarding the nature of the proposals, the relevance of the location, the potential impacts of the project and the means put in place to reduce these impacts. They should also not be prominently visible from significant vantage points including tourist routes, viewpoints and recreation sites, in order to preserve the amenity and environmental value of these areas (Government of Western Australia, 2004).

Use of existing non-ICT specific infrastructures and camouflage

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).

Local authorities have a role to play to limit the visual impact of telecommunication infrastructures. To facilitate the use of buildings by telecommunication operators, a UK technical working group suggested that planning authorities encourage the designers of new buildings to include a provision for ICT equipment within their plans and design, in order for the antenna to appear to fit in the building rather than to appear bodged on it. For instance, a dedicated space can be designed below the roofline to place an antenna. By using Glass Reinforced Plastic, the antenna can be placed behind the façade of the building. Some aesthetic aspects which operators can have in mind when building the equipment (see also pictures below):

- Keep the equipment in proportion to the building or structure;
- Respect architectural styles;
Best Environmental Management Practice in the Telecommunications and ICT Services Sector

- Have minimal impact above the roof line commensurate with technical constraints;
- Not be detrimental to important views and skylines;
- Avoid creating clutter;
- Use clean lines and maintain symmetry;
- Be painted to correspond with the background or to reduce contrast (Mobile Operators Association et al., 2013).

Figure 112: Pole camouflage in rooftops with artificial chimneys (PT, 2010)
In addition to placing antennas on existing buildings, network operators have made use of camouflage techniques to limit the visual pollution linked to their infrastructures. Cellular providers have disguised towers as flag poles, church steeples, light poles, chimneys, trees, silos, lighthouses and bird nests (Nagle, 2012). Here again, Glass Reinforced Plastic can prove itself useful to mould the structure into any shape and colour it appropriately. It can, for example, be used to simulate masonry and stone features such as chimneys and plinths (Mobile Operators Association et al., 2013).

### 8.2.6 Applicability

Although the practices mentioned in 8.2.5 do contribute to the reduction of the impact of ICT infrastructures on the surrounding landscape, some limitations must be taken into account.

**Issues linked to the colocation of antennas**

Colocation on a single tower might not always be the appropriate solution to environmental issues. Among the issues that can result from colocation are:

- Coverage problems: the antenna may be poorly located or not high enough to provide a good coverage
- Radio interference: to avoid interferences, antennas must be separated from each other, which could increase the breadth of the tower’s equipment significantly, hence increasing its visual impact.
- Structural loading: Due to an increased weight of the equipment carried by the tower, it may need to be strengthened or replaced with a bigger structure with a consequent effect on visual amenity (Mobile Operators Association et al., 2013).
- Commercial disputes: the relationship between operators due to the status of the tower (e.g. shared property, property by one operator and leasing to another) can lead to disputes, hence making the management of the tower more complicated. (Nagle, 2012)

**Risks linked to the use of existing non-ICT specific infrastructures and camouflage**

The integration of ICT infrastructure in its environment should not expose people to additional risks. When a tower is replaced by the placement of an antenna on an existing building, the activity of the users of the building must be taken into consideration: people maintaining antennas or lifts, roofers, etc. These people should not be impacted by the installation of ICT infrastructures on buildings.

**Specificities of the rural context**

In some areas, existing infrastructures are not appropriate or adequate to install ICT infrastructures. Additional towers have to be built to increase the network coverage. This is especially true in rural areas, where the coverage is lower than in urban areas. In addition to the visual impact, this can have an impact on the local ecosystem due to the need to dig trenches on several kilometres to connect the tower to the grid, for instance. Stakeholders in a rural context might consider the economic benefits of extended telecommunication coverage as offsetting the visual impact on the landscape. Operators should however still try to minimise the impact of their infrastructure on the landscape.

**8.2.7 Economics**

Most measures linked to the prevention and correction of impacts on the landscape can be associated with cost savings for network operators. Colocation implies that less towers need to be built by operators, and that the cost of existing towers can be shared among them. In addition, operators implementing good practices in this domain can avoid costs linked to regulatory issues.

Some practices can also represent an investment for operators, and increased operating and maintenance costs. This is the case for camouflage measures, which require operators to pay to conceal the tower and to maintain it. 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.

**Lack of information on costs and benefits**

**8.2.8 Driving force for implementation**

Several factors combine to support the development of these practices:

- **Regulation**: One of the major factors boosting the development of practices to reduce the impact on landscape is planning policies regarding the construction of ICT infrastructures. Most countries have regulations and policies in place...
regarding the environment, the telecommunication sector, and on local planning. In addition, legal issues with third parties complaining in court due to impacts on landscape (e.g. impact of an ICT infrastructure on price of properties due to visual pollution) encourage network operators to prevent such events.

- **Costs:** If operators are able to share sites (i.e. colocation of antennas), and install more equipment on each site, this reduces the overall visual impact of network infrastructure. As a consequence, fewer sites are needed to improve network coverage, making the coverage more cost-effective to deploy (Mono Consultants for Kingston Upon Thames Council, 2015).

### 8.2.9 Reference organisations

In several countries, network operators have worked together to define good practices regarding the impact of their equipment on the landscape. This is for instance the case of the following organisations:

- **Mobile Operators Association in England:** 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. As presented in 8.2.5, the code gives a framework to allow the engagement of operators with local communities and other interested parties. If the code can apply to all forms of wireless development, it is most relevant for the construction of new equipment (towers, antennas and base stations) and significant additions or extensions to existing sites.

The code encourages the use of a two-step process regarding the installation of ICT infrastructures.

The so-called “Traffic Light Rating Model” allows a site to be rated by the operator according to its likely sensitivity in terms of environmental, planning and community considerations (first step). Depending on that rating a plan is devised that sets out the likely appropriate level of consultation (second step).

The first step is the definition of a sensitivity profile linked both to community issues and planning and environmental issues. When planning an installation, the company can rate the probability that the following items will constitute an issue for the installation.

Regarding planning and environmental issues, items to be considered include:

- Located within special land use (national parks, world heritage sites, registered parks or gardens, archaeological sites, special landscape areas, etc.)
- Proximity to a listed building
- Siting – matters to be considered include existence of topographical features and natural vegetation, flora and fauna, impact on skyline or horizon, townscape clutter, site in relation to existing masts, structures and buildings (including historical or traditional character), views of recognised importance.
- Design – matters to be considered include height in relation to surrounding area, appearance of the installation, material, colouration, dimensions (other than height), overall shape, solid or open framework, transmission solutions (i.e. impact of dish).
- Site type – new site, upgrade, swap out, mast share. In respect of upgrades, swap outs, or mast shares it is anticipated that the score under siting and appearance will be less than for new installations. The matter that is being given consideration is the impact of the proposed alteration in comparison to the existing installation.
- Proximity to residential property or homes
- Proximity to schools, nurseries, playgroups, play grounds, recreation grounds, hospital property
- Local development plan policies (potentially negative, positive or neutral for the project)
- Precedents/site history (were the previous applications rejected or successful?)

Regarding community issues, items to be considered include:

- Previous residents’ activity (considerable opposition or little opposition)
- Interest of local and key stakeholders and NGOs (active interest or no interest)
- Involvement of political representatives (e.g. a member of parliament)
- Previous media interest (e.g. negative publicity).

The aggregated rating of these items allow the operator to position the project in a sensitivity category, from very sensitive in red to less sensitive in green on the graph below:

![Traffic Light Rating Model for Public Consultation](image)

**Figure 115: Traffic Light Rating Model for Public Consultation (Mobile Operators Association et al., 2013)**

The rating in the red category does not mean that the proposal should not be progressed; rather, it simply indicates that a higher level of public consultation may be needed prior to the planning application being submitted.

Once the rating has been determined then the consultation strategy is used to provide the options available in respect of the level of public consultation. It is important to seek local planning authority input into the process where possible.

Under the Traffic Light Rating Model, if a site is rated green then generally the statutory consultation is deemed to be sufficient. The more sensitive issues have been identified by the operator, the more consultation tools can be used. The Code of Best Practice identifies the following tools: consultation letter; site notice; informal, drop-in session; key stakeholder briefing session; leaflets; public notice placed in local press.
The operator should consider on a case by case basis whether these additional consultation methods should be employed.

- **Fédération Française des Télécommunications in France** (FFTélécoms, 2004): 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. These practices include:
  
  o 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
  
  o Practices regarding new antennas on buildings
    
    - **Continuity**: new antennas shall look like they are part of the building on which they were installed
  
  o 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
  
  o 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

### 8.2.10 Reference literature


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8.3 Reducing noise and electromagnetic radiation from telecommunication and broadcasting networks

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| Environmental indicators | • EMF in Volt per meter of an antenna<br>• EMF in % of recommended emission threshold<br>• Sound emitted by the equipment (dB) compared to the maximum legally authorised sound value in an area | |

| Benchmarks of excellence | • Measure, monitor and report information regularly on EMF exposure of the companies’ ICT infrastructure | |

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- Local legislation must be analysed prior to designing measures to limit EMFs and noise, because specific frameworks can already exist regarding these issues.

- NA

8.3.1 Description

Electromagnetic fields (EMF) are a major public concern in relation to the telecommunication sector. Telecommunications and ICT services use electromagnetic fields for operating: radio waves, microwaves, satellite waves, etc. These waves are emitted by radio and television broadcast stations, transmitting antennas, mobile communication base transceiver stations, etc.
The 25,000 scientific publications on the topic published in the past 30 years have not come to any significant conclusion whether exposure to EMFs could have a major negative impact on wildlife and human health. According to the WHO, the current level of knowledge on EMFs is significantly higher than for most other health related topics (WHO, 2015). The WHO estimated that below a certain level of exposure, EMFs do not seem to be harmful for humans. This, however does not mean that a higher level of exposure would be harmful. In addition, the current levels of EMFs from telecommunication infrastructures are usually way below the levels identified by research as potentially damaging. As a consequence, scientific conclusions do not constitute a real incentive for operators to improve their performance in this domain.

However, EMFs can be real issues for ICT operators, not so much due to actual proven impact on wildlife and health issues, but rather due to public concern and media interest of EMFs. Indeed, in the past few decades, there have been plenty of newspaper articles regarding potential health impacts of EMFs coming from electric lines, computer and TV screens, mobile phones and base stations (WHO, 2015). The graph below shows that the level of concern about potential EMF risks varies among EU countries, with an average concern of 46% of people (Directorate General for Health and Consumer Affairs, 2010).
However, only 20% of respondents declared having received information (by any actor) on EMFs. Among these 20%, almost half are not satisfied with the information received, with the first reason for dissatisfaction being that the information is unsufficient. This supports the need for telecommunication providers to increase their level of communication on EMFs.
In addition to risks for human health, electromagnetic radiation is a form of environmental pollution which may hurt wildlife. Phone masts located in their living areas are irradiating continuously some species that could suffer long-term effects, like reduction of their natural defences, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive behavioural response in birds, mammals, amphibians, insects, trees and plants. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts (Balmori, 2009).

As a consequence, telecommunication services providers can decide to take further measures that are beyond national and international regulation such as the EU Directive on EMF exposure and ICNIRP guidelines to better manage their EMF emissions. This includes:

- Increasing transparency to decrease the concerns of the public (measuring EMFs, informing the public, co-planning with local stakeholders)
- Limiting public access to antennas tower locations (rooftop access controls, physical barriers, etc.);
• Following good engineering practice in the siting and installation of directional links (e.g. microwave links)

Noise is another concern for telecommunication service providers. The operation of backup power generators is the main source of noise from telecommunications facilities. Power generators run once a week for less than an hour to ensure their good functioning in case of a power outage. Another source of noise is the cooling system for the cabinets at the basis of base stations. Unlike backup power generators, air conditioning systems run on a daily basis to ensure the normal functioning of the base station. Good practices from telecommunication providers include:

• Installing noisy equipment far enough from noise-sensitive areas
• Installing noise reducing equipment with a sufficient Noise Reduction Coefficient

8.3.2 Achieved environmental benefits
Several benefits from good practices in the field of EMFs can be identified:

• The level of exposure of the public can be decreased if the access to high emissions zones close to antennas is controlled, and if antennas are not installed too close to living areas with a high level of occupancy.
• Appropriate measures can decrease the impact of EMF exposure of animals, birds, insects and plants. These are particularly exposed when a base station is built close to natural environment of fragile species (Philips, 2013).

The benefit from noise reduction measures is a decreased fatigue and stress for people and animals living close to the source of the noise.

8.3.3 Appropriate environmental indicators
When publishing data on the EMF emissions of antennas, telecommunication operators can use the following indicators to standardise information and increase intelligibility:

• EMF in absolute terms: Volt per meter emitted by an antenna can be the unit chosen to harmonise information
• EMF in relative terms: % of recommended emission threshold based on the EU directive and ICNIRP recommendations.

Regarding noise pollution, relevant indicators include:

• Sound emitted by the equipment of a base station (power generator and air conditioning system, in dB). The sound can be compared to the maximum legally authorised sound value in an area.

8.3.4 Cross-media effects
Some measures to decrease exposure to EMFs are not desirable due to potential impacts on other environmental aspects.

• In order to decrease public exposure to EMFs, operators might want to increase the height of the support structure. This approach has major drawbacks, including increased costs for the support structure, potentially increased environmental effects due to larger foundations, increased visual pollution, and on top of a relatively low impact on the level of EMF exposure.
• In order to avoid installing antennas in some areas, an increased spacing of antennas might decrease the quality of the coverage, hence increasing the exposure of mobile users.
8.3.5 Operational data

EMFs

- **Increasing transparency to decrease the concerns of the public**

Telecommunication providers can act to decrease the concern of the public (described in 8.3.1) in several ways:

  o **by making long-term measurements in the monitoring of electromagnetic fields (EMF), with the end-purpose of providing the general public with accessible data on EMF levels.** These measurement can be either spontaneous or answer to a formal demand from any stakeholder (single citizen or group of citizens, local authorities, companies etc.). They must be transparent, which implies that a single unit (e.g. volt per meter of an antenna) should be used for all analysis, in addition to a percentage of the maximum authorised level of emission. The impact of any antenna can be subject to measurement, meaning that the measurement can provide information on EMFs in any location, office, street, house, school etc. This information should not be retained by operators but should be disclosed for public use, in order to maximise the level of information disclosure to the public (FFTélécoms, 2004).

  o **by consulting local authorities and population in the planning phase** for the installation of additional base stations and antennas, thereby increasing the acceptance and understanding of the project. The consultation process pattern has been described in 8.2.5.

  o **by ensuring that all relevant staff have an adequate awareness of EMF issues.** The staff which is likely to handle the concern of the public, including employees answering phones and call centres, and other front line employees and engineering staff. Operators can provide training to their employees on these issues to make them sufficiently knowledgeable (Energy Networks Association, 2013).

- **Limiting public access to antennas tower locations** (rooftop access controls, physical barriers...)

There are several situations where precautionary measures to protect the population must be taken:

  o For amplitude modulation (AM), a set of antennas -often with a height of dozens of meters- is installed. These installations are usually located in remote areas, and are protected by a closed radius around the antennas. As a consequence, the public cannot come close to the tower (only professionals can access for maintenance purposes).

  o Antennas for frequency modulation are much smaller, and are installed on towers or on buildings. People can access the zone located directly below antennas, where EMFs emissions are lower than the levels recommended by ICNIRP. Antennas for television, radio and mobile transmissions are more and more installed on buildings to limit the construction of towers. These cases are potentially problematic, if the access to antennas is not limited to professional maintenance agents. A good practice from telecommunication providers is to make sure that the public cannot access these EMF-intense zones (WHO, 2015) (ITU, 2014).
• **Following good engineering practice in the siting and installation of directional links** (e.g. microwave links)

To limit the exposure of the public to EMFs, telecommunication providers can try to **sit antennas at a reasonable distance from living areas** with a high level of occupancy, like homes, schools, libraries etc. This practice is reinforced by other non EMF-related reasons like audible noise, vibrations, access by public to high emissions zones on buildings etc. This should be done by providers in case the effort is considered to be "**reasonably practicable**" (Energy Networks Association, 2013), meaning that the extra-costs are not too high, and that the quality of service provided remains of a similar quality.

**NOISE**

• **Install noisy equipment far enough from noise-sensitive areas**: To avoid overtaking the maximum noise emission levels, noise generating sources may be located away from residential or other noise-sensitive areas, or noise suppression shields and mufflers may be created. It can nevertheless happen that backup power generators are necessary in dense urban areas.

• **Install noise reducing equipment**: Certain equipment may necessitate the installation of barriers, absorptive material or mufflers to reduce the transmission of sound beyond the site where it is installed. The level of noise reduction is usually expressed in NRC (Noise Reduction Coefficient), with 0 being perfect reflection and 1 perfect absorption. Unpainted concrete block, for instance, can have an NRC of 0.35 (Hammett & Edison, 2015). Barriers should be solid (>4 pounds per square foot) and airtight. Examples of sound wall materials include: 4” thick poured in place or pre-cast concrete panels, 6” thick CMU wall, 1-½” thick board and batten, tongue and groove wood on one side of post, or cementitious wood panels. An earthen berm alone or in conjunction with a wall can be used (Sound Solutions, 2015).

**8.3.6 Applicability**

The applicability of the above mentioned best practices can be impacted by local authority planning permission (GMSA, 2012).

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. Depending on the country, local authorities can decide to prevent the construction of ICT infrastructures for several reasons, such as environmental and public safety reasons.

The size and location of the infrastructure will also often determine which processes must be followed. Smaller sized towers and antennas are not always subject to specific authorisations (in that case, operators can voluntarily decide to adopt some of the best practices mentioned above). Larger projects can necessitate more complex processes; operators can be required to adopt specific measures regarding EMF and noise-related impacts. The same can apply for specific locations (e.g. historic districts).

**8.3.7 Economics**

The economics of best management practices for noise and EMFs are unbalanced, due to a good knowledge of costs but often uncertain and non-measurable benefits.
Additional costs include the increased public relation activities to deal with authorities and agencies; setting practices beyond the legal requirements; communication and consultation directed towards the public; the systematic measurement of EMFs and noise; training costs for the staff; and, installation of noise reducing equipment.

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.

Need for information on costs of measures to address EMFs and noise

8.3.8 Driving force for implementation

The main driver for the implementation of good practices regarding EMFs is the strategic risk linked to the public concern. As described in 8.3.1, telecommunication providers can be impacted by the lack of trust of users and authorities. This lack of trust can materialise in a loss of consumers and revenues, delays in for the installation of antennas and other ICT infrastructures, legal issues and complaints. Implementing measures to increase the knowledge of the public on EMFs and answering to their complaints regarding emissions can help mitigate these risks.

Regarding noise pollution, the main driver for implementing good practices is a decrease of legal risks due to complaints of people living in the area of the ICT infrastructure.

8.3.9 Reference organisations

- The French Federation of Telecommunication Providers (FFTélécoms, 2004) acknowledged that operators must provide data on EMF exposure whenever they are asked or whenever the data is available to them, in order not to let fear grow amongst the public.

FFTélécoms agreed with the Federation of French Mayors to systematically provide information on the exposure to EMFs if they are asked to by any citizen or organisation. The request for information can concern any location, home, office, school etc. The result (in volt per meter and percentage of recommended threshold) can either come from an onsite calculation or from an estimate, carried out in either case by a certified agency. Telecommunication providers pay for the measurement of the EMF emissions in any case on simple demand from the enquirer. To protect themselves from abusive requirements, telecommunication providers can discuss with mayors to decide upon an appropriate response a case-by-case basis.

The recipients of the measurements are mayors, who can then communicate the results to the enquirer. The result is forwarded to the French Frequencies Agency which aggregates all results on a single database, available publicly on its website (www.anfr.fr).

Need for a non-French benchmark

8.3.10 Reference literature


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9 BEMP related to improving the energy and environmental performance in other sectors

9.2 Introduction / scope

The projects SMART 2020 and SMARTer 2020 conducted by the Global e-Sustainability Initiative (GeSI) found that ICT is a key sector in climate change mitigation. The GeSI’s SMARTer 2020 report demonstrated that ICT “could cut the projected 2020 global greenhouse gas (GHG) emissions by 16.5%, amounting to $1.9 trillion in gross energy and fuel savings and a reduction of 9.1 Gigatonnes carbon dioxide equivalent (GtCO2e) of greenhouse gases”, which is more than the ICT sector projected own GHG emissions.

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63 For more information about SMARTer 2020: http://gesi.org/SMARTer2020
These projects identified 4 main ways through which ICT can reduce GHG emissions:

- **Digitalization and dematerialization** will allow substitution and elimination of emissions-intensive products or processes (transportation, printed documents, etc.).

- **Data collection and communication** will allow real-time data analysis and feedback, in order to enable better decision-making. Developing such applications intend to improve the efficiency of systems by reducing risks and enhancing the coordination between suppliers and consumers or among users.

- **System integration** will help managing 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 optimization** will improve efficiency through simulation, automation, redesign or control.

Six main end-use sectors in which such solutions may be implemented have been identified in these projects: **Power, Transportation, Manufacturing, Service and Consumer, Agriculture and Land Use, and Building**.

The following figure resumes examples of solutions that can be implemented into the 6 previous economic end-use sectors through the 4 ways of change enabled by ICT services.
Figure 120: Example of ICT solutions enabling carbon saving (source: (GeSI, 2012))

The BEMPs to be described the following section will be:

**Provide services to improve the environmental performance of client activities**

1. Establish energy and environmental performance criteria for ICT equipment used by customers
   a. Service providers should set strict energy and environmental standards for the equipment that they lease / provide to their customers, e.g. set top boxes, routers
   b. Provide additional environmental information to products and services sold
2. Collect and recover used ICT equipment from customers (partially covered under waste BEMP section 7)
3. Provide ICT services that reduce commuting and business travel (see BEMP 2.5 for sustainable offices)
   a. Teleworking
   b. Video-conferencing
4. Provide ICT services that reduce paper consumption and consumables
   a. Digitalisation
5. Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment
   a. Cloud computing
6. Provide other ICT services that reduce the environmental impact of other sectors
   a. Green apps
   b. Data processing and analysis
   c. Data modelling
Develop solutions to improve the overall environmental performance of other sectors

1. Power sector
2. Transportation sector
3. Manufacturing sector
4. Service and consumer goods sector
5. Agriculture and land use sector
6. Building sector
## 9.3 Provide services to improve the environmental performance of client activities

**SUMMARY OVERVIEW:**
ICT services providers can develop offers to help reduce their clients’ environmental footprint. ICT services providers can help customers reduce their environmental impact by offering them services that will raise their awareness on environmental impacts due to the use ICT devices.

### ICT components

<table>
<thead>
<tr>
<th>Data centre</th>
<th>Telecommunication network</th>
<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
</tr>
</thead>
</table>

### Relevant lifecycle stages

<table>
<thead>
<tr>
<th>Design and installation</th>
<th>Selection and procurement of the equipment</th>
<th>Operation and management</th>
<th>Renovation and upgrades</th>
<th>End-of-life management</th>
</tr>
</thead>
</table>

### Main environmental benefits

<table>
<thead>
<tr>
<th>Energy consumption</th>
<th>Waste production</th>
<th>Air emissions</th>
<th>Water use &amp; consumption</th>
<th>Noise and electromagnetic radiations</th>
<th>Landscape and biodiversity</th>
</tr>
</thead>
</table>

### Environmental indicators

- Total and share of ICT equipment collected from customers, reused, recycled, sent to disposal
- Avoided GHG emissions

### Benchmarks of excellence

- tbd

### Cross references

**Prerequisites**
- 3: BEMP to improve the energy performance of telecommunications network
- 4: BEMP to improve the energy performance and minimising the environmental impacts of data centres
- 7.2: Improving waste prevention
- 7.3: Improving WEEE collection, recycling and recovery
- 5.2: Procurement for energy-efficient equipment
- 5.3: Improving the energy efficiency of ICT equipment

### Related BEMPS

- 3: BEMP to improve the energy performance of telecommunications network
- 4: BEMP to improve the energy performance and minimising the environmental impacts of data centres
- 7.2: Improving waste prevention
- 7.3: Improving WEEE collection, recycling and recovery
- 5.2: Procurement for energy-efficient equipment
- 5.3: Improving the energy efficiency of ICT equipment

### 9.3.1 Description

ICT sector has a role to play to help customers reduce their environmental impact while using ICT devices. Companies of the ICT sector can provide different types of services or equipment to improve the environmental performance of an activity.

ICT operators can offer services to help their customers reduce their environmental impact by:

- Establishing energy and environmental performance criteria for ICT equipment used by customers
Collecting and recovering used ICT equipment from customers

Other types of services to help clients reduce their carbon footprint can be developed. The carbon trust report (Carbon Trust, 2015) on BT’s methodology for carbon abatement, lists different services to reduce the CO₂ emissions:

<table>
<thead>
<tr>
<th>BT Product</th>
<th>Carbon benefit enabled</th>
<th>Unit of measurement</th>
<th>Carbon abatement (tCO₂e per unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadband enabled Telecommuting</td>
<td>Telecommuting to avoid commuting travel</td>
<td>Number of telecommuters enabled by BT</td>
<td>0.95</td>
</tr>
<tr>
<td>Flexible working services</td>
<td>Reduced energy consumed by offices employing flexible working</td>
<td>Number of contracts</td>
<td>886</td>
</tr>
<tr>
<td>Audio conferencing</td>
<td>Teleconferencing substituting for business travel</td>
<td>Number of conference calls</td>
<td>0.0281</td>
</tr>
<tr>
<td>Video conferencing (Telepresence)</td>
<td>Teleconferencing substituting for business travel</td>
<td>Number of Telepresence suites</td>
<td>94.4</td>
</tr>
<tr>
<td>Broadband enabled e-commerce</td>
<td>Reduced energy consumption by commercial, retail and wholesale space replaced by e-commerce</td>
<td>Number of business broadband connections</td>
<td>0.083 [see note 1]</td>
</tr>
<tr>
<td>Broadband enabled dematerialisation</td>
<td>Dematerialisation and reduced consumer travel due to use of internet</td>
<td>Number of residential broadband connections</td>
<td>0.031</td>
</tr>
<tr>
<td>BT Vision</td>
<td>Reduced travel and dematerialisation of disc media</td>
<td>Number of films downloaded</td>
<td>0.00078</td>
</tr>
<tr>
<td>Field Force Automation</td>
<td>Information services reducing miles travelled by vehicle service fleets</td>
<td>Number of vehicles</td>
<td>4.74</td>
</tr>
<tr>
<td>Data centre services</td>
<td>Reduction in energy by moving from dedicated on site hosting to shared centralised hosting</td>
<td>Number of virtual machines</td>
<td>1.95</td>
</tr>
<tr>
<td>Cloud Contact</td>
<td>Reduction in energy by virtualisation of the hosted network switching platform</td>
<td>Number of customers</td>
<td>3.08</td>
</tr>
<tr>
<td>One Cloud</td>
<td>Reduction in energy by moving from customer based PABX or IPT server to virtualised network switching</td>
<td>Number of users</td>
<td>0.00194</td>
</tr>
<tr>
<td>Managed mobility</td>
<td>Reduction in travel by flexible working practices enabled by the N3 NHS network</td>
<td>“one off” calculation for the N3 network</td>
<td>N/A</td>
</tr>
<tr>
<td>Inbound calling</td>
<td>Conference calling facilities, where BT provides communications infrastructure</td>
<td>Number of conference calls</td>
<td>0.0281</td>
</tr>
<tr>
<td>Super-fast broadband enabled dematerialisation</td>
<td>Additional dematerialisation and reduced consumer travel due to use of super-fast broadband ( fibre-optic internet access).</td>
<td>Number of residential fibre broadband connections</td>
<td>0.142</td>
</tr>
<tr>
<td>Broadband enabled SME use of Cloud Computing</td>
<td>Reduction in energy by SME’s adopting the cloud based services - email, CRM and groupware.</td>
<td>Total carbon abatement for all UK SMEs</td>
<td>Proportion of UK total allocated to BT</td>
</tr>
</tbody>
</table>
These different types of services can be regrouped in services categories:

- Provide ICT services that reduce commuting and business travel: audio and video conferencing, broadband enabling telecommuting.
- Provide ICT services that reduce paper consumption and consumables: dematerialization.
- Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment: cloud computing and data centre services.
- Provide energy efficient software and operating systems.
- Provide other ICT services that reduce the environmental impact of other sectors (see subchapter 9.4)

**Establish energy and environmental performance criteria for ICT equipment used by customers**

Over the past few years, some mobile telecom operators have developed eco-rating schemes to communicate to their customers the sustainability and environmental performance of the products they buy. Different approaches are observed to evaluate and communicate the sustainability and environmental performance of products:

- The comparison of the performance of different devices based on a rating system;
- The certification of devices that meet a minimum level of performance.

At the sell point during the interaction with the customer and the sale of the product, services can be provided to customers to raise customers’ awareness on their environmental footprint and give them sufficient information to help make decisions in full awareness. The extension of contract length will encourage customers to keep the equipment longer and increase using lifetime of the product. The display of the environmental performance of the product sold is another way to raise customers’ awareness.

**Collect and recover used ICT equipment from customers**

To reduce the impact of the disposal of ICT product, service providers can ensure that the equipment is properly disposed at the end-of-life. Collect, recovery and recycling measures can be put in place so that customers can easily dispose of the product. This practice is related to the BEMP on WEEE management (Chapter 7).

**Provide ICT services that reduce commuting and business travel**
The development of ICT equipment and telecommunications tools such as video conferencing and high speed Internet access in the home is the opportunity to reduce the need for commuting to go to work or for business travel. Significant pollution impact can be avoided with the potential to reduce GHG emissions especially on air travel. ICT service providers can develop services enabling videoconferencing and teleworking.

**Provide ICT services that reduce paper consumption and consumables**

Substitutions solutions of information can be implemented through the use of ICT services. Substitutions may be partial: dematerialisation or complete: virtualization. The broad use of computers and other devices such as mobile or tablets increase the ease with which information is communicated and assimilated. Therefore, it reduces the transaction costs and eliminates environmental costs associated with ‘traditional’ media of transaction such as paper or CDs.

Consumables refer to office supplies such as:
- Paper
- Writing and stationary supplies (file, folders)
- Mailing supplies (envelopes, shipping boxes, wrapping)
- Toner and ink cartridges
- Cleaning supplies
- Commercial supplies

ICT services providers can provide ICT equipment integrating solutions to help organisations reduce their consumables consumption.

**Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment**

Companies can use cloud computing services to optimise their activities. The cloud computing enables outsourcing all IT needs such as storage, computation and software through large Internet. The use of such service-oriented computing eases management and administration process involving software upgrades and bug fixing (Kumar Garg & Buyya, 2011).

Clouds are virtualised datacentres and applications services that companies can subscribe to. ICT services providers offer solutions to companies to externalise the management of ICT. The use of cloud datacentre can reduce the energy consumed through consolidation and virtualisation (see chapter 4 for more details on BEMP to improve the energy performance of data centres).

**9.3.2 Achieved environmental benefits**

**Establish energy and environmental performance criteria for ICT equipment used by customers and collect and recover used ICT equipment from customers**

According to GSMA, global connections passed 7 billion in 2014. As the overall number of mobile subscriptions almost reaches the total population, the improvement of the sustainability performance of individual handsets can have a significant cumulative impact on the environment and reduce associated negative environmental impact. One of the main environmental challenge regarding mobile phones is to improve the life-cycle of products. The fast evolving technologies and trends encourage customers to change mobile phones more frequently and reduce mobile phone’s shelf life (Brightsar Intelligence, 2014):

- Shelf life has declined by almost 50% since 2005.
- Average shelf-life for some mobile phone is currently 8 to 10 months.
Mobile phones can last as few as 4 months on a retailers’ shelf. Telecommunication companies can develop a set of procurement criteria and establish an eco-rating of the products to enhance products life cycle and reduce the total amount of WEEE created. Eco-rating scheme encourages manufactures to improve the environmental performance of their products. For instance, the O2 eco-rating program helped brought to the market the Sony Ericsson Naite which was the first manufacturer’s green range mobile phone which reduced by 15% the carbon footprint.

Service providers can also developed offers to encourage customers not to change mobile phone. It will help reduce equivalent CO₂ emissions. For instance O2 in the UK proposed to customers who do not upgrade to a new handset each year a preferential tariff offer. Two million handsets were counted on O2 simplicity offer in 2010. Assuming that these customers would have upgraded to new handsets without the offer, the company claims that the cut in carbon emissions is equivalent to 3,700 cars off the road each year.

The solutions that telecommunication companies can offer can help reducing the all industry environmental impact and throughout the life cycle of the products. Companies who launched eco-rating programs ensure continuous improvement in the sector by making sure manufacturer ratings never drop.

**Provide ICT services that reduce commuting and business travel**
The use of communication technologies such as videoconferencing and teleworking reduces the need for commuting and especially for business air travel and reduces the associated GHG emissions.

**Provide ICT services that reduce paper consumption and consumables**
The use of ICT solutions such as dematerialisation and virtualisation reduce the consumption in natural resources through the reduction of material means of communication such as paper or CDs. It also reduces the need for printing documents and thereby reduces the consumption of toners.

**Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment**
The use of solutions such as cloud computing also reduces the carbon footprint of organisations. According to an Accenture report, small companies reduced their emissions up to 90% while using Cloud resources. Large companies can save from 30 to 60% of carbon emissions (Accenture, 2010). According to Accenture Report (Accenture, 2010), there are four key factors that enable Cloud computing to lower energy usage and carbon emissions from ICT:

- **Dynamic Provisioning:** avoid to develop more infrastructures than needed
- **Multi-tenancy:** Cloud computing infrastructure reduces overall energy usage and associated carbon emissions by serving multiple companies on same infrastructure and software.
- **Server Utilization:** using virtualization technologies leads to an optimised utilisation level up to 70%. Thus, it dramatically reduces the number of active servers.
- **Datacentre Efficiency:** by using the most energy efficient technologies, Cloud providers can significantly improve the PUE of their datacentres.

9.3.3 Appropriate environmental performance indicators

Establish energy and environmental performance criteria for ICT equipment used by customers

To manage the environmental performance of mobile phones, eco-rating scheme can be developed by telecommunication companies. Eco-rating scheme measures the sustainability and environmental performance based on different categories of impacts (ITU, Review of mobile handset eco-rating schemes, 2012):

- Measurement of the manufacturing impacts considering GHG emissions, environmental policies, etc.
- Measurement of the sustainability of the supply chain elements based on transportation distances, mineral sourcing, etc.
- Measurement of the performance of a handset based on its energy consumption, the components, the recyclability, the packaging, etc.

<table>
<thead>
<tr>
<th>Examples of criteria used to rate mobile phones</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telefonica – O2</strong></td>
</tr>
<tr>
<td>- The material used</td>
</tr>
<tr>
<td>- The environmental impact during the manufacturing process</td>
</tr>
<tr>
<td>- The amount of resources used for the packaging</td>
</tr>
<tr>
<td>- The efficiency of the device</td>
</tr>
<tr>
<td>- The ease for recycling the device after use</td>
</tr>
<tr>
<td>- Ethical principles of the manufacturer</td>
</tr>
</tbody>
</table>

To encourage continuous improvement, a follow-up of the ratings of manufacturers can be done to make sure their rating never drop and keeps improving. Follow-up indicators on the rated products can also be put in place to evaluate the impact of eco-rating on customers’ purchasing decision:

65 http://www.o2.co.uk/thinkbig/planet/sustainable-products-and-services/eco-rating
66 http://www.vodafone.com/content/sustainability/operating_responsibly/customers_and_the_environment.html
67 http://www.orange.com/fr/content/download/2443/24790/version/1/file/DPOrangeacteurengagedanslaprotectiondel'environnement.pdf
• Number of eco-rated products sold by brands;

• The equivalent environmental benefits from the selling of the eco-rated products: equivalent CO₂ emissions avoided, preserved resources, energy consumption reduction.

Collect and recover used ICT equipment from customers

To help customers reduce the environmental impact created by the use of IT equipment, telecommunications companies can offer services to manage the end-of-life of the products. Telecommunications companies can develop take-back programmes in particular for mobile phones. Performance indicators can be implemented to evaluate the performance of the programme:

• Total of devices collected
• Total of WEEE reused
• Total of WEEE recycled
• Total of WEEE to disposal

According to GSMA (2006) an efficient take-back programme allows the reuse and recycling of a major part of a mobile phone and only a small part, less than 10%, should go for disposal.

Take-back program can include some incentives to encourage customers to give back their old mobile phone. It can be a financial incentive by offering money for the old mobile phone or a discount on a new one. It can also be in partnership with charities for donation or with social enterprises. It can also be associated with offset programs such as reforestation. Performance indicators can be used to evaluate these impacts:

• Total amount paid to customers for old mobile phones;
• Social impact: job creation;
• Environmental impact: number of planted trees.

Provide ICT services that reduce commuting and business travel

The measurement of the environmental benefits from the reduction of commuting and business travel is calculated through the reduction of GHG emissions.

More specific indicator can focus on measuring the carbon saving per telecommuter and the number of telecommuters enabled by the company. Carbon avoidance can also be calculated on the basis of the number of conference calls using the company’s service.

Provide ICT services that reduce paper consumption and consumables

The environmental benefit from the reduction of the consumption of paper and consumable is measured through the follow-up of the consumption of these resources:

• Total amount of paper consumed
• Total amount of toners consumed

Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment
As explained in previous section, the use of cloud computing allows the reduction of the carbon footprint of organisations. The environmental benefit is therefore calculated through the measurement of the reduction of the GHG emissions. Appropriate indicators to follow regarding data centre energy-efficiency are detailed in chapter 4. The main indicator regarding energy efficiency is the PUE.

The sustainability of software can be measured by the software green quality factor which describes how software behaves in the system.

9.3.4 Cross-media effects

Some actors in the telecommunication sector developed Eco-rating methodologies to rate the sustainability and environmental performance of mobile phones. The methodologies are different from one company to another. This heterogeneity can create confusion on the environmental performance of mobile phones. A potential drawback for the manufacturers is that they have to collect different types of information in different ways and therefore adds to workload and expense.

According to a GSMA study in 2012 (Forum for the future, 2014), the schemes are similar between different tools from different companies on shared common principles. However, an ITU study (2012) reviewing different eco-rating methodologies recommends the alignment of baselines on some specific topics. For instance, the reporting of GHG emissions could be done based on an international recognized scheme such as the ITU-T L.1420 Methodology for energy consumption and greenhouse gas emissions. Regarding the environmental performance implementation, the evaluation could be based on Environmental Management system such as ISO standards (ISO 14001).

The main differences between the different eco-rating scheme remains in the scope considered in the evaluation. In order to avoid any misinterpretation, companies should be fully transparent on the elements taken into account.

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. To support their communication on the subject, companies should ensure the overall process is properly managed until the proper disposal of non-recyclable components. Some mobile phones collected through take-back programmes are sent in developing countries to be reused. One issue is the potential risk of phones being discarded in these countries that lack the necessary recycling infrastructures to manage end-of-life of electronic equipment (GSMA, 2006).

Regarding other services provided by ICT services companies, the main adverse effect results from the increase use of ICT devices. The broad use of information solutions and digital devices increase the capacity of users to access information and therefore the time users will spend using them. Overall increase in the use of ICT equipment can increase the overall energy consumption.

The demand of Cloud infrastructures continuously rises and the measures to ensure the energy-efficiency of the data centres shall be ensured.

Certain ICT services may lead to “rebound effects” meaning that despite energy and material savings, the overall consumption continues to grow (Skouby & Windeklide, 2010). For example, e-working that reduces the commute to work may mean that people will have more time available and may potentially engage in more carbon intensive activities.
9.3.5 Operational data

Establish energy and environmental performance criteria for ICT equipment used by customers

Telecommunication companies can develop solutions and propose services to reduce the use of the IT equipment they provide. They can be developed at the different step of the life cycle of the product.

Companies from the telecommunication sector can ensure to offer products which meet specific environmental criteria to help customers improve their environmental footprint. The selection of the product can be integrated in a green procurement policy. The methodology to establish a procurement policy taking into account environmental criteria is detailed in section 5.2. on the procurement for energy efficient equipment. In order to reduce the environmental impact, the different impacts throughout the product life-cycle must be assessed. The methodology for the life-cycle assessment of IT devices is tackled in section 7.2. on WEEE management and life cycle assessment of ICT equipment.

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

![Figure 122: Mobile phone life cycle stages (Vodafone)](image)

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

- **Select energy-efficient products**: the main challenge regarding mobile phone energy efficiency is to improve batteries performance and reduce the energy consumption during standby mode (refer to section 5 for more details on energy-efficient IT equipment).

- **Select products composed of sustainable materials**: mobile phones are composed of rare and hazardous materials. The ecodesign of the equipment is an important stage to reduce the environmental impact. Ecodesign can reduce the amount of material used for the production of a device. Sustainable materials can also be used such as polylactic acid plastic made entirely from corn starch or glucose, renewable and biodegradable.

- **Select product for easy disassembly and repair**: many mobile phones are designed to stop users from opening them and replacing specific parts by...
gluing parts together and putting special crews. Prevent those elements will prevent planned obsolescence. Some materials put together are difficult to recycle, the goal is also to minimise mixing of materials such as metals embedded in plastics.

- **Reduce packaging and accessories:** the environmental impact can also be reduced during the conditioning of the product. The reduction of the material used and the reduction of the number of accessories are key solutions to reduce the overall impact. Many buyers already have compatible chargers when they buy a new mobile phone, some accessories such as chargers may be unnecessary.

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

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

In order to ensure the reliability of the rating, the evaluation process requires the intervention of an independent third-party. The third-party can be an NGO or a national institution focusing on environmental impacts. The methodology can be based on official and standard baseline established by international institutions such as ISO standards (ISO 14 0140 and ISO 14 044 for life cycle analysis). For instance, Orange developed its environmental performance evaluation in partnership with WWF based on ADEME environmental impact analysis and reviewed by the consulting firm Bio Intelligence service. Vodafone’s questionnaires to manufactures are verified by two independent third parties, Bureau Vertitas and SKM Enviros.

Telecommunication companies can also use ecolabel to communicate the environmental performance of products. TCO and Blue Angel are the two main ecolabels available for mobile phones (European Commission, Green Public procurement, Mobile phone technical background report, 2010). The TCO Swedish standard Version 2 was published in 2006. It focuses mainly on the level of emitted radiation. Blue Angel last version launched in 2008 also covers health and environmental aspects.

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

**Collect and recover used ICT equipment from customers**

The management of mobile phones end of life is regulated by the WEEE directive detailed section 7.
Customers tend to replace their mobile phone along with trends and evolution of technology. This replacement cycle drives the need to put in place collect, decommissioning, reuse and recycle solutions for used mobile phones. Mobile phones contain potentially dangerous and rare materials which could harm the environment if not responsibly recycled. For instance, old batteries contain cadmium, a toxic substance which if leaking into landfill site could cause contamination. Other materials such as plastic do not degrade easily and should be recycled. Telecommunication companies can help customers to properly dispose of their mobile by offering collecting and recycling solutions.

![Mobile phone supply chain integrating recycling and reuse (Vodafone)](image)

**Figure 123: Mobile phone supply chain integrating recycling and reuse (Vodafone)**

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

Once the customer returned its old mobile phone, it can be sent to a company in charge of the refurbishment so that it can be sold for reuse. Telecommunication companies can establish partnerships with companies who will manage the end-of-life of products. Different solutions can be considered:

- **Refurbishment to extend life:** the refurbishment depends on the quality of the product. First the product is evaluated to determine if it is suitable for reuse or for further repair. Faulty part will then be replaced and the device will be reconditioned.
- **Reuse phone in developing countries:** when a device is suitable for reuse, it can be sent to developing countries to enhance the lifecycle of product.
- **Recycling products:** when a product can no longer be used, it must be properly recycled. Components must be properly separated and sorted in various types to be reprocessed by specialist recyclers. Some materials can be recycled into new products such as nickel cadmium and lithium ion/polymer batteries which can be recovered and reuse for power tools, saucepans and new batteries.
- **Disposal:** the remaining parts of a mobile phone which cannot be recycled must be sent for environmentally sound disposal.
Efficient and eco-friendly treatment of mobile phone requires sophisticated facilities and expertise and the transparency of the company recycling the devices. The telecommunication company must ensure that all the steps and the final disposal are properly done.

Provide ICT services that reduce commuting and business travel
ICT service providers enable users to put in place organisational solutions to reduce business travel and develop teleworking.
- Through the provision of broadband network, ICT companies enables workers to telecommute and to work remotely using a broadband connection.
- Telecommunication operators can also provide audio and video conferencing service. The development of such software reduces the need for business travel for physical meetings.

Provide ICT services that reduce paper consumption and consumables
Paper documents are time-consuming and costly to manage. They require process in place to distribute, file, store, retrieve, reproduce and dispose. The use of digital documents outweighs the benefits of print. All communication supports: publish, print, ship newspapers, documents, books, CDs and DVDs can de dematerialised. Instead, new digital online services can be offered. ICT service providers can enable their client to offer these solutions such as:
- Online interactive reports
- E-invoicing

Provide ICT services that minimise the energy consumption and environmental impact of managing ICT equipment
The model of cloud usage is described in the scheme below.

Figure 124: An example of take-back program and donations. Source: Orange take back programme review
ICT services providers can develop green cloud offers:

- Design energy efficient applications: Cloud computing for running applications owned by clients requires energy efficient software. The energy consumption depends on the application design. ICT providers shall develop application requiring less memory and shorter running and lower CPU. Refer to the next part on green software for more information.

- Use energy efficient network devices: cloud computing efficiency depends on how the network performs traffic management. The power consumption in transporting data through the network represents a significant proportion of cloud storage services energy consumption. ICT sector companies can develop energy efficient network (see section 3 BEMP to improve the energy performance of telecommunication networks3.2).

- Cloud energy efficient data centres: cloud datacentres require conditioning equipment and cooling infrastructures. These infrastructures and large amount of equipment require the implementation of energy-efficient solutions (see section 4 BEMP to improve the energy performance and minimising the environmental impacts of data centres3 BEMP to improve the energy performance of telecommunication networks3.2).

Provide energy efficient software and operating systems

The main goal when developing energy-efficient software is to get the workload achieved as fast as possible in order to get back the server back to idle and to reduce energy consumption (Intel, 2011).

Techniques of computational efficiency consist in delivering better performance and as well as better energy-efficiency (Intel, 2011). Programmers should develop new software according to the following principles:

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68 An existing program can be transformed into a similar output program that uses less energy by taking better advantage of the underlying processor architecture. For that purpose, an optimising compiler can be purchased and used for minimising the time taken to execute a code.
• Design efficient algorithms by writing a compact design of codes and data structures and by sticking to the only functions presented in the requirement stage (Mahmoud S. and Ahmad I., 2013);
• Develop multi-threading software where different parts of a sequential code can be run simultaneously on multiple processors (or multiple cores).
• Vectorise the code, by using advanced instructions such as Single-Instruction Multiple Data.

Data efficiency reduces data movement (Intel, 2011). It can be achieved by:
• Designing algorithms minimising data movement;
• Memory hierarchies that keep data close to processing elements;
• Application software that efficiently use cache memories.

9.3.6 Applicability
The implementation of an eco-rating scheme and of a take-back program is relevant for telecommunications companies to rate manufacturers’ mobile phones. The eco-rating evaluation requires the participation of manufacturers and the availability of information on their products.

The establishment of a collecting program and recycling channels depends on the availability of this type of services and skills in the country.

The development of services to help clients reduce the impact of their activities requires the integration of functionalities in ICT equipment such as office equipment.

New services such as cloud computing and green software can be developed for different types of client and can be applied to large and small companies.

9.3.7 Economics
As detailed in previous part, the development of an eco-rating system requires the intervention of an independent third-party. The company will have to mandate and pay the intervention of an external reviewer to support its approach.

The development of recycling channels will also require the establishment of a partnership with expert companies.

Some take-back programs include an offer to customers who bring back their old mobile phone. Companies can pay back customer an amount calculated according to the type of mobile phone collected or offer a preferential contract. These financial incentives must be taken into account.

The development of green offers such as cloud computing and software will require investments in Research of Development to ensure the energy-efficiency in the design of these offers.

9.3.8 Driving force for implementation
Services telecommunications companies can provide to their customers to help reduce the environmental impact from the use of IT equipment support companies’ sustainability policy and communication. It can also be used as a competitive advantage as customers will be more willing to pay for identified ethical and responsible products. For instance, a Telefonica study in the UK showed that sustainability credentials influenced the purchasing decisions of 44% of their customers (ITU, Review of mobile handset eco-rating schemes, 2012).
9.3.9 Reference organisations

Different telecommunications companies implementing services to help customers reduce their environmental impact have been identified (ITU, 2012):

- Bouygues Telecom: Mobile phones are collected, sorted out, tested, and refurbished by Les Ateliers du Bocage. 300,000 mobiles have been recycled since 2010. Since 2012, more than 10 million euros have been paid back to customers for giving their old mobile phones in the framework of the take-back programme.

- Vodafone: eco-rating of mobile phones and take-back programme.

- Orange: eco-rating of mobile phones in association with WWF and the implementation of a take back programme of mobile phones.

- O2 – Telefonica: eco-rating of mobile phones and take-back programme.

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9.4 Provide services to help reducing other sectors’ environmental impacts

SUMMARY OVERVIEW:
ICT technologies are used throughout many sectors and transform companies’ activities. The use of ICT technologies helps companies reduce their environmental footprint by dematerializing, collecting data and optimising processes.

<table>
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<th>Broadcasting</th>
<th>Software publishing</th>
<th>Desktop architecture</th>
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</thead>
<tbody>
<tr>
<td>Relevant lifecycle stages</td>
<td>Design and installation</td>
<td>Selection and procurement of the equipment</td>
<td><strong>Operation and management</strong></td>
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<td>Main environmental benefits</td>
<td><strong>Energy consumption</strong></td>
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9.4.1 Description
The rise of ICT has transformed the economy and has impacted different sectors and behaviours. The increased use of ICT in other industries through broadband networks, cloud computing and smartphones, contributed to economic growth and transformation of other sectors’ activities.

ICT has the potential to address environmental issue by helping other sectors improving their activities. Studies showed that the ICT sector contributed 16% of the overall GDP growth from 2002 to 2007 while the sector grew from 5.8 to 7.3%. The ICT sector contribution is projected to remain high and to represent 8.7% of worldwide GDP growth by 2020 (GeSI, 2012).

ICT service providers can provide companies software to help them optimise their activities and reduce their environmental impact. ICT services providers can develop software that optimises algorithms and generates alternatives for carbon intensive
processes. The design of software can integrate energy efficiency criteria in the process of information and performance of computations (Intel, 2011).

There are different ways in which the ICT sector can positively transform other sectors:

- Digitalisation and dematerialisation: by substituting or eliminating the need for emissions-intensive products or process;
- Data collection and communication: allowing real time information and data analysis to improve decision making;
- System integration: by managing and optimising the use of resources;
- Process, activity and functional optimisation: by improving efficiency through automation, simulation and control.

These different applications can be applied in different sectors and each of these sectors has to answer sustainability challenges:

- Power: the power sector represents 21% of the global GHG emissions (GeSI, 2012). It is based on fossil fuel and coal combustion which releases GHG. ICTs have a role to play in increasing the efficiency and the managing and controlling of power grid through smart grids (European Commission, 2015).
- Transport: Transport accounts for more than 13% of worldwide CO₂ emissions (Ericsson Network Society Lab, 2014). ICT has already demonstrated that it can provide significant fuel savings by optimising logistics and through fleet management systems. New models of transport are integrated in smart cities connected by ICTs.
- Manufacturing: the manufacturing sector is the biggest contributor to climate change emitting 31% of global emissions (GeSI, 2012). Industrial processes are energy-intensive and could be optimised through smart appliances.
- Service and consumption: it is the sector with the smallest contribution to climate change with less than 5 Gt CO₂e (GeSI, 2012) but the transformation of the sector with the adoption of online services and e-commerce is supporting the growth of the sector. ICT sector has a role to play in the transformation of the economy and mode of consumption by influencing consumer behaviour and developing collaborative and shared consumption. Agriculture and land use: the agriculture sector is confronted to major challenges with growing population and reduced natural resources. Increase and more prosperous population must be fed and issues such as water shortage, soil fertility decline must be taken into account (Stienen, Bruinsma, & Neuman, 2007). The sector represents about 20% of global emissions with livestock emissions having substantial emissions.
- Buildings: the achievement of CO₂ emissions reduction in the building sector is challenging because of the growth of population, the number of household will grow significantly by 2050. The building sector’s CO₂ emissions grew by 2.2% a year between 1995 and 2007 (IEA, Energy technology perspectives 2010. Scenarios and strategies to 2050, 2010). Buildings account for 40% of energy end-use in the EU which makes the building sector a topical issue for energy efficiency (European Commission, 2015). ICT sector can help the building sector adopting smart building approach integrated in smart cities development.
9.4.2 Achieved environmental benefits

The integration of ICT throughout the economy helps other sectors reduce their CO2 emissions. The GeSI study, Smart2020, shows the potential of CO$_2$ emissions abatement through the use of ICT in different sectors. The potential abatement of ICT across all listed sectors is represented in the chart below.

**Figure 126: ICT abatement potential by sector (GeSI, 2012)**

The potential CO$_2$ abatement was also calculated according to the different technologies used across the sectors.

**Figure 127: ICT abatement potential by change lever (GeSI, 2012)**

The main benefit from the implementation of ICT techniques is the reduction of energy consumption and consequently the reduction of GHG emissions. In the transport
sector, the implementation of ICT solutions helps optimising fleet and avoiding unnecessary commuting, thereby it reduces transport assets energy consumption. In the building sector ICT allows energy consumption reduction through energy efficient heating, cooling and lighting. In the manufacturing sector, the optimisation and automation of industrial processes reduce the need for energy. In the consumer and service sector, the development of e-commerce and online services reduce the need for consumer of commuting. More specifically in the power sector the use of ICT improves the level of information available on energy consumption through smart grid. Smart grids regulate peak demand and reduce directly GHG emissions. The actual environmental benefits of smart grid are difficult to measure. It must take into account opportunities enabled by ICT technologies but also the impact related to the increased use of ICT. The IEA scenario considers that smart grid could cut by half CO₂ emissions by 2050.

![Figure 128: Smart Grid CO₂ reductions in 2050 compared to baseline scenario (IEA, 2010)](image)

Other environmental benefits can be related to the integration of ICT technologies in different sectors. ICT technologies help collecting and analysing data really quickly. Through real time information, ICT helps matching needs and resources. For instance, in the agriculture sector, information on the quality of soils and health of animals can help adapt the level of pesticides and food to use. In the consumer and service sector, e-commerce helps matching offer and demand more easily. This increase in data availability has a positive impact on the environment by reducing waste and reducing the amount of resources needed. For instance, smart farming by analysing soils and weather will help cutting down the use of chemicals and water.

Finally, the development of e-commerce and online services reduces the need for materials necessary to protect a good while transport.

### 9.4.3 Appropriate environmental performance indicators

As the main impact of the integration of ICT in other sectors is the reduction of energy consumption, the most relevant performance indicator is the follow-up of energy consumption and of GHG emissions.

Companies can measure the energy reduction achieved through the use of ICT technologies. The carbon footprint can be calculated based on the energy consumption on the scope 1, 2 and 3.

The optimisation of processes allows the reduction of the amount of resources needed. The cut in resources can be tracked: reduction of materials and reduction of water.
These different measures can be made compared to business as usual scenario without the use of ICT solutions.

9.4.4 Cross-media effects
ICT technologies enhance the use of data in daily business activities. The main concern regarding the use of software aggregating data is the protection of private and sensitive data.

The use of ICT technologies in the different previously listed sector is emerging and there is the need to control and safeguard data. Companies can subcontract ICT services and confidentiality must be ensured.

The use of ICT in different sectors can help increase companies competitiveness but the implementation of ICT depends on the maturity of technologies and networks where the company is located. The use of ICT technologies can create gaps in some sector and between different geographical areas. For instance, the coverage of wireless and broadband will be different from one country to another.

Finally, any savings achieved through ICT services and efficiency improvements can lead to “rebound effects” meaning that the overall resource consumption continues to grow (Skouby & Windekilde, 2010). For example, fuel efficiency can lead to more goods being transported.

9.4.5 Operational data
Power sector
The integration of ICT in the power sector can be done through two main techniques:

- Those facilitating the integration of renewable: integrating renewables in power generation, virtual power plant and off-grid renewables and storage. Virtual Power Plants VPP emerging technology combining distributed generation installations and runs them collectively to allow integrating of renewables. Help providing higher efficiency and more flexibility to avoid peak load and fluctuations. ICT helps managing these types of complex optimization, control and communication systems.

- Those enabling the smart grid: a smart grid is an electrical grid using information and communication technology to gather information. It helps collecting data to analyse consumers’ behaviour. It will help improving the efficiency, reliability of the production and distribution of electricity. According to IEA (2011), a smart grid “co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability”.

- Smart meter systems balance information asymmetries between electricity producers and consumers and help optimise electricity consumption.

ICT technologies can be applied throughout the value chain of the energy sector. At the generation stage, ICT equipment can help generating and regulate the production of renewable energies and manage small-scale electricity generation. The transmission and distribution of electricity require grid management to avoid losses and peak load. The retail stage can be improved through real-time information on consumption and distribution. At the consumption level, ICT can help improving energy efficiency and electricity conservation and automated demand management systems. IEA mapped the different domains of ICT application in a smart grid as showed in the following figure.
Smart grids optimize, control, secure and sustain procurement and supply of cleaner distributed energy (European Commission, 2009).

**Transport and logistics services sector**

The need for transportation is increasing in the globalised economy which implies more travel for people and for goods. Significant improvement can be made to improve the efficiency of transportation system and to avoid unnecessary travels.

ICT solutions can be implemented at different level in the transport sector: In a large-scale system, in a small-scale transport system.

Transport infrastructure must respond to increasing demands. An integrated solution can provide sharing information and bring together different stakeholders. ICT techniques can be implemented at different levels as showed in the following scheme:
ICT technologies provide solutions to improve the collection of data and the optimisation of transport assets such as fleet management. The fleet management allows the optimisation of route planning and logistics network to help transport and logistics companies allowing the right amount of resources at the right time. Systems can track real-time information and trigger alerts to intervene as fast as possible.

In small-scale transport services, ICT can help develop smartphone applications based on interactivity and networking among users. The type of services aggregate suppliers’ information and commuter demand.

The development of ICT technologies created new services and a better access to transport assets. New ways of transport usage emerged in the past few years with shared bike and car rental services.

ICT technologies transformed individual behaviour in the use of transport. At the individual level IT technologies support eco-driving to help drivers reduce their environmental impacts. It also reduces the need for commuting with the development of videoconference and telecommuting.

The solutions provided by ICTs enable the transformation of the transport sector by developing connected solutions to optimise logistics and user commuting. Solutions such as: smart card travel card, contactless cards and smartphones apps, electronic payment solutions, support the development of smart transport. Smart transport is integrated and is a core element for an effective smart city.
Manufacturing sector

ICT can help the manufacturing sector reduce its environmental footprint by reducing electricity wasted through inefficient processes.

Production can use digital innovation based on data capturing, planning and control, modelling and simulation, cloud computing and big data analysis. ICT can provide different solutions:

- Automation of industrial processes: involves the modernisation of plants. A better monitoring and control of equipment will help reduce energy consumption.
- Optimisation of variable speed motor systems: motor systems are energy-intensive and operate continuously at constant speed which creates inefficiency and electricity wastes. Variable speed motor will help adjust the activity and use energy when needed.
- Intelligent energy management: with real time e-monitoring.

Industrial processes are energy-intensive and large amount of materials must be heated, cooled, evaporated or pulverised. Intelligent measurement, management and control of the production process ensure energy efficiency.

Agricultural sector

Farming involves different risks and uncertainties regarding soils, drought, erosion and pests. Improvement relies on information and control and new ways to optimise production and regulate quality control. ICT can tackle key challenges in the agricultural value chain. ICT technologies have the possibility to make farming more efficient on different topics:

- Livestock management: controlling livestock emission will help decrease the overall emissions. Sensors can be used for monitoring and detection of reproduction events and health disorders in animals. For instance data such as the body temperature, the animal activity, pulse and GPS position can be analysed.
- Smart farming: using satellite imagery to control crop inputs and measure temperature and health of plants. Based on this information, the amount of fertilizer and water can be adapted.
- Smart water: by remotely controlling irrigation systems and to reduce the amount of water needed.
- Soil monitoring and weather forecasting: ICT soil monitor can give accurate information on the level of fertilizer and water that should be used.

The different types of technologies involved in smart farming are presented in the chart below:
Building sector

The building sector is highly concerned with increasing energy efficiency. Buildings consume energy mainly through heat, air conditioning, and lighting. ICT can help monitor energy consumption. A building management system, an ICT computer-based system, can be implemented to monitor the energy consumption.

Building management systems require the analysis of behaviours and needs in the building. It can be established through the detection of the occupancy and a schedule defined to turn in off lighting, heat or air-conditioning.

**Figure 131:** Smart farming technologies (Beecham research, 2014)

**Figure 132:** Lighting control scheme, source: (Aghemo, et al., 2013)
Moreover, the ICT sector can deliver tools to collect, process and manage data to analyse the energy efficiency of a building. These information can help identify ICT can be used to achieve energy efficiency through modelling, simulation, analysis, monitoring and visualisation tools. ICT instruments will facilitate the adoption of a holistic building approach (European Commission, 2015).

Buildings today are complex interlinked structures, systems and technologies. ICT technologies can 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 (Institute for building efficiency, 2015). They are connected and responsive to the smart power grid (refer to the power sector section).
Service and consumer sector

ICT transformed the consumer sector. The e-commerce is developing and changing ways consumers purchase products. E-commerce sales growth rate was of 19% between 2012 and 2013. By 2020, it is estimated that 14% of global retail spending will be on online products.

Consumer-packaged-goods companies use technologies to create direct contact with consumers. Applications are developed for online shopping.

ICT technologies also support the development of new way of payment, using electronic payment services and mobile payment solutions.

Other services are developed such as e-paper, electronic invoicing and online media which helps companies to reduce their environmental footprint by reducing the amount of paper used (refer to the BEMP Provide services to improve the environmental performance of client activities on reduce consumption of paper and consumable).

ICT also have a role to play in the transformation of consumers’ behaviour and the development of collaborative and sharing economy (to be developed).
9.4.6 Applicability
ICT technologies are primarily relevant for big companies with the need to monitor great amount of resources and data. For instance, in the transport sector ICT play a key role in intermodal travel and large fleet monitoring. It can be more difficult to use in area with low population density and less needs.

The implementation of ICT technologies in companies has the potential to transform business models and companies activities. For instance, the shift from physical store to e-commerce is a change in the core business of a company and requires new functions. These radical transformations rely on the involvement and on new skills that are not always available inside the company. Companies may need to adapt their business model and anticipate the disruptive change it may imply.

In some sectors, companies and individuals may not be aware of the potential benefits they could get from the use of ICT technology. For instance, in the agriculture sector, many farmers are unaware of the possibilities from smart farming.

9.4.7 Economics
In the power sector the use of certain technologies do not have a positive net present value. For instance, the cost effectiveness of renewable energy technologies depends on the availability of natural resources and the price of electricity in a region (GeSI, 2012). Therefore, renewable may not always be competitive compared to traditional sources of energy. Other technologies have net positive value but have long term payback period or require a too large capital to invest.

In the transport sector, sublevers have a net positive value and a short payback period.

In the manufacturing and building sectors, the use of ICT technologies allows energy efficiency. The return on investment can be easily calculated based on the reduction in energy consumption.

9.4.8 Driving force for implementation
The main driver for the implementation of ICT technologies in other sectors is the possibility to transform a company activity and to increase competitive advantage.

The competitive advantage can be obtained in different ways:

- Offer new services to customers. For instance consumer and services sector can be more competitive by developing an on-line purchasing platform by reaching new customers. In the transport sector, the use of applications and real time information improve the quality of service and enhance the users’ experience.

- Increase the activity and economies of scale through process optimisation. In the manufacturing sector, the automation and optimisation of production lines and processes can increase the activity.

The previously listed environmental benefits can also drive the implementation of ICT technologies. ICT offers the opportunity to reduce energy consumption. The related cost reduction is an incentive for companies.

9.4.9 Reference organisations
To be developed
Power

Transport
- BT: BT calculated the carbon footprint and carbon benefits resulting from global telepresence solution. The final result of the study showed that there was 9,850 tonnes of CO₂ abatement due to videoconferencing instead of business travel.

Consumer goods and services

Agriculture

Manufacturing

Building

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10 Conclusion

10.1 General aspects

10.2 Specific conclusions

10.3 BEMP

10.4 Emerging techniques and approaches

10.5 Applicability of this document for SMEs

10.6 Specific key performance indicators

10.7 Benchmark of excellence and links to BEMP and specific indicators
### Table 15: Overview of benchmarks of excellence for each BEMP and related specific indicators

<table>
<thead>
<tr>
<th>Benchmark of excellence</th>
<th>BEMP</th>
<th>Recommended indicator</th>
<th>Unit</th>
<th>Remarks</th>
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<tbody>
<tr>
<td><strong>Energy performance and GHG emissions</strong></td>
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<td>Change of access network technology</td>
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<td>Consolidating the location of network components</td>
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<td>Consolidating data and optimising traffic using routing protocols</td>
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<td>Better site location and planning of data centres</td>
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<td>Optimising data centre utilisation and management</td>
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<td>Efficient cooling technologies and systems</td>
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<td>Airflow management and design, and reuse of heat</td>
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<td>Procurement for energy-efficient equipment and installation</td>
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<tr>
<td>Improving energy efficiency of ICT equipment</td>
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<td>Use of renewable energy sources</td>
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<td>Reduction of energy losses due to electricity conversion</td>
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<td>Energy monitoring and management</td>
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<td><strong>Raw materials and waste management</strong></td>
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<tr>
<td>Improving life cycle asset management and waste prevention</td>
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<td>Improving WEEE collection, recycling and recovery</td>
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<td>Benchmark of excellence</td>
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<td><strong>Landscape</strong></td>
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<td>Reducing the effects of ICT infrastructures on landscape</td>
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<td>Reducing noise and electromagnetic radiations from networks</td>
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<td><strong>Improving the energy and environmental performance in other sectors</strong></td>
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<td>Improving the environmental performance of client activities</td>
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<td>Reducing the environmental impact of other sectors through ICT services</td>
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