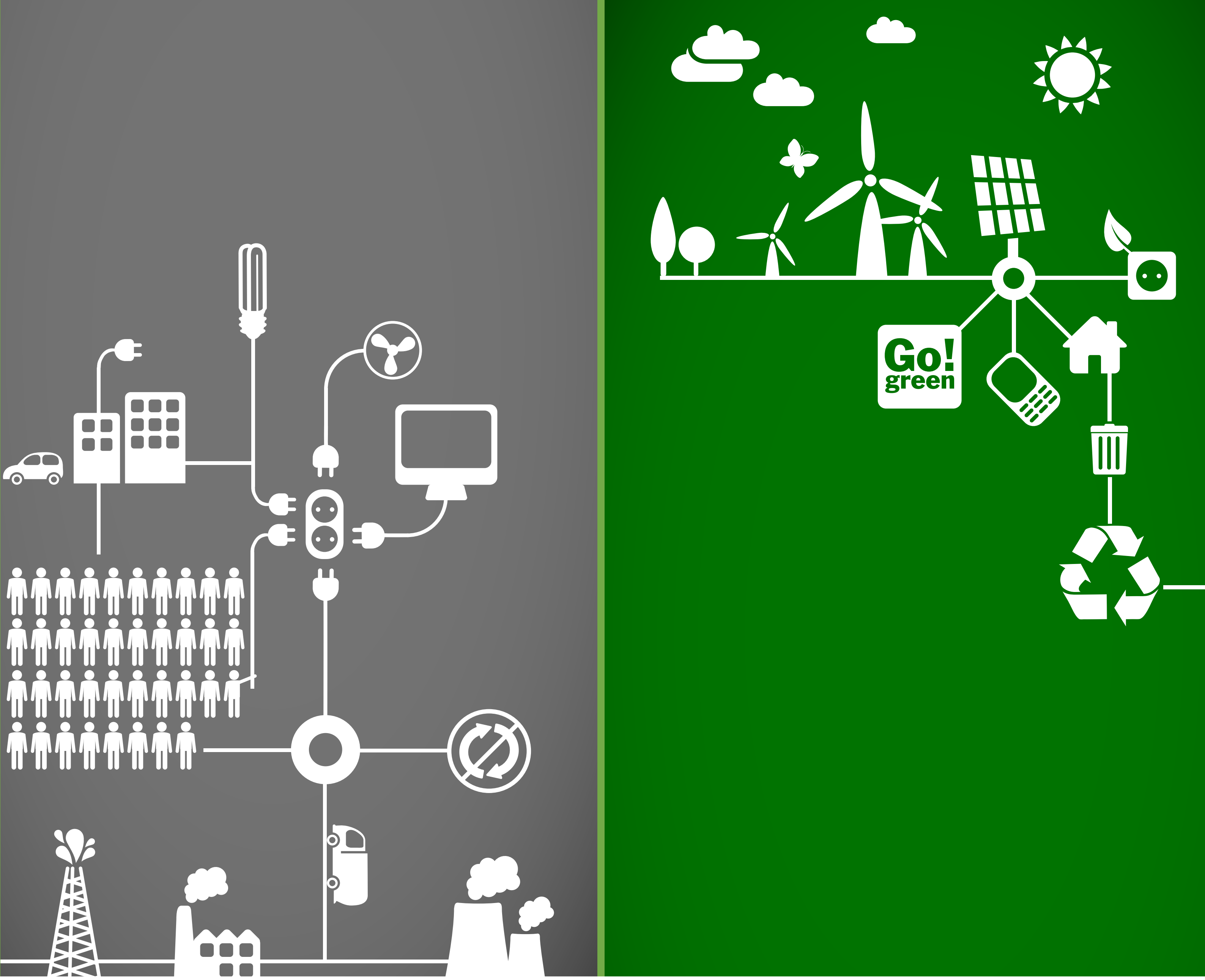

Toolkit on environmental sustainability for the ICT sector

itu.int/ITU-T/climatechange/ess

Acknowledgements

This toolkit was developed by ITU-T with over 50 organizations and ICT companies to establish environmental sustainability requirements for the ICT sector. This toolkit provides ICT organizations with a checklist of sustainability requirements; guiding them in efforts to improve their eco-efficiency, and ensuring fair and transparent sustainability reporting.

The toolkit deals with the following aspects of environmental sustainability in ICT organizations: sustainable buildings, sustainable ICT, sustainable products and services, end of life management for ICT equipment, general specifications and an assessment framework for environmental impacts of the ICT sector.

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Additional information including the full list of contributory organizations can be found at: www.itu.int/ITUT/climatechange/ess/index.html

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Toolkit on environmental sustainability for the ICT sector

Table of contents

Executive summary

Table of contents

Toolkit on environmental sustainability for the ICT sector

Executive summary

The Smart 2020 report found that the full life cycle carbon footprint of the ICT industry represents around 2% of worldwide emissions, and is projected to grow at a 6% annual compound growth rate. Although the sector's emissions are rising, its largest influence is expected to be through enabling increased energy efficiencies and improved environmental performance in other sectors.

A significant challenge for ICT companies is that in enabling better environmental performance elsewhere, the ICT sector is itself taking on significant burdens, at a time when there is greater scrutiny applied to environmental performance, and, often, at much greater cost. As a result, it is important for ICT organizations to use sustainability actions to drive their own business performance, while being more responsible corporate citizens.

The Toolkit on Environmental Sustainability for the ICT sector is an ITU-T initiative which provides plenty of detailed support on how ICT companies can build sustainability into the operations and management of their organizations, through the practical application of international standards and guidelines.

The basic components of the toolkit are a number of individual documents, each covering a separate area, as follows:

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

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

Although the toolkit is wide-ranging and designed to help improve business *and* sustainability performance, some companies may decide that they cannot afford to use such tools, particularly in the light of a negative business outlook. This document explores why companies cannot ignore their sustainability performance if they seek superior financial performance.

Finally, the document covers how the toolkit may mature and develop in future, through extending its scope, deepening its metrics, lowering the questionnaire burden on ICT companies, and through the provision of an implementation program to enable national regulators, policy-makers and individual ICT organizations to use the toolkit to achieve their own objectives.

1 Introduction

If a CEO's pronouncements were all the evidence we needed that a business was doing something, then sustainability would be top of the strategy charts.

Over half of the McKinsey Global Survey 2010[1] participants consider sustainability – the management of environmental, social and governance issues "important" or "extremely important" to their businesses. An even more optimistic Accenture study[2] of 766 CEOs found 81% claiming that sustainability is part of the strategy and operations of their businesses.

In practice, for most companies, word and deed diverge.

The same McKinsey study reports that most companies are not actively managing sustainability, or seeking opportunities for such investments or making it part of their business practice. Yet, the best sustainability performers comfortably beat their competitors on sheer economic grounds.

If anything, information and communications technology (ICT)[3] companies should pay even closer attention to sustainability than companies of many other sectors. The Smart 2020 report[4] confirmed that the full life cycle carbon footprint of the ICT industry represents around 2% of worldwide emissions, and that ICT footprint is projected to grow under business-as-usual (BAU) conditions at a 6% compound annual growth rate to 1.4 GTonnes of CO_2 by 2020. At such rates, the ICT industry's footprint would comfortably exceed that of a sector such as airlines.

Although its own emissions[5] are rising, ICT's largest influence is expected to be through enabling increased energy efficiencies and energy use reductions in other sectors. In this context, the Smart 2020 report also found that the scale of this ICT-enabled opportunity was found to be a massive 7.8 GTonnes of CO_2 by 2020, equivalent to 15% of all emissions under BAU projection.

A significant challenge for ICT companies is that in enabling all this environmental efficiency in other sectors the ICT sector is itself taking on significant burdens. For example, as companies migrate from on-premises software applications systems (where all the systems run on their own hardware, powered by their own energy, etc.) to cloud-based systems (where the cloud service provider provides the server hardware and pays for data centers, energy, backup, etc.), the ICT provider takes on a greater burden of environmental impacts (and costs) in the new model compared to the old one.

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1 McKinsey Global Survey Results: How companies manage sustainability, McKinsey, 2010, https://www.mckinseyquarterly.com/Strategy/Strategy_in_Practice/How_companies_manage_sustainability_McKinsey_Global_Survey_results__2558.

2 Lacy, P., Cooper, T., Hayward, R., Neuberger, L., A new era of sustainability, Accenture, 2010, www.accenture.com/us-en/Pages/insight-new-era-sustainability-summary.aspx.

3 On the definition of "ICT", ISO/IEC Joint Technical Committee (JTC) – 1 N 9475 developed the clarification of the term ICT: "ICT includes the specification, design and development, integration and interoperability of systems, tools and applications dealing with the capture, representation, accessibility, processing, security, transfer, interchange, presentation, management, organization, storage and retrieval of information, and their related cultural, linguistic adaptability and societal aspects."

4 SMART 2020: Enabling the low carbon economy in the information age, The Climate Group, 2008, www.smart2020.org/publications/.

5 An organization is responsible for greenhouse gas (GHG) emissions in a number of ways, either directly by burning fuel or processing chemicals, or indirectly by purchasing energy from other sources. ICT companies need to be aware of where and how their emissions are counted. This should then drive their emission reduction strategies, against which they should be accountable through their sustainability reporting. See Annex.

Yet, for many companies, managing sustainability[6] performance is often seen to be a "good" thing for a company to do, even the "right" thing, but not necessarily a business driver for success. Word and deed are still separated.

So how do companies get their deeds to match their words? And why should they bother? Both questions need to be answered so that ICT companies can get their sustainability actions to drive business performance inside their own organizations and in their customers, and help them be more responsible corporate citizens.

2 The components of the Toolkit on environmental sustainability

The Toolkit on environmental sustainability for ICT companies is an ITU-T initiative, carried out together with over 50 partners, which provides plenty of detailed support on how ICT companies can build sustainability into the operations and management of their organizations. It puts international standards and guidelines into context and brings them to life with real-life examples, showing how ICT organizations around the world are dealing with their sustainability challenges.

The toolkit covers a range of sustainability issues that impact the performance of an ICT organization. While much of the material is focused for use by an ICT organization, the pervasiveness of ICT does mean that all sorts of end-user organizations can also benefit from the material in the toolkit, as they manage the in-use aspects of ICT sustainability.

The basic components of the toolkit are a number of individual documents, each covering a separate area, as follows:

- sustainable ICT in corporate organizations;
- sustainable products;
- sustainable buildings;
- end-of-life management;
- general specifications and key performance indicators;
- assessment framework for environmental impacts.

2.1 Sustainable ICT in corporate organizations

This document focuses on the main sustainability issues that companies face in using ICT products and services in their own organizations across four main ICT areas: data centers, desktop infrastructure, broadcasting services and telecommunications networks.

Historically, data center managers only focused on maximizing their computing performance and expanding the availability of IT resources. Today, the rate of increase of data processing has outpaced the center's

[6] On the definition of "sustainability", ISO 14021 states, "The concepts involved in sustainability are highly complex and still under study. At this time there are no definitive methods for measuring sustainability or confirming its accomplishment. Therefore, no claim of achieving sustainability shall be made." Currently, "sustainability" has been used as an umbrella term for all of human activity to meet current needs without hindering the ability to meet the needs of future generations in terms of economic, environmental and social challenges. Sustainability may be defined as a means of configuring civilization and human activity so that society and its members are able to meet their needs and express their greatest potential in the present while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals indefinitely. Sustainability is a general term that states a visionary goal for a sustainable society of human beings. Every business and technology sector can do appropriate actions within its scope and capabilities to improve on its own measure of sustainability and, most importantly, to improve the measure of sustainability for other sectors.

ability to support such systems. As a result, environmental factors such as energy and water have become the main limiting factor in the data center environment – as strong a business reason as possible to focus the attention of management on sustainability. This document covers a number of IT efficiency and utilization metrics that data center managers can use to enhance their business and sustainability performance.

The management of desktop infrastructure is just as important inside ICT companies as it is with user organizations, since most of the energy consumed by IT equipment is wasted, mostly because computers are on with no one using them. Not only do the computers waste energy, they also create an indirect impact by heating their surroundings and causing a greater load on air-conditioning, for example. This document covers best practices on desktop infrastructure, use of alternative data management techniques, and the use of software to measure and manage the environmental performance of desktop infrastructure.

Telecoms network infrastructure and devices are responsible for over a third of the ICT industry's greenhouse gas emissions. Thanks to new technologies and energy-efficient products, the energy usage per device is improving. This document outlines a number of different metrics that can be used in managing power utilization in a network, plus it covers codes of conduct and policies that help manage the sustainability impact of network infrastructure.

Similar issues face the broadcasting services industry, where energy is a key consideration in an industry which uses bright lights, huge audio and video files, and many different types of networks. This document explores best practices in delivering such services, and the metrics that can be used by broadcasting services organizations to deliver a combination of desktop infrastructure, data centers, telecommunications network, broadcast infrastructure and customer in-use energy management.

2.2 Sustainable products

One of the best ways for the ICT industry to provide its customers with more sustainable products is to build them from the start using environmentally-conscious design principles and based practices, covering development and manufacture, through to end-of-life treatment. The document provides design assistance with two categories of products: network infrastructure equipment and customer premise equipment.

Product design needs to cover five "Green Focal Areas" in order to create sustainable products: energy, product weight, packaging, hazardous substances and recyclability. Customers can use green programs and initiatives, such as US EPA Green Star, EPEAT, RoHS and so on, to ensure that the ICT products they buy meet the environmental standards laid out in such programs, while designers need to ensure that the standards are adhered to in their products.

This document also discusses how life cycle assessment (LCA) methodologies, such as ITU-T methodologies to assess the environmental impact of ICT, can assist designers in directly evaluating the environmental impacts of a product or its sub-assemblies.

2.3 Sustainable buildings

Across Europe and the US, buildings are the largest driver for both energy use and CO_2 emissions, with European buildings contributing 40% of energy use and emissions, and US buildings accounting for 48% of the corresponding number.

ICT companies build and operate facilities that can demand large amounts of energy and material use in all phases of the life cycle. This document applies sustainability management to buildings through the stages of construction, lifetime use and de-commissioning. The use of standards, methodologies and tools, such as LEED, Green Globes and BREEAM, is discussed, as is the use of life cycle assessment to evaluate actual performance of buildings, as opposed to buying into certain prescribed practices.

2.4 End-of-life management

The growing volumes of end-of-life (EOL) and near end-of-life ICT equipment around the world is becoming a matter of concern. The failure of close the loop on e-waste leads not only to significant adverse environmental impacts, but also to the systematic depletion of the resource base of secondary equipment.

When equipment no longer satisfies the original user's needs, we should not assume that it is in poor operational condition, or has become obsolete. Instead, it may be possible to extend its life through use for the same purposes by other users. Or, it can be re-used (in part or whole) for other purposes, or the materials contained within it can be recycled or recovered.

This document outlines the various EOL stages (and accompanying legislation), and provides support in creating a framework for environmentally-sound management of EOL ICT equipment.

2.5 General specifications and key performance indicators

While the ICT industry plays an important role in enabling organizations of other sectors to improve their sustainability performance, the sector's own negative environmental impacts continue to rise. The industry needs excellent procedures and processes to deal with environmental data to improve its sustainability tracking, management and performance.

This document focuses on environmental KPIs that can be used by an ICT organization to quantify and evaluate performance in this area. There are already a number of standards and methodologies in place that can be the basis of just such a management system. What this document does is identify how to choose KPIs that relate to specific business strategy targets the organization has. It then explores how to build standardized processes with KPIs to make the data as useful as possible to management. It then covers how to ensure that the right data is collected, and once collected, is verified and validated.

2.6 Assessment framework for environmental impacts

There are a number of standards and guidelines that have been created by standards organizations regarding the management of energy, GHG emissions and waste, from the perspective of ICT products, projects and organizations. This document maps all the standards and guidelines across two dimensions:

- assessment targets, including product, organization, project, city or country; and
- assessment criteria, including inventory, carbon footprint, life cycle assessment, ICT enablement accounting, product eco-design, labelling, and validation/verification.

The resulting mapping of the standards uses these dimensions to explore their application, their inter-dependencies, complementarities, and so on. As a consequence, organizations can use the various standards and guidelines to create their own sustainability assessment framework.

3 Business drivers for sustainability performance

Although the Toolkit on sustainability for the ICT sector is wide-ranging and is designed to help improve business *and* sustainability performance, some companies may decide that they cannot afford to use such tools, particularly in the light of a negative global business outlook.

The problem with such a perspective is that sustainability performance and business performance are so closely tied together. This next section explores reasons why companies cannot ignore their sustainability performance if they seek superior financial performance.

3.1 The best sustainability performers are the best performers. Period.

Accenture's study of 275 global Fortune 1 000 companies [7] analysing business and sustainability performance metrics shows that the top 50 companies ranked on sustainability outperform the bottom 50 by 16% when it comes to shareholder returns over a three year period.

Over five years, the results are even more skewed in favour of the best sustainability performers: the top 50 outperform the bottom 50 and middle 50 peers by 38% and 21%, respectively.

So the best sustainability performers make more money. Of course, it is not clear which is cause and which is effect here, but it's still a great reason to get involved in sustainability.

3.2 Operating efficiency is a sustainability virtue

One important factor driving economic performance is resource efficiency. As companies deal with depletion of resources, environmental impacts, and materials security, they seek new and improved ways of doing what they do, often driven by ICT enablement. The consequence of this is improved performance inside the business, and improved ability on the part of the company to transition into the low-carbon world that is already being shaped into place.

Resource efficiency is also an area where it's very important to be forward looking. According to World Wildlife Fund,[8] the world economy took as much as the planet can offer (in terms of natural resources and as a sink for our waste, including global warming gases) in 1988. Since then, we have been borrowing from future generations and, as economies continue to grow, so does our deficit with nature. Many are predicting a crunch in the natural world as devastating as the financial credit crunch experienced in 2008. It's unlikely to happen as quickly as the financial crises, but businesses should be building it into their long term-cost forecasts.

In many ways, the recent price hikes in energy, commodities and food are all linked to long-term sustainability related trends, and are an early indication of the internalization of many externalized costs that are currently unaccounted for.

3.3 Keeping out of regulatory trouble is a sustainability driver

It is clear the world's economies have done a poor job of preserving the planet's natural resource amenities, such as air fresh water, and carbon. As a result, most Organization for Economic Co-operation and Development (OECD)-based businesses have had to pay for some of the pollution they cause.

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7 Berthon, B., Abood, D.J., and Lacy, P., Can business do well by doing good?, Accenture, 2010, www.accenture.com/SiteCollectionDocuments/PDF/Accenture_Outlook_Can_Business_Do_Well_by_Doing_Good_Sustainability.pdf.

8 www.wwf.org.uk/what_we_do/about_us/building_a_one_planet_future.cfm.

Historically, in the US and most OECD countries, polluters have paid around 2 to 2.5% of GDP to clean up their worst pollution. However, United Nations Environmental Program (UNEP)[9] estimates that the annual environmental cost from global human activity was 11% of global gross domestic product (GDP) in 2008, and the number will rise to more than 17% by 2050. So we are not paying for anywhere near all the costs we incur.

Why is this relevant?

Because the day is coming closer that businesses will have to pay for the environmental damage they cause. UNEP and Trucost, the environmental data provider, together estimated[10] that over USD 2 trillion of environmental damage in 2008 was caused by the world's 3 000 top public companies. If these businesses actually had to pay for these damages, then around a third of them would no longer be profitable. Of course in reality prices to the end customer would rise to reflect the increased operating costs and cleaner technologies would become commercially preferable.

Externalized costs are a good at foretelling probable areas of new regulation that will ultimately drive all businesses toward sustainability, with measures such as the Carbon Reduction Commitment, Greenhouse Gas Emissions Allowance Trading Scheme and the Environmental Liability Directive all being relatively recent examples of the way governments are seeking to get responsible behaviour from their corporate citizens.

3.4 Reputation? What reputation?

While paying attention to the law, it is important to remember that there can be an even higher court that holds businesses to account, the court of the consumer. Even if a business is meeting the letter of the law, but is violating its supposed social contract in some way, it can attract consumer boycotts and loss of revenue.

Of course many businesses are hidden away in the supply chains of big brands. But this can still make the big brand vulnerable, as many ICT companies have found to their cost when it comes to working conditions in their supply chain. On the environmental front, the common accusation is that companies are only interested in "greenwash," not a genuine performance in the area of sustainability. As a result many large businesses are increasingly building sustainability issues into their procurement standards. Some ICT companies are also making public their supplier lists in an effort to demonstrate transparency on these issues.

The key here is to understand why the business may be vulnerable to sustainability-related risks, prioritize and, if possible, monetize them, and then introduce mitigation strategies.

Meeting customer and other stakeholder expectations is about winning the licence to operate, while exceeding them is about building brand loyalty and enhancing customer "stickiness." The first step here is to understand what those expectations are and how addressing them delivers business value. The trouble with talking to stakeholders is that it always generates a long list of expectations. But companies need to be prepared to deal with dilemmas, as different stakeholder groups can pull the business in opposite directions!

3.5 Employees care about sustainability too

Increasingly, it is the company's own employees that are the reason why businesses want to do better when it comes to sustainability. This is because the employee knows the most about how a business is really

9 www.unep.org/.

10 http://archive.constantcontact.com/fs015/1103244704571/archive/1103736519020.html.

operating, and can often see through greenwash or corporate untruths. When a company's reputation takes a battering from external pressure groups, (Greenpeace, Shell and Brent Spar is the classic example of such external action on a company's brand), it is the employee workforce that often needs to be encouraged that their employer is doing the right thing.

A company's employees are often a fairly representative cross section of society and, given the low levels of public trust in business, many will be questioning the motivations of their bosses. Finding ways of motivating employees by being seen to be doing the 'right' thing, or even better involving them in it, builds employee motivation. And 'happy' employees mean more productive employees, and improved customer relations.

Increasingly, attracting and retaining talent is also influenced by the company's sustainability reputation, particularly when it comes to graduate recruitment.

3.6 New opportunities

Finally, but by no means least, new sustainable products are opening up major new markets and creating business opportunities. These opportunities span from clean technologies, such as renewable energy generation, to sustainable sourcing in the food and agriculture sectors, to innovative design that makes our businesses and homes more efficient. As already discussed, the ICT sector will play a key role in enabling other sectors to achieve superior sustainability performance.

But is there really a New World of opportunity out there?

Let's take carbon as an example. Already, businesses have started transitioning to a low-carbon economy, whether driven by climate change regulation, high oil prices, energy security, or plain competitive pressures from peers that have already made such investments.

Whatever initiatives are currently in place, as a planet we have only made baby steps. It is widely expected that for global temperatures to rise by less than two degrees centigrade, global greenhouse gases should fall by 90% from today's levels by 2050[11]. In 2000, it took 32 billion tons of carbon to produce USD 32 trillion of global GDP. Taking economic growth into account, McKinsey estimates[12] that by 2050, we will need to use 5-10 billion tonnes of carbon to produce around USD 145 trillion of global GDP.

To put it another way, carbon productivity is going to have to rise by 5-7% a year till 2050, when in the previous fifty years (when carbon was not seen to be an issue) the historic rate is 1%.

Making these huge changes to the way we work today will create generations of new global winners, and some massive global losers. Sustainability, enabled by ICT, will be the key strategic weapon in this world.

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11 Weaver, A., Zickfeld, K., Montenegro, A., and Eby, M., Long-term climate implications of 2050 emission reduction targets, Geophysical Research Letters, 2007, http://wikyonos.seos.uvic.ca/people/alvaro/Emi_2050.pdf.

12 Boccaletti, G., Loffler, M., Oppenheim, J.M., How IT can cut carbon emissions, McKinsey, 2008, https://www.mckinseyquarterly.com/How_IT_can_cut_carbon_emissions_2221.

4 Conclusions and next steps

Although the Toolkit on sustainability for the ICT sector is wide-ranging in its scope, and substantial in the assistance it offers ICT companies in dealing with their business and sustainability challenges, it is by no means complete in itself. There is room for it to mature and develop. Here are some ways in which this can happen.

4.1 Extending the scope

Although there is a document covering e-waste in detail, and quite a few other documents explore other environmental issues, much of the focus of the toolkit is on energy and greenhouse gas emissions. This is entirely appropriate, as the world starts to figure out how to deal with the interactions between climate change and human activity. It also reflects the fact that most other standards setting organizations have focused on carbon footprints and GHG emissions in the work they have done.

However, environmental management needs to be more than just carbon or energy. It is also about water, land use, waste and pollutants. Sustainability practices, as well as the tools, guidelines and methodologies, need to move into the wider sphere of environmental impacts if they are to be helpful to organizations beyond carbon.

4.2 Deepening the metrics

Thanks to the focus on carbon and GHG emissions, KPI metrics relating to these issues have good coverage in the ICT sector. However, more work needs to be done to extend the metrics to other environmental KPIs.

Possibly a more significant challenge is the fact that sustainability KPIs are unevenly distributed across the ICT sector. Data centers, for example, are very well covered when it comes to environmental metrics such as energy, water, as well as more business-focused metrics, such as processor utilization. It is the two types of metrics, taken together, that give data center managers significant insight on the performance and management of their resources.

Other areas of the ICT sector, such as broadcasting or desktop infrastructure, are much further back when it comes to having suitable metrics that tie together business performance and environmental performance. Desktop infrastructure metrics, for example, are usually tied to the energy performance of a single PC. The metrics here need to extend to cover the performance of the desktop infrastructure taken together, and related to how the infrastructure is used. Broadcasting, which requires the working together of many different ICT disciplines such as data centers, networks, PCs and broadcast systems, needs the development of a similar set of metrics that bring together metrics developed for other areas into a context that is relevant to how broadcasting organizations use such assets.

4.3 Lowering the questionnaire burden

As many companies around the world implement sustainable supply chain practices, they have started engaging with their suppliers, often via a questionnaire that seeks answers to specific issues that are important to that particular company. However, in reality, many of the questionnaires cover the same issues. So, in practice, an ICT company may receive many questionnaires from different customers, often asking for the same information, sometimes in slightly different ways. The consequence is questionnaire fatigue, resulting in poor data and lower supplier engagement.

What might be helpful is a common set of metrics that apply across the ICT sector, which companies provide the data for via public reporting. The Toolkit on sustainability for the ICT sector already has check-lists in each document that provide a helpful summary of the metrics and methods that ICT companies can use to help their sustainability management. The next step could be the application of a standardized data set, covering check-lists, metrics and tools that all ICT companies use for reporting their sustainability performance.

4.4 Implementing the toolkit

While there are some exemplars within the ICT sector who are already utilizing best practices in the sphere of sustainability management, many companies have not got started, either because they have not understood the issues well enough, or because the entry bar is too high in terms of knowledge and the need for tools.

The Toolkit on sustainability for the ICT Sector offers an excellent starting point for the company that wants to start or deepen its management of sustainability issues. It identifies the issues, helps in the prioritization of those issues, and then in the selection of standards, tools and methods that enable these issues to be brought to life in the context of the company's workings.

However, some companies will need more than this. They will need a training and implementation plan so that they can have a practical approach to bringing this area into standard management practice in their organizations. Such a training and implementation plan does not currently exist.

Further, the issues raised in the toolkit have significance for policy-makers. In many countries, policy-makers are already exploring putting together rules, regulations, directives and guidelines, or have already started doing so. What the toolkit offers is a guide on all the issues that companies may face on sustainability issues. However, it might be really helpful for policy-makers to have access to a tool that captures the sustainability impacts discussed in the toolkit in a way that enables them to think about reasonable formulations of policies and regulations that they can apply to their national economies.

Finally, given the enabling role that the ICT sector plays in other industries, and the way its own negative impacts are expected to grow, it would be useful to have access to industry-wide information about the performance of the ICT sector in the management of sustainability impacts. The Toolkit offers a starting point for what these metrics could be. If ICT companies adopt these ideas, it might be useful to bring researchers and universities into play, so that the data from the companies can be consolidated and analysed to provide further insight on the performance of this sector. There is a further potential benefit in that universities that engage on this might well provide really good training resources for companies that want to learn how to implement sustainability management in their own set-ups.

The combination of an implementation guide, engagement with policy-makers, and working with universities and researchers might have a particularly helpful impact when it comes to getting these ideas working in developing countries, where getting access to the skills and resources needed might be harder, and could result in the so-called standardization gap.

4.5 Suggestions for further work for ITU-T Study Group 5

Throughout the toolkit, a number of areas have been identified where there is need for initial or further studies in order to develop standards of practice. ITU-T Study Group 5 (SG5) is working on a series of activities relating to ICTs and climate change[13]. A number of issues listed in the documents of the toolkit deserve further work, and it is suggested that ITU-T SG 5 initiates studies in these areas:

- Much more work has been done on creating a set of metrics and standards for data centers than for desktop infrastructure, broadcasting services and networks. The latter areas need the same level of definition, industry-wide acceptance and adoption of metrics and standards as has been achieved so far with data centers.
- A new ITU-T Recommendation on metrics for data centersis needed which integrates energy consumption metrics with metrics relating to business strategy and business use. It is possible to turn off sections of the data center in line with business needs and yet improve the PUE score. This feels counter-intuitive with good business strategy. We need to see metrics in this regard where better metric scores align with better business practice. Could the use of metrics based on watts per gigabyte of data, or watts per user provide metrics that align better with business practice?
- Standard specifications are needed on the interface of a DC power feeding system and its architecture.
- There are considerable energy efficiency gains in the area of cooling, including fresh air cooling, direct air economizers and indirect air economizers, but further studies are needed to show how these benefits can be introduced and managed in data centers. As ETSI and ASHRAE are developing work items in this area, one possible way might be for ITU-T SG 5 to work jointly with these bodies.
- Organizations that are seeking to manage desktop infrastructure can benefit from access to energy consumption data regarding ICT equipment, particularly if this data can be integrated into their energy management applications. However, data from organizations such as Energy Star and EPEAT are currently not available via API access. ITU-T SG 5 can define standards by which such data can be shared in open formats.
- Most metrics relating to desktop infrastructure apply to individual machines as opposed to a divisional or organizational footprint, where much work needs to be done, both in terms of metrics and on best practice frameworks.
- Thanks to a number of studies, it is possible to understand what good practice looks like in terms of energy utilization in data centers. However, there is no such depth of information available when it comes to benchmarking of desktop infrastructure.
- Metrics and frameworks for best practice are needed on energy stations needed to power mobile network nodes.
- Although next generation networks (NGN) are expected to deliver 30-40% energy savings compared to traditional networks, a study is needed to capture the sources of energy savings in NGNs so that their benefits are not lost.
- Although there are metrics relating to energy consumption of DSLAMs, there is a need for energy metrics that apply across an entire network.
- Network equipment needs power saving modes which can be fully operable at low or no traffic periods. Standards are needed for such modes to be implemented fully across networks.

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

- A study is needed on energy savings possible through the use of alternative power schemes in cellular base stations, including alternative energy sources as well as optimized methods where diesel generators are run for a few hours at full power to charge batteries, and then the generator is switched off at other times while the station runs on battery power.
- A study is needed on the energy efficiency metrics applicable in the broadcasting industry, covering production, lighting, storage, post-production, transmission and networking.
- A study is needed on the relative sustainability impacts of terrestrial, cable, satellite and online distribution channels.
- For further work, guidance could be provided on a solution to the following problem: a person or organization needs to procure a basket of ICT services – what is the best combination of transmission system(s) to choose from in order to meet the service requirements and have the least environmental impact? The available technologies include: broadcast services (TV and radio), mobile cellular (2, 3, and 4G), fibre (passive optical network and point-to-point), twisted pair, Ethernet (LAN), WLAN and cable (TV) networks.
- Overall, the broadcasting industry has not benefited from the sort of wide-ranging work that has been done in other sectors, such as data centers where there is considerable sophistication in measuring and managing environmental performance.
- A study is needed on the energy efficiency metrics applicable in the broadcasting industry, covering production, lighting, storage, post-production, transmission and networking.
- The document on product sustainability currently addresses only the environmentally conscious aspects of an ICT product’s total life cycle. As they only address the environmental considerations for product design, they stop short of full sustainable design, which would encompass social and ethical aspects. The recommendation is that SG 5 initiates studies and evaluations for the next step of integrating social and ethical aspects into the overall toolkit.
- Life cycle assessment is a key method to helping designers evaluate an ICT product and determine opportunities to improve on its measurements and performance. As such, the suggestion is for the further development of tools and their associated databases that support designers in their development of ICT products for a low carbon society, i.e. tools that promote more efficient and simplified approaches to deriving eco-impact results. This applies to both the measurement and assessment of the direct eco-impacts associated with the life cycle stages of the product, and also to the enabling effects associated with the ICT product applications and its benefits to helping society attain a sustainable economy and life style.
- As energy efficiency is a critical factor in having the most potential to reduce the eco-impacts of ICT products over their entire life cycle, SG 5 should focus future work on metrics for measuring energy efficiency of ICT products and in their deployment within systems, networks and grids. These latter entities can be quite complex in scope and operation, and therefore need the development and standardization of suitable metrics and tools for their effective evaluation and improvement.
- Materials and their selection and use within ICT products to produce eco-sustainable products is another topic that needs further work. It is suggested that SG5 should address the development of collective lists of sustainable materials that designers can apply in their product development work. These lists can categorize materials according to their characteristics and sustainable attributes – environmental, social and economic. From this, designers can choose appropriate materials and also provide labelling indicating such choices – or in reverse, list any product materials that are not on the sustainable lists.
- Recycling materials needs to be further emphasized, with information being provided to recycling entities that would help create an understanding of the major types and classes of materials that are within a particular product family. This can be emphasized with certain key materials such as precious metals, rare metals/rare earth metals. Further research into the recycling and reuse of plastics within

the ICT product can also be addressed by SG5. This would include the use of bio-plastics and their full life cycle evaluation as a substitute for more traditional fossil fuel based plastics.

- ICT product design issues, including clean supply chain; reduction of the demand on limited natural resources, which is measurable and tractable; designing products that through their different life cycle stages reduce environmental impact and waste generation; designing, producing, labelling in compliance to the requirements of legislation in place, commercialization of products that have a reasonable extensive life and that once they achieved the end of life, can easily be repaired or dismantled for reuse or its value recovered via recycling or its life finalized in the best environmental possible manner without impacting economic growth.
- Technical guidance applicable to refurbishment and repair facilities as well as marketing of used ICT equipment, including risk prevention and minimization; processing and management of equipment and components destined for reuse; management of materials, components and residuals destined for recycling or disposal; and, record keeping and performance measurement (partly covered here).
- Environmental and socio-economic aspects**:** uncontrolled burning, disassembly, and disposal causes a variety of environmental problems affecting directly or indirectly human health such as erosion of land, high water demands and contamination of ground sources, air pollution with carcinogens and neurotoxins. Fumes include dioxins and furans. Inappropriate method of processing waste could lead to, deforestation and the inevitable relocation of communities, animal life as well as the disappearance of ecological habitats. In addition, this could lead to health problems including occupational health and safety issues, affecting those who are either directly and indirectly involved, due to the methods of processing the waste; etc. (partly covered here). There must be a direct guidance to the industry in order to help governments and communities to end bad practices such us uncontrolled burning and to secure that material is being handled properly. This industry movement needs to take into account the micro-economics that have been developed around those practices harmful as they are to society and the environment, because they represent are the only income for thousands of families who cannot be excluded from employability access in the world.
- Principles for donors of ICT equipment**:** ensure that products are functional and that appropriate products are provided; availability of technical support in the country of destination; and, ensure full transparency, contract and notification and consent prior to delivery.
- Development of national ICT policies**: e**nsure that the life-cycle approach is used for developing national ICT policies. This means that such issues, as, *inter alia*, green design, collection, recycling, disposal should be considered in the policy.
- Develop a map or guidance document that lists all different end-of-life standards currently available around the world, highlighting the aim, resources needed, pros/cons, boundaries, expectations, possible overlapping or relation with others, as well as the differences among them. This document, which would need to be updated regularly, will be of help to the user to identify, differentiate, and make an independent decision over which standard to use according to the needs and objectives of the stakeholder on its specific role within the recycling chain.
- Development of a global CO_2 – equivalent market**: d**eveloping a market for CO_2 trading will help to directly control and incentivize reduction on pollution emissions through the use of best practices available and technology, as well as making use of economic incentives and fees over the direct effect of the environmental impacts generated by inappropriate ICT disposal, locally or overseas.

Recovery of rare metals and green ICT supply chain: in the effort to achieve a green supply chain within the ICT sector, it is suggested that ITU-T SG5 actively includes and facilitates access to the recycling and precious metals industry in the discussions and possible developments that aim to return such metals to the industry with the physical and technical characteristics needed to satisfy new equipment production requirements. It is this industry that has the practical knowledge on the technical aspects and feasibility opportunities and limitations of the recovery process.

Annex A note on emissions protocols

An organization is responsible for greenhouse gas (GHG) emissions in a number of ways, either directly by burning fuel or processing chemicals, or indirectly by purchasing energy from other sources. ICT companies need to be aware of where and how their emissions are counted. This should then drive their emission reduction strategies, against which they should be accountable through their sustainability reporting.

The Greenhouse Gas Protocol is a collaboration between the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD).[14] It differentiates between three different categories of emissions, known as Scope 1, Scope 2 and Scope 3.

Recommendation ITU-T L.1420[15] explains how ICT companies need to consider the various categories:

Scope 1 GHG emissions

Scope 1 covers the GHG emissions generated by facilities within the boundaries of an organization. For most ICT companies, this usually refers to the combustion of fuels for heating offices, power supply of ICT equipment either for backup or, in more recent times, for cogeneration, or the power needed to cool ICT equipment. It also covers emissions resulting from intentional or unintentional releases of coolant from equipment, such as air conditioning plants in data centers. Scope 1 emissions will also cover emissions from vehicles owned by ICT companies.

Scope 2 GHG emissions

Scope 2 covers the indirect emissions from the generation of purchased electricity, heat or steam consumed by the organization. Most ICT organizations buy the majority of their electricity from utilities in order to power their computers, data centers, communications equipment, heating, lighting, cooling and use of other office equipment. As a result, most emissions from the internal operations of ICT companies are reported in this category.

Scope 3 GHG emissions

Scope 3[16] covers a company's entire value chain emissions impact, and enables a company to track the full impact of its upstream and downstream impacts. It is at the company's discretion what it reports under scope 3 and most companies will keep it to easily measured items such as corporate business travel. Full life cycle scope 3 reporting is still very rare.

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[14] Since the publication of the first edition of The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Corporate Standard) in 2001, more than 1 000 businesses and organizations worldwide have developed their GHG inventories using the GHG Protocol. Some of the world's largest companies are using the GHG Protocol's Corporate Standard. www.ghgprotocol.org/.

[15] Recommendation ITU-T L.1420 Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communications technologies in organizations, International Telecommunication Union, February 2012.

[16] Companies wanting to assess Scope 3 GHG emissions need to take into account the categories listed in Annex C of Recommendation ITU-T L.1420 Methodology for energy consumption and greenhouse gas emissions impact assessment of Information and Communication Technologies in organizations.

Sustainable ICT in corporate organizations

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Table of contents

Page

Sustainable ICT in corporate organizations

Executive summary

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

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

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

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

Data centers

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

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

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

Desktop infrastructure

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

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

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

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

Telecoms infrastructure and networks

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

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

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

Broadcasting services

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

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

1 Introduction

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

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

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

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

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

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

1.1 Objective and target audience

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

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

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

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

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

1.2 A note on digital convergence

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

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

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

2 Data centers

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

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

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

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

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

2.1 The main components of a data center

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

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

2.2 Drivers impacting energy efficiency of a data center

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

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

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

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

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

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

2.3 PUE is the key sustainability metric

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

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

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

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

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

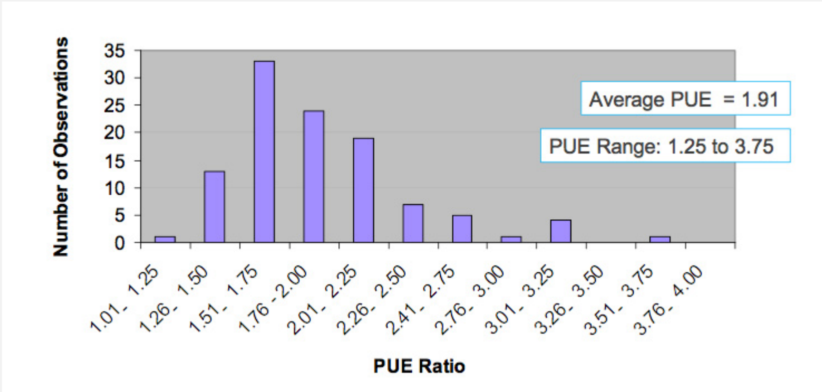
Unfortunately, there is no comprehensive, transparent, publicly available data set publishing accurate PUE statistics for data centers, though the move towards global harmonization should help improve matters. In 2010, the US EPA studied the PUE of 108 US data centers and published the following PUE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

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

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

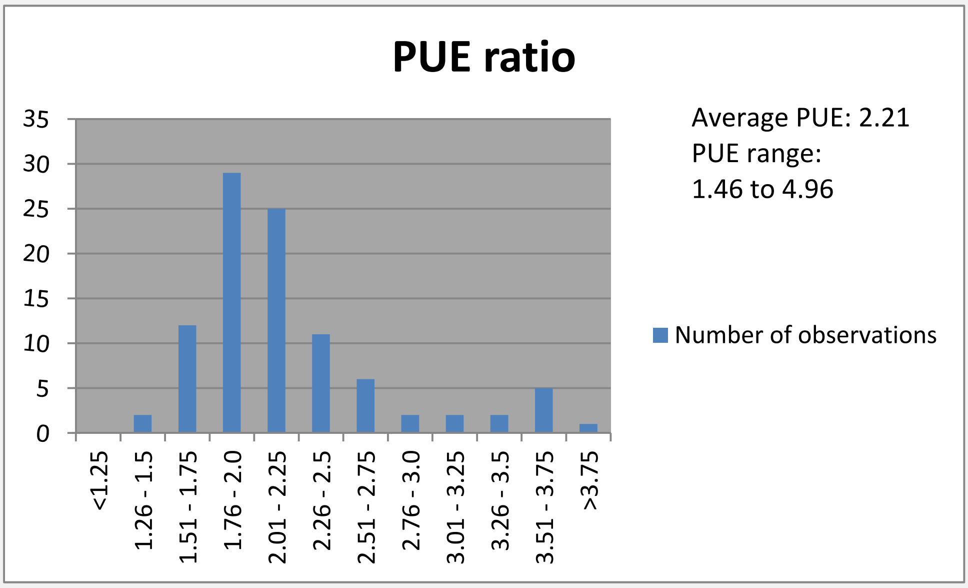
6 Sullivan, A., "ENERGY STAR® for Data centers," US EPA, ENERGY STAR, February 2010.

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



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

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



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

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

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

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

So is it worth pursuing such a metric?

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

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

$$PUE = \text{Cooling Load Factor (CLF)} + \text{Power Load Factor (PLF)} + 1.0$$

All the above factors are ratios:

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

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

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

2.4 Managing other sustainability metrics

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

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

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8 PUE and DCiE Efficiency metrics.

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

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

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

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

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

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

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

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

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

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

Finally, there are other metrics that can be considered:

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

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

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

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

Figure 4: Comparing different data center metrics

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

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

2.5 Guidelines on sustainability in data centers

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

EU Code of conduct

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

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

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

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

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

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

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

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

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

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

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

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

2.6 Best practices in data centers

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

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

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

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

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

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

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

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

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

Table 1: Data center best practices

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

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

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

1) IT strategy

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

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

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

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

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

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

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

4) Site physical structure overhead, based on PUE metrics

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

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

Table 2: Top energy efficiency actions for data center managers

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

Source: Energy Star

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

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

Aisle containment

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

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

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

DC distribution

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

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

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

Fresh air cooling

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

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

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

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

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

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

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

Case study: Logicalis

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

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

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

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

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

2.7 KPIs for data centers

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

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

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

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

3 Desktop infrastructure

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

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

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

3.1 The elements of desktop infrastructure

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

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

3.2 Sustainability drivers in desktop infrastructure

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

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

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

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

[26] Bray, 2006.

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

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

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

2) *Screensavers save energy*

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

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

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

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

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

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

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

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

Measuring power consumption of desktop infrastructure

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

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

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

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

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

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

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

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

Source: Bray, 2006 referencing Kawamoto et al 2004

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

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

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

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

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

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

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

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

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

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

3.3 Regulations and guidelines

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

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

3.4 Best practices on desktop infrastructure

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

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

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

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

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

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

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

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

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

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

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

The management challenge

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

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

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

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

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

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

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

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

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

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

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

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

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

2) *Set up a green IT champions team*

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

3) *Figure out power metrics*

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

4) *Assemble and implement an action plan*

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

5) *Optimize a strategy*

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

Case study – Politecnico di Torino

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

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

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

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

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

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

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

Case study: Microsoft IT

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

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

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

Organizational structure

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

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

Power PC management − challenges and opportunities

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

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

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

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

Technical issues

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

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

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

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

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

3.5 Evaluation of the shift from one technology to another

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

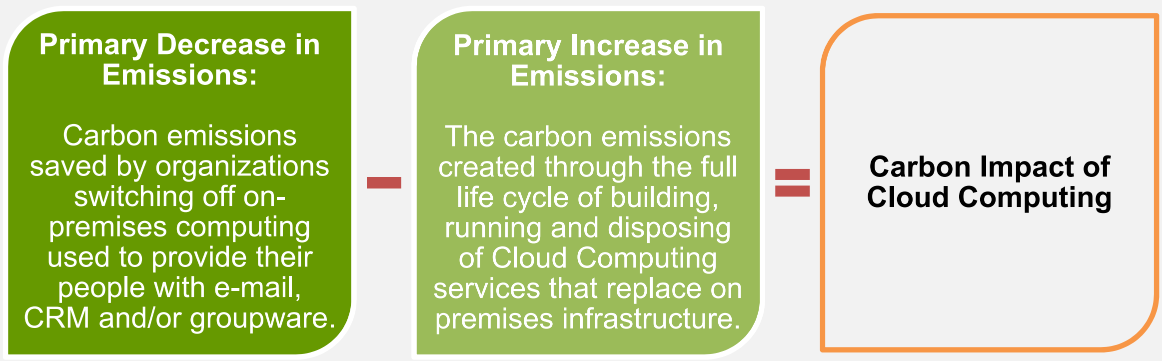
Cloud computing, in its emergent form, represents less a technological innovation and more a business model innovation within the ICT industry. Yet it has significant implications for the entire sector and its customers. It enables computing services (software, platforms and/or infrastructures) that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

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

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

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

Figure 5: Calculating the carbon impact of cloud computing



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

The following best practices can be identified:

- When enterprises switch to the cloud, their now redundant on-premises servers must be switched-off; failure to do so will negate any potential carbon savings
- Applications need to consider small-/micro-sized firms. Nearly 60% of the savings potential relates to small-/micro-sized firms
- Energy mix may be more influential than power usage effectiveness (PUE); i.e. where a Cloud data center is located is more important in CO_2 terms than the overall efficiency of the data center (measured by its power use effectiveness) – a cleaner energy source will more readily deliver better carbon savings that investing in efficiency
- Desktop infrastructure needs to be controlled to hibernate efficiently when not accessing cloud services.

3.6 Key performance indicators

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

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

4 Telecoms infrastructure and networks

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

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

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

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

4.1 The building blocks of a network

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

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

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

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

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

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

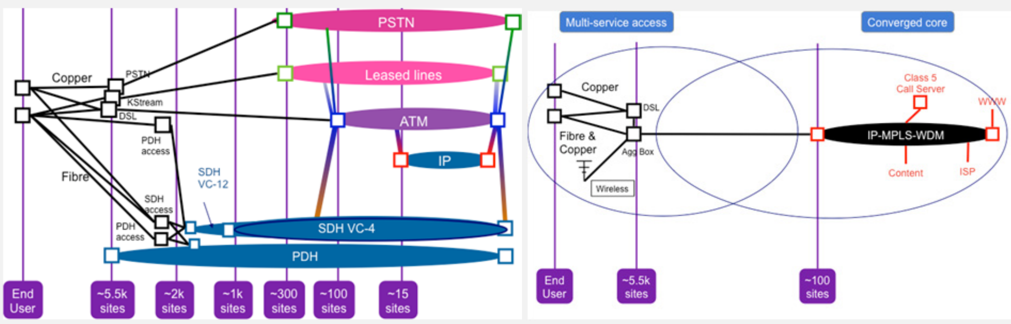
Corporate networks cover the hardware components, computers, software, and communications channels that a company may use to allow the sharing of information and resources within the boundary of the organization. Corporate networks often connect to public mobile and fixed networks as well, usually as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

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

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

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

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



4.2 Sustainability impacts of a network

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

Measuring power consumption in a network

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

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

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

where:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3 Guidelines

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

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

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

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

4.4 Best practice energy efficiency in networks

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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[49] European Telecommunications Standards Institute, ETSI TR 102 530.

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

Case study – BT and Telecom Italia

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

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

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

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

Case study: unified communications within Microsoft

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

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

Case study: GreenTouch

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

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

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

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

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51 www.greentouch.org.

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

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

4.5 Evaluating the shift from one technology to another

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

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

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

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

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

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

Some general considerations emerge:

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

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

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

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

4.6 Key performance indicators

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

Wired access:

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

Wireless access:

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

5 Broadcast services

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

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

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

5.1 The main activities of broadcasting

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

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

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

5.2 The building blocks of broadcasting

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

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

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

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

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

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

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

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

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

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

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

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

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

5.3 Measuring sustainability impacts in broadcasting

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

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

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

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

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

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

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

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

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

5.4 Guidelines and best practices

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

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

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

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

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

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

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

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

5.5 Broadcasting case studies

Cost and power consumption implications of digital switchover

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

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

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

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

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

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

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

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61 www.greenproductionguide.com/.

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

63 www.fox.com/greenitmeanit/.

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

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

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

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

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

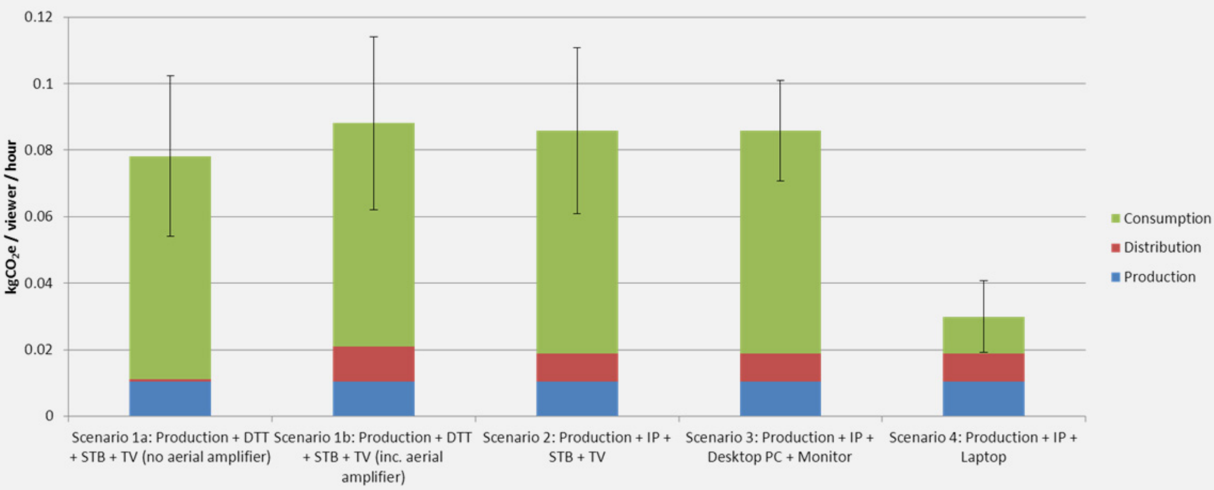
signals, as an aerial amplifier is always on and takes a significant power consumption. The largest environmental impact from watching television is from the consumer equipment. This amounts to 76% of the total for DTT and 78% and 37% for VoD using desktop and laptop computers respectively. The trend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

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

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

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

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



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

Comparing music delivery services

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

Sky's green initiatives

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

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

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

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

BBC for Sustainable Production

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

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

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

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

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

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

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

5.6 Key performance indicators

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

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

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

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

6 Checklists

The aims of sustainability checklists are to:

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

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

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

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

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

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

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

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

6.1 Service provider checklist

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

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

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

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

6.2 End user checklist

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

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

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

6.3 Data center energy checklist

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

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

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

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

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

6.4 Telecoms and networks energy checklist

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

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

6.5 Desktop energy checklist

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

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

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

6.6 Broadcasting checklist

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

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

7 Conclusions

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

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

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

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

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

7.1 Suggestions for ITU-T SG 5

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

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

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

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

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

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

8 Glossary

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

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

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Sustainable products

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Table of contents

Sustainable products

Executive summary

Introduction

This document, part of the ITU-T Toolkit on Environmental Sustainability for the ICT Sector, provides technical guidance on design for the environment principles and best practices as to how ICT companies can provide products that are more "environmentally conscious" throughout their full life cycle, from development and manufacture, through to end-of-life treatment.

Environmentally conscious design, or "Design-for-Environment" (DfE), is defined as the systematic integration of environmental considerations into product and process design. The process focuses on minimizing the costs and adverse environmental impacts of products throughout their entire life cycle.

This document provides product guidance in two sections: ICT network infrastructure equipment (NIE), and ICT customer premises equipment (CPE). A third section provides information and guidance on the use of life cycle assessment (LCA) to assess the environmental sustainability of ICT network infrastructure equipment and customer premises equipment.

Network infrastructure equipment

The entire environmental performance of the product needs to be evaluated, with priority consideration given to those aspects that can be substantially influenced through product design, and are major environmental impacts. Energy consumption is usually an excellent example of this. The designer needs to consider the most energy-efficient "on-modes" as well as transitions to "energy-saving modes" as the default modes of operation.

However, energy saving is not the only sustainability design consideration. Avoiding or eliminating substances hazardous to either humans or the environment is another example where design has to take sustainability impacts into consideration. Other issues include material efficiency, chemical use, product packaging, noise emissions, end-of-life treatment such as product dismantling, battery use and design for recycling and design for disassembly.

With the emergence of End-of-life (EOL) Management as a significant way in which an organization can operate more efficiently while ensuring the reuse, recovery and recycling of equipment, designers need to consider how to simplify EOL issues in their designs.

Sustainability metrics are used to measure and manage the performance of the organization. Designers can use reporting metrics in five "Green Focal Areas" – energy, product weight, packaging, hazardous substances and recyclability.

Customer premises equipment

Equipment aimed at customers has to meet environmental standards – meeting the requirements of these standards need to be baked into the design of the products from the outset. Legislation could include the EU RoHS Directive, and standards could include programs such as US EPA Energy Star, EPEAT, ECMA 341, and REACH.

Again, the use of sustainability metrics can enhance product planning and design. Apart from the "Green Focal Areas", designers can consider metrics covering disassembly time, number of plastic materials used, percentage of recycled material in the plastics, or the presence of halogenated compounds in electronics such as PCBs and encapsulants for integrated circuits.

Life cycle assessment (LCA)

The document also provides information and guidance on life cycle assessment methodologies, standards and tools. LCA results allow a designer to directly evaluate the environmental impacts of a product or its individual sub-assemblies. The technique that enables this to happen is known as life cycle thinking, where the environmental impacts caused by a product throughout its life cycle stages are integrated into the product design and development process.

While a designer can always use sustainability metrics in their design work by means of metrics such as energy, SO_x, NO_x, carbon and particulates, using the LCA approach might result in a designer taking into account other metrics, such as global warming potential, acidification potential, human toxicity, eutrophication and land use.

1 Introduction

This document provides technical guidance on environmentally conscious design principles and best practices as to how ICT companies can provide products that are "environmentally conscious" throughout their full life cycle including development, manufacture, transport, usage, and end-of-life treatment. Environmentally conscious design, or "Design-for-Environment" (DfE), is defined as the systematic integration of environmental considerations into product and process design. The process focuses on minimizing the costs and adverse environmental impacts of products throughout their entire life cycle. However, eco-design only adds environmental considerations to product design. It stops short of full sustainable design, which would encompass social and ethical aspects. In practice, eco-design is a way of thinking and analysing the impact a potential product may have on the environment over the different life cycle phases of the product. This section of the document addresses the guidelines, checklists and analytical tools that, when applied in product design, can help to producing a more eco-sustainable product – i.e. one that reduces resource and energy use over its life cycle while providing for increased end-user value and productivity.

This document provides product guidance in two sections: ICT network infrastructure equipment (NIE), and ICT customer premises equipment (CPE). A third section provides information and guidance on the life cycle assessment (LCA) methodologies, standards, life-cycle thinking approaches, estimators, tools, databases and other information for using LCA to assess the environmental sustainability of ICT network infrastructure equipment and customer premises equipment.

In consolidating the principles in this document, the following criteria were used to select the guidance and best practices offered:

- Designer-based − the principle is within the scope of a product designer.
- Actionable – the principle proposes a means for improving the design.
- Broad-ranged – the principle applies to a broad range of products within the ICT sector.
- Best-in-Class − the principle focuses on creating the best solution possible.

1.1 Target audience

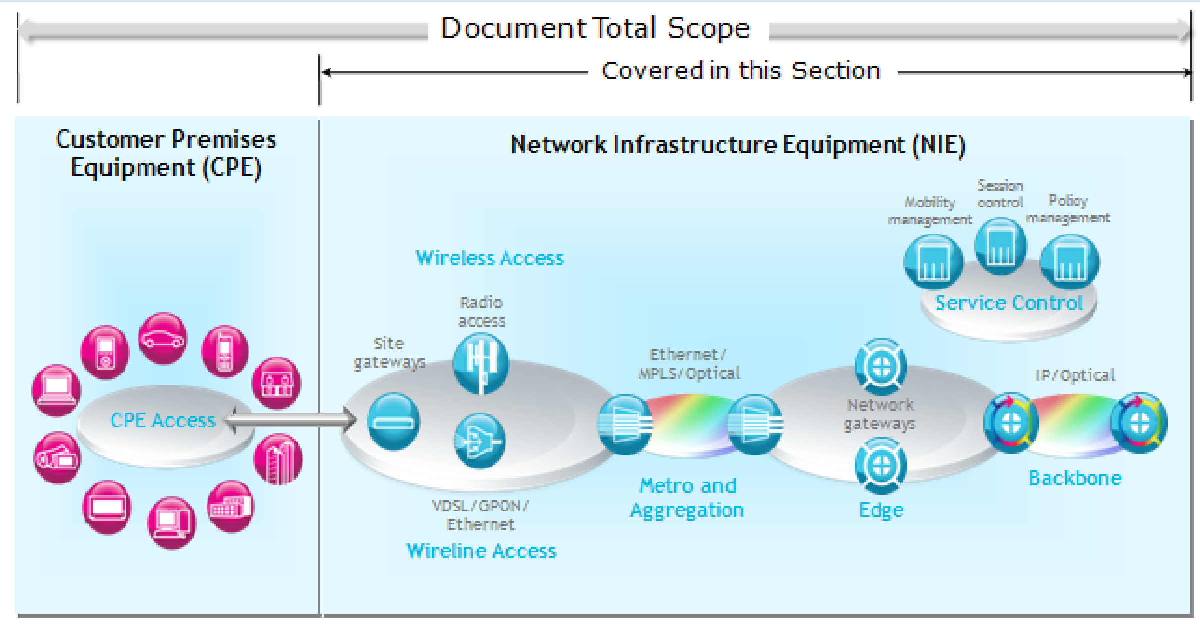
This document provides an overall perspective on environmentally-conscious design and development to the following target audience:

- designers, engineers and developers of ICT goods, including manufacturers of ICT goods;
- management of environment and sustainability functions in ICT organizations;
- management staffs of environment and sustainability functions of non-ICT organizations who want to account for improvements in environmental impacts enabled through the use of ICT.
- Ombudsman who can decide whether the improved design from the manufacturer's perspective does not simply pass the carbon footprint or energy to the end-user.

2 Network infrastructure equipment (NIE)

This ICT products section covers network infrastructure equipment (NIE), which is equipment that is set up and operated by service providers to offer shared network services to private and public end users. This document is provided for NIE within four major life cycle phases: environmentally conscious product development, eco-efficient manufacturing, smart usage, and end-of-life treatment. The diagram below shows the type of ICT products that are covered in this NIE section.

Figure 1: This section of the document covers Network Infrastructure Equipment as used by the providers of ICT services.



2.1 *Environmentally conscious product development*

2.1.1 Scope

This section covers technical guidance for NIE equipment design and addresses resource consumption (e.g. energy, water), material selection and use (e.g. material efficiency, safe and environmentally friendly materials, recyclability), packaging design, and design considerations for proper end-of-life treatment.

2.1.2 General references to other standards/work streams

International standards[1]

- Carbon Trust – Code of Good Practice for Product Greenhouse Gas Emissions and Reduction Claims – October 2008.
- ECMA-341 (4th Edition, December 2010) – Environmental Design Considerations for ICT and CE Products.
- ETSI TS 103 199 V1.1.1 (2011-11) – Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements.
- IEC TC 111 – Environmental standardization for electrical and electronic products and systems. Covers test methods for hazardous substances and help manufacturers declare which materials they are using in their products. It published the following standards:
  - ◊ IEC 62321 (2008-12), Electrotechnical products – Determination of levels of six regulated substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers).
  - ◊ IEC 62430 (2009-02), Environmentally conscious design for electrical and electronic products.

1 Non-exhaustive list in alphabetical order.

- ◊ IEC/PAS 62545 (2008-01), Environmental information on Electrical and Electronic Equipment (EIEEE).
- ◊ IEC/PAS 62596 (2009-01), Electrotechnical products − Determination of restricted substances − Sampling procedure – Guidelines.

- ISO 14001:2004 – Environmental Management Systems – Requirements with guidance for use. It should be noted that EMS or ISO 14001 accreditation is about being in compliance with local environmental regulations only, and currently there are disparities globally.
- ISO 14044:2006 – Environmental management – Life cycle assessment – Requirements and guidelines.
- ISO/TR 14062:2002 – Environmental management – Integrating environmental aspects into product design and development.
- ISO 14064-1:2006 – Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.
- ISO 14064-2:2006 – Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.
- ISO 14064-3:2006 – Greenhouse gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions.
- PAS 2050: 2008 – British Standards Institute: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.
- Recommendation ITU-T L.1410 (2012), Methodology for environmental impact assessment of information and communication Technologies goods, networks, and services.
- Recommendation ITU-T L.1420 (2012), Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations.

2.1.3 Best environmental practices

2.1.3.1 General principles and guidance

I. Ensure sustainability of resources by[2]:

- ◊ specifying renewable and abundant resources;
- ◊ specifying renewable forms of energy;
- ◊ layering recycled and virgin material where virgin material is necessary;
- ◊ exploiting unique properties of recycled material;
- ◊ employing common and remanufactured components across models;
- ◊ specifying mutually compatible materials for recycling;
- ◊ specifying one type of material for the product and its sub-assemblies;
- ◊ specifying non-composite, non-blended materials (e.g. avoid alloys where possible);
- ◊ specifying recyclable, or recycled materials, especially those within the company or for which a market exists or needs to be stimulated.

II. Ensure inputs and outputs in the product life cycle do not cause environmental degradation or adversely affect human health by:

- ◊ installing protection against release of pollutants and hazardous substances;
- ◊ specifying non-hazardous and otherwise environmentally “clean” substances, especially in regards to user health;

[2] “A Compilation of Design for Environment Principles and Guidelines”. C. Telenko, C. Seepersad, M. Webber; Proceedings of IDETC/CIE 2008 ASME 2008 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference August 3-6, 2008.

- ◊ ensuring that wastes are water-based and biodegradable, though care needs to be taken in this area. For example, a supermarket bag is biodegradable but breaks into tiny 'nurdles' which fish mistake for plankton and eat. The consequent change to their diet results in smaller fish. Similarly, just being water-based can be too simplistic, as water-based wastes can create problems such as silver ink (silver nano-particles) which can affect mammalian reproduction.
- ◊ specifying the cleanest source of energy; though, the cleanest source may not be a local source.
- ◊ specifying clean production processes for the product and in selection of components;
- ◊ concentrating any environmentally hazardous elements for easy removal and treatment.

III. Eco-design means applying product life cycle thinking to minimize environmental impacts as early as possible in the product design and development process while opportunities remain to improve the environmental performance of the product. Eco-design involves minimizing material and energy use and maximizing reuse and recycling. This concept simultaneously improves business productivity and profitability and reduces pollution and resource usage.

IV. Inputs to the development and maintenance of eco-design guidelines should include an outlook on future changes in product related eco-design requirements (called a product eco-roadmap) and results from detailed product LCAs. The product eco-roadmap typically covers developments in legislation, standards, customer requirements and internal company goals.

V. Balancing conflicting requirements − The requirements expressed in different technical specification sections might conflict with each other in some cases. For instance, end-of-life/disassembly may recommend that the product be as small and lightweight as possible, whereas product value/lifetime may recommend modularity, which tends to increase the product size. Decisions should be made on a case-by-case basis taking into account:
   - ◊ product requirements, which might provide clear arbitration of the conflicting requirements; and
   - ◊ environmental impacts prioritization.

   Energy use during lifetime and energy consumption matters should be prioritized when conflicting with other product specifications as they are identified by the life cycle assessments of products as having the most significant environmental impact.

VI. Designer considerations – The designer should identify the latest environmental related legal and market requirements (from customers, government, environmental groups, industrial associations, etc.). Benchmarking should be used in order to address the comparison of energy efficiency, material efficiency, and the use of hazardous substances or preparations. They should also gather and evaluate experience from the subsequent manufacturing, sales, product usage, maintenance, and disposal stages, to continually improve the process of environmentally conscious product design.

The entire environmental performance of the product should be evaluated, while the considerations should give priority to those aspects that can be substantially influenced through product design and are identified as major environmental impacts (for example, very often energy consumption). The evaluation should take into consideration the functions and normal usage of the product as well as the technical and economical feasibility. As a minimum, the designer should document decisions by some means, such as by maintaining a design checklist covering environmental aspects (see additional guidance provided in section 1.4 of Part I – Checklists).

2.1.3.2 Specific guidance

2.1.3.2.1 Product value/lifetime extension

I. From a life cycle perspective, it often looks attractive to prolong the useful lifetime of products. Extension of the product lifetime is strongly advocated by non-governmental organizations (NGOs), and is also reflected in environmental product legislation such as European Union (EU) Directive

2002/96/EC on waste electrical and electronic equipment (WEEE) and EU Directive 2005/32/EC "Energy using Products" (EuP)[3]. However, when taking a closer look there is a balance. On one hand, prolonging the product's lifetime reduces the environmental impact of producing new materials/products (such as the GHG emitted during extraction/manufacturing) and disposing of the old products. On the other hand, prolonging the lifetime can delay the introduction of improved functionality and features that can benefit the environment such as higher energy efficiency features.

II. Durability − Ensure appropriate durability of the product and components by:
   - ◊ reusing high-embedded energy components;
   - ◊ improving aesthetics and functionality to ensure the aesthetic life is equal to the technical life;
   - ◊ ensuring minimal maintenance and minimizing failure modes in the product and its components;
   - ◊ specifying better materials, surface treatments, or structural arrangements to protect products from dirt, corrosion, and wear;
   - ◊ indicating on the product which parts are to be cleaned/maintained in a specific way;
   - ◊ making wear detectable;
   - ◊ allowing easy repair and upgrading, especially for components that experience rapid change;
   - ◊ requiring few service and inspection tools;
   - ◊ facilitating testing of components;
   - ◊ allowing for repetitive disassembly/reassembly.

III. Economic vs technical lifetime – The most efficient product design carefully matches the targeted economic lifetime with the technical lifetime of the product. The technical lifetime of a product does not necessarily equal the economic lifetime. For example, in the telecommunication network equipment industry, reliability has always played a significant role in the design of products. As such the reliability has to be guaranteed for a certain time period, which is often regarded as the technical lifetime of the product. When prolonging the technical lifetime of a product, it needs to be designed in such a way that the reliability of the product can be guaranteed over this longer period. In most cases, this requires additional measures to ensure better cooling (e.g. less compact, more materials), selection of more reliable components (often using more expensive materials), or the need to build in redundancy.

The economic lifetime of a product is primarily determined by the evolution of functionality. Once the functionality is no longer matching the customer's needs, the product will be upgraded or replaced. Upgradeability and reuse of hardware assets should be considered and compared with deploying a new product. The key objective should be to match the design as much as possible with the expected economic lifetime of the product.

IV. Energy use vs lifetime – As new generations of products are designed, they often surpass their prior generation with respect to energy efficiency. As energy use is one of the key environmental impacts of ICT products, there is a balance between the lifetime of the product (with the older generation consuming more energy) vs introducing a new generation (production and end-of-life treatment while having higher energy efficiency). We also need to account for energy savings in manufacture vis-à-vis savings for the consumer or end-user.

V. A number of options are generally available for extending a product's functional life as described below:

- Modularity – Allows the product to be more easily upgraded to extend its function/value and also possibly improve it (certain portions of it can be swapped out with components that can provide increased function/value). The key is that while new modules can be added, older modules can remain in place and continue operating for a longer period of time.

[3] On 11 March 2008, an amending Directive to the Ecodesign Directive 2005/32/EC was adopted: Amending Directive (2008/28/EC); On 21 October 2009, the recast of the Ecodesign Directive 2005/32/EC was adopted (extension to energy related products): Ecodesign Directive (2009/125/EC). See: http://ec.europa.eu/enterprise/policies/sustainable-business/documents/eco-design/legislation/framework-directive/index_en.htm.

- Standardization of mechanical parts – Standard mechanical parts can allow for continued use even in those cases where the product functionality changes significantly.
- Software update − Implementation of new features (updated and/or added functionality/value) can be completed by remote software download.
- Reuse of parts – In theory, parts can be reclaimed and reused many times in new products. In practice, the following issues should be taken into consideration:
  - ◊ Electronic/electro-mechanical components that are recovered from end-of-life products must meet reliability requirements for new products.
  - ◊ In order to make reuse of mechanical parts environmentally and economically viable, the parts from old equipment should be able to be efficiently recovered without requiring much rework.

  To encourage the optimization of a product's useful life, information on available options for upgrading, expanding and repair of products should be made available to end users, if appropriate.

VI. Specifics on design for upgradeability may need to be identified based on product categories, and/or initial cost of a product. There are categories of products for which upgradeability features may not be applicable, for example, single use cameras and pocket calculators.

2.1.3.2.2 Energy efficiency

Energy efficiency requirements continue to be included in legislation and standards as shown in the listing below.

Legislation, regulations and voluntary commitments

- EU Code of Conduct on Energy Consumption of Broadband Equipment.
- EU Code of Conduct on Data Centers Energy Efficiency.
- EU Directive 2009/125/EC– "Energy-related Products" ("ErP"), or EcoDesign Directive and its specific implementing measures, such as External Power Supply, Simple Set-top Boxes, and Standby-Off Modes.

International standards[4]

- ATIS 060015.2009 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting – General Requirements.
- ATIS 060015.01.2009 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting – Server Requirements.
- ATIS 060015.02.2009 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting – Transport Requirements.
- ATIS 060015.03.2009 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting for Router and Ethernet Switch Products.
- ATIS 060015.04.2010 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting DC Power Plant – Rectifier Requirements
- ATIS 060015.06.2011 – Energy Efficiency for Telecommunication Equipment: Methodology for Measurement And Reporting of Radio Base Station Metrics.
- Energy Star – Joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy; also EU Energy Star Program.
- EN 62301-1 – Requirements for low power measurements of electrical and electronic equipment.

[4] Non-exhaustive list in alphabetical order.

- ETSI TR 102 530 V1.2.1 (2011-07) – Environmental Engineering (EE); The Reduction of energy consumption in telecommunications equipment and related infrastructure.
- ETSI TS 102 533 V.1.1. (2008-06) – Environmental Engineering (EE) Measurement Methods and limits for Energy Consumption in Broadband Telecommunication Networks Equipment.
- ETSI TS 102 706 V.1.2.1 (2011-10) – Environmental Engineering Measurement Method for Energy Efficiency of Wireless Access Network Equipment.
- ETSI EN 300 119-5 V1.2.2 (2004-12) − Environmental Engineering (EE); European telecommunication standard for equipment practice; Part 5: Thermal management.
- ETSI TR 102 489 V1.2.1 (2010-02): Environmental Engineering (EE); European Telecommunications standard for equipment practice; Thermal Management Guidance for equipment and its deployment.
- IEC 62075 Ed. 1.0 (2008-01) − Audio/video, information and communication technology – Environmentally conscious design. Telcordia GR-3028 – Thermal Management In Telecommunications Central Offices.
- 3GPP – the 3GPP standardization group is targeting the base stations of cellular networks (see document: “3GPP Green activities/Energy Saving V0.0.3 [2010-10]” summarizing the activities).

Industry Codes of Conduct

- EU Code of Conduct on Energy Consumption of Broadband Equipment
- EU Code of Conduct on Data Centers’ Energy Efficiency

Energy efficiency guidance

- *General energy efficiency measures:*
  - ◊ To focus efforts on increasing energy efficiency, the designer should be aware of the product life cycle stage that will consume the most energy. The intended use patterns of the product, including its typical system interactions, need to be considered. Where possible, the designer should strive for improving the overall system performance with respect to energy efficiency.
  - ◊ All available energy saving features should be documented during the design process. Information on the product’s energy consumption and, where applicable, its related energy modes should be made available to the end user.
  - ◊ The effects of the improved design decisions compared to previous similar designs should be quantified and communicated to product marketing departments in order to enable them to promote products with lower adverse total environmental impact through lower energy consumption.
  - ◊ The designer should enable the most energy efficient “on-modes” and transitions to “energy-saving modes” as the default modes. Consideration should be given to the product’s performance after transitions to energy-saving modes as the default mode. If this is not reasonably achievable, the end user should be made aware of this and instructions on proper use of available energy saving controls and/or settings should be provided to the end user.
  - ◊ Software is relevant for the overall energy efficiency of a system. The designer should balance the flexibility of software running on multi-purpose devices and the energy efficiency of special purpose hardware. Consider power saving modes and peak energy shaving opportunities. The key will be to make sure that service and/or functionality is not adversely affected when the system goes into and later recovers from sleep or peak-shave mode.

- *Product- or system-related power saving measures* – Since power requirements are greatly impacted by system architecture, power dissipation and efficiency should be considered early during the architecture and systems engineering stage. The following items should be considered:
  - ◊ System architecture and feature specification development documents should clearly indicate power consumption information at the appropriate product functionality or network/system application level. This information will need to be measured and reported in accordance with applicable standards and industry metrics.
  - ◊ Power dissipation of battery charging systems should be minimized when the functional system is connected to its main power source. Regulatory agency efforts to reduce energy consumption (e.g. the US Environmental Protection Agency Energy Star Program, and the EU Energy Star Program) for many electronic devices have established a power consumption threshold for such devices in "standby/low-power" mode (i.e. the lowest power state that the device enters while connected to a power source).
  - ◊ Identify power-hungry components and features (e.g. low efficiency power supply modules) and evaluate alternatives for decreasing the associated power demand.
  - ◊ Design systems in such a way that additional power can be added incrementally as the capacity of the system, and its incrementally higher need for power, grows. Do not over-specify (size to the sum of the maximum draws) the power supply for the basic configuration of a modular system. In particular, apply root sum square (RSS) modelling to achieve reasonable power supply sizing. On the other hand, consider that there are cases where this approach could result in the power system generating alarms or being unable to support its load because it goes into current or voltage limiting mode at high loads.
  - ◊ Power sources (primary and backup) that have high efficiency and/or derive their energy from renewable means (photovoltaics, fuel cells, micro-turbines, advanced energy storage systems) should be considered.
  - ◊ Research customers' power budgets both at the node and network level to better architect the allocation of functions/nodes.
  - ◊ Provide a means of monitoring power consumption in telecom equipment so that it allows power consumption assessment and promotes more efficient use.
  - ◊ Provide a means to measure the power consumption of specified traffic routes in a system to enable decisions for improved traffic management.

- *Power modes and related energy efficiency measures* – Power mode definitions and applied terms vary depending on the product type. Therefore, rather than providing precise definitions of power modes in these guidelines, typical modes are described in generic terms. The intent is to balance the technical complexity with the simplicity needed for ease of use.

  Establish realistic specifications for a product's aggregate load (traffic, service, and/or transactions) that the system must support. The system should be designed such that the energy consumption of the network as a whole is minimized, including the use of adjunct power supplies and terminal power products as appropriate. For example, in addition to minimizing the energy consumption of each "node" in a network, consider the total energy consumption of all nodes in a given network. Traffic and service functionality may be served better by employing fewer nodes (with individual higher capabilities and power dissipation) than more nodes (with individually lower capabilities and power dissipation).

  Consider high-energy efficiency features when selecting original equipment manufacturer (OEM) devices (e.g. disk drives, printers, PCs, monitors) that are to be incorporated into or bundled with products. Identify specific power modes, which apply to the product under development and consider energy efficiency measures for the identified power modes.
  - ◊ Operational modes – Are states in which the device performs its intended duties. Usually the on-mode can be categorized by four terms:
    - – On-maximum: Power during operation with all options applied.
    - – On-normal: Power during operation with default/standard configuration.

    - Low power: Energy saving modes in which the equipment is ready to resume an operational mode, within a user acceptable timeframe, through the use of remote control or another signal.
    - On-idle: Power with minimum system load by user and ready to operate without delay.
  - ◊ NOTE: It may be worth noting the distinction between “on-idle state” and “low power state”. When in “on-idle state”, the device has minimal (almost null) functionalities and should drain the minimum amount of power. From on-idle state, the device can be activated to on-normal or low power state. In “low power state”, the device is operational but with limited functionalities (e.g. transmission at lower rate or lower power). Such states are for instance already available in today’s laptops, e.g. idle state is the “stand-by”, low power state is, for instance, when the laptop is powered by battery.

  Consider using low power consuming components and design options as well as efficient power supply components such as voltage regulators and DC-DC converters to reduce the power consumption in the “on” modes. Consider identified modes when specifying the power supply. The AC-DC conversion efficiency should be high in the most used modes.
  - ◊ Automatic low power and on-idle modes – Energy-saving modes (often denoted as low power, sleep, deep sleep or stand-by) are states in which the equipment is connected to an electrical supply and is ready to resume an operational mode, within a user acceptable timeframe, through the use of remote control or another signal. In complex systems, various save modes may be present.
    - Consider practical design options to automatically switch from on mode to save modes. The save mode settings should be adjustable by the user. Other innovative solutions shall be considered.
    - Consider design options to reduce the power consumption in the energy save modes by also applying similar methods as described in the “operational modes” clause.
    - Inform the user of the higher power consumption if the save mode is disabled.
  - ◊ Power-off modes – The power-off mode has the lowest power consumption when the device is connected to an electrical supply. The off mode can be characterized by two terms:
    - Soft-off: The equipment is switched off by the device itself or initiated by the user via remote control or command.
    - Hard-off: The off-power state in which the device uses zero Watts. The equipment is manually switched off with the main power switch.
  - ◊ Consider design options to automatically switch from save mode to off mode where practical. Consider design options to reduce the power consumption in the soft-off mode to the lowest energy consumption value (i.e. zero Watts if feasible). Place the main power switch on the product in a position that the user can easily reach and use it. Inform the user through documentation or other means whether “zero Watts” is not achievable in the hard-off state.
  - ◊ No-load modes – The no-load mode is defined to be the condition in which external power supplies or chargers are connected to an electrical supply, but are not connected to electrical or electronic equipment for which they have been designed to charge. A typical example is the mobile phone charger, which is plugged in, but the phone is not connected. Consider design options that reduce power consumption of the no-load mode to the lowest value possible.

- *Operational environment improvement*
  - ◊ Cooling methodology – to minimize the need for forced air cooling, design the product in such a way that natural convection and thermal conduction provide adequate cooling of the electronics. Telcordia’s Thermal Management in Telecommunications Central Offices (GR-3028) provides requirements for managing the thermal environments found in most service providers’ physical locations.
    - Minimize heat generation in printed wiring boards (PWBs) and components. Such practices will improve overall energy efficiency of the product, and avoid the need for

active (energy consuming) cooling devices such as fans and auxiliary heating, ventilation and air conditioning (HVAC) systems.

  – If cooling fans are used, select variable speed rather than constant speed fans.
  – Consider using a more tolerant climatic range specification, e.g. raise the 35° range (between 5 and 40°C) typically specified for conventional network equipment to a greater 50° range (between -5 and 45°C). As a result, the network equipment sites may be fresh-air cooled in most countries rather than requiring special energy intensive air conditioning. In evaluating the tolerance range, consideration will need to be given to equipment for a potential reduction in reliability aspects.

- ◊ ETSI TR 102 489 provides guidance on cooling methodologies at the cabinet and room level, and aids the designer in achieving an efficient cooling system. ETSI EN 300 119-5 gives requirements for cooling solutions at the rack and sub-rack level by standardizing the air flow path within the racks and sub-racks. The latter document also provides the design parameters that should be used for their efficient deployment.
- ◊ Consider the effect of the operating environment specification provided to users and installers. For example, over-specifying the maximum allowed ambient (room) operating temperature for large telecom, server or storage equipment can lead to energy inefficiencies in the room cooling systems.

2.1.3.2.3 Substances and materials

Hazardous/restricted substances

Substances hazardous to either humans and/or the environment are restricted by legislation, customers and/or internal requirements. These substances could be present in components and materials that are selected during the design phase of both products and packaging. The use of these substances should be either avoided or eliminated as appropriate.

Legislation, regulations and voluntary commitments

- EU Directives 2002/95/EC – Restriction of certain Hazardous Substances (RoHS) and its Recast (RoHS II); and its associated implementation into the European Economic Area, such as Norway and Swizerland.
- EU Regulation 2006/1907/EC – Restriction, Evaluation and Authorization of Chemicals (REACH).
- PRC Management Method (China RoHS) – PRC Management Methods for Controlling Pollution by Electronic Information Products.
- USA/California AB-826 – Perchlorate Contamination Prevention Act of 2003 (for “CR” type Coin Batteries containing perchlorate).

International standards

- JIG – Joint Industry Guide Material Composition Declaration for Electronic Products.
- Regulatory demands – The EU Restriction of certain Hazardous Substances (RoHS) Directive is the most well-known of all the legislation impacting substances in products. RoHS targets electrical and electronic equipment only and addresses 6 substances: cadmium, hexavalent chromium, lead, mercury, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE). Exemptions for the use of restricted substances under the EU RoHS are reviewed by the European Commission on a four-year cycle. However, exemptions may be eliminated independent of the review if substitution is determined to be technically feasible.

  There are other legal requirements with a more general scope (e.g. restricting the use of asbestos, chlorofluorocarbons [CFCs]) that affect ICT products. These regulations either restrict the use of the substances or require tracking their presence (e.g. PRC RoHS step 1, USA State of California, EU REACH). Additionally, there are other substances that are not directly regulated but which a company must track in connection with legislation (e.g. beryllium oxide – following the WEEE requirement to communicate product recycling information).

- End-user demands – Additional demands for substance restrictions beyond legislative requirements. These demands are sometimes set either as preparation for existing or future legislation (e.g. stricter than RoHS), driven by regional concerns and Non-Governmental Organizations, or other hazards (e.g. polyvinyl chloride (PVC) when exposed to fire decomposes and in contact with water may produce acids, which are hazardous to personnel as well as corrosive to other equipment and the environment).

Material efficiency

- Material selection – Has a significant impact on the environment. When specifying materials, the designer should consider design alternatives that:
  - ◊ reduce the variety of materials used;
  - ◊ reduce the amount of material used and consequently the weight of the product;
  - ◊ use materials that have lower adverse environmental impact;
  - ◊ seek to use materials that can be easily recycled; and
  - ◊ avoid the use of materials that have end-of-life concerns, e.g. PVC releases dioxins if improperly incinerated.
- Consumables – Products should be designed such that the use of consumables can be optimized relative to the functionality of the product. Designers should consider:
  - ◊ functions to reduce or save the use of consumables; and
  - ◊ ease of replacement and maintenance of consumables;
  - ◊ the manufacturer should provide end users with information on the proper use of consumables relative to the functionality of the product and, where appropriate, end-of-life management of the consumables.
- Material selection for NIE transmission infrastructure – Specific guidance on materials selection for the following transmission infrastructure:
  - ◊ Utility poles – Avoid use of the following preservatives for wooden utility poles: creosote-based oils, chromated copper arsenate (CCA).
  - ◊ Wireless transmission towers/poles – Choose lower eco-impacting metals and anti-corrosive finishes; choose materials with high recycled content.
  - ◊ Communications cables – Use materials that have lower adverse environmental impact and also materials that can be easily recycled. Avoid the use of PVC plastic where possible.

2.1.3.2.4 Emissions

Legislation

- EU Directive 2000/14/EC – Acoustic Noise Emissions in the Environment by Equipment for Use Outdoors (Power generators > 400 kW).

International standards

- ECMA-74 (Dec. 2010) – Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment.
- ETSI ETS 300 753 ed.1 (1997-10) – Equipment Engineering (EE); Acoustic noise emitted by telecommunications equipment.
- ISO 3741:2010 – Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for reverberation test rooms.
- ISO 3744:2010 – Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane.

- ISO 3745:2012 – Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for anechoic rooms and hemi-anechoic rooms.
- ISO 7779:2010 – Acoustics – Measurement of airborne noise emitted by information technology and telecommunications equipment.
- ISO 9296:1988 – Acoustics – Declared noise emission values of computer and business equipment.
- Telcordia GR-63 – NEBS™ Requirements: Physical Protection.

Chemical emissions

- Products should be designed such that chemical emissions with adverse environmental impact during use are reduced wherever possible. For products that use an electrostatic process, emission rates, as determined according to ISO/IEC 28360, should be made available.

Noise emissions

- The designer should consider techniques to reduce noise emissions. Reduced noise emissions typically improve energy efficiency.
- Noise emissions should be evaluated according to ISO 7779, for products covered by ISO 7779 (or ECMA-74). For products under the scope of this document and not covered by a product-specific international standard noise test code, such as ISO 7779 (or ECMA-74), noise emissions do not have to be evaluated. If noise emissions are evaluated for products under the scope of this standard but not covered by either ISO 7779/ECMA-74 or another product-specific international standard noise test code, the basic sound power standards, ISO 3741, ISO 3744 or ISO 3745, and the basic emission sound pressure standard, ISO 11201, should be used. The test conditions used should be recorded. The resulting sound power levels and, where applicable, emitted sound pressure levels (including emission sound pressure measurement distance if not covered by ISO 7779/ECMA-74) shall be declared according to ISO 9296 (or ECMA-109) and should be documented according to available eco-declaration standards (such as ECMA-370). The levels should be made available in the product information to the end user.

2.1.3.2.5 Batteries

These guidelines apply to batteries that are incorporated (embedded) into ICT products to provide temporary backup power for data and program instruction storage, or similar functions. Since batteries, in general, contain metals as part of their chemistry, they can have a significant impact on the environment during their manufacture and disposition. While this primarily applies to high volume consumable batteries, it also applies to embedded batteries that are more permanently affixed within ICT equipment.

Batteries are regulated from the perspective of their chemistry, by both substance restrictions (e.g. mercury ban) and mandatory labelling on battery and/or product (e.g. chemistry identification, disposal mark). In addition, return schemes for batteries, by producer or importer, is requested by law in some regions.

Legislation

- 42 USC 14301 – 14336 – Mercury-Containing and Rechargeable Battery Act of 1996.
- EU Directives 91/157/EEC, 93/86/EEC, 98/101/EC – Batteries and Accumulators Containing Certain Dangerous Substances.
- EU Directive 2006/66/EC – Batteries and Accumulators and Waste Batteries and Accumulators.
- USA/California AB-826 – Perchlorate Contamination Prevention Act of 2003 (for “CR” type coin batteries containing perchlorate).
- US DOT Regulation CFR section 173 – Shippers − General Requirements for Shipments and Packaging.

International standards

- IEC 60896-21:2004 – Stationary Lead Acid Batteries – Part 21: Valve Regulated Types – Methods of Test; and Part 22: Valve Regulated Types – Requirements (for an example of specifications for lead-acid batteries including testing requirements, please refer to Product Specification KS-24597 Battery, Valve Regulated Lead-Acid [VRLA]).
- IEC 61429/1135:1995- Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135.

Guidance – batteries

- Batteries with reduced environmental impact should be considered. When materials with adverse environmental impact cannot be avoided (for example, mercury in button cells), the material and its justification should be documented during the design process. Product designs that prolong the durability of batteries should be considered.
- Designers should be aware of the requirements for import, transportation and shipping of hazardous materials (e.g. USDOT Regulation 49 CFR – Section 173) and dangerous goods (i.e. ICAO/IATA Special Provisions) as they relate to batteries.
- Restricted substances and materials in batteries – This shall comply with all applicable restrictions regarding restricted substances and preparations. For example, the use of batteries with intentionally-added mercury is restricted by battery legislation in both the US and EU. In addition Nickel-Cadmium containing batteries have come under severe legislative pressure and are therefore not preferred. Batteries with reduced environmental impact, such as lithium-ion (Li-ion) and nickel-metal hydride (NiMH), should be considered.
- Replaceability/removability – Both the EU Battery Directives and the US Federal “Mercury-Containing and Rechargeable Battery Act” of 1996 require that batteries be easily removable from products. These regulations, as well as best ECD practices, dictate easy battery removal for replacement and recycling of the battery, and for the eventual disassembly of the product. Consider the following for the design and placement of batteries:
  - ◊ Batteries shall be easily identifiable and removable (dependent upon the type of product) by users and/or skilled professionals, without requiring any special tools.
  - ◊ Where a battery’s expected life span is less than that of the product, the battery compartment should be designed in such a way that individual batteries are easily exchanged.
  - ◊ Batteries should not be permanently attached (soldered) to the PWB or any other component or product.
  - ◊ Battery management features that help to prolong battery life should be considered.
  - ◊ When specifying OEM products, the above requirements should be included in the specification.
- Alternative to battery backup functionality – Embedded batteries are often used to provide temporary backup power for data and programme instruction storage, or similar functions. For these types of applications batteries should be avoided, where possible, through implementing solutions based on IC technologies such as flash memory – a type of electrically erasable programmable read only memory (EEPROM). While flash memory is an added cost solution, its eco-environmental benefits, as well as lack of maintenance costs, make it an option worth considering.

2.1.3.2.6 Product packaging/packing

The principle purpose of packaging is protection and easy handling of parts, components, and the product during transport from the production site to the customer, including interplant transport. Packaging/packing includes any box, container, wrapper, cushioning, tape, inks, colorants or other material used to contain, protect, store and transport a product or component prior to its use.

Product Packaging Engineers and Project Teams may use this guideline to make environmentally conscious decisions during the design and/or specification of product packaging, while maintaining the functional requirements of the packaging, including:

- containment of the product to ensure its integrity and safety;
- protection of the product from physical damage, electrostatic discharge (ESD), atmospheric conditions (water, humidity, etc.) and/or deterioration;
- convenience of use and consumer acceptance;
- compliance to legal and regulatory requirements;
- conveyance of information/data.

Legislation/regulations

- EU Directive 1994/62/EC – European Parliament and Council Directive 94/62/EC on Packaging and Packaging Waste (O.J. L 365, 31 December 1995), as amended by Commission Decision 97/129/EC establishing the identification system for packaging materials pursuant to the European Parliament and Council Directive 94/62/EC on Packaging and Packaging Waste (O.J. L050, 20 February 1997).
- EU Directive 2004/12/EC – European Parliament and of the Council of 12 February 2004 amending Directive 94/62 on Packaging and Packaging Waste.
- GB 18455-2001 – People's Republic of China – Packaging Recycling Marks.
- SJ/T11364-2006 – People's Republic of China Industry Standard – Marking for Control of Pollution Caused by Electronic Information Products.

International standards[5]:

- EN 13427:2004, Packaging – Requirements for the use of European Standards in the field of packaging and packaging waste.
- ISPM No. 15 (2002) with modifications to Annex I (2006) – Guidelines for Regulating Wood Packaging Material in International Trade.
- RESY – Packaging Requirements for paper and cardboard packaging, including the use of the RESY symbol.

Guidance – restricted materials in product packaging

It is suggested that the following substances not be intentionally added to any packaging materials, nor used in the manufacture of packaging materials, or in packaging materials used for products:

- Asbestos (CAS# 1332-21-4 and others) and asbestos-containing materials
- Cadmium (CAS# 7440-43-9) and cadmium compounds
- Copper chromium arsenate pressure treated wood
- CFCs – CFC 11, CFC 12, CFC 13, CFC 111, CFC 112, CFC 113, CFC 114, CFC 115, CFC 211, CFC 212, CFC213, CFC 214, CFC 215, CFC 216, & CFC 217.
- The following chlorinated hydrocarbons, and their isomers:
- Carbon tetrachloride (CAS# 56-23-5)
- Methyl chloroform/1,1,1 trichloroethane (CAS# 71-55-6)

5 Non-exhaustive list in alphabetical order.

- Hexavalent chromium compounds (CAS# varies)
- Lead (CAS# 7439-92-1) and lead compounds
- Mercury (CAS# 7439-97-6) and mercury compounds
- CFCs/Hydrochlorofluorocarbon (HCFCs)
- Cobalt Dichloride
- Dimethylfumarate (DMF) – used in silica gels.

The sum of the concentrations of cadmium, hexavalent chromium, lead and mercury present as incidental or background contamination should not exceed 100 parts per million (ppm) by weight in any packaging or packaging component (requirement per the European Directive 94/62/EC, and for several states in the USA).

Phyto-sanitary requirements for wood packaging – Many countries require that solid wood packaging (for example, wood used for pallets, crating, blocking, or bracing) must be in compliance with the International Standard for Phyto-Sanitary Measures (ISPM 15). Heat treatment is typically a preferred treatment process for compliance with ISPM 15. Packaging must have appropriate certification stamps. Material exempt from ISPM-15 compliance include manufactured wood material including plywood.

NOTE: ISPM 15 includes treatment processes using methyl bromide fumigation and chemical pressure impregnation with copper chromium arsenate (CCA) treatment processes. Both of these methods have numerous secondary environmental, health and safety issues and should not be used.

Guidance – product packaging/packing

- Material selection – When selecting packaging materials, the material type and amount should be consistent with the functional requirements of the package and its contents. Product material specifications should include use of recycled material content to the maximum extent possible. Use of post-consumer and post-industrial materials which include household, institutional, commercial and industrial recycled material is strongly encouraged. Materials that are reusable and that have minimal environmental impacts when disposed of in either landfills or incinerators are encouraged. Preferred materials for product packaging include but are not limited to:
  - ◊ Paperboard, wood, plywood, corrugated fibreboard, natural craft corrugated fibreboard is recommended instead of bleached white corrugated fibreboard.
  - ◊ Recyclable plastics examples include:
    - polyethylene (PE);
    - low-density polyethylene (LDPE);
    - high-density polyethylene (HDPE);
    - polyethylene terephthalate (PET);
    - polypropylene (PP).
- The following materials should be avoided in new packaging designs:
  - ◊ Plastics that contain flame retardants additives, particularly those that contain brominated flame retardants
  - ◊ Chlorine-based plastics that produce dioxins when improperly incinerated, such as PVC. Use of PVC in product packaging is prohibited in some countries
  - ◊ Foams that are blown with chlorofluorocarbons (CFC-blown)
  - ◊ Thermosets such as polyurethane and foam-in-place urethane
  - ◊ Packaging materials that require special solvents for cleaning or removing labels and markings
  - ◊ Polystyrene (PS) and expanded polystyrene foam (EPS) – Due to ESD concerns related product/components, as well as some countries such as South Korea which limit its use.

- The packaging designer should consider:
  - ◊ Materials that are easily sorted and recycled, including limiting the types of packaging materials used
  - ◊ Eliminating or reducing secondary and tertiary packaging
  - ◊ Materials that reduce the overall weight and volume of the package
  - ◊ Using the minimum amount of material needed to provide the required level of performance
  - ◊ Bulk packaging for interplant transportation programmes
  - ◊ Packaging that is easily broken down to reduce the volume of stored or transported packaging materials
  - ◊ Geometry of the package and components to optimize the packaging required
  - ◊ Materials and designs optimized for the specific supply chain design in use for the finished product
  - ◊ Designs that accommodate all possible transportation modes including air, sea and land cargo.
  - ◊ Packaging selection for product distribution
    - o should be designed for re-use or re-cycling
    - o should follow National Packaging Waste Database (NPWD) guidelines

Incorporating these considerations may help to reduce the primary packaging costs, energy consumed during transportation, and space needed for warehousing.

Design for reuse or return

Reusable packaging avoids the use of additional packaging materials by supporting the downstream reuse of existing product packages. Returnable packaging avoids the disposal of packaging material by returning the material to the original packager for multiple reuses. Packaging designers are encouraged to consider materials that can be reused, such as foamed plastics and wooden crates.

NOTE: Reusable packaging may need features such as handles, latches, ramps that are not cost-effective for disposable packaging.

Reusable packaging should:

- permit easy packing, unpacking, storage and repacking;
- avoid specific sequencing or rotation/placement of materials to provide maximum potential for reuse;
- avoid foam cushions that break apart and compress with high rates of reuse;
- facilitate quick/easy replacement of worn or damaged packaging;
- allow for effective labelling and re-labelling (for example, relabelled packages do not lose labels, or is not over-labelled so that shipment is compromised).

Design for disassembly and recycling

In addition to the material selection guidelines above, the following are design guidelines that facilitate product packaging recycling:

- Minimize use of staples, hot melt adhesives, plastic tapes and envelopes by considering use of paper tape and starch based glues.
- Incorporate parts that are easily removable. Furthermore:
  - ◊ avoid gluing or bonding to the container;
  - ◊ inserts and filler should be constructed of paper or cardboard;
  - ◊ if rigid plastics or foam inserts are required, these should be separable and extractable.

- Avoid waxing or coating the surface of the package – Cartons made with a combination of plastics and paperboards are used, they should be primarily made of paperboard with the plastic separable in the aqueous phase.
- Avoid mixed packaging materials or minimize the number of different materials to facilitate recyclability.
- Segregate anti-static, ESD, and static dissipative plastic materials from non-treated plastics.
- Packaging that is stackable or easily broken down to reduce the volume of stored or transported packaging materials.
- Avoid specific sequencing or rotation/placement of materials to provide maximum potential for reuse.
- Avoid foam cushions that break apart and compress with high rates of reuse.
- Facilitate quick/easy replacement of worn or damaged packaging.

Design for marking and labelling

- To facilitate collection, reuse, and recovery of the packaging materials, the packaging producer must state on the packaging the type of packaging material(s) used. Such marking should not be easily erased or removed using a relatively long-lasting method.
- Packaging parts made of plastic, weighing individually more than 25 grams, should be marked with the ISO 1043 and ISO 11469 compliant resin codes (Annex C).
- Other marking and labelling should be implemented where practicable/feasible as follows:
    - ◊ Minimize marking on packaging
    - ◊ Use water-based printing ink or vegetable-based paint
    - ◊ Specify use of polypropylene tapes to reduce the harmful emissions when other types of adhesive tapes are subjected to thermal recycling
    - ◊ Specify moulded-in labels or print labels on plastic materials of the same type of plastic as the packaging to be labelled to allow for easy recycling
    - ◊ Avoid adhesives that inhibit recycling of the material.

2.1.3.2.7 Designing for end-of-life treatment

The end-of-life of a product can have significant impact on the environment in polluting ground, air or water by substances contained in the product. End-of-life can also have positive impacts if the product is recycled and resulting substances are used to manufacture new equipment, reducing natural resources consumption. The recycling of metals, for example, requires much less energy than mining and extraction from ore. In addition, product end-of-life dismantling and recycling can have adverse health and safety effects on workers performing such operations.

Take back of electronic equipment by the producer may be required by law in some regions. Selecting environmentally friendly materials and proactive design for disassembly helps to reduce the end-of-life related costs.

Dismantling and recycling processes – Recyclers usually handle a very wide range of electric and electronic equipment of all types and sizes. Dismantling and recycling processes are designed to handle any kind of equipment with minimal customization. Under such conditions, recyclers will generally not use product documentation, unless there are specific questions or issues with the considered product. Consequently, disassembly and end-of-life key points should be understood without using the end-of-life information document.

Legislation/regulations

- EU Directive 2002/96/EC (Articles 4, 7 and 11) – Directive of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE).

International standards

- Cenelec EN 50419 – Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE).
- ECMA-341 (Annex C) – Environmental Design Considerations for Information and Communication Technology (ICT) and Consumer Electronic (CE) Products.
- ISO 11469:2000 – Plastics – Generic identification and marking of plastics products.

Guidance – designing for end-of-life treatment

- *General principles* – The following design principles, where appropriate for the expected end-of-life processes, should be applied:
  - ◊ easy and safe separation of parts containing hazardous substances and preparations should be possible;
  - ◊ materials (including electronic modules) connected to the case, housing parts or chassis, intended for different end-of-life treatment, should be easily separable;
  - ◊ disassembly down to the module level (for example, power supply, disk drive, circuit board) should be possible using commonly available tools and all such modules should be easily accessible; and
  - ◊ mark type of polymer, copolymer, polymer blends or alloys of plastic parts, including additives weighing 25 grams or more and with a flat area of 200 mm2 or more, in conformance with ISO 11469.
- *Size and weight of the product* – The environmental impact of a product at end-of-life is influenced by its size and weight. From LCAs it has been determined that the shipping weight of a product is the dominant parameter that can be influenced by a designer, in determining the impact on GHG emissions from the transportation phase. In addition, logistic costs, which generally are the biggest part of the end-of-life costs, are proportional to product weight and volume. Consequently, it is recommended to make the product as light and small as possible.
  - ◊ Materials used in the product – See section 1.3.2.3 of Part II – Substances and Materials.
  - ◊ Recyclability and recovery – The use of recyclable materials is preferred; they generally reduce the end-of-life environmental impacts. Components that are suitable for later reuse or recycling should also be considered. The EU WEEE Directive sets an overall target for recycling and recovery of the telecommunication equipment category:
    a. Recycling must exceed 65% of the total product weight
    b. Recovery must exceed 75% of the total product weight.
  - ◊ These targets do not have to be individually met by each product. However, if results are well below the target, improvement actions should be taken for next generation products.
- *Reduction of material diversity* – Eases separation at the end-of-life and improves product recycling. Different plastics can be associated if compatible when recycling: a compatibility table is provided in ECMA-341 Annex C standard. Wherever possible, select the same or compatible plastics for small parts attached to the main construction parts.
- *Finishing* – Any coating or other surface treatment of a mechanical part makes it difficult to recover secondary material from the basic material and therefore inhibit recycling; hence, painting, plating, coating, foils and anodization should be avoided wherever permitted by product specifications.
  - ◊ Product assembly – Maintenance, de-installation and disassembly aspects must be considered during the design phase. Ease of disassembly facilitates end-of-life treatment and recycling.
  - ◊ Identification of plastics composition – Marking of plastics in accordance with ISO/Cenelec standards. Designers should make sure that any plastic part weighting 25 grams or more is marked.

2.1.4 Metrics

The collection and reporting of eco-metrics information is a tool that can be used to assist developers and designers to practically gather data in one place to:

- assist in completion of a product eco-declaration (document that contains the essential eco-information about the product);
- assist in completion of a recycling treatment information document (typically provided to recyclers for proper product treatment at end-of-life);
- provide a basis for evaluating the environmental performance of products and for establishing objectives and targets for eco-environmental performance improvement;
- design products that are safe, energy-efficient, can be installed/serviced/uninstalled safely, and can be recycled or disposed of in an environmentally responsible manner;
- support ISO 14001 Environmental Management System requirements to demonstrate continual improvement.

For reporting eco-environmental/sustainable attributes of ICT products, a company can produce an environmental declaration. Such declarations can be self-declarations, in which case ECMA Standard 370 (2nd edition; December 2006) should be referenced. This document meets the basic principles of ISO 14021 (Environmental labels and declarations – Self-declared environmental claims) and also eco-design standards such as ECMA-341.

Reporting metrics may be concentrated on the following five "Green Focal Areas":[6]

- energy;
- product weight;
- packaging;
- hazardous substances;
- recyclability.

In addition, there should be reporting metrics regarding the life cycle perspective.

2.2 Eco-efficient manufacturing

2.2.1 Scope

This section covers resource consumption and possible non-product material consumption and waste occurring during manufacturing.

2.2.2 General references to other standards/work streams

International standards

- ISO 50001:2011 – Energy management systems – Requirements with guidance for use.

[6] Green Metrics at Philips: de Caluwe, N. Business benefits from applied Ecodesign. Proceedings of 2004 International IEEE Conference on Asian Green Electronics, AGEC. 2004, pp. 200-205.

2.2.3 Best environmental practices

2.2.3.1 General principles and guidance

The general principle for eco-efficient manufacturing is to minimize resource consumption in production and transport of the ICT product.

- The product designer should communicate the key environmentally conscious criteria to the manufacturer such as types of components, selection of materials, and specification of manufacturing processes (intermediate, assembly, testing, and packaging) that will deliver the expected eco-benefits.

2.2.3.2 Materials and energy required in manufacturing the product

- The manufacturer should provide for efficient manufacturing processes that minimize resource and energy usage within their operation.
- The manufacturer should use minimal resources in the production phase by:[2]
  - ◊ specifying lightweight materials and components;
  - ◊ specifying materials that do not require additional surface treatment;
  - ◊ structuring the product to avoid rejects and minimize material waste in production;
  - ◊ minimizing the number of components;
  - ◊ specifying materials with low-intensity production;
  - ◊ specifying clean, high-efficiency production processes;
  - ◊ simplifying as few manufacturing steps as possible.

2.2.3.3 Eco-impact of transport/logistics/product distribution

- The manufacturer should use minimal resources in transporting materials, components, sub-assemblies and finished products by:
  - ◊ employing folding, nesting or disassembly to distribute products in a compact state;
  - ◊ applying structural techniques and materials to minimize the total volume of material;
  - ◊ specifying lightweight materials and components.

2.3 Smart usage

2.3.1 Scope

This section covers issues/concerns relating to the deployment and use of ICT products at customers' facilities. Examples include: efficient operation, cooling, ancillary equipment needs/usage, maintenance/repair.

2.3.2 General references to other standards/work streams

- **International Standards**[7] *Alliance for Telecommunications Industry Solutions* (ATIS) – In March 2009, the Network Interface, Power, and Protection (NIPP) committee of ATIS published three specifications of telecommunication systems. The specifications describe a methodology for measurement and reporting of energy efficiency. One of the documents describes the general requirements and serves as the base requirements. The other two describe the requirements for servers and transport. ATIS specifications define a metric for energy efficiency – namely the Telecommunications Energy Efficiency Ratio (TEER) that is defined as the ratio of Useful Work to Power. Useful Work depends on the equipment in question and examples include performance measures like data rate, throughput, processes/s, etc. Power is the actual measured equipment power in watts.

[7] Non-exhaustive list in alphabetical order.

- *Climate Savers Computing Initiative* (CSCI) – The focus of CSCI is on energy-efficient PC and servers. CSCI promotes the development, deployment and adoption of energy-efficient technologies for PC power delivery and use of power-down states for reducing the idle state energy consumption.
- *Green Grid* – Green Grid's charter includes defining meaningful, user-centric models and metrics for data center efficiency. It also promotes the adoption of energy-efficient standards, processes, measurement methods and technologies. The Green Grid is best known for publishing the Power Usage Effectiveness (PUE)/Data Center infrastructure Efficiency (DCiE) and Data Center Productivity (DCP) metrics for data centers.
- *ITU-T*: Study Group 5 (SG5) on Environment and Climate Change – See their work product: "Energy efficient power feeder/supplies for ICT devices".
- *US EPA Energy Star* – The Energy Star programme aims to generate awareness of energy saving capabilities and accelerate the market penetration of more energy-efficient technologies for ICT products such as computers. In July 2009, Energy Star released Version 5 of its specifications for PCs, laptops, power supplies, displays, workstations and thin clients.
- *3GPP* – The 3GPP standardization group is targeting the base stations of cellular networks (see document "3GPP Green activities/Energy Saving V0.0.3 [2010-10]" summarizing the activities).

2.3.3 Best environmental practices

2.3.3.1 Usage

- Ensure efficiency of resources during use of the installed ICT product by:[2]
  - ◊ implementing reusable supplies or ensuring the maximum usefulness of consumables;
  - ◊ implementing fail safes against heat and material loss;
  - ◊ minimizing the volume, area and weight of parts and materials to which energy is transferred;
  - ◊ implementing default power-down for subsystems that are not in use;
  - ◊ ensuring rapid warm up and power-down;
  - ◊ maximizing system efficiency for an entire range of usage conditions;
  - ◊ interconnecting available flows of energy and materials within the product and between the product and its environment;
  - ◊ incorporating partial operation and permitting users to turn off systems partially or completely;
  - ◊ using feedback mechanisms to indicate how much energy or water is being consumed;
  - ◊ incorporating intuitive controls for resource-saving features;
  - ◊ incorporating features that prevent waste of materials by the end user;
  - ◊ defaulting mechanisms to automatically reset the product to its most efficient setting.
- Guidance for establishing a green data center. Many data centers have exploited various techniques to improve energy efficiency such as inducing cold air into a server room in the winter season. The best practice guidance for establishment of the green data centers will be very helpful to save energy consumption of data centers.
- Energy efficiency measurement methods for data center equipments (e.g. power supply unit (PSU), server systems, AC/DC rectifiers, DC/DC converters, batteries, etc.).
- Data center energy efficiency methodology: PUE and DCiE are unique evaluation factors developed by the Green Grid.
- DC power distribution – Specification of DC power voltage, outlet and connector types.
- Real-time energy consumption monitoring: Real-time energy consumption monitoring can help manage and reduce energy consumptions of all types of industries and organizations. A monitoring infrastructure will be involved with various technical issues such as networking, system and application interfaces, and reference architecture. Relevant energy sources are electric power, fossil fuels such as

coal, oil and natural gas, and renewable energy sources such as wind, solar, geothermal, hydrogen and biomass.

- Per ETSI guidelines given in TR 102 530:
  - ◊ −48V DC power distribution – To reduce losses in power transportation, the distance between the power supply and load shall be reduced (voltage drop of power distribution should be less than 0.5V). Supervision boards of DC distribution unit should be a low power consumption design.
  - ◊ High voltage (up to 400 V) DC power distribution – The efficiency figures of this power architecture are given in the TR. This power distribution is described in ETSI TR 102 121 and the requirements are in the standard EN 300132-3. The energy savings of this power architecture can be up to 10% in respect to the classical –48V DC distribution. This is because there are lower losses in the voltage distribution and conversion.
  - ◊ AC/DC power systems – These power supply systems have a good efficiency at maximum loads. As the load in a telecom system depends on traffic and redundancy, the power supplies rarely operate at the full-load condition. It is then suggested to use energy management software to turn off some modules during periods of low traffic.
- ICT infrastructure equipment consolidation – This is a proven method that increases utilization of infrastructure and helps reduce energy consumption substantially. Put simply, consolidation involves deploying multiple applications/services on a common shared virtualized resource pool. Consolidation improves energy efficiency since it enables infrastructure to be used at higher levels of utilization. It also reduces space usage and the embodied carbon footprint.
- Energy proportional design – This principle implies that a device should use negligible power when it is powered on but doing no work. As the load of system increases, the power consumption should increase in proportion. However, in reality many devices consume substantial power even at zero load. Non-proportional behaviour exists in data center equipment such as switching, storage, power supplies, uninterrupted power supplies (UPS), air conditioning and air handling systems. The designer should strive to achieve proportional behaviour through technological improvements such as standby/sleep/hibernation mode and the use of multi-core central processing units (CPUs).

2.3.3.2 Cooling

- For the outdoor telecom systems, recommendations for the thermal management include:[8]
  - ◊ adopt suitable working temperature and reduce the working time of air conditioner, heat exchanger and heater as short as possible;
  - ◊ adjust the fan speed as a function of the internal equipment temperature;
  - ◊ choose appropriate airflows (external airflow distribution, ensure fresh air flows into the cabinet is not mixed with the outgoing airflow);
  - ◊ choose the appropriate cooling system; priority of selecting cooling style is: convection cooling, fan cooling, heat exchange, air conditioner; and
  - ◊ choose appropriate painting materials/colours (i.e. light paint absorbs less solar radiation).

2.3.3.3 Servicing

- Minimize the degree of routine servicing that is required to maintain product operation and continued functionality. If necessary, consider new means of remote servicing techniques, such as software downloads from the network that can provide certain repairs or functionality improvements.

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8 "ETSI Work Programme on Energy Saving". B. Gorini; ETSI EE/EPS, 978-1-4244-1628-8/07/ pp. 177-178; 2007.

2.4 *End-of-life treatment*

2.4.1 Scope

This section covers issues/concerns relating to the end-of-life treatment of ICT products.

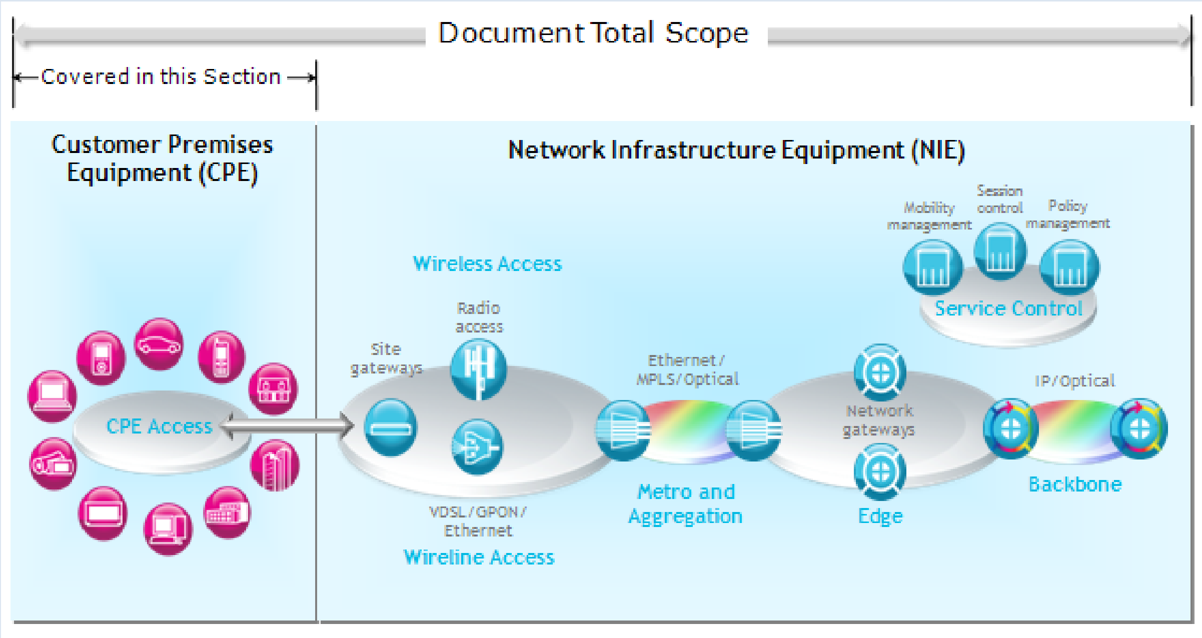
2.4.2 Best environmental practices

- Enable disassembly, separation, and purification by:[2]
  - ◊ indicating on the product how it should be opened and make access points obvious;
  - ◊ ensuring that joints and fasteners are easily accessible;
  - ◊ maintaining stability and part placement during disassembly;
  - ◊ minimizing the number and variety of joining elements;
  - ◊ ensuring that destructive disassembly techniques do not harm people or reusable components;
  - ◊ ensuring reusable parts can be cleaned easily and without damage;
  - ◊ ensuring that incompatible materials are easily separated;
  - ◊ making component interfaces simple and reversibly separable;
  - ◊ organizing a product or system into hierarchical modules by aesthetic, repair, and end-of-life protocol;
  - ◊ implementing reusable/swappable platforms, modules, and components;
  - ◊ condensing into a minimal number of parts;
  - ◊ specifying compatible adhesives, labels, surface coatings, pigments, etc., which do not interfere with cleaning;
  - ◊ employing one disassembly direction without reorientation;
  - ◊ specifying all joints so that they are separable by hand or only a few, simple tools;
  - ◊ minimizing the number and length of operations for detachment;
  - ◊ marking materials in moulds with types and reutilization protocols;
  - ◊ using a shallow or open structure for easy access to sub-assemblies.

3 Customer premises equipment (CPE)

This section covers ICT customer premises equipment (CPE), which is equipment that is set up and operated by individual entities (e.g. enterprises, academic/governmental organizations, residential customers) to provide dedicated private applications and services for their respective end use. Typically, these entities own and have the equipment located on their premises and provide the equipment's operating power. The following diagram shows the types of ICT products that are covered in this section.

Figure 2: This section of the document covers equipment in use at customer premises.



3.1 *Environmentally conscious design*

3.1.1 Scope

This section covers design considerations with respect to resource consumption (energy, water) and material selection and use (raw material efficiency, safe and environmentally friendly, recyclability, etc.). It covers products and packaging.

3.1.2 General references to other standards/work streams

Standards

- US EPA Energy Star – Voluntary labelling programme designed to identify and promote energy efficient products, e.g. major appliance, office equipment, home electronics, etc. Devices carrying the Energy Star logo, such as computer products and peripherals, kitchen appliances, buildings and other products, generally use 20–30% less energy than required by US federal standards. However, many European-targeted products are labelled using a different standard, combining energy usage and ergonomics ratings from the Swedish Confederation of Professional Employees (TCO) instead of Energy Star. TCO Development, a company owned by TCO, maintains an international environmental labelling system, TCO Certification. The label addresses safety issues such as 'emissions, ergonomics, ecology, and energy' for computers, monitors and printers, as well as mobile phones and furniture (TCO claims that 50% of displays worldwide are labelled with the TCO label and that it is even more rigorous in its ranking, including emissions, ergonomics, ecology, and energy).
- EPEAT – Voluntary system to help end users evaluate, compare and select electronic products based on their environmental attributes. The system currently covers desktop and laptop computers, workstations and computer monitors. Registered products are rated gold, silver or bronze depending on the percentage of optional criteria they meet above the baseline criteria (see also IEEE 1680.1 below).
- ECMA-341 (4th Edition, December 2010) – Environmental Design Considerations for ICT and CE Products.

- ECMA 370 (4th Edition, June 2009) – The Eco Declaration (TED). This standard specifies environmental attributes and measurement methods for ICT and CE products according to known regulations, standards, guidelines and currently accepted practices.
- ECMA-383 – "Measuring the Energy Consumption of Personal Computing Products" – This standard applies to desktop computers and notebook computers, defining how to evaluate and report energy consumption, performance and capabilities being the vital factors for the energy efficient performance of testing targets, i.e. those computers. Additionally, it provides a standardized results reporting format.
- EuP (Ecodesign) Directive 2009/125/EC – The related implementing measure for Standby Power states that the standby consumption limit (1-2 Watts) will become 0.5-1 Watt from 2013.
- Underwriters Laboratories (UL) – The not-for-profit product safety testing and certification organization, Underwriters Laboratories (UL), has announced graded certification levels, up to Platinum level certification, indicating achievement of the highest level of environmental performance recognized by the new UL Environment requirements. For example, UL ISR 110 sets environmental requirements for "environmentally preferable" mobile devices by measuring environmentally sensitive materials, energy management, manufacturing and operations, impact to health and environment, product performance, packaging, and product stewardship. The UL standards development process encourages innovation and excellence by establishing a baseline level for environmental design and performance, as well as a tiered approach that rewards environmental leadership.
- RoHS – Directives such as RoHS 2002/95/EC play a key role in reducing exposure to undesirable chemicals, and as there is an associated "acceptable limits" reduction roadmap, with an end goal (in some cases) of phasing the material out completely, manufacturers can decide whether to implement their phasing out earlier in order to demonstrate a leadership position. They can also seek to reduce longer term costs, as incremental compliance is likely not to be the most cost-effective route to take in the long run.
- EU Directive 2009/125/EC – 'Energy-related Products' (ErP) or Ecodesign Directive, and its specific implementing measures, such as External Power Supply, Simple Set-top Boxes, and Standby Mode.
- IEEE 1680.1 – The Standard for Environmental Assessment of Personal Computer Products including Notebook Personal Computers, Desktop Personal Computers, and Personal Computer Displays. This Standard consists of environmental criteria and other materials that relate specifically to personal computer products. Stakeholders have expressed a strong interest in adding electronic products to the declaration and verification system developed under IEEE 1680. In 2007, the Zero Waste Alliance conducted the "EPEAT Standard Development Roadmap" (SDR) project to provide suggestions for development of environmental leadership standards for electronic products.
- WEEE Directive – The Waste Electrical and Electronic Equipment Directive is the European Community Directive (2002/96/EC) on waste electrical and electronic equipment, or WEEE, also known as e-waste which, together with the RoHS Directive (2002/95/EC), became European Law in February 2003, setting collection, recycling and recovery targets for all types of electrical goods. The Directive imposes responsibility for the disposal of waste electrical and electronic equipment on the "manufacturers" of such equipment, in most cases this is the importer or retailer. Companies are compelled (but not yet legally required) to use the collected waste in an ecologically-friendly manner, either by ecological disposal or by reuse/refurbishment of the collected WEEE. Note: Updated information in the WEEE 2012 Recast and BSI PAS 141, which encourages reuse of used electrical and electronic equipment (UEEE).
- World Resources Institute's (WRI) Green Supply Chain (GSC) project – The project's rationale is based on the idea that sustainable supply chains are good business for companies, suppliers, and consumers. It is not a standard in itself but a widely respected process. The drivers of business value include efficiency gains, waste reduction, risk avoidance, staying ahead of the curve with respect to regulations, new product opportunities that capitalize on consumer demand for eco-friendly products, and cost control. "The intended result of this work is to improve the transparency of environmental data in the

supply chain, reduce the burdens on suppliers, and ultimately work toward a more holistic understanding of 'green' that brings together priority sustainability issues in a manner that is comprehensive and easily communicated".

- ISO 14006 Environmental management systems – Guidelines for incorporating ecodesign – The standard provides a guideline to organizations wishing to include eco-design principles in their existing Environmental Management Systems (EMS), such as, ISO 14001. It includes planning, implementation and operation of these principles within product design and development.

3.1.3 Best environmental practices

3.1.3.1 General CPE guidance

During the design phase, a number of measures aimed at reducing the impacts in the subsequent life cycle phases can be adopted. Several requirements can be derived when considering the usage scenarios, end-of-life procedures, and the manufacturing processes. Optimizing the overall environmental performance of the products starts from the design phase. Making successive generations of products more sustainable is a journey, and could be broken down into a series of steps. A possible roadmap would be as follows:

Nearer-term opportunities:

- Assess the current product portfolio and rationalize packaging, finishes and materials.
- Review current energy performance and PSU, aiming to at least match best practice.
- Begin to formulate an outline Environmental Product Declaration (EPD) and carbon footprint.
- Engage with corporate marketing to clarify brand needs and its associated impacts.

Medium-term opportunities:

- Finalize EPDs for key products.
- Obtain eco-label accreditation (or alignment) on products.
- Create third-party audited carbon footprint.
- Adopt biodegradability and recyclability in materials, both for product itself and packaging.
- Standardize and optimize product portfolio packaging.
- Move the supply chain for each product towards a zero waste goal.
- Reduce reliance on fossil fuel industry (e.g. by at least 25%) in the supply chain.

Longer-term/aspirational goals:

- Zero waste across product portfolio.
- EPDs for all major products.
- Obtain eco-label accreditation (or alignment) on all major products.
- Close loops in the supply chains (to remove or reuse "waste").
- Material flows of products become increasingly seen in terms of technical and biological "nutrients" (using circular economy (CE) or cradle-to-cradle (C2C) terminology).
- Minimize reliance of fossil fuel industry in the supply chain.
- Application of biomimicry where this can lead to product innovations.

Directives like Ecodesign 2005/32/EC use RoHS as part of a design process, which can be broadly related to Environmental Product Declarations (EPD) that some companies have begun to adopt. EPDs do not necessarily claim any environmental advances, but they provide a mechanism to present the "ingredients" of the product and how it was made. An EPD can also include a roadmap for the reduction or phasing out of certain materials and processes, and because of this, it is a very trusted form of transparent accountability.

EPEAT provides a graded standards process for a wide variety of electronic goods, based on national and international standards. It provides an open database on products coming close to EPDs. This empowers purchasers to make an informed purchasing decision based on independent third-party ranking of environmental performance.

In practical terms, the following best practices can be adopted in terms of improvements with respect to the previous generation of products performing the same (or similar) functions:

I. General aspects:

The following are offered as a collation of good practice and aspirational guidelines:

- ◊ The product should exceed RoHS2 (RoHS Recast) limits.
- ◊ The product should have class-leading energy saving features (e.g. EU ErP Directive).
- ◊ The product should meet an external "gold standard" ranking, such as Blue Angel, UL, TCO or EPEAT.
- ◊ The product should demonstrate an element of closed loop material and value flow in its supply chain and life cycle.[9]
- ◊ The product should have an Environmental Product Declaration (EPD) or equivalent available online and demonstrate production transparency.
- ◊ The product should have an independent internal practitioner review or a third-party assured review for its life cycle eco-impact assessment, as deemed appropriate for the assessment's results (refer to ISO 14044).
- ◊ The manufacturing process should meet ethical standards in the workplace as per the *triple bottom line* approach for integrating economic, environmental, and societal values.

II. Plastic case:

- ◊ Adopt a mechanical design that will minimize the dimensions.
- ◊ Reduce the overall weight of the plastics used for the case.
- ◊ Avoid using a large number of different plastics – the ideal solution is to have all plastic components made of one material only.
- ◊ Choose plastic materials that can be recycled in high percentages; or, directly adopt polymers containing some percentage of recycled material.
- ◊ Avoid using flame retardants containing halogenated compounds in addition to the compliance with the European RoHS Directive.

III. Electronics:

- ◊ Reduce the printed wiring board's dimensions by adopting solutions that have greater integration of electronic components, e.g. use application specific integrated circuits (ASICs) in lieu of field programmable gate arrays (FPGAs) as they use fewer materials and components, and consume less energy.
- ◊ Adopt soldering solutions with low environmental impact, minimizing the presence of substances that, even if used as additives, could affect manufacturing workers' health and complicate the disposal process of the electronic part.
- ◊ Adopt halogen-free solutions for the printed wiring boards.

IV. Noise emissions:

- ◊ The designer should consider techniques to reduce noise emissions. Reduced noise emissions typically improve energy efficiency.

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9 See, for example the "Circular Economy" at: www.ellenmacarthurfoundation.org/about/circular-economy.

- ◊ Noise emissions should be evaluated according to ISO 7779, for products covered by ISO 7779 (or ECMA-74). For products under the scope of this document and not covered by a product-specific international standard noise test code, such as ISO 7779 (or ECMA-74), noise emissions do not have to be evaluated. If noise emissions are evaluated for products under the scope of this standard but not covered by either ISO 7779/ECMA-74 or another product-specific international standard noise test code, the basic sound power standards, ISO 3741, ISO 3744 or ISO 3745, and the basic emission sound pressure standard, ISO 11201, should be used. The test conditions used should be recorded. The resulting sound power levels and, where applicable, emitted sound pressure levels (including emission sound pressure measurement distance if not covered by ISO 7779/ECMA-74) shall be declared according to ISO 9296 (or ECMA-109) and should be documented according to available eco-declaration standards (such as ECMA-370). The levels should be made available in the product information to the end user.
- ◊ NOTE: The additional noise from cooling systems is a frequent issue for audio and video systems and computers in home or silent office environments.

V. Packaging:

- ◊ The product's packaging should be as compact as possible, i.e. reduce the dimensions and weight of the package.
- ◊ Packaging should be made from a high percentage of recycled materials, with an aspirational goal towards having 100% recycled materials content in such packaging materials.
- ◊ Adopt a single material solution for the package, with strong preference for the adoption of recycled cardboard and paper.
- ◊ All packaging inks should be vegetable-based (versus petroleum-polymers).

VI. Design for end-of-life treatment:

- ◊ The case/cabinet and the electronic parts must be easily separated during the end-of-life phase. This implies that during the design phase a limited number of screws and snap fits must be adopted, obviously ensuring at the same time the required functionality and satisfying the safety requirements, security and market preferences. If the product will be easily disassembled at the end of its useful life, then two parallel processes for the waste treatment will be activated and could be implemented in order to minimize the impacts (e.g. recycling loop for the plastics, metals recovery for electronics, etc.).
- ◊ NOTE: Designers need to balance the degree of disassembly with the actual level that recyclers employ to provide for economic viability of their end-of-life processes (now and in the future when current products will reach their recycling stage). The degree of disassembly can vary from complete disassembly down to component parts to product level shredding with no disassembly.
- ◊ The majority of the product's outer casing/enclosure should be made from either recycled plastic or bioplastic, exceeding WEEE 2012 limits.
- ◊ The material recovery and recycling phase of end-of-life computing equipment should be taken into account by manufacturers during product design, by considering the issues of increased recyclability and reduction in toxicity.
- ◊ A number of materials that are being used in the manufacture of new computing equipment, such as beryllium, mercury, flame retardants, etc., have been identified by ICT equipment recyclers as substances of particular concern during the processing of end-of-life computing equipment. Manufacturers should give consideration to the use of substitute materials that perform the same function.
- ◊ Computing equipment manufacturers should collaborate to address the recyclability of plastics in computing equipment. Specifically, consideration should be given to greater consistency in material selection during the design stage for all computing equipment which would allow plastics recyclers to eliminate sorting steps necessary to achieve compatibility of plastics types.
- ◊ An incentive should be offered or be made available to promote the return of ICT products at their end of life to the retailer or an appropriate recycling or refurbishment route.

If these principles and associated materials are recorded in an EPD, along with future product target timelines for on-going improvements, then this provides a good foundation to begin meeting TCO, UL or other (e.g. Blue Angel) eco-label specifications. Whether a product is formally tested by these bodies may be a decision to be made on cost and marketing grounds, but these standards offer guidance on best practice.

NOTE: The marketing and public relations of products must be done in an honest and transparent way, so as to avoid claims by the media and the public of "green-washing" and spinning up green credentials.

3.1.3.2 Battery guidance

In January 2010, the revised EU Batteries Directive came into force with the primary intention to divert batteries away from landfill and avoid metals such as cadmium and mercury in those batteries from getting into the environment. Note that in 2010 the UK government estimated the current rate of battery collection and recycling was only around 3%. The Directive requires that governments increase this to a minimum of 25% by 2012 and 45% by 2016. For any product that wishes to move towards a Circular Economy approach for industrial design and supply chains, easy and informative battery disposal information is essential.

3.1.3.3 Packaging guidance

Reducing packaging size and weight has many positive environmental benefits including a reduction in the usage of resources and in transportation related emissions. The EU Packaging Directive states that packaging should be as minimal as possible whilst maintaining its performance in the areas of safety, hygiene and acceptance by the consumer.

The materials used for packaging need to minimize resource utilization and facilitate simple recycling. If there is no clear safety or marketing reason, the packaging should avoid use of virgin materials and make use of renewable material sources. Ideally it should be fibre or cardboard based derived from post-consumer or post-industrial waste. Where fibre is not applicable, post-consumer recycled plastics can be a good alternative. Regardless of the type of material used, the packaging should be easily recyclable in standard municipal waste treatment systems or biodegradable.

Clarifying biodegradability for consumers should also lead to manufacturer best practice, with perhaps the key directives and standards supporting this, being Directive 94/62/EC, International Standards ASTM 6954-04 and BS EN 13432:2000. Accompanying best practice in biodegradability in packaging and literature (among other potentially disposable items) is the evolution and adoption of vegetable-based inks.

Plastics and paper-based materials in packaging (and products) have varying degrees of degradation when disposed of in landfill. There are two aspects to degradation: how long it takes and what benefit (or not) there is in the process. Most petro-chemical plastics take hundreds of years to degrade in the soil and many leach undesirable chemicals into the soil then onto ground, water, and ultimately into the food chain. An EC Consultation Paper recently raised concerns that the distinction between compostable and biodegradable is not clear enough, with the ambiguity giving rise to a "proliferation of littering". Packaging companies, converters, environmental bodies and the public have all been invited to suggest ways of improving biodegradability requirements of packaging products – including boosting its visibility to consumers through labelling schemes.

Although images printed on packaging contribute a small proportion of a consumer product's total eco-impact, the images consume ink and energy as they are applied. They also have an impact on the recyclability of the product at the end of its life, and certainly the biodegradability. Vegetable-based ink may be the solution to the environmental health and safety concerns of the printing industry, offering more eco-effective recycling and higher grades of biodegradability. Vegetable-based ink may help to reduce the environmental burden of the printing industry as they come from a renewable source, and ideally that do not compete with the human food supply.

3.1.4 Metrics

A few simple parameters can provide a quantitative measure of the environmental improvements in a CPE product. The basic hypothesis is that all quantitative measures must be comparative, with reference to the performance of a previous product that the new CPE is replacing (even if there are more functions related to the evolution of the product's usage). Examples can be:

- total weight of plastic material for case;
- total weight of electronics;
- disassembly time (e.g. time to separate all plastic parts from electronics – although this can be a very subjective parameter depending on the who is disassembling and the methodology used);
- number of plastic materials used;
- percentage of recycled material in plastics (for each material used);
- presence of halogenated compounds in plastics (Yes/No);
- presence of halogenated compounds in electronics such as printed wiring boards and encapsulants for integrated circuits (Yes/No).

For reporting eco-environmental/sustainable attributes of CPE products, a company can produce an environmental declaration. Such declarations can be self-declarations, in which case ECMA Standard 370 (2nd edition; December 2006) should be referenced. This document meets the basic principles of ISO 14021 (Environmental labels and declarations – Self declared environmental claims) and also eco-design standards such as ECMA-341.

Reporting metrics may be concentrated on the following five "Green Focal Areas":[6]

- energy;
- product weight;
- packaging;
- hazardous substances;
- recyclability.

3.2 Eco-efficient manufacturing

3.2.1 Scope

This section covers resource consumption and possible non-product material consumption and also toxins to both humans and the environment as well as waste occurring during manufacturing. Subsections include:

- materials and energy required to manufacture the product;
- emissions generated as a result of manufacturing the product;
- eco-impact of logistics/product distribution.

3.2.2 General references to other standards/work streams

- Standards ISO 14001 – this standard provides a framework for an Environmental Management System (EMS) to enable manufacturing organizations to set and meet clear environmental goals and objectives.

- Underwriters Laboratories (UL) – UL 880 sets sustainability requirements for manufacturing organizations by measuring governance, environmental management, workforce, customers and suppliers, and community engagement. The UL standards development process encourages innovation and excellence by establishing a baseline level for environmental performance, as well as a tiered approach that rewards environmental leadership.

3.2.3 Best environmental practices

Consideration should be given to "circular economy" (CE) or "cradle-to-cradle" (C2C) principles such as those being advanced by organizations such as the Ellen McArthur Foundation: www.ellenmacarthurfoundation.org/about/circular-economy.

These principles encourage steps that move from today's largely linear "take, make, dispose" model towards models with "close loops", i.e. where the "waste" from one process can be usefully used as input (or "nutrient") to another process, thereby removing waste and increasing efficiency.

Two companies from another sector that are widely recognized as having made significant progress towards sustainable processes and good environmental practices are *InterfaceFLOR* and *Desso*. Further information is available here:

- www.desso.com/Cradle_to_Cradle_Brochure_EN.pdf.
- www.interfaceflor.eu/sustainability.

Tackling e-waste should be as high on the agenda as energy and carbon reductions are today. The following sources provide additional structure to existing business models to help aid e-waste cost-benefit analysis.

- BS 8886 and BS 8887
- "The Five Capitals" model, see:
- www.forumforthefuture.org/project/five-capitals/overview.
- "The Natural Step", see: www.biothinking.com/applysd/natural.htm.

3.3 Smart usage

3.3.1 Scope

This section covers issues and concerns relating to the deployment and operation of CPE at consumer premises. Examples include: efficient operation, cooling, ancillary equipment needs and usage, maintenance and repair.

3.3.2 General references to other standards/work streams

The main references for the operation phase are related to the energy efficiency requirements, definition of targets, and guidelines for testing, which include:

- DoE/California Energy Commission – Appliance Efficiency Standard for Battery Charging Systems.
- Energy Star Eligibility Criteria for Home Networking Equipment.
- ETNO – Requirements for performing benchmark activities on home gateways (GREEN benchmark requirements).
- ETSI ATTM – Standard series ES 202 874 related to Common Power Supplies for Customer Premises Equipment: requirements and implementation specifications.

- ETSI EE – On-going activities on test method definition for energy efficiency measurements on customer premises equipment.
- European Code of Conduct for Broadband Equipment – Version 4.
- European Code of Conduct for Digital TV Systems – Version 8.
- EU Integrated Product Policy – Energy Efficiency Index for Mobile Phones. Home Gateway Initiative – Requirements for an Energy Efficient Home Gateway.
- Home Gateway Initiative – Requirements for Common Power Supplies for Home Networking Equipment.
- International Energy Efficiency Mark.
- Recommendation ITU-T G-Supplement 45 – "GPON power conservation," and Recommendation ITU-T G.987.3, "10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification," clause 16.
- Voluntary Industry Agreement for Energy Efficiency of Complex Set-Top Boxes.

3.3.3 Best environmental practices

Energy efficiency

With reference to energy efficiency, the most important distinction is to be made between products that must always remain on due to their service requirements and others that can be switched off. In the first case, a number of measures to implement low power mechanisms can be adopted, while in the latter automatic power-down mechanisms in case of inactivity can be implemented, as well as remote wake-up solutions. Another key consideration is that many CPEs use external power supplies, which may introduce additional energy consumption. The external power supply may not be designed as efficiently as the actual product since it may be required to operate with multiple products. A user may also forget to turn off or disconnect the power supply if the CPE no longer requires its use or is disconnected. In this instance, although not active, the power supply may continue to draw a certain amount of 'no-load' energy.

- Target energy consumption limits must be fixed (e.g. following the codes of conduct) per product category when the product is in full operation state ("ON" mode).
- Mechanisms to enter low power states when possible, with respect to the needs for supporting services, must be implemented, so that the periods of low activity will correspond to a significantly reduced power usage. Also in this case, for specific low power states that can be defined per product category (e.g. home gateways), the codes of conduct can help to identify target power values to be adopted as reference.
- Power profiles allowing users to specify a particular combination of performance and energy usage.
- Equipment that can be switched off should implement internal mechanisms that will enforce a shut-down after a specific time of inactivity.
- Equipment that can be switched off should implement protocols enabling the equipment to "publish" the actual power state, so that remote or local energy management systems can be aware of it.
- Equipment that can be switched off should also implement mechanisms for receiving a command capable of enforcing specific power consumption states (from low power to off).
- Equipment that can be switched off should implement a mechanism for being switched on when needed (e.g. wake-on LAN).

Extending product life

With reference to the possibilities of repairing customer premises equipment, in theory, this activity will extend the useful life of the product, and this will imply an automatic environmental advantage. Sometimes, the economical sustainability of the repairing processes is not ensured, due to the low cost of specific devices, so that this kind of procedure is not adopted. But if the eco-design phase took into account the possibility of repairing the products (for example, enabling easy disassembling, reducing the number of parts, etc.), this will be easier. As a general rule, the product should be repaired if the problem is purely aesthetic (but its correct functionality can be checked). On the other hand, repairing the electronic part could be more difficult if the related costs are too high. If the product cannot be repaired and is then sent to final disposal, then the best practices described in section 4 of this Part should be applied.

One additional feature of a product that allows its useful life to be extended is the possibility of remote or local upgrading of its operating firmware. This will allow in theory the support of new services without changing the product, and will further extend its useful lifetime. Managing CPEs remotely can also allow diagnostics actions to be performed, and will also simplify the CPE's operation and maintenance procedures, sometimes avoiding substitutions and thereby offering more efficient use of resources.

3.3.4 Metrics

Metrics about energy efficiency can be found in the various documents already elaborated at the European level or by working groups promoted by the US Environmental Protection Agency. For most of the equipment categories, measurement methods have been defined as well as targets to be adopted to measure the actual energy efficiency performances. As examples:

- For home gateways, targets and test conditions can be found in the European Code of Conduct for Broadband equipment. The measurement method can be found in the ETNO document describing requirements for the GREEN benchmark (ETSI EE is currently working on a work item dealing with the same subject; the expected date for the final deliverable is December 2011).
- For set-top boxes, efficiency criteria are fixed by the European Code of Conduct on Digital TV systems as well as measurement methods.
- For telephony devices, test methods and parameters to be measured can be found in the Energy Star programme requirements for telephony and other CPE equipment such as set-top boxes.

3.4 Responsible end-of-life

3.4.1 Scope

This section covers CPE operational considerations pertaining to end-of-life. This includes user-based recycling metrics or policies.

3.4.2 Best environmental practices

The environmental impact of the end-of-life procedures is strongly influenced by the eco-design rules that are adopted at the beginning of the product's life cycle. The following practices can be considered, provided that during that phase a number of solutions for facilitating disassembly, avoiding the usage of specific materials, and reducing the number and quantity of materials, etc., will be adopted:

- When a product failure is detected, consider all the possible solutions to repair it coming back to the use phase and avoiding sending the device to final disposal. This possibility is also mentioned in section 3.3 of this Part. The product's reuse is always the first possible option to be examined. Note that the economical sustainability of this process must be considered and will also depend on the basic cost of the product.

- If repairing the device is not possible or is not economically sustainable, a process including the separation among packaging elements, plastic parts and electronics should be adopted (Note: When separated, the three categories of "wastes" can be treated separately).
- For packaging, provided that all the plastic bags will be separated from the rest, all the paper and cardboard parts must be sent to the recycling processes in order to recover the material. Most of the cardboard packages for various applications can in fact contain percentages of recycled materials up to 100%.
- Assuming that the plastics used for the product's case are homogeneous due to eco-design choices, all parts should be sent to a process where polymers are ground and introduced into the recycled plastics market, in order to most efficiently reuse these materials. In some cases, recyclability of the typical polymers used in CPEs is high (e.g. Acrylonitrile Butadiene Styrene can be used for other applications in percentages up to 100%). In other cases, for example PC+ABS, a blended solution can limit the possibility of re-usage, but technically speaking the adoption of significant (up to 30%) percentages of recycled blend in new products is feasible. From the point of view of the recycling process, the blend can be treated as if it was a single polymer and can be mixed with virgin blend before the moulding process. Obviously, the percentage of recycled material can vary on the basis of the corresponding changes in the mechanical characteristics of the final new plastic component. Note – some plastics can be used in a smelter to recover energy from the heat of combustion and help with the recovery of precious metals.
- As far as the electronic boards' disposal is concerned, there is the possibility of sending the PWBs equipped with electronic components to specific recycling processes aimed at recovering metals and/or energy through thermal treatments. In fact, boards can be ground and different materials can be separated through a mechanical process. As an alternative, PWBs can be treated in blast furnaces in order to recover energy and get at the end of the process a number of different metals, thus avoiding sending the electronic waste to controlled landfill.

3.4.3 Metrics

To evaluate the environmental performance of a CPE in relation to its end-of-life phase, a few parameters can be proposed. For example:

- percentage of products dismissed in a specific time unit (e.g. yearly);
- disassembly time;
- number of recycling processes receiving input from the disposed CPE;
- percentage (in weight) of the product sent to recycling processes;
- percentage (in weight) of the product sent to incineration processes.

4 Life cycle assessment

4.1 Scope

This section provides information and guidance on LCA methodologies, standards, life cycle thinking approaches, estimators, tools, databases and other information for using LCA to assess the environmental sustainability of ICT network infrastructure equipment and customer premises equipment.

4.2 Guidance

LCAs are an important tool in evaluating potential environmental impacts of a product throughout its life cycle stages – from the extraction of raw materials, the manufacture of finished goods, and their use by final consumers, or for the provision of a service, recycling, energy recovery and ultimate disposal. LCA results allow us to directly evaluate the environmental impacts of a product or its individual sub-assemblies, and to then continually improve on its design, material selection, and operating characteristics, e.g. energy efficiency. These impacts can typically be provided in categories such as global warming impact (carbon emissions), natural resource depletion, eco-toxicity, and water resource consumption. LCAs are used to identify significant environmental aspects: as a benchmarking tool to demonstrate the 'green' evolution of a product line; at the product assembly level – to determine target areas for environmental improvement for new products (i.e. recyclability or material reduction); and, at the component level, as an aid to materials selection. The eco-impact guidelines and checklists within each technical specification area can be updated based upon the results of LCAs.

4.2.1 Life cycle thinking (LCT) aspects

Within the limits of the designer's responsibility, the designer should consider life cycle thinking (LCT). LCT means integration of the environmental impact caused by a product throughout all life cycle stages as early as possible in the product design and development process when opportunities exist to make decisions to improve the environmental performance of the product.

Basic considerations include:

- a goal to minimize the overall adverse environmental impact be defined by the manufacturer/organization;
- significant environmental aspects of the product be identified; and
- trade-offs associated with both environmental aspects and life cycle stages should be considered.

Balanced compromises associated with both the environmental aspects and the life cycle stages need to be evaluated. Any decision should be balanced with technical features and economic viability and should not compromise health and safety.

4.2.2 The designer's role

It is the designer's responsibility to deal with attributes directly dependent on the product design. The designer should ensure that products comply with all relevant regulations governing product design. Then, the designer should take into account the environmental impact of the product throughout its life and to identify the significant impacts that can be reduced by alternative design solutions.

General environmental aspects of life cycle stages such as extraction/processing of raw materials, manufacturing and transportation should be considered within existing environmental and procurement policies and guidelines of the organization. Designers should follow the design relevant aspects of those policies and guidelines. Any emphasis on a single stage of a product's life cycle may alter another stage and therefore the overall environmental impact. The designer's responsibility is limited by the possibilities within the requested functionalities and market requirements. Balanced compromises will need to occur in optimizing the environmental impact across the product life cycle.

4.2.3 Reducing GHG emissions during the product manufacturing phase

- GHG emissions from Ball Grid Array (BGA) and Quad Flat Pack (QFP) integrated circuits (ICs) is much higher (in some cases by orders of magnitude) than other smaller ICs (e.g. Dual in-line [DIP], Plastic Leaded Chip Carrier [PLCC], Thin Small Outline Package [TSOP]), transistors, capacitors and coils. However, the use of large ICs can offset GHG emissions due to more energy efficient and physically smaller/lightweight printed wiring board designs.

- GHG emissions from PWBs can be also significantly reduced by selecting a PWB with less layers (almost linear reduction of GHG emissions) or by selecting a PWB with a different surface treatment than say, nickel/gold (Ni/Au).
- Silver (Ag) in "lead-free" solder paste can have as much as ten times greater GHG emissions than solder paste compounds containing copper, lead or zinc. However, the move to lead-free solder may warrant the need for silver in solder paste.

  Note: Substitute materials for lead-free solders that meet ICT product technical specifications and are more environmentally benign are being researched within the ICT industry, and as they become commercially available, should be considered.
- GHG emissions from smaller/simpler components such as signal diodes, LEDs, surface mounted "chip" resistors and capacitors are very small and normally need not be a concern in reducing eco-impacts of printed wiring boards.
- GHG emissions from aluminium used in cabinets, frames and chassis are significantly greater than the use of steel (based on the metal's manufacture from mined ores). However, this can be offset by selecting metals with high recycled content as well as deriving eco-life cycle benefits from aluminium's lighter weight and the need for less protective finishes. See table below for GHG emissions from selected metals with different recycled contents.
- GHG emissions from selected plastics (e.g. polycarbonate, ABS, polystyrene) are provided in the table below. Currently recycling technologies have not been adequately developed and deployed such that plastics with high recycled content can be easily specified.

Material	Estimated GHG emissions[10,11] (kg CO_2e) extraction/mfg stages (to produce 1 kg of material)		Material finished product form – typical recycled content
	0% recycled content	100% recycled content[12]	
Metal – aluminium (Bayer refining, Halle-Heroult smelting)	22.4	1.07	• Typical (world) – 40% • Extruded forms – up to 85% • Sheet products – up to 50%-63% • Electronic components – < 5%
Metal – zinc (electrolytic process)	4.6	1.84	• Typical (world) – 36% • Die castings – 10%
Metal – lead (lead blast furnace)	2.1	0.74	• Typical (world) – 47% • Battery plates – ~50% • Sheathing/foil – ~50% • Solder – <5%
Metal – steel (integrated route – BF and BOF)	2.33	0.53	• Typical (world) – 47% • Structural forms – ~80% • Rolled sheet goods – 25% to 35%

10 "Assessing the environmental impact of metal production processes". T.E. Norgate, S. Jahanshahi, W.J. Rankin; CSIRO Minerals, Australia; 21 June 2006.

11 "The role of metals in sustainable development". T.E. Norgate and W.J. Rankin; CSIRO Minerals; Green Processing; 2002.

12 Value attainable after 20 or more reiterative recycling.

Material	Estimated GHG emissions[10,11] (kg CO_2e) extraction/mfg stages (to produce 1 kg of material)		Material finished product form – typical recycled content
	0% recycled content	100% recycled content[12]	
Metal – stainless steel (electric furnace and argon-oxygen decarburization)	6.8	1.8	• Rolled sheet goods
Metal – copper (smelting/converting and electro-refining)	3.33	0.55	• Typical (world) – 38% • Structural – 75% • Electrical/electronic – < 5%
Metal – nickel (flash furnace smelting and Sherritt-Gordon refining)	11.4	NDA	• Typical (world) – 34%
Metal – titanium (Becher and Kroll processes)	35.7	NDA	
Plastic – polycarbonate (PC)	8.57[13]	6.1[14]	
Plastic – acrylonitrile butadiene styrene (ABS)	5.45[7]	3.9[8]	
Plastic – polystyrene (PS)/styrene acrylonitrile (SAN)	5.09[7]	3.9[8]	
Plastic – polyethylene terephthalate (PET)	4.93[7]	*	
Plastic – polyethylene, low density (PE-LD)	3.71[7]	*	
Plastic – polypropylene (PP)	3.51[7]	*	
Plastic – polyhydroxy- alkanoates (PHA) (“bio plastic”)	0.49[15]	*	

NDA – no data available

**Under study/evaluation within plastics recycling industry*

4.3 Reference standards

The International Organization for Standardization (ISO) has published a number of standards designed to highlight environmental problems and areas for improvement in the production and use of products:

- ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework It provides a clear overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of life cycle assessment.

13 PE International – PlasticsEurope Data w/ Gabi V4.4.

14 “Assessing the benefits of design for recycling for plastics in electronics: A case study of computer enclosures”. Masanet, Eric, Horvath, Arpad; Lawrence Berkeley National Laboratory; 31 December 2007.

15 “The Greenhouse Gas Emissions and Fossil Energy Requirement of Bioplastics from Cradle to Gate of a Biomass Refinery”. Jian Yu and Lilian X.L. Chen; American Chemical Society, 2008.

- ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines It is designed for the preparation of, conduct of, and critical review of, life cycle inventory analysis. It also provides guidance on the impact assessment phase of LCA and on the interpretation of LCA results, as well as the nature and quality of the data collected.
- ISO/TR 14047:2012: Environmental Management – Life cycle Assessment – Examples of application of ISO 14042 (ISO 14042 has been withdrawn and revised by ISO 14040:2006 and 14044:2006)
- ISO/TS 14048:2002: Environmental management – Life cycle assessment – Data documentation format.

LCAs must follow ISO 14040 and ISO 14044 standards as they provide the essential requirements in performing the analysis[16]. The following publications use these ISO standards as their basis for providing further information and analysis of LCAs.

- The European Commission has published a handbook[17] that gives detailed guidance on all the steps required to conduct an LCA.
- The British Standards (PAS)[18] have published specifications for the assessment of the life cycle GHG emissions of goods and services.
- ETSI[19] (standards development organization) – recently published an LCA standard (ETSI TS 103 199) for ICT equipment, networks, and services entitled: Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services: General methodology and common requirements.
- ITU[20] (standards development organization) – has developed an LCA standard: Recommendation ITU-T L.1410 (2012): Methodology for environmental impact assessment of information and communication technologies goods, networks and services.
- The World Resources Institute (WRI)[21] has published the Greenhouse Gas Protocol (GHGP) Standards for Corporations and also most recently the Corporate Value Chain (Scope 3) Accounting and Reporting Standard (5 October 2011). This is being followed by the development of Supplementary Guidelines for the ICT Industry, which includes ICT Hardware and Equipment, and Telecommunications Network Services. These latter documents are planned for publication in mid-2012.

4.4 Demonstration models

Refer to the following publications and web links.

- A.S.G. Andrae (2009) Global Life-Cycle Impact Assessment of Material Shifts: The Example of a Pb-free Electronics Industry. ISBN-13: 978-1848826601, Springer UK, London, U.K. 183 pgs.
- A.S.G. Andrae, O. Andersen (2011): Life cycle assessment of integrated circuit packaging technologies. International Journal of Life Cycle Assessment 16(3), 258-267.M. Erlandsson, M. Almemark:

16 International Organization for Standardization. "Environmental management – Life cycle assessment – Principles and framework". ISO 14040:2006. "Environmental management – Life cycle assessment – Requirements and guidelines". ISO 14044:2006. Online: http://www.iso.org/iso/store.htm.

17 European Commission Joint Research Centre (2011). International Reference Life Cycle Data (ILCD) System Handbook: General Guide for Life Cycle Assessment – Detailed Guidance. 1st edition, Dictus Publishing (17 June 2011). See also online: http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-General-guide-for-LCA-DETAIL-online-12March2010.pdf; http://lca.jrc.ec.europa.eu/lcaainfohub/datasetArea.vm.

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4.5 Metrics

The number of quantitative parameters that can be provided by LCA analysis is huge. The problem is to identify a subset of them allowing comparisons between different generations of the same CPE in order to measure the actual environmental improvement of a new solution in comparison to the older one.

The following short list of resource usage/environmental emissions parameters should be evaluated, considering that ICT products share certain characteristics that are related to their inherent materials, manufacturing processes, and energy used. These parameters produce life cycle inventory results that are most relevant in terms of overall quantity (and can be then suggested as a basic set of parameters for performing LCA-like comparative analyses).

- gross energy
- CO_2
- NO_x
- SO_x
- N_2O
- NH_3
- CFC
- HCFC
- particulate matters

In the assessment phase, the following mid-point environmental impact assessment categories can be evaluated (on the basis of the inventory data mentioned):

- global warming potential (GWP);
- ozone depletion potential (ODP);
- acidification potential (AP);
- nitrification potential (NP);
- human toxicity, cancer effects (HTC);
- human toxicity non-cancer effects (HTNC);
- respiratory inorganics/particulate matter (RI/PM);
- ionizing radiation, human health (IRH);
- ionizing radiation, ecosystems (IRE);
- eutrophication, aquatic (EA);
- eutrophication, terrestrial (ET);
- photochemical ozone formation (POF);
- ecotoxicity, freshwater (ETFW);
- land use (LU);
- resource depletion, water (RDW);
- resource depletion, mineral, fossil, and renewable (RDMR).

The LCA practitioner should decide which mid-point impact categories to consider and how to calculate them, based on the studied ICT product system and the purpose of the LCA study. For further information on determining and assessing these mid-point impact categories, refer to the European Commission Joint Research Centre (2011) International Reference Life Cycle Data System (ILCD) Handbook: "Framework and Requirements for Life Cycle Impact Assessment Models and Indicators"; 1st edition; Dictus Publishing (17 June 2011).

5 Checklists

An eco-design checklist can assist designers with considering eco-design requirements and guidance during the product's development. The design checklist is intended solely for use of the designer. It is not intended to document environmental features for end users or to be used by end users to compare products. It is usually not needed for products in the research phase of development. It can provide:

- verification of completeness of the eco-design process and its requirements;
- record for quality (e.g. ISO 9001, TL9000) and for Environmental Management Systems (ISO 14000, EMAS 18000);
- basis for establishing product design objectives and targets and in evaluating eco-performance of a products.

It is generally recognized that ICT products cover a wide range of eco-attributes. For this reason, it is not possible to provide a unique checklist for every type of ICT product or family/group of products. Designers should generate a design checklist based on the design requirements of this document and also standards referenced within this document such as ECMA-341, and through other reference material and technical reports that will accurately reflect their specific product or family of products.

Based on the material above, a template can be constructed for a checklist that ensures that environmentally conscious design is being practiced in an ICT organization.

5.1 Best environmental practices – general

The material in this checklist refers to sections 2.1.3 and 3.1.3.

For the environmentally conscious design of ICT products, has consideration been given to the following?

- Ensure sustainability of resources.
- Ensure inputs and outputs in the product life cycle do not cause environmental degradation or adversely affect human health.
- Minimize environmental impacts as early as possible in the product design and development process.
- Minimize material and energy use and maximize reuse and recycling.
- Evaluate the outlook on future changes in product related eco-design requirements (e.g. a product eco-roadmap).
- Balance conflicting requirements (if any).
- Identify the latest environmental related legal and market requirements.
- Give priority to those aspects that can be substantially influenced through product design and are identified as major environmental impacts.

5.2 Product value/lifetime extension

The material in this checklist refers to section 2.1.3.2.1

Has the product design been assessed for the following?

- Prolong the product's useful lifetime – balancing between a legacy product and a newer more eco-efficient product.
- Ensure durability of product and components:
  - ◊ minimal maintenance and minimizing failure modes;
  - ◊ easy repair and upgrading;
  - ◊ facilitate testing of components;
  - ◊ promote repetitive disassembly/reassembly.
- Balance between technical and economical lifetime:
  - ◊ ensure better cooling;
  - ◊ selection of more reliable components (versus other trade-offs such as more expensive materials);
  - ◊ need to build in redundancy.
- Balance between energy use versus lifetime.
- Extend the product's functional life by:
  - ◊ modularity – allow for ease of repair and upgrading;
  - ◊ standardization of mechanical parts;
  - ◊ software updates;
  - ◊ reuse of mechanical parts.
- Information is made available to end users (if appropriate) on available options for upgrading, expanding and repair of product.

5.3 Energy efficiency

The material in this checklist refers to section 2.1.3.2.2.

Has the product design been evaluated for the following?

- Product meets applicable regulatory requirements, voluntary measures within the industry (e.g. codes of conduct) and international standards.
- Product has been assessed for general energy efficiency measures:
  - ◊ Designer is aware of the product's life cycle "use stage" and the intended patterns of use and system interactions.
  - ◊ Energy savings features are documented during the design process. Information on energy use/energy saving modes is made available to the end user.
  - ◊ Enable the most energy efficient "on-modes" and transitions to energy saving modes as the default mode.
  - ◊ Balance the flexibility of software running on multipurpose devices and the energy efficiency of special purpose hardware. Consider power saving modes and peak energy shaving opportunities.
  - ◊ Consider product or system related power savings measures:
    - – system architecture/feature specification;
    - – power dissipation of battery charging systems;
    - – identify power-hungry components and features;
    - – power added incrementally per the system capacity – do not over-specify;
    - – high efficiency/renewable power sources;

– means of monitoring power consumption by the end user.

◊ Consider power modes and related energy efficiency measures:

  – establish realistic specifications;

  – high energy efficiency features when selecting OEM devices.

◊ Consider operational modes – on maximum; on-normal; low power; on-idle.

◊ Consider automatic low power, on-idle modes, power-off modes (soft-off; hard-off), and no-load modes.

◊ Consider operational environment improvements:

  – cooling methodology;

  – effect of operating environment specification to users/installers.

5.4 Substances and materials

The material in this checklist refers to section 2.1.3.2.3.

Has the product design assessed the following substances and materials issues?

- Hazardous/restricted substances:
  - ◊ Product meets applicable regulatory requirements and international standards.
  - ◊ Product meets other materials of concern issues (e.g. issues driven by end-users, stakeholders and other interests).
- Materials efficiency:
  - ◊ When specifying materials has consideration been given to:
    - – reduced variety of materials used;
    - – reduced amount and weight of materials;
    - – use materials with lower adverse environmental impact;
    - – use materials that can be easily recycled;
    - – avoid materials that have end-of-life concerns (e.g. PVC being improperly incinerated and releasing dioxins).
  - ◊ Products should use consumables that can be optimized relative to the product's functionality.
  - ◊ Select materials for NIE transmission infrastructure that avoid chromated copper arsenate and creosote oils; have lower eco-impacting metals and finishes; and have materials with high recycled content; cables and wires avoid use of PVC plastic.

5.5 Emissions

The material in this checklist refers to section 2.1.3.2.4.

Has the product's potential emissions been evaluated in the design process for the following?

- Product meets applicable regulatory requirements and international standards regarding emissions to the environment.
- Chemical emissions – reduce chemical emissions with adverse environmental impact.
- Noise emissions – reduce noise emissions (which typically improve energy efficiency).

5.6 Batteries

The material in this checklist refers to sections 2.1.3.2.5 and 3.1.3.2.

If the product design includes batteries, has the design been assessed for the following?

- Product containing batteries meets applicable regulatory requirements and international standards.
- Consider products that need to include batteries to:
  - ◊ Use battery materials with reduced environmental impacts, i.e. Lithium-ion, nickel-metal hydride, and battery materials that are recyclable.
  - ◊ Design battery compartment such that batteries can be identified and removed/replaced easily without tools.
  - ◊ Design batteries that are not permanently attached (e.g. soldered to the PWB or any other component of the product).
  - ◊ Battery management features that help to prolong battery life.
  - ◊ Consider alternatives to back up batteries, e.g. flash memory.
  - ◊ Evaluate measures to prevent /detect battery failure and potential rupture, which may pose safety or environmental issues.
  - ◊ Provide battery compartments with adequate ventilation and cooling.
  - ◊ Provide temperature and voltage monitoring, particularly for parallel strings of batteries.
  - ◊ Provide battery high temperature alarms and low float voltage alarms (for large storage batteries).
  - ◊ Include an inspection and maintenance schedule – with decreased maintenance intervals (i.e. more frequent maintenance) in warmer climates.

5.7 Product packaging/packing

The material in this checklist refers to sections 2.1.3.2.6 and 3.1.3.3.

For the design of a product's packaging/packing, have the following environmental issues been evaluated/considered?

- Product packaging/packing meets applicable environmental regulatory requirements and international standards.
- Conformance with the following restricted materials:
  - ◊ Asbestos (CAS# 1332-21-4 and others) and asbestos-containing materials
  - ◊ Cadmium (CAS# 7440-43-9) and cadmium compounds
  - ◊ Copper chromium arsenate pressure treated wood
  - ◊ CFCs – CFC 11, CFC 12, CFC 13, CFC 111, CFC 112, CFC 113, CFC 114, CFC 115, CFC 211, CFC 212, CFC213, CFC 214, CFC 215, CFC 216, & CFC 217
  - ◊ Selected chlorinated hydrocarbons, and all their isomers:
  - ◊ Carbon tetrachloride (CAS# 56-23-5)
  - ◊ Methyl chloroform/1,1,1 trichloroethane (CAS# 71-55-6)
  - ◊ Hexavalent chromium compounds (CAS# varies)
  - ◊ Lead (CAS# 7439-92-1) and lead compounds
  - ◊ Mercury (CAS# 7439-97-6) and mercury compounds
  - ◊ CFCs/hydrochlorofluorocarbons (HCFCs)
  - ◊ Cobalt dichloride
  - ◊ Dimethylfumarate (DMF) – used in silica gels
  - ◊ Sum of heavy metals concentrations (cadmium, hexavalent chromium, lead and mercury) present as incidental or background contamination does not exceed 100 parts per million (ppm) by weight in any packaging or packaging component.
- Material design and selection – use preferred materials: e.g. natural craft corrugated fiberboard, wood, plywood recommended instead of bleached white corrugated fibreboard. Also use high recycled content corrugated fibreboard over other materials of original resource content or plastics derived from non-renewable/limited resources. Avoid the following materials:

- ◊ Plastics that contain flame retardants additives, particularly those that contain brominated flame retardants
  - ◊ Chlorine-based plastics that produce dioxins when improperly incinerated, such as PVC (use of PVC in product packaging is prohibited in some countries)
  - ◊ Foams that are blown with chlorofluorocarbons (CFC-blown)
  - ◊ Thermosets such as polyurethane and foam-in-place urethane
  - ◊ Packaging materials that require special solvents for cleaning or removing labels and markings
  - ◊ Polystyrene (PS) and expanded polystyrene foam (EPS).
- Design and use of reusable packaging/packing.
- Design packaging/packing for disassembly and recycling; and marking/labelling of packaging to facilitate recycling (e.g. EU – Green Dot symbol).
- Optimize transportation by designing for pallet loading requirements, mode of transport, handling requirements, etc.
- Consider packaging that is stackable or easily broken down to reduce the volume of stored or transported packaging materials.

5.8 Designing for end-of-life treatment

The material in this checklist refers to sections 2.1.3.2.7, 2.4 and 3.4.

Has the product's design taken into consideration aspects related to its end-of-life (EoL) treatment, as follows?

- Assure compliance with applicable EoL treatment regulatory requirements, e.g. WEEE in the European Union, and with international standards, e.g. ISO 11469, ISO 1993 (plastics marking for EoL treatment).
- Positive impacts of EoL treatment based on the product being fully recycled and resulting in reduced natural resource consumption for materials/substances used to manufacture new equipment.
- Conform to general EoL principles, such as:
  - ◊ easy and safe separation of parts containing hazardous substances and preparations;
  - ◊ materials (including electronic modules) connected to the case, housing parts or chassis, intended for different end-of-life treatment, should be easily separable;
  - ◊ disassembly down to the module level (for example, power supply, disk drive, circuit board) should be possible using commonly available tools and all such modules should be easily accessible;
  - ◊ mark type of polymer, copolymer, polymer blends or alloys of plastic parts, including additives weighing 25 g or more and with a flat area of 200 mm^2 or more, in conformance with ISO 11469.
- Size and weight of products – make the product more lightweight for less eco-impact from EoL transport, and more manageable for product disassembly and handling.
- Finishes (coatings/surface treatments) should avoid materials that inhibit recycling.
- Enable disassembly, separation and purification (per section 4.3 – Best practices).

5.9 Design for manufacturing

The material in this checklist refers to sections 2.2 and 3.2.

Has the product designer considered the general principle for eco-efficient manufacturing – minimize resource consumption in production and transport of the ICT product? Has the designer further considered the following?

- Specify lightweight materials and components.

- Specify materials that do not require additional surface treatment.
- Structure the product to avoid rejects and minimize material waste in production.
- Minimize the number of components.
- Specify materials with low-intensity production.
- Specify clean, high-efficiency production processes.
- Simplify as few manufacturing steps as possible.
- Use minimal resources in transporting materials, components, sub-assemblies and finished products.

5.10 Smart usage

The material in this checklist refers to sections 2.3 and 3.3.

Has the following best environmental practices been considered for the use of the installed ICT product?

- Ensure efficiency of resources consumed within the product's use stage.
- Follow guidance for establishing a green data center, if applicable.
- Employ energy efficiency measurement methods for data center equipment, if applicable.
- Monitor real-time energy consumption to assess energy sources – with interest in renewable energy sources.
- Conform to ETSI TR 102 530 guidelines regarding power distribution (low and high voltage) and AC/DC power systems.
- ICT infrastructure equipment consolidation – with interest in improving energy efficiency through higher levels of utilization.
- Energy proportional design – achieve such proportionality through technical improvements such as standby/sleep/hibernation modes and the use of multi-core CPUs.
- Cooling – consider recommendations for thermal management.
- Servicing – minimize degree of routine servicing, e.g. remote servicing/software upgrades.

6 Conclusions

This document on sustainable products points to the deep challenges that today's product designers face in creating products that have the least environmental impacts, from design and development, through to manufacture, use, recovery and recycling. By focusing on environmentally-conscious design, this document provides a template for the kind of framework that a designer can use, including taking advantage of the best practices captured in existing standards and guidelines.

Clearly, what is needed for ICT designers to take advantage of this is the following:

Foster environmental intelligence

Possibly due to time constraints, lack of knowledge and/or lack of resources, few ICT designers have been adequately exposed to the fundamental concepts of environmentally-conscious design. A new wave of designers needs to build environmental intelligence in to their core work.

Design relationships, not objects

A key thread throughout the document is how decisions made at one stage of the life cycle impact many or all other stages. As a result, ICT designers need to consider the relationships that are created and mediated as a result of their design work. These relationships cover manufacturing, sourcing, sales, use, reuse, recycling, and recovery. Environmentally-conscious designers will need to keep this web of relationships in focus as they seek to minimize the environmental impacts of their products.

Balance qualitative and quantitative decisions

There is a risk that designers who focus entirely on environmental metrics, checklists and/or regulations could end up ignoring the basic principles of artistic and pragmatic design. This needs new perspectives in the design community on how the theories and structures of environmentally-conscious design can be illuminated with good traditional design practice.

6.1 Suggestions to ITU-T SG 5

During the development of this document, the following issues have been identified as future work recommendations for the ITU-T Study Group 5:

- **Full sustainable design** – This document on product sustainability currently addresses only the environmentally conscious aspects of an ICT product's total life cycle. As they only address the environmental considerations for product design, they stop short of full sustainable design, which would encompass social and ethical aspects. The suggestion is that SG 5 initiates studies and evaluations for the next step of integrating social and ethical aspects into the overall toolkit.
- **Efficient tools and sustainability data** – Life cycle assessment is a key method to helping designers evaluate an ICT product and determine opportunities to improve on its measurements and performance. As such, the suggestion is for the further development of tools and their associated databases that support designers in their development of ICT products for a low carbon society, i.e. tools that promote more efficient and simplified approaches to deriving eco-impact results. This applies to both the measurement and assessment of the direct eco-impacts associated with the life cycle stages of the product, and also to the enabling effects associated with the ICT product applications and its benefits to helping society attain a sustainable economy and life style.
- **Energy efficient metrics for ICT systems, networks and grids** – As energy efficiency is a critical factor in having the most potential to reduce the eco-impacts of ICT products over their entire life cycle, SG 5 should focus future work on metrics for measuring energy efficiency of ICT products and in their deployment within systems, networks and grids. These latter entities can be quite complex in scope and operation, and therefore need the development and standardization of suitable metrics and tools for their effective evaluation and improvement.
- **Sustainable materials choices** – Materials and their selection and use within ICT products to produce eco-sustainable products is another topic that needs further work. The suggestion is that SG5 should address the development of collective lists of sustainable materials that designers can apply in their product development work. These lists can categorize materials according to their characteristics and sustainable attributes – environmental, social and economic. From this, designers can choose appropriate materials and also provide labelling indicating such choices – or in reverse, list any product materials that are not on the sustainable lists.
- **Materials recycling advancements** – Recycling materials needs to be further emphasized, with information being provided to recycling entities that would help create an understanding of the major types and classes of materials that are within a particular product family. This can be emphasized with certain key materials such as precious metals, rare metals/rare earth metals. Further research into the recycling and reuse of plastics within the ICT product can also be addressed by SG5. This would include the use of bio-plastics and their full life cycle evaluation as a substitute for more traditional fossil fuel based plastics.

7 Glossary

3GPP	3rd Generation Partnership Project
ABS	Acrylonitrile Butadiene Styrene
AC	Alternating Current
Ag	Silver
ASIC	Application Specific Integrated Circuit
ASTM	American Society for Testing and Materials
ATIS	Alliance for Telecommunications Industry Solutions
BGA	Ball Grid Array
BS	British Standards
BSI	British Standards Institute
C2C	Cradle-to-Cradle
CAS	Chemical Abstracts Service
CCA	Chromated Copper Arsenate
CE	Circular Economy
CE	Consumer Electronics
CFC	Chlorofluorocarbons
CFR	Code of Federal Regulations (of the USA)
CO_2	Carbon Dioxide
CPE	Customer Premises Equipment
CPU	Central Processing Unit
CSCI	Climate Savers Computing Initiative
DC	Direct Current
DCiE	Data Center infrastructure Efficiency
DCP	Data Center Productivity
DFE	Design-for-Environment
DIP	Dual Inline Package
DMF	Dimethylfumarate
DOT	Department of Transportation (of the USA)
EC	European Commission
ECD	Environment Conscious design
ECMA	European Computer Manufacturers Association
EEPROM	Electrically Erasable Programmable Read Only Memory
EMS	Environmental Management System
EN	European Standard
EPD	Environmental Product Declaration

EPS	Expanded Polystyrene (foam)
ErP	Energy-related Products (European Union Directive)
ESD	Electrostatic Discharge
ETNO	European Telecommunications Network Operators (association)
ETSI EN	ETSI European Standard
ETSI TR	ETSI Technical Requirements
ETSI	European Telecommunications Standards Institute
EU	European Union
EuP	Energy-using Products (European Union Directive)
FPGA	Field Programmable Gate Array
GHG	Greenhouse Gas
GHGP	Greenhouse Gas Protocol (of the WRI)
GPON	Gigabit Passive Optical Network
GSC	Green Supply Chain
HCFC	Hydrofluorocarbons
HDPE	High-density Polyethylene
HVAC	Heating, Ventilation and Air Conditioning
IATA	International Air Transportation Association
IC	Integrated Circuit
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
ILCD	International Reference Life Cycle Data System
ISO	International Standards Organization
ISPM	International Standard for Phytosanitary Measures
ITU	International Telecommunication Union
JIG	Joint Industry Guide
JTC	Joint Technical Committee (of ISO)
LAN	Local Area Network
LCA	Life Cycle Assessment
LCT	Life Cycle Thinking
LDPE	Low-density Polyethylene
LED	Light Emitting Diode
Li-ion	Lithium ion (battery)
N_2O	Di-nitrogen Oxide
NGO	Non-Governmental Organization

NH_3	Ammonia
Ni/Ag	Nickel – Gold
NIE	Network Infrastructure Equipment
NiMH	Nickel-Metal Hydride (battery)
NIPP	Network Interface, Power and Protection
NO_x	Nitrogen Oxides (various forms)
OEM	Original Equipment Manufacturer
PAS	Publicly Available Specification (of BSI)
PBB	Polybrominated Biphenyl
PBDE	Polybrominated Diphenyl ether
PC	Personal Computer (ICT device)
PC	Polycarbonate (plastic)
PE	Polyethylene
PE(LD)	Polyethylene (low density)
PET	Polyethylene Terephthalate
PHA	Polyhydroxy-alkanoates
PLCC	Plastic Leaded Chip Carrier
PP	Polypropylene
PRC	Peoples Republic of China
PS	Polystyrene
PSU	Power Supply Unit
PSWG	Product Sustainability Work Group (of the ITU-T)
PUE	Power Usage Effectiveness
PVC	Polyvinyl Chloride
PWB	Printed Wiring Board
QFP	Quad Flat Pack
REACH	Restriction, Evaluation and Authorization of Chemicals
RESY	Recycling Symbol
RoHS	Restriction of certain Hazardous Substances
SAN	Styrene Acrylonitrile
SG5	Study Group 5 (of the ITU-T)
SO_x	Sulfur Oxides (various forms)
TC	Transmission Convergence
TEER	Telecommunications Energy Efficiency Ratio
TSOP	Thin Small Outline Package
UK	United Kingdom

UL	Underwriters Laboratories
USA	United States of America
USC	United States Code
USEPA	United States Environmental Protection Agency
VRLA	Valve Regulated Lead-Acid (batteries)
WEEE	Waste Electrical and Electronic Equipment (European Union Directive)
WRI	World Resources Institute

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Sustainable buildings

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Table of contents

Page

Sustainable buildings

Executive summary

In most countries, buildings are the largest driver for both energy use and CO2 emissions. Europe's buildings use over 40% the continent's energy and are responsible for 40% of its carbon emissions. In the US, the corresponding figures are even larger, with buildings accounting for 48% of total US GHG emissions.

Among developing countries, the share of buildings in total energy use and emissions is much lower, with China's buildings, for example, representing a 10% share of that nation's energy use. But rapid economic growth and industrialization in these countries is pushing a booming construction sector. As a result, by 2030, Asian countries are expected to contribute a third of worldwide GHG emissions. Consequently, the challenge to reduce the energy and GHG footprints of new and existing buildings is a very serious one.

ICT companies build and operate facilities that can demand large amounts of energy and material use in all phases of the life cycle. Managing their environmental impacts on their buildings results in economic benefits and helps them meet their societal obligations.

Applying sustainability management to buildings requires work under three main headings: construction, lifetime use and decommissioning. Throughout these stages, the three-fold objective is to be efficient in the use of resources, protective of the occupants' health and well-being, and reducing the negative impacts, such as waste and pollution.

There are a number of standards, methodologies and tools that have been put in place to assist organizations in delivering excellent environmental performance with regard to their building stock. The document discusses alternative offerings such as LEED, Green Globes, Green Building (Europe), BREEAM, the International Green Construction Code, the German Sustainable Building Council, the Green Building Council of Australia, Estidama from the UAE, and CASBEE from Japan. Apart from design and construction, best practices are also discussed with regard to buildings operation and maintenance, and improvements.

While good design can reduce energy bills by 25%, the initial capital costs may not be the lowest. In order to deal with a narrow economic outlook, some designers and owners have started using life cycle assessment as a scientific evaluation of actual performance, rather than simply buying into certain prescribed practices.

1 Introduction

In most countries, buildings are the largest driver for both energy use and CO_2 emissions. The approximately 160 million buildings of the EU, for example, are estimated to use over 40% of Europe's energy and to drive over 40% of its carbon dioxide emissions. According to the US Energy Information Administration, the share of energy and greenhouse gas (GHG) emissions associated with buildings is even larger in the US, amounting to 48% of total emissions.

In several developed countries, emissions from buildings, and their proportion on total emissions, have been steadily increasing over the last fifty years. Larger sized buildings and an increasing number of energy-using appliances within these buildings have been the main drivers for such growth.

In developing countries, on the other hand, the share of buildings on total energy use and emissions is much lower (e.g. in the order of 10% of the total in China). However, with rapid industrialization and urbanization, energy use and the GHG emissions associated with buildings are increasing rapidly in those developing countries where dramatic economic growth is associated with a booming construction sector. A significant number of new buildings are therefore added every year in many developing countries. In the 2000-2005 periods, for example, China added about 6.5 billion square meters of new residential buildings.

Projections for GHG emissions associated with buildings estimate that worldwide GHG emissions will reach about 15 billion CO_2 by 2030, with Asian countries contributing to about 1/3 of such emissions.

Reducing the energy and GHG footprint in both existing and new buildings represents therefore a key challenge and opportunity to tackle global warming.

ICT companies build and operate facilities that can demand large amounts of energy and material consumption in all phases of the life cycle. Increasing energy efficiency is always a key goal for ICT companies and it can begin with the facilities themselves. There are numerous schemes that have been adopted globally that can lead to more sustainable design, construction and operation of buildings.

Sustainable building refers to both the structure and a process that is more environmentally responsible during the entire life cycle of a building. These life cycle stages are:

- site selection;
- design;
- construction;
- operation and maintenance;
- renovation;
- demolition.

Looking at it more broadly, it could possibly be combined under three main headings:

1. Construction – site selection, design, construction
2. Lifetime use – operation and maintenance
3. Decommissioning – renovation and demolition.

New building technologies, and in particular ICT automation and new materials, are constantly being introduced to enhance the sustainable building process with the goal of reducing the impact of the building on the surrounding environment by:

- using resources more efficiently (e.g. energy, water);

- enhancing and protecting the health and well-being of the occupants;
- reducing negative impacts (e.g. waste, sewage, pollution).

Sustainable buildings optimize one or all of these objectives during all phases of the life cycle.

Sustainable or "green" building codes and assessment schemes have been developed on a global basis to give guidance on the factors to review during a building's life cycle that enhance sustainability and minimize environmental impact.

As an example, the Leadership in Energy and Environmental Design (LEED) standards have seen great adoption within the North American market in particular. LEED standards are guidelines to designing, building and operating more environmentally friendly buildings.

A final step in almost all sustainable or "green" building codes and schemes is an independent assessment to determine whether a building has met the requirements of a scheme and a final ranking that demonstrates how sustainable a building has been built or is being operated.

Using LEED as an example, a building can be rated as Platinum, Gold, Silver or Certified after an assessment.

To a large degree, decisions made at the budgeting, design, procurement and construction stages of a development affect the success of the building in terms of sustainability outcomes (Great Britain, Dept. of Health, 2011). Therefore, sustainability and its implications for planning and design should be considered at the onset of all new-builds, as the earlier it is considered the more the sustainability benefits are maximized. For example, the on-site layout and form of the building offer the best opportunities to improve environmental benefits without major capital costs. In addition, choices about heating and cooling, which contribute largely to energy use, are important considerations to meet carbon targets (Lockie and Bourke, 2009). Failure to take sustainability into account at the onset can result in costly alterations having to be made at a later stage and opportunities missed to include sustainable measures into the design and structure of the building.

1.1 Target audience

This document gives an overview of green building design and construction specifications according to a number of global standards. The section explores different areas of concern with regards to developing more environmentally friendly buildings.

Its content is appropriate for any company in the ICT sector that:

- designs and builds facilities, including data centers;
- operates and maintains facilities;
- is looking to add green procurement criteria to building and space procurement process.

There are many business benefits for deciding to pursue a strategy and process for sustainable buildings. These benefits can be:

- lower operating costs;
- higher return on investment;
- greater tenant attraction;
- enhanced marketability;
- productivity benefits;
- reduced liability and risk;

- a healthier place to live and work;
- demonstration of a commitment to corporate social responsibility;
- future proofed assets;
- competitive advantages.

2 Design and build specifications

2.1 Overview

Sustainable buildings are structures that are built in an environmentally responsible manner by maximizing use of materials, minimizing use of resources and ensuring the health and well-being of occupants and the surrounding built environment both today and for generations to come.

With respect to the LEED guidelines (and this is consistent with almost all other "green" building guidelines), there are seven topics that should be addressed in the designing and building of new environmentally friendly buildings.

1) **Sustainable sites**: Sites should be selected by determining which site would pose the least environmental threat if construction were to take place. Pollution prevention including controlling soil erosion, waterway sedimentation and airborne dust generation are important factors to be considered. Sites should also be chosen that are closer to urban development where supporting infrastructure is available; this will preserve green spaces and wildlife areas. The redevelopment of brownfields would be preferential as no new land is needed. Alternative transportation is another important factor to consider. The availability of public transport, bicycle parking and shower facilities can minimize the GHG emissions associated with travel to a building. Other factors that promote sustainability would be, for example, preferential parking for low-emission vehicles and/or hybrids. Biodiversity can be promoted by designing large amounts of open space in the new building complexes. Another factor are the water management systems that take into account the natural environment design for storm-water systems to ensure proper management of water. Reduction of the heat island effects from roofs and parking lots as well as the reduction of light pollution is another factor that should be taken into account to promote sustainability.
2) **Water efficiency**: The main goal is to increase water efficiency use within the building, thereby reducing the amount of water needed for operations. Some methods which can be designed in a building include water efficient landscaping to reduce irrigation requirements and the use of innovative wastewater management technologies.
3) **Energy and atmosphere**: Energy systems should be properly installed and calibrated to perform to their intended efficiency levels. This should reduce the overall energy use and lower operating costs. A minimum level of acceptable energy performance for the facility should be determined and monitored. A refrigerant management system to reduce refrigerant losses and resulting potential ozone depletion. Various methods for on-site renewable energy production can reduce the overall footprint of the building and other means of using green power. Methods to monitor, verify and continually improve on energy consumption are key to ensuring that energy performance is maintained. In the UK, it is estimated that construction is responsible for 50% of the emissions of greenhouse gases and 60% of that emission is attributable to space heating of buildings. Buildings also use energy in the heating of water, lighting, mechanical ventilation and machinery such as lifts
4) **Materials and resources**: The construction process is highly energy dependent, particularly through the manufacture and **transport** of materials. (Morton R., 2009). The amount of landfill waste created during construction and operation can be reduced by efficient use of materials and designing for recycling. Specifying used construction materials can reduce the need for virgin materials. Specifying materials that are locally sourced, that come from certified sustainable sources (e.g. Forest

Stewardship Council (FSC) forest products), that contain recycled materials or are rapidly renewable enhances overall environmental sustainability and lowers the embedded carbon footprint of a building.

5) **Indoor environmental quality**: To enhance the well-being of occupants, design should use low emitting materials in construction including sealants, adhesives, paints, coatings, flooring, wood and agrifibre. Ventilation systems that promote outdoor air ventilation are preferable and should not allow for outside pollution to enter the building, if possible. Buildings should be designed to maximize the use of natural light for all occupants. Lighting and heating systems should be designed to manually or automatically turn off to reduced energy consumption.

6) **Innovation in design**: Design decisions should be made early in the process as good design can greatly reduce the energy consumption of a building; for example, the orientation and location of a building can compromise shading and ventilation decisions. This part of the assessment encourages and rewards design and construction methods that are particularly innovative. Since there are no real criteria, this allows for architects and contractors to experiment and innovate and receive credit in the scoring system.

The UK guidance below proposes[1] that a Low Carbon Design Taskforce should be created and that this taskforce could develop a blueprint that focuses on four levels in design:

- site selection – transport and integration with other services;
- orientation – to maximize daylight, shade, and ventilation naturally;
- thermal issues – shape, density, materials and systems for winter heating and summer cooling;
- use of renewable forms of energy.

7) **Regional priority**: Designs should be maximized to take into account regional priorities. In colder climates, buildings could be designed to maximize heating efficiency; in hotter climates, cooling and water usage would gain more importance in the design process.

Green buildings are designed to minimize their environmental footprint and, at the same time, improve the well-being of the persons who live, work and play in those buildings:

"While improved building performance significantly reduces resource use, effective urban planning reduces a city's overall environmental impact by reducing the movement of people between buildings and pressure on municipal infrastructure."[2]

2.2 Standards

2.2.1 LEED

The U.S. Green Building Council (USGBC) is a Washington, D.C.-based organization that was established to develop a cost-efficient and energy-saving green building process to enhance economic prosperity and sustainability. USGBC works toward its mission of market transformation through the LEED green building certification programme, a wide range of educational offerings, advocacy work in support of green buildings and communities and a network of chapters and affiliates to engage all interested stakeholders in the process.

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[1] Great Britain National Health Service, Sustainable Development Unit Saving carbon improving health: NHS carbon reduction strategy for England, 2009, NHS Sustainable Development Unit, Great Britain National Health Service, www.sdu.nhs.uk/documents/publications/1237308334_qylG_saving_carbon,_improving_health_nhs_carbon_reducti.pdf.

[2] www.vancouvereconomic.com/userfiles/file/green-building-profile.pdf.

The LEED® green building certification programme is a voluntary, consensus-based national rating system for buildings designed, constructed and operated for improved environmental and human health performance. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality.[3]

Prerequisites and credits in the LEED 2009 for New Construction and Major Renovations address seven topics:

- sustainable sites (SS);
- water efficiency (WE);
- energy and atmosphere (EA);
- materials and resources (MR);
- indoor environmental quality (IEQ);
- innovation in design (ID);
- regional priority (RP).

Figure 1: LEED 2009 for New Constructions and Major Renovations: Prerequisites and Credits	
SS Prerequisite 1: Construction activity pollution prevention	To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation.
SS Credit 1: Site selection	To avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site.
SS Credit 2: Development density and community connectivity	To channel development to urban areas with existing infrastructure, protect green fields, and preserve habitat and natural resources.
SS Credit 3: Brownfield redevelopment	To rehabilitate damaged sites where development is complicated by environmental contamination and to reduce pressure on undeveloped land.
SS Credit 4.1: Alternative transportation – Public transportation access	To reduce pollution and land development impacts from automobile use.
SS Credit 4.2: Alternative transportation – Bicycle storage and changing rooms	To reduce pollution and land development impacts from automobile use.
SS Credit 4.3: Alternative transportation – Low-emitting and fuel-efficient vehicles	To reduce pollution and land development impacts from automobile use.
SS Credit 4.4: Alternative transportation – Parking capacity	To reduce pollution and land development impacts from automobile use.
SS Credit 5.1: Site development – Protect or restore habitat	To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.
SS Credit 5.2: Site development – Maximize open space	To promote biodiversity by providing a high ratio of open space to development footprint.
SS Credit 6.1: Storm-water design – Quantity control	To limit disruption of natural hydrology by reducing impervious cover, increasing on-site infiltration, reducing or eliminating pollution from storm-water run-off and eliminating contaminants.

[3] www.usgbc.org/Default.aspx.

SS Credit 6.2: Storm-water design – Quality control	To limit disruption and pollution of natural water flows by managing storm-water run-off.
SS Credit 7.1: Heat island effect – Non-roof	To reduce heat islands to minimize impacts on microclimates and human and wildlife habitats.
SS Credit 8: Light pollution reduction	To minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve night-time visibility through glare reduction and reduce development impact from lighting on nocturnal environments.
WE prerequisite 1: Water use reduction	To increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.
WE Credit 1: Water efficient landscaping	To limit or eliminate the use of potable water or other natural surface or subsurface water resources available on or near the project site for landscape irrigation.
WE Credit 2: Innovative wastewater technologies	To reduce wastewater generation and potable water demand while increasing the local aquifer recharge.
WE Credit 3: Water use reduction	To further increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.
EA prerequisite 1: Fundamental commissioning of building energy systems	To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents. Benefits of commissioning include reduced energy use, lower operating costs, fewer contractor callbacks, better building documentation, improved occupant productivity and verification that the systems perform in accordance with the owner's project requirements.
EA prerequisite 2: Minimum energy performance	To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.
EA prerequisite 3: Fundamental refrigerant management	To reduce stratospheric ozone depletion.
EA Credit 1: Optimize energy performance	To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.
EA Credit 2: On-site renewable energy	To encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use.
EA Credit 3: Enhanced commissioning	To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.
EA Credit 4: Enhanced refrigerant management	To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.
EA Credit 5: Measurement and verification	To provide for the ongoing accountability of building energy consumption over time.
EA Credit 6: Green power	To encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis.
MR Prerequisite 1: Storage and collection of recyclables	To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.
MR Credit 1.1: Building reuse – maintain existing walls, floors and roof	To extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to material manufacturing and transport.

MR Credit 1.2: Building reuse – maintain interior non-structural elements	To extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to material manufacturing and transport.
MR Credit 2: Construction waste management	To divert construction and demolition debris from disposal in landfills and incineration facilities. Redirect recyclable recovered resources back to the manufacturing process and reusable materials to appropriate sites.
MR Credit 3: Materials reuse	To reuse building materials and products to reduce demand for virgin materials and reduce waste, thereby lessening impacts associated with the extraction and processing of virgin resources.
MR Credit 4: Recycled content	To increase demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials.
MR Credit 5: Regional materials	To increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation.
MR Credit 6: Rapidly renewable materials	To reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials.
MR Credit 7: Certified wood	To encourage environmentally responsible forest management.
IEQ prerequisite 1: Minimum indoor air quality performance	To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.
IEQ Prerequisite 2: Environmental tobacco smoke (ETS) control	To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS).
IEQ Credit 1: Outdoor air delivery monitoring	To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.
IEQ Credit 2: Increased ventilation	To provide additional outdoor air ventilation to improve indoor air quality (IAQ) and promote occupant comfort, well-being and productivity.
IEQ Credit 3.1: Construction indoor air quality management plan – during construction	To reduce indoor air quality (IAQ) problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants.
IEQ Credit 3.2: Construction indoor air quality management plan – before occupancy	To reduce indoor air quality (IAQ) problems resulting from construction or renovation to promote the comfort and well-being of construction workers and building occupants.
IEQ Credit 4.1: Low-emitting materials – adhesives and sealants	To reduce the quantity of indoor air contaminants that is odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.
IEQ Credit 4.2: Low-emitting materials – paints and coatings	To reduce the quantity of indoor air contaminants that is odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.
IEQ Credit 4.3: Low-emitting materials – flooring systems	To reduce the quantity of indoor air contaminants that is odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.
IEQ Credit 4.4: Low-emitting materials – composite wood and agrifibre products	To reduce the quantity of indoor air contaminants that is odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

IEQ Credit 5: Indoor chemical and pollutant source control	To minimize building occupant exposure to potentially hazardous particulates and chemical pollutants.
IEQ Credit 6.1: Controllability of systems – lighting	To provide a high level of lighting system control by individual occupants or groups in multi-occupant spaces (e.g. classrooms and conference areas) and promote their productivity, comfort and well-being.
IEQ Credit 6.2: Controllability of systems – thermal comfort	To provide a high level of thermal comfort system control37 by individual occupants or groups in multi-occupant spaces (e.g. classrooms or conference areas) and promote their productivity, comfort and well-being.
IEQ Credit 7.1: Thermal comfort – design	To provide a comfortable thermal environment that promotes occupant productivity and well-being.
IEQ Credit 7.2: Thermal comfort – verification	To provide for the assessment of building occupant thermal comfort over time.
IEQ Credit 8.1: Daylight and views – daylight	To provide building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.
IEQ Credit 8.2: Daylight and views – views	To provide building occupants a connection to the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.
ID Credit 1: Innovation in design	To provide design teams and projects the opportunity to achieve exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.
Id Credit 2: Leed accredited professional	To support and encourage the design integration required by LEED to streamline the application and certification process.
RP Credit 1: Regional priority	To provide an incentive for the achievement of credits that address geographically-specific environmental priorities.

2.2.2 Green Globes

The Green Globes system[4] is a building environmental design and management tool through an online assessment protocol, rating system and guidance for green building design, operation and management. It is an interactive tool and provides market recognition of a building's environmental attributes through third-party verification.

The Green Globes assessment and rating system is the result of more than eleven years of research and refinement by a wide range of prominent international organizations and experts.

The genesis of the system was the Building Research Establishment's Environmental Assessment Method (BREEAM). In 1996, the Canadian Standards Association (CSA) published BREEAM Canada for Existing Buildings. More than 35 individuals participated in its development, including representatives from federal and provincial departments, the National Research Council and University of Toronto.

In 2000, the system took a leap forward in its evolution, becoming an online assessment and rating tool under the name Green Globes for Existing Buildings. Also in that year, the Canadian Department of National Defense and Public Works and Government Services supported the development of a system for the Design of New Buildings. The product underwent a further iteration in 2002 by a team of experts including representatives from Arizona State University, the Athena Institute, BOMA (Building Owners and Managers

[4] www.greenglobes.com/about.asp.

Association of Canada) and several federal departments including Public Works and Governments Services, and Natural Resources Canada.

In 2004, Green Globes for Existing Buildings was adopted by BOMA, where it now operates under the name BOMA BESt. In addition, the Green Building Initiative (GBI) acquired the rights to distribute Green Globes in the United States. GBI has committed to continually refine the system to ensure that it reflects ongoing advances in research and technology, by involving stakeholders in an open and transparent process. The Green Globes system has also been used by the Continental Association for Building Automation (CABA) to power a building intelligence tool, called Building Intelligence Quotient (BiQ).

To that end, in 2005, GBI became the first green building organization to be accredited as a standards developer by the American National Standards Institute (ANSI). The GBI ANSI technical committee was formed in early 2006 and the official Green Globes ANSI standard was published in 2010.

Today, the Green Globes system is used by large developers and property management companies, including, the Canadian federal government, which has adopted the programme for its entire real estate portfolio.[5]

2.2.3 Green Building (Europe)

In its Green Paper on Energy Efficiency, the European Commission (EC) identified the building sector as an area where important improvements in energy efficiency can be realized. According to the Green Paper, the building sector accounts for more than 40% of the final energy demand in Europe. At the same time, improved heating and cooling of buildings constitutes one of the largest potentials for energy savings. Such savings would also improve the energy supply security and the EU's competitiveness, while creating jobs and raising the quality of life in buildings.

The Green Building Programme[6] (GBP) is a voluntary programme that started in 2005. It is meant to enhance the realization of cost-effective energy efficiency potentials by creating awareness and providing information support and public recognition to companies the top management of which is ready to show actual commitment to adopt energy efficient measures in non-residential buildings.

These are the important requirements for participation:

- an Energy Audit;
- an Action Plan;
- execution of the Action Plan;
- commitment to report energy consumption on a regular basis.

The GBP is managed by the European Commission Directorate General (DG) Joint Research Council (JRC), which sets the rules and the structure of the programme and is responsible for the final acceptance of GB Partners and GB Endorsers.

GBP provides documents ("Modules") defining the technical nature of an appropriate commitment for each energy service covered in the programme. The modules are complemented by Guidelines on horizontal issues, such as "Financing", "Energy Audit" and "Energy Management".

5 www.greenglobes.com/about.asp.

6 www.eu-greenbuilding.org/.

GBP encourages its Partners to tap a large reservoir of profitable investments without the need for specific incentives from the Commission. GBP investments use proven technology, products and services for which efficiency has been demonstrated.

Being a Green Building Partner gives a company the chance of presenting its actions for its organization's and the world's sustainable future to the broad public. The company will be an important multiplier to encourage other organizations to follow suit.

The benefits are:

- Recognition and approval of the action for enhancing the energy efficiency of the building stock by the European Commission
- Competitive advantages as an organization being certified for its responsibility in the field of energy efficiency
- Presentation and communication of the organization and the Good-Practice-Example within the public relations of the GB Programme.

GBP will be complementary to the Building Energy Performance Directive as it will stimulate additional savings in the non-residential building sector.

2.2.4 BREEAM – Europe

BRE Environmental Assessment Method (BREEAM[7]) is a voluntary measurement rating for green buildings that was established in the UK by the Building Research Establishment (BRE).

BREEAM is one of the world's foremost environmental assessment methods and rating systems for building. There are over 200 000 buildings with certified BREEAM assessment ratings and over a million registered for assessment since it was first launched in 1990.

BREEAM sets standards for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognized measures of a building's environmental performance.

A BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. They include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and management processes.

BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties.

BREEAM:

- uses a straightforward scoring system that is transparent, flexible, easy to understand and supported by evidence-based science and research;
- has a positive influence on the design, construction and management of buildings;
- defines and maintains a robust technical standard with rigorous quality assurance and certification.

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7 www.breeam.org/page.jsp?id=66

Figure 2: Issues covered in BREEAM Handbook for New Construction BREEAM Handbook for New Construction[8]	
Energy	**Water**
Reduction of CO_2 emissions	Water consumption
Energy monitoring	Water monitoring
Energy efficient external lighting	Water leak detection and prevention
Low or zero carbon technologies	Water efficient equipment (process)
Energy efficient cold storage	**Waste**
Energy efficient transportation systems	Construction waste management
Energy efficient laboratory systems	Recycled aggregate
Energy efficient equipment (process)	Operational waste
Drying space	Speculative floor and ceiling finishes
Transport	**Materials**
Public transport accessibility	Life cycle impacts
Proximity to amenities	Hard landscaping and boundary protection
Cyclist amenities	Responsible sourcing of materials
Maximum car parking capacity	Insulation
Travel plan	Designing for robustness
Land use and ecology	**Pollution**
Site selection	Impact of refrigerants
Ecological value of site / protection of ecological features	NO_x emissions from heating/cooling source
Mitigating ecological impact	Surface water run-off
Enhancing site ecology	Reduction of night-time light pollution
Long-term impact on biodiversity	Noise attenuation
Health and well-being	**Management**
Visual comfort	Sustainable procurement
Indoor air quality	Responsible construction practices
Thermal comfort	Construction site impacts
Water quality	Stakeholder participation
Acoustic performance	Service life planning and costing
Safety and security	**Innovation**
	New technology, process and practices

2.2.5 International Green Construction Code

In 2009, the International Code Council launched the development of a new International Green Construction Code (IgCC) initiative, subtitled “Safe and Sustainable: By the Book,” committed to developing a model code focused on new and existing commercial buildings addressing green building design and performance.

8 www.breeam.org/BREEAM2011SchemeDocument/.

2.2.6 German Sustainable Building Council (DGNB)

The DGNB[9] focuses heavily on the establishment and further development of its certification system. As a tool for the assessment and certification of sustainable buildings, it is one of the leading systems worldwide, mainly due to its comprehensive quality concept, which takes equal account of economics, ecology, and socio-cultural aspects and is based on a holistic view of the building's entire life cycle. It is therefore possible to define sustainability targets beginning in the planning phase.

The results are anticipated to be future-oriented buildings with high quality standards documented by the DGNB certificate in gold, silver, or bronze. The DGNB System can also be used outside of Germany. Due to its conformity with present and future EU regulations, it is a tool that can ensure high building quality and performance.

The criteria in the DGNB's core system define sustainable building in six fields. The site quality does not play a role in the assessment of the total performance index.

Figure 3: Six criteria in the DGNB assessment	
Ecological quality	
Global warming potential	Ozone depletion potential
Photochemical ozone creation potential	Acidification potential
Eutrophication potential	Risks to the local environment
Other effects on the local environment	Sustainable use of resources/wood
Microclimate	Non-renewable primary energy demand
Total primary energy demand and proportion of renewable primary energy	Other uses of non-renewable resources
Waste by category	Drinking water demand and volume of waste water
Space demand	
Economic quality	
Building related life cycle costs	Suitability for third-party use
Sociocultural and functional quality	
Thermal comfort in winter	Thermal comfort in summer
Interior air hygiene	Acoustic comfort
Visual comfort	User control possibilities
Quality of outdoor spaces	Safety and risk of hazardous incidents
Handicapped accessibility	Space efficiency
Suitability for conversion	Public access
Bicycling convenience	Assurance of design and urban development quality in a competition
Per cent for art	Quality features of use profile
Social integration	
Technical quality	
Fire prevention	Sound insulation
Quality of building envelope with regard to heat and humidity	Building services' backup ability

9 www.dgnb.de/_en/index.php.

Building services' ease of use	Building services' equipment quality
Durability	Ease of cleaning and maintenance
Resistance to hail, storms, and flooding	Ease of dismantling and recycling
Process quality	
Quality of project preparation	Integral planning
Optimization and complexity of planning method	Evidence of sustainable aspects in call for and awarding of tenders
Creation of conditions for optimal use and management	Construction site/construction process
Quality of contractors/pre-qualification	Quality assurance for construction
Commissioning	Controlling
Management	Systematic inspection, maintenance, and servicing
Qualification of operating staff	
Site quality	
Risks in the micro-environment	Conditions in the micro-environment
Public image and condition state of site and neighbourhood	Access to transportation
Proximity to use-specific facilities	Connections to public services (utilities)
Legal situation for planning	Extension options/reserves

2.2.7 Green Building Council of Australia

Launched in 2002, the Green Building Council of Australia (GBCA[10]) is an organization that is committed to developing a sustainable property industry for Australia by encouraging the adoption of green building practices. It is uniquely supported by both the industry and governments across the country.

The Green Building Council's mission is to develop a sustainable property industry for Australia and drive the adoption of green building practices through market-based solutions.

Objectives: Its key objectives are to drive the transition of the Australian property industry towards sustainability by promoting green building programs, technologies, design practices and operations as well as the integration of green building initiatives into mainstream design, construction and operation of buildings.

Green Star is a comprehensive, national, voluntary environmental rating system that evaluates the environmental design and construction of buildings. With more than 4 million square metres of Green Star-certified space around Australia, and a further 8 million square metres of Green Star-registered space, Green Star has transformed Australia's property and construction market.

Green Star was developed for the property industry in order to:

- establish a common language;
- set a standard of measurement for green buildings;
- promote integrated, whole-building design;
- recognize environmental leadership;
- identify building life cycle impacts, and

[10] www.gbca.org.au/.

- raise awareness of green building benefits.

Green Star covers a number of categories that assess the environmental impact that is a direct consequence of a project site selection, design, construction and maintenance. The nine categories included within all Green Star rating tools are:

- management;
- indoor environment quality;
- energy;
- transport;
- water;
- materials;
- land use and ecology;
- emissions;
- innovation.

2.2.8 Estidama – United Arab Emirates

The Abu Dhabi Urban Planning Council (UPC) is recognized internationally for large-scale sustainable urban planning and for rapid growth. Plan Abu Dhabi 2030 urban master plan addresses sustainability as a core principle. Estidama[11], which is the Arabic word for sustainability, is an initiative developed and promoted by the UPC. Estidama is the intellectual legacy of the late Sheikh Zayed bin Sultan Al Nahyan and a manifestation of visionary governance promoting thoughtful and responsible development. The leadership of Abu Dhabi are progressing the principles and imperatives for sustainable development, through Estidama, while recognizing that the unique cultural, climatic and economic development needs of the region require a more localized definition of sustainability.

Estidama is not just a rating method or something people do, it is a vision and a desire to achieve a new sustainable way of life in the Arab world. The ultimate goal of Estidama is to preserve and enrich Abu Dhabi's physical and cultural identity, while creating an always improving quality of life for its residents on four equal pillars of sustainability: environmental, economic, social, and cultural. This touches all aspects of life in Abu Dhabi – the way they build, the way they resource, the way they live, the choices they make – all in an effort to attain a sustainable state of living.

Estidama arose from the need to properly plan, design, construct and operate sustainable developments with respect to the traditions embedded within the rich local culture, on one hand, and the harsh climatic nature of the region on the other. To this end, project owners, developers, design teams and even residents need to think differently about how they approach the design and planning process.

Estidama began in 2009 and is the first programme of its kind that is tailored to the Middle East region. In the immediate term, Estidama is focused on the rapidly changing built environment. It is in this area that the UPC is making significant strides to influence projects under design, development or construction within the Emirate of Abu Dhabi.

Estidama will continually evolve to embrace the rapidly changing concepts for sustainability, and ground them in the environmental, social, cultural, and economic needs of the Gulf Cooperation Council (GCC) region. Estidama sets the path for a bright future for the Emirate, its citizens, its residents and the

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[11] http://estidama.org/?lang=en-US.

generations to follow. Consequently, the success of Estidama will depend on everyone in the Emirate to create a better future for all.

The Pearl Rating System for Estidama aims to address the sustainability of a given development throughout its life cycle from design through construction to operation. The Pearl Rating System provides design guidance and detailed requirements for rating a project's potential performance in relation to the four pillars of Estidama.

The Pearl Rating System is organized into seven categories that are fundamental to more sustainable development. These form the heart of the Pearl Rating System:

- **Integrated development process**: Encouraging cross-disciplinary teamwork to deliver environmental and quality management throughout the life of the project.
- **Natural systems**: Conserving, preserving and restoring the region's critical natural environments and habitats.
- **Liveable buildings**: Improving the quality and connectivity of outdoor and indoor spaces.
- **Precious water**: Reducing water demand and encouraging efficient distribution and alternative water sources.
- **Resourceful energy**: Targeting energy conservation through passive design measures, reduced demand, energy efficiency and renewable sources.
- **Stewarding materials**: Ensuring consideration of the 'whole-of-life' cycle when selecting and specifying materials.
- **Innovating practice**: Encouraging innovation in building design and construction to facilitate market and industry transformation.

2.2.9 CASBEE – Japan

Construction, which consumes and discards resources and energy in enormous quantities, is a field that must be acted upon to develop and promote techniques and policies able to assist the drive towards sustainability.

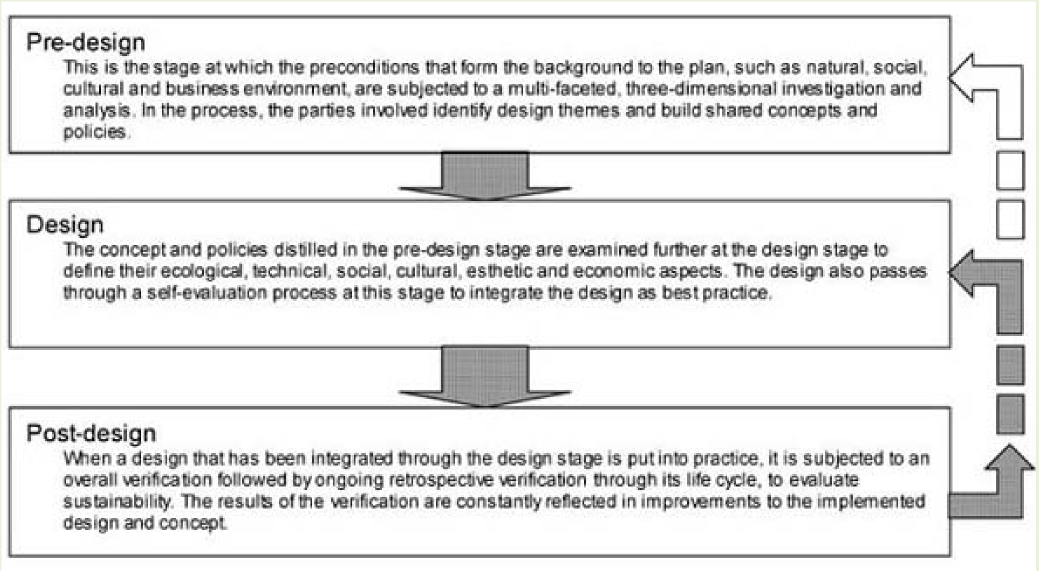
There has been a growing movement towards sustainable construction since the second half of the 1980s, leading to the development of various methods for evaluating the environmental performance of buildings. Methods developed overseas include BREEAM (Building Research Establishment Environmental Assessment Method) in the UK, LEEDTM (Leadership in Energy and Environment Design) in the USA, and GB Tool (Green Building Tool) as international projects. These methods have attracted interest around the world. This kind of assessment, with the publication of the results, is one of the best methods now available to provide an incentive for clients, owners, designers and users to develop and promote highly sustainable construction practices.

CASBEE[12] was developed according to the following policies:

1) The system should be structured to award high assessments to superior buildings, thereby enhancing incentives to designers and others.
2) The assessment system should be as simple as possible.
3) The system should be applicable to buildings in a wide range of applications.
4) The system should take into consideration issues and problems peculiar to Japan and Asia.

[12] www.ibec.or.jp/CASBEE/english/overviewE.htm.

Figure 4: CASBEE - The cyclical process of business design



2.3 Best environmental practices

Case study: Waterfront Toronto Minimum Green Building Requirements –Toronto, Canada

LEED Gold Certification

Intent: To confirm, through third-party certification, that high-level green building performance has been achieved.

Requirements: Achieve Gold certification under LEED® Canada-NC 2009, or the most up-to date version of LEED® Canada-NC at the time of Request for Proposal (RFP) issuance, for all eligible buildings. Must achieve the following credits:

a) WEc1: Water Efficient Landscaping (4 points)

b) WEc3: Water Use Reduction (4 points)

c) EAc1: Optimize Energy Efficiency (50% cost savings relative to Model National Energy Code for Buildings (MNECB) (1997) [excluding process loads and assuming a code compliant heating and cooling plant])

d) EAc2: On-Site Renewable Energy (3% of annual energy cost, 2 points)

e) EAc5: Measurement and Verification (3 points).

Figure 5: Toronto Waterfront: Green Building Requirements

Smart building	To encourage conservation among building residents and occupants by providing them with a means to track and control their utility usage, and to pay for energy based on each suite's actual consumption, and to satisfy the requirements for data transfer associated with the Waterfront Toronto Intelligent Communities (WTIC) network.
Electric vehicle infrastructure	To reduce non-point source emissions associated with automobile use.
Green roof	To create buildings that provide a visual connection between community residents and plant life, provide habitat and increase biodiversity, help reduce the

	urban heat island effect, and contribute to sustainable storm-water management.
Engagement and support	To provide building owners/operators and occupants with the information necessary to operate and maintain the building optimally.
Bicycle parking and storage	To reduce emissions associated with automobile use by supporting effective bicycle infrastructure.
Waste management	To minimize waste going to landfills and to encourage all building residents and occupants to participate in responsible waste management.
District energy	To provide buildings with cost-effective, energy from community-scale clean energy sources.
Community integration	To engage the development team to consider how building design options can positively impact the adjacent buildings and surrounding community.
Long-term flexibility	To provide building characteristics that allow for future changes without structural modifications.
Progress tracking system	To track developer progress with respect to fulfilling Waterfront Toronto's Minimum Green Building Requirements.

Case Study: UNEP Building – Nairobi, Kenya

An architectural piece that exemplifies sustainable building design is the United Nations compound located on the outskirts of Kenya's capital city. The new building takes environmental sustainability to a new level. It consists of four buildings linked by airy walkways, flooded with natural light, and with green areas individually landscaped and themed, all of which can accommodate 1,200 staff members.

The simple design enables the building to act as a chimney, where warm air is drawn up from ground level and through the office areas, and then escapes beneath the sides of the vaulted roof, maintaining comfortable temperatures in the offices and air circulation throughout the building.

Figure 6: UNEP Building, Nairobi - Green building features

Water	Water features at the entrance to each of the four blocks are fed by rainwater harvested from the roof. Water saving taps and lavatories will reduce water consumption. Wastewater is treated in a state-of-the-art on site aeration facility and the clean water is used to irrigate the landscaped compound. Rainwater is collected from the roof and used to irrigate the landscaped areas around the building. No fresh water will be needed to irrigate the planted areas.
Lighting	Glazed roof lights are set into the building's flat roof, and toughened glass set at floor level beneath them on each floor, enabling natural light to penetrate right through the ground floor. Low energy fluorescent lighting, together with a daylight sensing and presence detection system significantly reduces energy use while ensuring adequate light to work by.
Solar power	Solar panels cover the roof space and will generate all the building's energy needs, making it energy neutral over the year. Water for the coffee station kitchens is solar heated.
Light and ventilation	A central atrium runs the length of the building, allowing natural light to flood into offices, while encouraging airflow and comfortable internal temperatures by drawing warm air up and out of the building.

Ventilation	Open plan offices help air circulation and temperature control, and also encourage a more cooperative working environment. Windows can be opened and closed for temperature regulation, while high quality solar glass insulates the building against the heat and the cold.
Technology	Data centers that use air and cool water to maintain server temperatures remove the need for costly air conditioning.
Design	The building faces north-south, achieving maximum daytime lighting with minimum heat intake.
Green areas	The area around the building has been planted with indigenous trees. Landscaped areas beneath the atrium in the center of each block are planted to need minimal water, to encourage biodiversity, and to create cool and beautiful interior gardens.
Green IT	Notebook computers use only a third of the electricity used by desktop PCs, which are being replaced throughout the building.
Materials	The carpets have a very high recycled content and are 100% recyclable, and all paints are environmentally friendly.

Case study: Toronto Green Standards – Toronto, Canada

The Toronto Green Standard (TGS[13]) is a two-tiered set of performance measures with supporting guidelines related to sustainable site and building design for new public and private development. The supporting guidelines include:

- Urban Design Streetscape Manual
- Bird Friendly Development Guidelines
- Guidelines for the Design and Management of Bicycle Parking Facilities
- Design Guidelines for 'Greening' Surface Parking Lots.

Toronto's Energy Efficiency Office (EEO) reviews the energy reports submitted to determine if the building has been designed to achieve, at minimum, the TGS Tier 2 target. A key feature of the programme is that buildings that meet the requirements of TGS may be eligible for financial incentives for the energy savings achieved.

The "High Performance New Construction Program" offers design assistance and substantial financial incentives for building owners and design decision makers who exceed the electricity efficiency specified in the Ontario Building Code.

The Toronto Green Standard and the Better Buildings Partnership-NC won the 2009 Federation of Canadian Municipalities-CH2M Hill Sustainable Communities Award in the Buildings category, as an example of an innovative project contributing to sustainable community development in Canada.

Case study: Suzlon One Earth – Pune, India

Suzlon Energy Limited[14] pledged to create the greenest office in India. The building is three levels high and is located on 10.5 acres. It achieved LEED for New Construction Platinum certification from the India Green Building Council, as well as Five-Star GRIHA (Green Rating for Integrated Habitat Assessment) certification.

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13 www.toronto.ca/planning/environment/greendevelopment.htm.

14 http://demo.usgbc.name/projects/suzlon-one-earth.

5% (154 kilowatts) of its annual energy is generated on-site through conventional and building-integrated photovoltaic panels (20%) and wind turbines (80%). All balance energy required for the campus is generated through Suzlon's off-site wind turbines, making One Earth technically a zero energy project.

Drawing clues from vernacular architecture while respecting nature and culture, the design provides 90% of the work stations with daylight and external views, allowing inhabitants to enjoy seasons and weather conditions, and to connect with the time of the day. Aluminium louvers act as a protective skin, allowing daylight and cross-ventilation. Energy is saved by employing LED lighting systems and solar water heating. 100% of sewage grey water is recycled into flushing, landscaping and air cooling systems, while 100% of rainwater is harvested. Glass exhaust chimneys with tropical plants act as visual connectors between all floors and allow aeration of the basement parking area. The focus of the complex is a central courtyard that features a forty-metre traditional obelisk reaching out to the sky from the basement and a waterfall facing a crescent cafeteria. This central garden plaza encourages communication, informal interaction and team gathering amongst Suzlon's more than 1 500 colleagues and provides a visual presentation for occupants and visitors. This corporate campus is a counterblast to prevailing glass-box architecture occurring across India and is a game changer in terms of how corporate campuses have been designed to-date in India.

The project site was selected for the advantages of an already-developed area. It is flanked by offices of other corporations and a high-density residential area. Given its location, the building has accessibility to urban infrastructure and facilities, public transport, and established infrastructure for power and water supply.

Suzlon One Earth is a 100% renewable energy campus with both on- and off-site renewable energy that includes wind and solar. 100% of outdoor lighting and the communication server are run on renewable energy resources. Energy efficiency is also met through intelligent lighting occupancy sensors, efficient envelope design featuring high-performance glazing, over-deck insulation, reduced interior light density and day lighting optimization made possible through the use of glass cylinders and open interactive bays.

In terms of water usage, 100% of wastewater is recycled by an on-site sewage plant and used for landscaping, air conditioning and washroom flushing. Site landscaping features native and adapted plant species combined with pebble drains to collect excess water. Together, these strategies drastically reduce storm-water run-off. Inside, low-flow faucets, touchless urinals with bytronic sensors and concealed dual-flush toilets conserve water.

Around 80% of materials used in construction were regional materials from within a radius of 800 kilometres. Additionally, around 10% of the materials are rapidly renewable, such as bamboo. 85% of construction waste was recycled.

To address indoor environmental quality, CO_2 sensors were installed in densely-occupied spaces and near workstations. The heating, ventilation and air conditioning (HVAC) system was designed for 30% higher ventilation rates than American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards.

Suzlon One Earth strives for its occupants to be environmentally aware, socially responsible and compatible with the built space. The Synefra project team, along with the Suzlon Human Resources team, conducted pre-occupancy education programmes to orient tenants to the facility and explain the norms that would need to be adopted. Suzlon has identified various processes to recognize and develop human behavioural skills to understand and appreciate the inter-relationship between man and his biophysical surrounding, and has modified its policy at One Earth to match the infrastructure.

The project is based upon the principle of promoting awareness about sustainability, to the extent of even declaring the entire campus a non-smoking zone, which led many employees to drop their age-old smoking habits. The campus is used as a communication tool to portray the interdependence of the natural and man-made environments. Among the various communication strategies adopted at Suzlon One Earth are green design education, green signage and green tours. The end result is an inter-disciplinary human resource that learns about and from the environment on a continuous basis.

Case Study: Infosys BPO Limited, Jaipur, India

The building housing Infosys BPO Limited, the business process outsourcing subsidiary of Infosys Technologies Limited, in Jaipur, India, has a LEED Platinum rating. Built on a total floor area of 330,000 square feet, the Infosys BPO building is one of the largest platinum rated buildings in India. The building was conceived and built with a holistic approach to sustainability in five key areas: sustainable site development, water saving, energy efficiency, materials selection and indoor environmental quality. This building is expected to consume 30% less energy as compared to the base case building, as per ASHRAE 90.1-2004 requirements.

Salient features of the Infosys BPO building in Jaipur include:

- Efficient building envelope: a high performance building envelope consisting of insulated walls and spectrally selected windows with a low window to wall ratio, reduces the total heat gain in the building.
- Efficient lighting & equipment: a lighting design specification of 0.65 watts per square foot achieves a 40% improvement over traditional designs. Lighting design coupled with the use of 5-star rated, energy efficient computers reduces the energy load as well as internal heat gains.
- Efficient air-conditioning: the air-conditioning system is equipped with multi-stage air handling units which operate on free cooling, evaporative cooling and air-conditioning modes during nights and winter, achieving more than 30% efficiency over a traditional system.
- Onsite renewable energy: a battery-free 250 KW roof top solar photovoltaic installation meets 7.5% of the total power requirement and takes advantage of the high solar insolation in Jaipur.
- Low energy materials: 13% of the total material is recycled material, thereby reducing virgin material exploitation. 80% of the total material is manufactured locally and over 59% of this material has also been extracted regionally, thereby reducing pollution due to transportation.
- Water sustainability: 57 interconnected recharge wells have been built across the campus to capture & sequester every drop of rain water. Low flow dual-flush toilets, sensor based urinals and other water efficient fixtures have been provided, reducing water consumption by over 40%. Sewage water is treated in a state-of-the-art Membrane Bio Reactor (MBR) plant and reused for flushing and air-conditioning. 100% of the water required for landscaping is from treated water and no potable water is used.

2.4 Metrics

2.4.1 LEED 2009 for new construction and major renovations project

Figure 7: Scoring system for LEED 2009: New constructions and major renovations

Scoring system		
Sustainable sites		**26 possible points**
Prerequisite 1	Construction activity pollution prevention	Required
Credit 1	Site selection	1
Credit 2	Development density and community connectivity	5
Credit 3	Brownfield redevelopment	1
Credit 4.1	Alternative transportation – public transportation access	6
Credit 4.2	Alternative transportation – bicycle storage and changing rooms	1

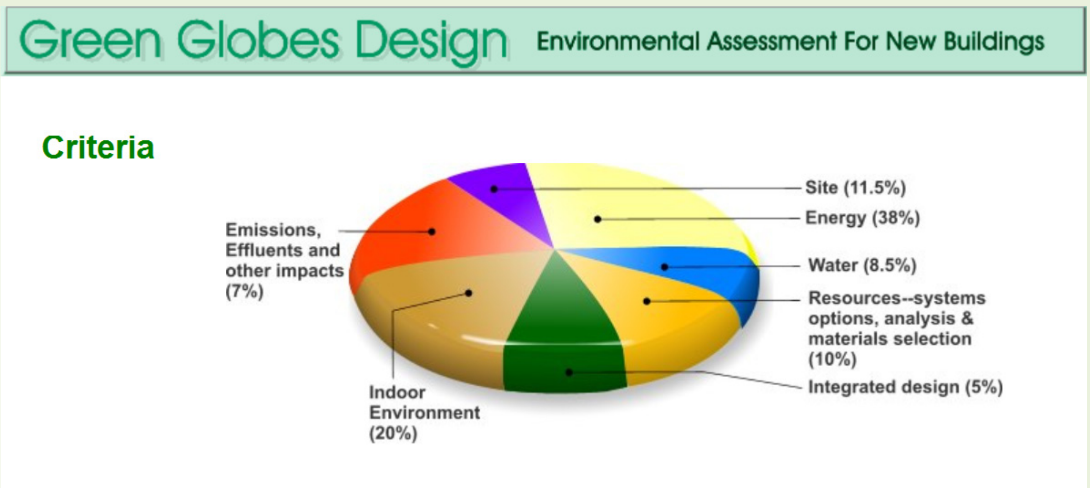
Credit 4.3	Alternative transportation – low emitting and fuel efficient vehicles	3
Credit 4.4	Alternative transportation – parking capacity	2
Credit 5.1	Site development – Protect or restore habitat	1
Credit 5.2	Site development – Maximize open space	1
Credit 6.1	Storm-water design – Quantity control	1
Credit 6.2	Storm-water design – Quality control	1
Credit 7.1	Heat island effect – Non-roof	1
Credit 7.2	Heat island effect – Roof	1
Credit 8	Light pollution reduction	1
Water efficiency		**10 possible points**
Prerequisite 1	Water use reduction	Required
Credit 1	Water efficient landscaping	2-4
Credit 2	Innovative wastewater technologies	2
Credit 3	Water use reduction	2-4
Energy and Atmosphere		**35 possible points**
Prerequisite 1	Fundamental commissioning of building energy systems	Required
Prerequisite 2	Minimum energy performance	Required
Prerequisite 3	Fundamental refrigerant management	Required
Credit 1	Optimize energy performance	1-19
Credit 2	On-site renewable energy	1-7
Credit 3	Enhanced commissioning	2
Credit 4	Enhanced refrigerant management	2
Credit 5	Measurement and verification	3
Credit 6	Green power	2
Materials and resources		**14 possible points**
Prerequisite 1	Storage and collection of recyclables	Required
Credit 1.1	Building reuse – Maintain existing walls, floors and roof	1-3
Credit 1.2	Building reuse – Maintain existing interior non-structural elements	1
Credit 2	Construction waste management	1-2
Credit 3	Materials reuse	1-2
Credit 4	Recycled content	1-2
Credit 5	Regional materials	1-2
Credit 6	Rapidly renewable materials	1
Credit 7	Certified wood	1
Indoor environmental quality		**15 possible points**
Prerequisite 1	Minimum indoor air quality performance	Required
Prerequisite 2	Environmental Tobacco Smoke (ETS) control	Required
Credit 1	Outdoor air delivery monitoring	1
Credit 2	Increased ventilation	1
Credit 3.1	Construction indoor air quality management plan – during construction	1
Credit 3.2	Construction indoor air quality management plan – before occupancy	1
Credit 4.1	Low-emitting materials – adhesives and sealants	1

Credit 4.2	Low-emitting materials – paints and coatings	1
Credit 4.3	Low-emitting materials – flooring systems	1
Credit 4.4	Low-emitting materials – Composite wood and agrifibre products	1
Credit 5	Indoor chemical and pollutant source control	1
Credit 6.1	Controllability of systems – Lighting	1
Credit 6.2	Controllability of systems – Thermal comfort	1
Credit 7.1	Thermal comfort – Design	1
Credit 7.2	Thermal comfort – Verification	1
Credit 8.1	Daylight and views – Daylight	1
Credit 8.2	Daylight and views – Views	1
Innovation in design		**6 possible points**
Credit 1	Innovation in design	1-5
Credit 2	LEED accredited professional	1
Regional priority		**4 possible points**
Credit 1	Regional priority	1-4

Figure 8: LEED 2009 scoring structure	
LEED 2009 for new construction and major renovations	
100 base points; 6 possible Innovation in Design and 4 Regional Priority points	
Certified	40-49 points
Silver	50-59 points
Gold	60-79 points
Platinum	80 points and above

2.4.2 Green Globes

Figure 9: Green Globes assessment criteria



2.4.3 BREEAM rating benchmarks

The BREEAM[15] rating benchmarks for new construction projects assessed using the 2011 version of BREEAM are as follows:

Figure 1: BREEAM rating benchmarks

BREEAM Rating	% score
OUTSTANDING	85
EXCELLENT	70
VERY GOOD	55
GOOD	45
PASS	30
UNCLASSIFIED	<30

In this respect, each BREEAM rating level broadly represents performance equivalent to:

- Outstanding: Less than the top 1% of the UK new non-domestic buildings (innovator)
- Excellent: Top 10% of the UK new non-domestic buildings (best practice)
- Very Good: Top 25% of the UK new non-domestic buildings (advanced good practice)
- Good: Top 50% of the UK new non-domestic buildings (intermediate good practice)
- Pass: Top 75% of the UK new non-domestic buildings (standard good practice).

Environmental section weightings

Environmental weightings are fundamental to any building environmental assessment method as they provide a means of defining, and therefore ranking, the relative impact of environmental issues. BREEAM uses an explicit weighting system derived from a combination of consensus-based weightings and ranking by a panel of experts. The outputs from this exercise are then used to determine the relative value of the environmental sections used in BREEAM and their contribution to the overall BREEAM score.

15 www.breeam.org/filelibrary/Technical%20Manuals/SD5073_BREEAM_2011_New_Construction_Technical_Guide_ISSUE_2_0.pdf.

Figure 11: BREEAM weightings for environmental assesssment

Environmental section	Weighting
Management	12%
Health & Wellbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land Use & Ecology	10%
Pollution	10%
Total	100%
Innovation (additional)	10%

2.2.4 Green Star certified ratings

The following Green Star certified ratings are available:

- **4 Star Green Star certified rating** (score 45-59) signifies 'Best Practice' in environmentally sustainable design and/or construction
- **5 Star Green Star certified rating** (score 60-74) signifies 'Australian Excellence' in environmentally sustainable design and/or construction
- **6 Star Green Star certified rating** (score 75-100) signifies 'World Leadership' in environmentally sustainable design and/or construction.

2.4.5 PEARL rating levels

Within each section, there are both mandatory and optional credits; credit points are awarded for each optional credit achieved. To achieve a 1 Pearl rating, all the mandatory credit requirements must be met. To achieve a higher Pearl rating, all the mandatory credit requirements must be met along with a minimum number of credit points.

Figure 12: PEARL rating benchmarks

Requirement	Pearl Rating Achieved
All mandatory credits	1 Pearl
All mandatory credits + 60 credit points	2 Pearl
All mandatory credits + 85 credit points	3 Pearl
All mandatory credits + 115 credit points	4 Pearl
All mandatory credits + 140 credit points	5 Pearl

3 Building maintenance, repair and operations

3.1 Overview

Sustainable building operations guidelines provide building owners and operators with the tools needed to minimize environmental impacts during the utilization phase of a building's life cycle. The guidelines for maintenance, repair and operations (MRO) were developed to ensure that buildings designed and constructed for environmental sustainability would continue to operate their systems in a manner that minimizes a building's impact and continues to ensure the health and well-being of occupants and the surrounding built environment.

Since many of the systems that have been integrated into a building to maximize energy efficiency and minimize environmental impact are dependent on ICTs, integrating MRO green building standards into an ICT company's built environment provides therefore an excellent opportunity for ICT companies to demonstrate not only their commitment to sustainability, but also the power of ICTs to reduce emissions.

3.2 Standards

3.2.1 LEED guidelines for existing buildings: operations and maintenance

The LEED 2009 green building rating system for existing buildings: operations and maintenance16 is a set of performance standards for certifying the operations and maintenance of existing commercial or institutional buildings and high-rise residential buildings of all sizes, both public and private. The intent is to promote high performance, healthy, durable, affordable, and environmentally sound practices in existing buildings.

LEED for existing buildings: operations and maintenance encourages owners and operators of existing buildings to implement sustainable practices and reduce the environmental impacts of their buildings over their functional life cycles. Specifically, the rating system addresses exterior building site maintenance programmes, water and energy use, environmentally preferred products and practices for cleaning and alterations, sustainable purchasing policies, waste stream management, and ongoing indoor environmental quality.

LEED for existing buildings: operations and maintenance provides owners and operators of existing buildings an entry point into the LEED certification process and is applicable to the following:

- building operations, processes, systems upgrades, minor space-use changes, and minor facility alterations or additions, and
- buildings new to LEED certification as well as buildings previously certified under LEED for New Construction, LEED for Schools, or LEED for Core and Shell; these may be either ground up new constructions or existing buildings that have undergone major renovations.

Categories:

- sustainable sites;
- water efficiency;
- energy and atmosphere;
- materials and resources;

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[16] www.usgbc.org/ShowFile.aspx?DocumentID=8876.

- indoor environmental quality;
- innovation in operations;
- regional priority.

Figure 13: LEED guidelines for Existing Buildings	
SS Credit 1: LEED certified design and construction	To reward environmentally sensitive building design and construction, thereby enabling high-performance building operations to be achieved more easily.
SS Credit 2: Building exterior and hardscape management plan	To encourage environmentally sensitive building exterior and hardscape management practices that provide a clean, well-maintained and safe building exterior while supporting high-performance building operations.
SS Credit 3: Integrated pest management, erosion control and landscape management plan	To preserve ecological integrity, enhance natural diversity and protect wildlife while supporting high-performance building operations and integration into the surrounding landscape.
SS Credit 4: Alternative commuting transportation	To reduce pollution and land development impacts from automobile use for commuting.
SS Credit 5: Site development – protect or restore open habitat	To conserve existing natural site areas and restore damaged site areas to provide habitat and promote biodiversity.
SS Credit 6: Storm-water quantity control	To limit disruption of natural hydrology by reducing impervious cover, increasing on-site infiltration, reducing or eliminating pollution from storm-water run-off and eliminating contaminants.
SS Credit 7.1: Heat island reduction – non-roof	To reduce heat islands4 to minimize impacts on microclimates and human and wildlife habitats.
SS Credit 7.2: Heat island reduction – roof	To reduce heat islands to minimize impacts on microclimates and human and wildlife habitats.
SS Credit 8: Light pollution reduction	To minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve night-time visibility through glare reduction and reduce development impact from lighting on nocturnal environments.
WE Prerequisite 1: Minimum indoor plumbing fixture and fitting efficiency	To reduce indoor fixture and fitting water use within buildings so that the burdens on potable water supply and wastewater systems will be reduced.
WE Credit 1: Water performance measurement	To measure building and subsystem water performance over time to understand consumption patterns and identify opportunities for additional water savings.
WE Credit 2: Additional indoor plumbing fixture and fitting efficiency	To maximize indoor plumbing fixture and fitting efficiency in buildings to reduce the use of potable water13 and consequent burden on municipal water supply and wastewater systems.
WE Credit 3: Water efficient landscaping	To limit or eliminate the use of potable water14, or other natural surface or subsurface resources available on or near the project site, for landscape irrigation.
WE Credits 4.1-4.2: Cooling tower water management	To reduce potable water15 consumption for cooling tower equipment through effective water management and/or use of non-potable make-up water.
EA Prerequisite 1: Energy efficiency best management practices – planning, documentation and opportunity assessment	To promote continuity of information to ensure that energy-efficient operating strategies are maintained and provide a foundation for training and system analysis.

EA Prerequisite 2: Minimum energy efficiency performance	To establish the minimum level of operating energy efficiency performance relative to typical buildings of a similar type to reduce environmental and economic impacts associated with excessive energy use.
EA Prerequisite 3: Fundamental refrigerant management	To reduce stratospheric ozone depletion.
EA Credit 1: Optimize energy efficiency performance	To achieve increasing levels of operating energy performance relative to typical buildings of a similar type to reduce environmental and economic impacts associated with excessive energy use.
EA Credit 2.1: Existing building commissioning – Investigation and analysis	Through a systematic process, to develop an understanding of the operation of the building's major energy-using systems, options for optimizing energy performance and a plan to achieve energy savings.
EA Credit 2.2: Existing building commissioning – implementation	To implement minor improvements and identify planned capital projects to ensure that the building's major energy-using systems are repaired, operated and maintained effectively to optimize energy performance.
EA Credit 2.3: Existing building commissioning – ongoing commissioning	To use commissioning to address changes in facility occupancy, use, maintenance and repair. Make periodic adjustments and reviews of building operating systems and procedures essential for optimal energy efficiency and service provision.
EA Credit 3.1: Performance measurement – building automation system	To provide information to support the ongoing accountability and optimization of building energy performance and identify opportunities for additional energy-saving investments.
EA Credit 3.2: Performance measurement – system-level metering	To provide accurate energy-use information to support energy management and identify opportunities for additional energy-saving improvements.
EA Credit 4: On-site and off-site renewable energy	To encourage and recognize increasing levels of on- and off-site renewable energy to reduce environmental and economic impacts associated with fossil fuel energy use.
EA Credit 5: Enhanced refrigerant management	To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to global climate change.
EA Credit 6: Emissions reduction reporting	To document the emissions reduction benefits of building efficiency measures.
MR Prerequisite 1: Sustainable purchasing policy	To reduce the environmental impacts of materials acquired for use in the operations, maintenance and upgrades of buildings.
MR Prerequisite 2: Solid waste management policy	To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills or incineration facilities.
MR Credit 1: Sustainable Purchasing – ongoing consumables	To reduce the environmental and air quality impacts of the materials acquired for use in the operations and maintenance of buildings.
MR Credits 2.1-2.2: Sustainable purchasing – durable goods	To reduce the environmental and air quality impacts of the materials acquired for use in the operations and maintenance of buildings.
MR Credit 2.1: Electric-powered equipment	
MR Credit 2.2: Furniture	
MR Credit 3: Sustainable purchasing – facility alterations and additions	To reduce the environmental and air quality impacts of the materials acquired for use in the upgrade of buildings.
MR Credit 4: Sustainable purchasing – reduced mercury in lamps	To establish and maintain a toxic material source reduction programme to reduce the amount of mercury brought onto the building site through purchases of lamps.

MR Credit 5: Sustainable purchasing – food	To reduce the environmental and transportation impacts associated with food production and distribution.
MR Credit 6: Solid waste management – waste stream audit	To facilitate the reduction of ongoing waste and toxins generated by building occupants and building operations that are hauled to and disposed of in landfills or incineration facilities.
MR Credit 7: Solid waste management – ongoing consumables	To facilitate the reduction of waste and toxins generated from the use of ongoing consumable products by building occupants and building operations that are hauled to and disposed of in landfills or incineration facilities.
MR Credit 8: Solid waste management – durable goods	To facilitate the reduction of waste and toxins generated from the use of durable goods by building occupants and building operations that are hauled to and disposed of in landfills or incineration facilities.
MR Credit 9: Solid waste management – facility alterations and additions	To divert construction and demolition debris from disposal to landfills and incineration facilities. Redirect recyclable recovered resources back to the manufacturing process and reusable materials to appropriate sites.
IEQ Prerequisite 1: Minimum indoor air quality performance	To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the health and well-being of the occupants.
IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) control	To prevent or minimize exposure of building occupants, indoor surfaces and systems to environmental tobacco smoke (ETS).
IEQ Prerequisite 3: Green cleaning policy	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants, which adversely affect air quality, human health, building finishes, building systems and the environment.
IEQ Credit 1.1: Indoor Air quality best management practices – Indoor air quality management program	To enhance indoor air quality (IAQ) by optimizing practices to prevent the development of indoor air quality problems in buildings, correcting indoor air quality problems when they occur and maintaining the well-being of the occupants.
IEQ Credit 1.2: Indoor Air quality best management practices – Outdoor air delivery monitoring	To provide capacity for ventilation system monitoring to help sustain occupant comfort and well-being.
IEQ Credit 1.3: Indoor air quality best management practices – Increased ventilation	To provide additional outdoor air ventilation to improve indoor air quality (IAQ) for improved occupant comfort, well-being and productivity.
IEQ Credit 1.4: Indoor air quality best management practices – reduce particulates in air distribution	To reduce exposure of building occupants and maintenance personnel to potentially hazardous particulate contaminants, which adversely affect air quality, human health, building systems and the environment.
IEQ Credit 1.5: Indoor air quality best management practices – Indoor air quality management for facility alterations and additions	To prevent indoor air quality (IAQ) problems resulting from any construction or renovation projects to help sustain the comfort and well-being of construction workers and building occupants.
IEQ Credit 2.1: Occupant comfort – occupant survey	Intent: To provide for the assessment of building occupants' comfort as it relates to thermal comfort, acoustics, indoor air quality (IAQ), lighting levels, building cleanliness and any other comfort issues.
IEQ Credit 2.2: Controllability of systems – lighting	To provide a high level of lighting system control by individual occupants or groups in multi-occupant spaces (e.g. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

IEQ Credit 2.3: Occupant comfort – thermal comfort monitoring	To support the appropriate operations and maintenance of buildings and building systems so that they continue to meet target building performance goals over the long term and provide a comfortable thermal environment that supports the productivity and well-being of building occupants.
IEQ Credit 2.4: Daylight and views	To provide building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.
IEQ Credit 3.1: Green cleaning – High-performance cleaning programme	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants, which adversely affect air quality, human health, building finishes, building systems and the environment.
IEQ Credit 3.2: Green cleaning – Custodial effectiveness assessment	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants, which adversely affect air quality, human health, building finishes, building systems and the environment, by implementing, managing and auditing cleaning procedures and processes.
IEQ Credit 3.3: Green cleaning – Purchase of sustainable cleaning products and materials	Intent: To reduce the environmental impacts of cleaning products, disposable janitorial paper products and trash bags.
IEQ Credit 3.4: Green cleaning – Sustainable cleaning equipment	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants that adversely affect air quality, human health, building finishes, building systems and the environment, from powered cleaning equipment.
IEQ Credit 3.5: Green cleaning – Indoor chemical and pollutant source control	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants that adversely affect air quality, human health, building finishes, building systems and the environment.
IEQ Credit 3.6: Green cleaning – Indoor integrated pest management	To reduce the exposure of building occupants and maintenance personnel to potentially hazardous chemical, biological and particulate contaminants that adversely affect air quality, human health, building finishes, building systems and the environment.
IO Credit 1: Innovation in operations	To provide building operations, maintenance and upgrade teams with the opportunity to achieve additional environmental benefits achieved beyond those already addressed by the LEED 2009 for Existing Buildings: Operations and Maintenance Rating System.
IO Credit 2: LEED® Accredited professional	To support and encourage the operations, maintenance, upgrade and project team integration required by LEED to streamline the application and certification process.
IO Credit 3: Documenting sustainable building cost impacts	To document sustainable building cost impacts.
RP Credit 1: Regional priority	To provide an incentive for the achievement of credits that address geographically specific environmental priorities.

3.3 Best environmental practices

3.3.1 Systems assessment

Using a systematic process, a thorough understanding of the operation of the building's major energy-using systems should be undertaken with the goal of the development of a plan to optimize energy performance and efficiency. As an example of such a systemic process would be to conduct an energy audit that meets the requirements of the American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE), Level II, Energy Survey and Analysis.

3.3.2 Building exterior and site

To operate a building in a more environmentally friendly manner, a plan to deal with the issue of the building site and outside operation and landscaping should be developed.

Areas to be considered could include:

- ice and snow removal;
- exterior cleaning;
- low water landscaping;
- green procurement;
- integrated or natural pest control;
- erosion control;
- availability and promotion of alternative or lower impact transportation;
- elimination of gasoline powered maintenance equipment and vehicles;
- reduction of heat island effect;
- open grid parking structures;
- storm-water management.

3.3.3 Building management system

The U.S. Green Buildings Council (USGBC) estimates that commercial office buildings use 20% more energy on average than necessary. Thus, implementing sustainable building operations provides an opportunity to optimize energy efficiency and reduce GHG emissions.

Building management systems (BMSs) use ICT hardware and software to manage many functions of a building which can include heating, ventilation and air conditioning (HVAC), lighting, electric power, security, access control, and fire management among others.

The features of BMS include the monitoring, controlling and optimizing of the above-mentioned systems with the goal of improving energy efficiency without impacting on the comfort of building occupants.

Another potential area for BMS use is with the continued expansion of the Smart Grid. The BMS can be used to minimize costs through reductions in electricity purchases based on real-time demand/pricing signals from the grid and the integration of renewable energy sources into a buildings electricity mix.

3.3.4 Lighting

Recent advances in lighting technology (including LEDs and higher efficiency fluorescents) can dramatically reduce electricity usage and costs. Many of these new innovations are especially useful in applications that require lighting to be turned on for an extended period of time, as they also have the benefit of extended lifetimes which reduce the overall life cycle costs. When designed properly, an LED circuit will approach 80% efficiency, which means 80% of the electrical energy is converted to light energy, and the remaining 20% is lost as heat energy.

3.3.5 Waste

A waste audit of a building's ongoing waste stream provides a benchmark that can be used to develop policies, procedures, recycling and reduction programmes to divert waste from landfill sites.

3.3.6 Sustainable procurement

Policies and procedures for more sustainable procurement can have a bearing on the environmental impact of a building and the comfort level for the occupants of the building. Green procurement standards that maximize energy efficiency can lead to a reduction in building energy demand. Procurement policies that minimize packaging and food waste result in lower cost and volume for solid waste removal. Procurement standards that minimize chemicals known to negatively affect indoor air quality through a process of prohibition or preferential treatment for substitutes (e.g. green cleaning supplies, low off gassing of new materials) will ensure a higher level of building occupant comfort and satisfaction.

This may be a key area for enhancing sustainability of projects. For example, in 2004 it was identified that the National Health Service (NHS) in the UK is responsible for 25% of England's public sector emissions; three primary sectors are namely responsible for this: travel (18%), building energy (22%) and procurement (60%). Procurement therefore provides a great opportunity to reduce a building's carbon footprint.

A study done by the Sustainability Development Commission and Stockholm Environment Institute showed that procurement, materials and transport can have a greater impact on carbon emission than the energy required running a facility (Sustainable development commission, 2009).

Case Study: FBI regional headquarters, Chicago, USA

The FBI Chicago Field Office[17] is over 800 000 square feet, a three-building complex consisting of a ten-story office building, two separate guard shacks, a two-level structured parking deck, two levels of below-grade parking that total 200 000 square feet, and a connecting one-story vehicular annex facility that is over 50 000 square feet. At any time, the facility can have from 650 to 700 employees, with these totals fluctuating higher on a frequent basis. The Chicago FBI is the only tenant and the project was designed as a build-to-suit for the government. Although the building was not rated green during construction, USAA pursued certification post-occupancy and, in December of 2008, was awarded the world's first LEED Platinum certification under the LEED for Existing Buildings: Operations and Maintenance rating system from USGBC.

USAA's approach to sustainability efforts is to drive the business case. Specifically, the team effort to improve efficiency and reduce the environmental impact was driven by the desire to maximize occupant comfort, as well as improve financial performance. The facility has many sustainable policies in place that have helped us achieve an ENERGY STAR rating of 95% and water use reduction of 43%.

[17] http://demo.usgbc.name/projects/fbi-regional-headquarters.

The exterior is comprised of a highly-finished architectural pre-cast concrete expressing a ten-foot module around openings consisting of light blue vision glass and a bluish-coloured spandrel glass panel. The combination of these two materials results in a very glassy looking building and conveys an attractive and professional appearance of this government facility. The parking garage is constructed of the same pre-cast material as the office building and is recessed into the landscape while surrounded by dense plantings.

The office building features a dramatic two-level main entryway with a large glass “net-wall” which has a stressed cable structure support. These very transparent and innovative walls help visually and symbolically connect the inner space to the exterior plaza. The main lobby features marble panels on the west wall, granite flooring, and pre-cast concrete with wood panels on the north and south walls. Additional features include upgraded general office areas, granite walls in the elevator lobbies, and upgraded executive office areas and conference rooms with materials such as granite, custom millwork and fabric wall covering.

The building’s facade, primarily composed of architectural pre-cast concrete, is a green material readily available from sources near the site and easily recycled at the end of a product’s life. The exterior walls with the 60% pre-cast concrete and high-performance, low-emissive glass creates a very energy-efficient envelope. Larger column bays and spans increase natural light and views to the outside. The window areas on the exterior translate to ample daylight for the interior, with large window units extending from the nine-foot, six-inch ceilings to a low sill height of approximately twenty inches above the finished floor. The result is enhanced employee comfort and productivity.

The project site is 12 acres located just west of downtown Chicago in an area called the Illinois Medical District. The FBI Chicago complex creates a major landscaped green space along the entire Roosevelt Road and Damen Avenue frontages, totalling approximately four acres or 40% of the entire site area.

The facility is located in the west loop area of Chicago, Illinois, and the overall design concept embodies the key features of a modern class-A private sector office building development, including: sensitivity to the neighbourhood context; creation of a flexible and attractive workplace; and inclusion of low environmental impact design concepts.

The land was previously used as a bus depot that had exceeded its useful life. The removal of this depot and the other undesirable material left on the site contributed to the revitalization of the area.

3.4 Existing buildings: checklist

Figure 14: LEED 2009 for Existing Buildings: Operations and Maintenance project checklist		
Sustainable sites		**26 possible points**
Credit 1	LEED certified design and construction	4
Credit 2	Building exterior and hardscape management plan	1
Credit 3	Integrated pest management erosion control and landscape management plan	1
Credit 4	Alternative commuting transportation	3-15
Credit 5	Site development: protect or restore open habitat	1
Credit 6	Storm-water quantity control	1
Credit 7.1	Heat island reduction: non-roof	1
Credit 7.2	Heat island reduction: roof	1
Credit 8	Light pollution reduction	1
Water efficiency points		**14 possible points**
Prerequisite 1	Minimum indoor plumbing fixture and fitting efficiency	Required

Credit 1	Water performance measurement	1-2
Credit 2	Additional indoor plumbing fixture and fitting efficiency	1-5
Credit 3	Water efficient landscaping	1-5
Credit 4.1	Cooling tower water management: chemical management	1
Credit 4.2	Cooling tower water management: non-potable water source use	1
Energy and Atmosphere		**35 possible points**
Prerequisite 1	Energy efficiency best management practices: planning, documentation and opportunity assessment	Required
Prerequisite 2	Minimum energy efficiency performance	Required
Prerequisite 3	Fundamental refrigerant management	Required
Credit 1	Optimize energy efficiency performance	1-18
Credit 2.1	Existing building commissioning: investigation and analysis	2
Credit 2.2	Existing building commissioning: implementation	2
Credit 2.3	Existing building commissioning: ongoing commissioning	2
Credit 3.1	Performance measurement: building automation system	1
Credit 3.2	Performance measurement: system level metering	1-2
Credit 4	On-site and off-site renewable energy	1-6
Credit 5	Enhanced refrigerant management	1
Credit 6	Emissions reduction reporting	1
Materials and resources		**10 possible points**
Prerequisite 1	Sustainable purchasing policy	Required
Prerequisite 2	Solid waste management policy	Required
Credit 1	Sustainable purchasing: ongoing consumables	1
Credit 2.1	Sustainable purchasing: electric-powered equipment	1
Credit 2.2	Sustainable purchasing: furniture	1
Credit 3	Sustainable purchasing: facility alterations and additions	1
Credit 4	Sustainable purchasing: reduced mercury in lamps	1
Credit 5	Sustainable purchasing: food	1
Credit 6	Solid waste management: waste stream audit	1
Credit 7	Solid waste management: ongoing consumables	1
Credit 8	Solid waste management: durable goods	1
Credit 9	Solid waste management: facility alterations and additions	1
Indoor environmental quality		**15 possible points**
Prerequisite 1	Minimum indoor air quality performance	Required
Prerequisite 2	Environmental Tobacco Smoke (ETS) control	Required
Prerequisite 3	Green cleaning policy	Required
Credit 1.1	Indoor air quality best management practices: Indoor air quality management program	1
Credit 1.2	Indoor air quality best management practices: outdoor air delivery monitoring	1
Credit 1.3	Indoor air quality best management practices: Increased ventilation	1
Credit 1.4	Indoor air quality best management practices: Reduce particulates in air distribution	1

Figure 15: LEED 2009 for Existing Buildings: scoring benchmarks	
LEED 2009 for Existing Buildings: Operations and Maintenance	
100 base points; 6 possible Innovation in Operations and 4 Regional Priority points	
Certified	40-49 points
Silver	50-59 points
Gold	60-79 points
Platinum	80 points and above

4 Building improvement

This section gives an overview of sustainability considerations that can be taken into account during the improvement or renovation phase of a building's life.

Building efficiency is essential to reducing energy consumption. The International Energy Agency shares as part of their World Energy Outlook that buildings account for 16% of the global energy consumption, and in the U.S. nearly 40% of the country's total energy use is for buildings. While commercial buildings are constructed each year, often to a high level of efficiency, the majority of opportunities in reducing energy consumption over the next few decades lie in existing building retrofits. This section will provide an overview of some of these opportunities.

4.1 Overview

There are many benefits to performing a building retrofit outside of energy efficiency, for example:

- **Increased building value** – Based on added building efficiency and modernization, a study conducted in 2009 by Henley University in the UK found that building sale prices could be increased by as much as 35% when LEED certified, and 31% if ENERGY STAR certified. These certified buildings were compared to comparable non-certified buildings when controlling for differences in lease contract, age, height, quality, and sub-market. For non-certified buildings, their value was increased by 5%.
- **Increased rent premiums** – According to a study sponsored by the Royal Institute of Chartered Surveyors, building owners can expect between 3% to 6%increases in rent premiums for certified eco-efficient buildings over their traditional counterparts.
- **Lower occupancy cost for tenants** – While higher rent prices can be expected for energy efficient buildings, this does not necessarily translate into higher occupancy costs. Lower energy usage, water consumption and healthier work environments all attribute to potential occupancy savings. There is also the potential for tenants and owners to split improvement costs over the term of the lease.
- **Fewer vacant buildings** – Occupancy rates are approximately 3% to 6% higher for certified spaces over comparable non-certified spaces, according to a research conducted by the University of Reading, UK.
- **Improved public relations and marketing value** – Energy efficiency and eco-efficient operations are becoming an important part of brand identity and has increased promotional value.
- **Reduced ownership risk** – Increased regulations on Greenhouse Gas emissions will have a probable impact on all energy-using sectors and society. These regulations will likely increase the cost of energy and have an impact on building operations. Therefore, the more efficient building operations are, the less impact these potential cost increases will have on building operations.

Building retrofits need to be implemented systematically. In order to complete such a project effectively and efficiently, there are a number of steps that should be taken to make sure that every improvement is measured.

The basic objectives of any building retrofit should include:

- Improve building performance by reducing energy consumption and associated operational expenses
- Improve building efficiency by reducing water consumption through operations management and fixture choices
- Improve indoor environmental comfort and quality for tenants
- Document and audit all improvements
- Divert construction waste from landfill.

A building retrofit can be conducted in depth, or it can focus just on the most significant areas of energy use and loss.

4.2 Standards

BRE Global is developing a new scheme for the assessment of non-domestic building refurbishment scheduled for launch in the summer of 2012. Further, LEED Standards for new construction can also be applied to major renovations.

4.3 Best practices

4.3.1 Data gathering and benchmarking

A preliminary step to any building retrofit is the establishment of the existing operating baseline. Some of these key steps, as defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), are:

- Whole Building Energy Use (WBEU) analysis based on historic utility bills for cost and comparison. This data is used to compare this facility to other similar facilities
- Comfort indexes – Compare the actual comfort conditions to the comfort requirements
- Energy indexes, energy demands divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings
- Actual energy demands.

4.3.2 Building audits

A building audit will identify ways to improve the overall building efficiency.

The main areas the audit should cover are:

- building and utility data, equipment analysis and energy bills;
- operating conditions and location of facility – seasonal factors;
- occupancy and operating schedule;
- evaluation of energy conservation measures currently in place;
- estimation of potential energy savings;
- identification of any customer specific requirements.

ASHRAE has defined three types of building energy audits, varying by rigor and detail:

Level I: walk-through survey

- Preliminary analysis to assess building energy efficiency and to identify simple and low-cost improvements.
- Based on visual verifications, study of installed equipment and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase.
- Simplest and quickest type of audit − Minimal interviews with building operators, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.
- Quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided.
- A list of energy conservation measures (ECM) or energy conservation opportunities (ECOs) requiring further consideration also provided.

Level II: detailed survey and energy analysis

- Based on the results of the pre-audit (benchmarking and level I)
- Energy use survey to provide a comprehensive analysis of the facility
- Quantitative evaluation of the ECOs/ECMs
- Can involve on-site measurements and sophisticated computer-based simulation tools to evaluate precisely the selected energy retrofits
- Utility bills are collected for a 12- to 36-month period to allow the auditor to evaluate the facility's energy/demand rate structures and energy usage
- Additional metering of specific systems is often performed to supplement utility data
- In-depth interviews with facility managers are conducted to provide a better understanding of major energy consuming systems and to gain insight into short and longer term energy consumption patterns
- Detailed financial analysis for each recommendation including implementation costs, operating savings, and investment criteria.

Level III: detailed analysis of capital-intensive modifications, also known as an investment grade audit (IGA)

- Detailed analysis of capital improvements focusing on ECOs requiring rigorous engineering study
- Evaluate return on Investment (ROI)
- Complete engineering study to justify capital investment.

4.3.3 Other best practices

In addition to energy management, there are other areas that should be focused on for a building retrofit.

4.3.3.1 Interior building considerations

- Energy consumption should include emission and consumption reduction strategies, building automation systems and the use of renewable energy
- Water efficiency should be evaluated both leveraging opportunities for water efficient fixtures (low flow toilets and sinks) and efficient water chillers and leveraging recirculation of water, where appropriate

- Indoor environment fixtures – Adding such things as waste stream diversion (recycling), recycled content and low volatile organic compounds (VOCs) for furniture, thermal comfort levels utilizing efficient HVAC settings, energy efficient lighting, lighting sensors and timers, and maximization of daylight
- Janitorial productions – Use of biodegradable products for cleaning
- Painting – Use of low VOC paints for any new application
- Janitorial productions – Use of biodegradable products for cleaning.

4.3.3.2 Exterior building considerations

- Landscaping – Use only regional appropriate flora, or use of xeriscaping practices which eliminate and minimize the need for supplemental watering, and if watering is required, ensure sprinkling at optimal times of the day and employ the use of rain sensors to shut off automatic sprinkling in times of rain
- Employ a light coloured roofing substrate to minimize heat absorption and install solar panels to supplement grid energy use
- Install bike racks and provide easy access to bus or rail lines – Encourage employees to use alternative transportation options.

4.4 Metrics

Below are some of the key metrics to consider tracking efficiency measures, comparing before and after results:

- kWh consumption/savings – look at totals;
- gallons of water consumed/savings;
- total metric tons CO_2e;
- visible light transmittance;
- foot candles – daylight illumination.

5 Technical buildings and outside plant

This section gives an overview of sustainability considerations which can be taken into account for specialized buildings appropriate to the ICT industry, specifically data centers.

5.1 Overview

Data centers are typically very energy-intensive buildings, due to the ICT equipment located within. While the design of the IT infrastructure within a data center has a major impact on total energy usage, the principles of green building design can also be implemented within the building framework and surrounding area to maximize environmental benefits. A well designed building, which will house a data center, will allow for the design of the IT Infrastructure that maximizes energy efficiency. While other types of buildings may exist, there are no specific standards that have been formalized. The use of standard green building guidelines would be appropriate to those situations.

5.2 Standards

5.2.1 BREEAM New Construction: data centers

BREEAM data centers[18] are an assessment method and certification scheme that can be used at the design, construction, and refurbishment phases of the building's life cycle. The scheme is used to assess the environmental impact of unoccupied or occupied data center buildings.

Data centers are used to house computer systems and associated components, such as telecommunications and storage systems. These buildings tend to be heavy consumers of energy and, as they have grown in number, interest in applying BREEAM to assess their environmental impacts has also grown.

Launched in 2010, the BREEAM data centers scheme allows for the assessment of this specialized type of building using the standard BREEAM methodology. The scheme recognizes the data centers energy intensive nature, and the rewarding efforts to reduce this impact. This is balanced against the need to reduce other key environmental impacts. Associated with the construction and operation of buildings, BREEAM data centers assessments can be carried out on:

- new data center buildings;
- major refurbishment of existing data center buildings;
- fit-outs of existing data center buildings.

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[18] www.breeam.org/page.jsp?id=157.

Figure 16: Weightings on BREEAM data assessments

BREEAM Section	Weighting (%) New builds, extensions & major refurbishments		
Data Centre type e.g. Data hall with;	Large associated function areas	Small associated function areas	No associated function areas
Management	12	12	12
Health & Wellbeing	10	10	0
Energy	37	39.5	44.5
Transport	5	0	0
Water	8.5	9	10.5
Materials	7	7.5	8.5
Waste	4.5	5	5.5
Land Use & Ecology	6	6.5	7
Pollution	10	10.5	12
Innovation	10	10	10

BREEAM Section	Weighting (%) Building fit-out only		
Data Centre type e.g. Data hall with;	Large associated function areas	Small associated function areas	No associated function areas
Management	12.5	12.5	12.5
Health & Wellbeing	10.5	10.5	0
Energy	39.5	42.5	48.5
Transport	5.5	0	0
Water	9	10	11
Materials	7.5	8	9
Waste	5	5	6
Land Use & Ecology	0	0	0
Pollution	10.5	11.5	13
Innovation	10	10	10

An additional 1% score can be added to a building's final BREEAM score for each Innovation credit achieved. The maximum number of Innovation credits that can be awarded for any one building assessed is 10; therefore, the maximum available score achieved for 'innovation' is 10%. Innovation credits can be awarded regardless of the final BREEAM rating, i.e. they are awardable at any BREEAM rating level.

There are three different ways in which a building can achieve an Innovation credit (all of which are summarized below). The first is by meeting exemplary performance criteria for an existing BREEAM issue:

Figure 17: BREEAM Innovation credit sources

Man 2 - Considerate Constructors
Hea 1 - Daylighting
Hea 14 - Office Space (BREEAM Retail & Industrial & Data Centres Schemes only)
Ene 1 - Reduction of CO_2 emissions
Ene 5 - Low or Zero Carbon Technologies
Wat 1 - Water Consumption
Wat 2 - Water Meter
Mat 1 - Materials Specification
Mat 5 - Responsible Sourcing of Materials
Wst 1 - Construction Site Waste Management

The second route is where the client/design team sets specific BREEAM performance targets/objectives and appoints a BREEAM Accredited Professional (AP) throughout the key project work stages to help deliver a building that meets the performance objectives and target BREEAM rating.

The final and third route is where an application is made to BRE Global by the BREEAM assessor to have a particular building feature, system or process recognized as 'innovative'. If the application is successful, an Innovation credit can be awarded.

5.3 Best practices

Case study: British Geological Survey data center, Nottingham, UK

The new computer suite at the British Geological Survey Campus at Keyworth in Nottingham19 is located within the courtyard of Blocks J, P, W and the new William Smith building on the campus.

The building is a data center in which existing data processing facilities are to be re-housed. The building is a direct replacement for the existing computer suite. It also provides space for future expansion of computing facilities. The building is unoccupied with control for the center operated from a nearby building. As such, none of the BREEAM Transport and Health and Well-being sections were applicable to the assessment.

The building will provide space for up to 52 server racks. The data center will process and store data produced by the British Geological Survey. The new building is intended to improve the efficiency of the technical facilities in terms of performance, energy efficiency and space standards. No demolition is required and a landscape scheme is proposed as an integral part of the development. The development will be linked to the existing campus and footpaths by a new corridor link and footpaths.

[19] www.breeam.org/page.jsp?id=310.

The Natural Environment Research Council (NERC) and the British Geological Survey (BGS) required in the brief of the project that an Excellent rating should be achieved. This requirement followed the achievement of another BREEAM Excellent rating for another office building in the same campus and is part of the master plan for the whole site.

Key facts

- BREEAM rating: excellent;
- Score: 75.79%;
- Size: 172 m^2 (GIFA);
- Stage: design and procurement;
- BREEAM version: data centers 2010 (PILOT).

Overview of environmental features

- waste heat from process recovered and used to heat the nearby core store building;
- overall 22% CO_2 emissions reduction due to reuse of waste heat;
- highly efficient energy use: power use effectiveness 1.34 (1.20 when core store building and waste heat recovered included) (Gold Standard < 1.43);
- Turbocor chiller cooling systems;
- use of construction materials with a very low environmental impact (Green Guide A-rated walls, roof, floor finishes/coverings, and hard landscaping and boundary protection);
- responsibly-sourced low thermal insulation levels specified to optimize energy demand and heat recovery;
- energy efficient external lighting;
- sustainable procurement policy adopted by the Research Councils' Shared Service Center (RCUK SSC);
- extensive storm water management plan SWMP covering several projects on the campus;
- use of recycled aggregates;
- substantial increase in ecological value of the site.

The BREEAM assessment

- waste: (100%);
- land use and ecology: (90%);
- water: (85.71 %);
- management: (75%);
- materials: (66.67%);
- energy: (65.38%);
- innovation: (50%).

Building services

Heat recovery was identified as the most sustainable method of utilizing the energy generated by the building operation. Alternative uses for the recovered heat were reviewed and the extension to the core store (existing Block N) was identified as the most appropriate use due to the space heating requirements and similar construction time-scales of this building. The principle is to utilize the heat generated by the servers to provide space heating to a core store extension by an underfloor heating system. For example, heat that would be normally rejected through the dry coolers is to be utilized for low grade underfloor heating.

The core store extension has a large thermal mass and there is a substantial heating demand for approximately 32 weeks of the year.

The internal heat gains from the server are significant and require mechanical ventilation systems to maintain acceptable temperatures around the server racks. Chilled water cooling is provided to the data center from Turbocor water chillers. The IT load is 300 kW; however, the system has been designed to be capable of being expanded to serve a further 300 kW IT load.

Power usage effectiveness (PUE) values of 1.34 and 1.20 (with heat recovered excluded/included, respectively) could still be reduced further by increasing heat recovery reuse in other spaces.

To provide best practice system redundancy, resilience and part load control, the cooling demand is to be provided via a combination of systems: dual "V" configuration chilled water cooling coils and DX back-up close control down flow units. This system provides multiple redundancy paths.

Green strategy

Construction site

Managed in an environmental and socially considerate and accountable manner demonstrated by the Considerate Constructors scheme target of 36. The data center is part of a larger master development with waste materials segregated for all developments using a communal waste segregation provided on site. At least 65% by volume of construction waste generated will be diverted from landfill and recycled by an approved waste management contractor.

Energy

The unit of measurement PUE was used to better understand the possible impact of influencing the design and specification data center to result in a more sustainable data center. From the typical standard of 2, this data center achieved a PUE of 1.34 and therefore achieved the Gold Standard.

The low/zero carbon technologies (i.e. waste heat from building process) installed will result in a 22.2% reduction in CO_2 emissions.

All IT equipment will be sustainably procured.

Land use and ecology

Emphasis in this area includes:

– reuse of land (brownfield);

– mitigation and enhancement of ecological impact.

Project team details

- Client: Natural British Geological Survey
- Project manager: Natural Environment Research Council
- Architects: Pick Everard
- Cost consultants: Pick Everard

- Building services engineers: Pick Everard
- Structural engineers: Pick Everard
- Contractor: Hallam Contracts
- BREEAM assessor: Pick Everard
- Sustainability Consultant: Pick Everard
- Landscape architect: Munro & Whitten
- Ecological consultant: Middlemarch Environmental.

5.4 Metrics

As with other BREEAM ratings, data centers can receive a rating of:

- Outstanding
- Excellent
- Very Good
- Good
- Pass.

6 Life cycle

In terms of the physical environment, it is estimated that good design can reduce energy costs by 25%, and by reducing energy bills, the overall costs will also be lower. Design quality and sustainability are therefore indivisible. As per the HM Treasury's Green Book, good design will not always result in the lowest initial capital cost. However, when expressed as a discount value, higher initial investment can over the life of the building result in lower whole life costs (Great Britain, Treasury, 2003).

A life cycle assessment (LCA) can help avoid a narrow outlook on environmental, social and economic concerns by assessing a full range of impacts associated with all the stages of a process from cradle-to-grave (i.e. from extraction of raw materials through material processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling). Impacts taken into account include (among others) embodied energy, global warming potential, resource use, air pollution, water pollution, and waste.

In terms of green building, the last few years have seen a shift away from a prescriptive approach, which assumes that certain prescribed practices are better for the environment, toward a scientific evaluation of actual performance through LCA.

Although LCA is widely recognized as the best way to evaluate the environmental impacts of buildings (ISO 14040 provides a recognized LCA methodology), it is not yet a consistent requirement of green building rating systems and codes, despite the fact that embodied energy and other life cycle impacts are critical to the design of environmentally responsible buildings.

In North America, LCA is rewarded to some extent in the Green Globes® rating system, and is part of the new American National Standard based on Green Globes, ANSI/GBI 01-2010: Green Building Protocol for Commercial Buildings. LCA is also included as a pilot credit in the LEED system, though a decision has not been made as to whether it will be incorporated fully into the next major revision. The state of California also included LCA as a voluntary measure in its 2010 draft Green Building Standards Code.

Although LCA is often perceived as overly complex and time consuming for regular use by design professionals, research organizations such as BRE in the UK and the Athena Sustainable Materials Institute in North America are working to make it more accessible.

In the UK, the BRE Green Guide to Specifications offers ratings for 1 500 building materials based on LCA.

In North America, the ATHENA® EcoCalculator for Assemblies provides LCA results for several hundred common building based on data generated by its more complex parent software, the ATHENA® Impact Estimator for Buildings. (The EcoCalculator is available free at www.athenasmi.org.) Athena software tools are especially useful early in the design process when material choices have far-reaching implications for overall environmental impact. They allow designers to experiment with different material mixes to achieve the most effective combination.

A more product-oriented tool is the BEES® (Building for Environmental and Economic Sustainability) software which combines environmental measures with economic indicators to provide a final rating. Particularly useful at the specification and procurement stage of a project, BEES 4.0 includes data on 230 products (including generic and manufacturer brands) such as siding and sheathing.

7 Checklist

There are a number of checklists listed in this document, usually sourced from the standards, such as LEED and BREEAM, that a company may be seeking for its buildings. In addition to those checklists, here is a basic checklist that an ICT organization may use in the management of its sustainability performance with respect to its buildings:

Figure 18: Checklist for managing building performance in ICT companies	
Does the company have a defined policy for sustainable buildings? Provide details.	
Does the company have defined goals and targets for sustainable buildings? Provide details.	
What percentage of company space is certified to a green building standard? Provide details on type and location.	
Does the policy require that company buildings meet green building standards for design and construction?	
Provide details of what standard and what level of certification is specified.	
Does the policy require that leased space meet green building standards for design and construction?	
Provide details of what standard and what level of certification is specified.	
Does the policy require that company space meet green building standards for operations and maintenance?	
Provide details of what standard and what level of certification is specified.	
Does the company have defined policies and procedures for suppliers related to ongoing operations that promote sustainability?	
Provide details.	

8 Conclusions

Overall, there are green building standards available for almost every type of building on a global basis and these standards are well developed and continuously being updated. These standards cover all phases of a building's life cycle from design through demolition. They are also available in a number of national standards and codes.

What is clear is that good sustainability performance is not simply about working in buildings that have been designed to be "green". Buildings that have been designed with sustainability standards in mind need to be operated and maintained using sustainability standards. Buildings that were not designed to meet sustainability standards when they were built can also be upgraded to meet sustainability standards that have been put in place for existing buildings.

Clearly, the investments that ICT companies have to make with certain types of facilities, such as data centers, has made the application of this area of work important for the sustainability performance of the company, but also drives its financial performance.

With respect to ICT usage in buildings to monitor and manage building systems, there is an opportunity to review the landscape and ensure that standards are in place and being used to ensure that equipment and systems from all manufacturers are compatible with each other.

This potential lack of compatibility may constrain building owners and operators from improving their systems when potential equipment purchases lack compatibility with current systems due to proprietary standards.

9 Glossary

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEES	Building for Environmental and Economic Sustainability
BGS	British Geological Survey
BiQ	Building Intelligence Quotient
BMS	Building Management Systems
BOMA BESt	Version of the Green Globes system operated in Canada for existing buildings by BOMA Canada
BRE	Building Research Establishment, UK
BREEAM	Building Research Establishment's Environmental Assessment Method
CABA	Continental Association for Building Automation
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CSA	Canadian Standards Association
DGNB	German Sustainable Building Council
EA	Energy and Atmosphere
ECM	Energy Conservation Measures
ECO	Energy Conservation Opportunities
EEO	Toronto's Energy Efficiency Office

FSC	Forest Stewardship Council
GB Tool	Green Building Tool
GBCA	Green Building Council of Australia
GBI	Green Building Initiative
GBP	Green Building Programme
GCC	Gulf Cooperation Council
GHG	Greenhouse Gas Emissions
GRIHA	Green Rating for Integrated Habitat Assessment
HVAC	Heating, Ventilation and Air Conditioning
ID	Innovation in Design
IEQ	Indoor Environmental Quality
IGA	Investment Grade Audit
IgCC	International green Construction Code
JRC	European Commission Directorate General Joint Research Council
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design standards for designing, building and operating more environmentally-friendly buildings
MR	Materials and Resources
MRO	Maintenance, Repair and Operations
NERC	Natural Environment Research Council
NHS	National Health Service
PUE	Power Usage Effectiveness
RP	Regional Priority
SS	Sustainable Sites
TGS	Toronto Green Standard
UPC	Abu Dhabi Urban Planning Council
USGBC	United States Green Building Council
VOC	Volatile organic compound
WBEU	Whole Building Energy Use
WE	Water Efficiency

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End-of-life management of ICT equipment

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Table of contents

End-of-life management of ICT equipment

Executive summary

The growing volumes of end-of-life (EOL)and near end-of-life ICT equipment around the globe is becoming a matter of concern, particularly as ICT equipment is characterized by high demand and a relatively short life-span. The failure to close the loop on e-waste leads not only to significant adverse environmental impacts, but also to the systematic depletion of the resource base of secondary equipment.

This document provides a definition of EOL management of ICT equipment, an outline of the various EOL stages (and accompanying legislation that applies to the stages), and a checklist that assists an organization in creating a framework for environmentally-sound management of EOL ICT equipment.

When equipment no longer satisfies the initial user's needs, we should not assume that it is in poor operational condition or has become obsolete. Instead, it may be possible to extend its life through use for the same purposes by other users. Or, it can be reused (in part or whole) for other purposes. Or, the materials contained within it can be recovered and recycled.

Decisions relating to whether the life of a piece of equipment can be extended starts with its owner, but extends to a large group of stakeholders who deal with the manufacture, transport, reuse, refurbishment, recycling, and disposal of ICT equipment.

Once it is decided that a piece of equipment is waste, it helps to apply a "waste hierarchy" to minimize the generation of waste. This requires using alternatives such as waste prevention, reduction, reuse, recycling and recovery of equipment before considering the possibility of disposal. Alongside these issues are related management issues, such as valuing the EOL assets and dealing with the security of the data that might be stored on those assets. A check-list is provided as a guide so that each of the EOL stages are dealt with, and not overlooked.

The document provides guidance for the recovery and recycling of materials contained in ICT equipment, and also discusses issues surrounding the use of conflict minerals in the context of clean supply chains.

Ultimately, for many organizations, their actions on EOL and e-waste are often tied to the choices they make regarding corporate social responsibility. In effect, smart management of their EOL assets can help them fulfil their duty to society. But, such actions should also lead to competitive business opportunities.

1 Introduction

Nowadays ICT equipment is characterized by high demand and relatively short life-span. The growing volumes of end-of-life and near-end-of-life ICT equipment around the globe is becoming a matter of concern. That is why it is important to specifically consider the end-of-life (EOL) management of ICT equipment, in particular, its aspects dealing with the sustainable use and disposal methods. End-of-life electronic and electrical equipment or e-waste is often viewed from a negative angle as simply another waste problem causing environmental and health adverse impacts, if not dealt with appropriately. However, the enormous impact of ICT equipment on resources is widely overlooked.

The failure to close the loop on e-waste leads not only to significant adverse environmental impacts, but also to the systematic depletion of the resource base of secondary equipment. Even though telecommunications is an industry of considerable energy consumption, it can also be a potential source of environmental benefits. Thus, it is critical to identify the key factors of success for the minimization and control of negative environmental impacts. This includes impacts generated by potentially inadequate solutions that could also represent contradictions to today's governmental environmental targets and standards, as well as to global trends and efforts specific to the ICT industry.

This document on End-of-life management is part of the ITU-T's Toolkit on environmental sustainability for the ICT sector.

1.1 Target audience

The target audience of this document are public and private organizations that manufacture, possess, commercialize, or use ICT equipment as part of their final product, offer services or as part of their functional infrastructure to transmit, support or deliver those services, products and supply chain.

The document provides a definition of the end-of-life management of ICT equipment and e-waste, followed by a description of EOL stages for ICT equipment and the applicable legislation. This ensures proper procedures and apportions responsibility to the stakeholders involved in the EOL through the provision of a checklist with specific questions and pointers for an environmentally sound management of EOL ICT equipment.

This document lists basic and minimum requirements for the EOL management that the actors engaged in this field should comply with, thus offering an important tool for decision-making for the EOL stage of the management of ICT equipment. It also introduces the reader to today's global efforts on the development of a clean supply chain and conflict minerals for ICT equipment as well as a brief description of the socio-economic issues.

Finally, this document describes the existing off-setting opportunities, possibilities for the development of future markets and several success stories on the reuse, refurbishing and recycling of ICT equipment.

1.2 Objectives

First, this document aims to give directions on how to find an environmentally sustainable solution for EOL equipment by providing a checklist that allows full monitoring of the decisions made in relation to ICT EOL management practices. For this purpose this document is designed to:

- describe the EOL management stages for ICT equipment and their hierarchy based on the principle of waste prevention (e.g. reuse, recycle, recovery, refurbishment, disposal) in order to protect human health, the environment as well as to support sustainable development;
- identify key challenges, opportunities and limitations faced by an EOL management provider at the different stages of ICT equipment management.

Secondly, this document aims to present different initiatives relevant to the EOL management which may be of interest to different companies, associations and other interested organizations (e.g. operators, manufacturers as well as end-users) and which may prove to be useful when looking for an EOL management solution. Such a solution should not only support the economic growth but also take into consideration the extended responsibility of producers and generators in relation to their ICT equipment on the local, national, regional and global scale.

This document identifies social, economic and environmental aspects related to the EOL management of ICT equipment.

Finally, this document intends to illustrate how the end-of-life management and its environmental aspect can be integrated into the design process as part of the life-cycle approach within the framework which is developed by the ITU-T Study Group 5 (SG 5).

2 End-of-life management

2.1 Definition of end-of-life for ICT equipment

Equipment reach its end-of-life once it becomes dysfunctional for the owner/user, becoming what some classify as waste for the particular need the user has, according to Morselli et al., 2006. The Basel Convention[1] on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the 'Basel Convention') defines waste as substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

However, when the equipment no longer satisfies the initial user's need, this does not necessarily mean that it is in poor operational condition or has become obsolete. On the contrary, this could be an opportunity for its life to be extended by either being used for the same purposes by other users whose needs can be satisfied with this equipment, or by reusing the equipment or its parts and components, in which case it is necessary to dismantle the equipment to recover its parts. It is also possible to extend the use of the material contained within it through part, component or material recovery and recycling, better known as the end-of-life management of ICT equipment.

Decisions related to extending the life of ICT equipment or choosing providers for ICT EOL practices belong to the owner or possessor who will decide to carry out this work on its own or commission a specialized company.

Whether the decision is made to either extend the life of equipment or to proceed with recovery and recycling, it must be done in compliance with environmentally sound management practices and techniques. In this regard, it is important to ensure that the service provider possesses high environmental performance capabilities.

Thus, it is important to employ the best available techniques and environmental practices for EOL of ICT equipment, which will determine the success of an environmentally responsible and sustainable outcome, without compromising economic goals. This also applies to the end-user equipment which needs to enter the collection system for the environmentally sound management reuse, recycling and disposal.

The end-of-life management of ICT equipment provides for different options offered to ICT users regarding how to recover value, securely remove data and dispose their equipment in a responsible and sustainable manner. However, end-of-life management should not be mistaken for end-of-use of ICT equipment which

1 See Annex II of this document.

is no longer used as intended by the previous owner, but may be fully functional and used appropriately by others.

It is advisable to conduct a functionality test, as suggested in ***Annex I:*** *Table 1: Example of functionality tests for used computing equipment*, as it can help to determine the best available options for either the extension or end-of-life treatment according to the state of the particular item.

One should bear in mind that in certain cases the entire item may not be considered in good operational conditions; however, its parts and components would, most of the time be in a good operational condition, which can be determined by running specific tests, usually in specialized facilities. To treat those parts and components as waste and directly dispose of them may be detrimental to the environment and a potential economic loss. There is an ongoing work as per Decision BC-10-3 of the Basel Convention to provide legal clarity of terms related to the implementation of the Basel Convention, including waste/non-waste, second hand goods, used goods, reuse, direct reuse.

Certain ICT products use complex technology and require more specialized testing methodologies that may be not available for general use. Telecommunication base stations and commercial mass storage systems are typically recovered directly by the manufacturer or through their trusted specialist decommissioning companies from around the world.

Transboundary movements of functional used ICT equipment destined for reuse (and not for operations listed under section B of Annex IV of the Basel Convention) are usually not subject to the control procedures of the Basel Convention (see 2.1 for more information). Under the Basel Convention certain Parties consider ICT equipment destined for repair, refurbishment or downgraded to waste, while others do not. If one of the countries concerned considers this equipment to be waste, the procedures on transboundary movements of e-waste should be followed.

Currently, technical guidelines on transboundary movements of e-waste are being developed by the Basel Convention Secretariat which, when adopted by the Conference of the Parties to the Basel Convention, will provide clear guidance on procedures for transboundary movements of used e-equipment and e-waste for different purposes.

Some argue that adding procedures, whether voluntary or mandatory, that aim to prevent illegal traffic of e-waste would add cost, time and resources needed for good management and performance. However, clear and predictable rules would reduce the risks associated with uncertainty for companies which transport in good faith used goods intended for resource recovery, recycling, disposal, etc., and would discourage producers or other players who look for "easier" solutions.

2.1.1 Definition of environmentally sound management of e-waste

There are a number of definitions of e-waste used by various institutions and organizations; however, for the purpose of this document, the definition of e-waste would be the one suggested by Morselli, et al. in their 2009 publication "*Waste Recovery, Strategies, Techniques and Applications in Europe*" that reads as follows:

> ***E-WASTE:*** *"Any device that for functional reasons is dependent on electric currents or electro-magnetic fields in order to work properly. It becomes e-waste when the holder discards, intends or requires to discard".*

Other definitions of e-waste include:

> "Waste electrical and electronic equipment' or 'WEEE' means electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 75/442/EEC, including all components,

subassemblies and consumables which are part of the equipment at the time of discarding (EU WEEE Directive (EC/2002/96)).

Electrical and electronic equipment that is no longer suitable for use or that the last owner has discarded (Guidance Document on the Environmentally Sound Management of Used and End-of-Life Computing Equipment, Partnership for Action on Computing Equipment (PACE)).”

The question of whether the ICT equipment is to be considered functional or waste is of fundamental importance to all stakeholders dealing with the manufacturing, transport, reuse, refurbishment, recycling, disposal of ICT equipment as the control measures set up by the relevant legal regimes differ for functional product or equipment and waste. In the case of ICT equipment, there are challenges to determine whether/when the equipment should be considered waste. Therefore, the technical guidelines on transboundary movements of e-waste, as referred to in subsection 1, aim to give guidance on how to clarify this issue. One important aspect of the transformation of equipment into waste is the intent of its owner. If equipment is disposed of, intended to be or required to be disposed of using one of the operations listed in parts A or B of Annex IV of the Basel Convention[2], this equipment will be defined as waste, and its transboundary movements shall be subject to the Basel Convention[3] control procedure. Companies in the ICT sector may choose to engage a specialized asset management company to evaluate the equipment and to certify ICT equipment as waste, if necessary. For further clarification, one may contact the Basel National Competent Authorities with questions regarding the classification of the equipment as waste (for the purpose of transboundary movements) and any relevant national definitions of waste.

In addition to the requirements of the Basel Convention, one must pay special attention to the applicable national legal framework, in particular instances where the Basel Convention provisions (e.g. the definition of “waste”) are further elaborated in the relevant rules and regulations, or where additional requirements are established concerning procedures for transboundary movements (as permitted under paragraph 11 of article 4 of the Convention). The following specific elements may be taken into account at the national level:

- The equipment or its components can be reused for the item’s original purpose;
- There is a market or demand for the equipment or its components and the equipment satisfies the technical requirements of the industry;
- The reuse of the equipment complies with the applicable requirements and does not lead to environmental or social risk;
- Contributes to climate change prevention by reducing and mitigating the effects of gas emissions;
- The market that demands the equipment or components for reuse or recycling has in place policies and legislations to control and ensure environmentally sound EOL management practices;
- The reuse or recycling of the equipment or components has no adverse effects on human health and the environment and no negative impact on economic growth and the development of healthy markets.

2.2 General description of the end-of-life management chain for ICT equipment

Once it is established that the equipment has become waste, the reverse supply chain that will allow a proper and environmentally sound management of e-waste is recommended. This process consists of three main subsequent steps:

1. The first fundamental step is identification and collection (categorized into 6 steps in the next section). The aim is to ensure that wastes that are generated are dealt with appropriately, whether that is for

[2] See Annex II of this document.

[3] For more information on the Basel National Competent Authorities visit the website: www.basel.int/Countries/CountryContacts/tabid/1342/Default.aspx.

final disposal or recycling. Particular attention should be given as to where and how waste is generated, collected and can undergo a proper treatment process. Appliances in use can indeed acquire the status of waste due to their technical specifications related to life-time, requests for new functionalities or failure (e.g. in the case of infrastructures), as well as due to consumer behaviour (e.g. in the case of end-user equipment, such as mobile phones). It is crucial to distinguish between waste generated and waste actually collected (for instance, consumers may choose to keep discarded appliances in drawers), and to highlight that distinction in each of the subsequent steps of the end-of-life management chain. Improper management could occur as a result of the stakeholders' improper behaviour as well as a lack of the appropriate technical infrastructure of the reverse supply chain.

2. After identification and collection, e-waste should enter a plant where sorting, dismantling and pre-processing (sometimes called just pre-processing) occurs; the aim is to liberate and direct e-waste to environmentally sound subsequent treatment processes. Hazardous substances have to be removed (the so-called "de-pollution phase") and stored or treated safely while components/materials that may be reused or recycled need to be taken out for reuse or to be directed to efficient recovery processes. This step could indeed include preparation for reuse and refurbishment activities for suitable components or appliances.
3. At the final phase, end-processing occurs for those fractions or components that are not destined for reuse. The aim is to ensure that final recovery of material is taking place (or safe disposal of hazardous components/substances), in order to ensure that raw materials are re-entering the economic cycle as new products.

The efficiency of the entire reverse supply chain and its ability to meet social, economic and environmental needs depends on the efficiency of each step and on how well the interfaces between these interdependent steps are managed. This means that all stakeholders involved in the different steps should properly interact and all responsibilities should be clearly defined.

In order to enhance the perception of sustainability within the EOL management, it is also important to look at the complexity of the structure of the ICT sector and its dynamics. Doing so will prevent overlooking opportunities that can arise when creating a closed loop cycle between the design of products or equipment and their disposal as a part of a global sustainable ICT solution.

There are companies that can perform either some or all of the processes associated with the EOL management of e-waste within their facilities. There are two considerations to be taken into account:

- The removal of hazardous components or substances. This is often done during the so-called the de-pollution phase and, sometimes, in specific high-tech processes as part of the downstream activities.
- The separation and recovery of the maximum possible amount of the main recyclable fractions (e.g. ferrous metals, copper, aluminium, glass, plastics), which is carried out in the pre-processing phase as well as in the further refining processes as part of the downstream activities.

2.2.1 Transboundary movements of hazardous wastes and other wastes

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the 'Basel Convention') was adopted on 22 March 1989 and entered into force on 5 May 1992. As of today, the Basel Convention has 178 Parties. The Basel Convention aims to protect human health and the environment against the adverse effects which may result from the generation and management of hazardous and other wastes. It emphasizes, amongst other principles, environmentally sound management (ESM) of hazardous and other wastes. ESM is defined as taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes. The Convention stipulates a number of specific requirements, including the following:

- the minimization of the generation of hazardous and other wastes;

- the reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention to the minimum consistent with the environmentally sound and efficient management of such wastes;
- specific conditions and a detailed control procedure for any proposed transboundary movement of hazardous and other wastes;
- cooperation to promote transfer of technology and use of low-waste technologies.

Key elements of the control procedure under the Basel Convention include prior notification and informed consent; prohibition of exports to or imports from countries which are not Parties to the Convention (except when a specific agreement exists as provided for by the Convention, see below); prohibition of exports to Parties that have prohibited imports under their national legislation; establishment of a duty to re-import when a movement cannot be completed as stated under the contract; and responsibilities of Parties when undertaking or involved in transboundary movements, including in the event of illegal traffic of wastes. The Basel Convention requires the state of export to notify (or require the generator or exporter to notify) in writing and obtain consent from all import and transit countries before any movement of hazardous or other wastes begins. Parties have adopted a notification document for this purpose.

It should be recognized that all Parties have the sovereign right to prohibit or restrict transboundary movements of hazardous and/or other wastes and can impose additional requirements on such movements in their territory.

Parties are required not to allow transboundary movements of wastes to proceed if they believe that the wastes in question will not be managed in an environmentally sound manner. Each shipment under the Convention must also be accompanied by a movement document from the point at which a transboundary movement begins to the point of disposal. The wastes must be transported according to generally accepted and recognized packaging, labelling and transport international rules and standards, such as the United Nations Recommendations on the Transport of Dangerous Goods and Model Regulations.

In addition to these provisions, at the second meeting of the Conference of the Parties to the Convention (COP) in March 1994, Parties adopted a decision to prohibit immediately all transboundary movements of hazardous wastes destined for final disposal operations from OECD to non-OECD States. By the same decision, Parties also agreed to phase out by 31 December 1997, and prohibit as of that date, all transboundary movements of hazardous wastes destined for recovery or recycling operations from OECD to non-OECD States (decision II/12). At its next meeting (COP-3) in 1995, Parties adopted a further decision III/1 in this regard as an amendment to the Convention (the 'Ban Amendment').

The Ban Amendment prohibits transboundary movements of hazardous wastes covered by the Convention and intended for final disposal from States listed in the Annex VII (Parties and other States which are members of the OECD, EC and Liechtenstein) to those not listed in Annex VII. It also prohibits transboundary movements of hazardous wastes covered by paragraph 1 (a) of Article 1 of the Convention to States not listed in Annex VII and that are destined for reuse, recycling or recovery operations.

At the COP 10 meeting in October 2011, Parties agreed on an interpretation of Article 17(5) of the Convention. Consequently, amendments to the Convention, including the Ban Amendment, enter into force between Parties having accepted them on the ninetieth day after the Depositary receives the relevant instruments of ratification, acceptance, approval or formal confirmation from at least three fourths of the Parties that were Parties at the time of adoption of the amendment. The Ban Amendment has not yet entered into force but it is already implemented by those Parties who ratified it.

Article 11 of the Convention concerns bilateral, multilateral and regional agreements or arrangements regarding the transboundary movement of wastes. As mentioned above, Parties cannot export to or import from countries that are not Parties to the Convention unless they have entered into an agreement or arrangement under Article 11. Parties may enter into such agreements or arrangements, resulting in transboundary movements with non-Parties, so long as those agreements or arrangements do not derogate from the environmentally sound management of hazardous wastes as required by the Convention, and those agreements or arrangements stipulate provisions which are not less environmentally sound than those provided for by the Convention, in particular taking into account the interests of developing countries.

Waste electrical and electronic assemblies or scrap containing certain components are listed in Annex VIII of the Basel Convention and can be considered as hazardous waste[4] (Entry A1180) or non-hazardous waste (Annex IX as B1110):

> **A1180** Waste electrical and electronic assemblies or scrap[5] containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors, or contaminated with Annex I constituents (e.g. cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B, B1110).[6]
>
> **B1110** Electrical and electronic assemblies:

- ◊ Electronic assemblies consisting only of metals or alloys.
- ◊ Waste electrical and electronic assemblies or scrap[7] (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex I constituents (e.g. cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A A1180).
- ◊ Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse[8], and not for recycling or final disposal.[9]

Electronic equipment will often contain hazardous components examples of which are indicated in the entry A1180 of Annex VIII. E-waste will therefore be assumed hazardous unless it can be shown that it does not contain such components.

While the used ICT equipment will not be subject to the Basel Convention’s control mechanism, unless national legislation and measures provide otherwise, the challenge is to distinguish between what is waste and non-waste. The lack of clarity in defining when used equipment and equipment is or is not considered waste has led to a number of situations where such equipment was exported, in particular to developing countries, for reuse. On arrival, a large percentage of the shipment was in fact discovered to be waste rather than functional equipment and it had to be taken back by the State for export or be disposed of in the country of import or transited as waste. The frequent presence of hazardous substances and components in this equipment or waste and a shortage of adequate installations to treat these in an environmentally sound manner have led to serious problems for human health and the environment in the countries receiving this e-waste.

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4 Wastes listed in Annex VIII of the Basel Convention are considered hazardous unless the hazardous characteristics in Annex III are used to demonstrate that the wastes are not hazardous.

5 This entry does not include scrap assemblies from electric power generation.

6 PCBs are at a concentration level of 50 mg/kg or more.

7 This entry does not include scrap from electrical power generation.

8 Reuse can include repair, refurbishment or upgrading, but not major reassembly.

9 In some countries these materials destined for direct reuse are not considered wastes.

2.3 End-of-life Management: steps for the organization

2.3.1 From an Internal Perspective

For successful e-waste management it is necessary that each organization not just understands what types of wastes it generates, but also streamlines the processes for its safe reuse, recycling or disposal. Here are 6 steps that will nudge organizations to grapple with the challenge of responsible e-waste disposal.

1. Who is responsible for End-of-Life within the organization?

   Identifying departments which are responsible is very important. Typically, within large corporates, e-waste that is generated (such as computers, monitors and telecommunication equipment) is the IT department's responsibility. These assets will be tagged and an inventory of such equipment is usually available with the IT department. Other types of electrical and universal wastes like fans, coffee machines, and printer cartridges could come under the jurisdiction of the Facilities department. Universal wastes, such as batteries, compact fluorescent lamps (CFL) mercury containing lamps, would also come under the jurisdiction of the facilities department. As there may be more than one department responsible for different types of e-waste, such as facilities, house-keeping, or accounts, etc, clear responsibilities with respect to end-of-life management options need to be assigned to each department. An individual with defined roles and responsibilities must be identified for each department.

2. What do we track?

   Understanding the end-of-life management options for the waste that the organization will generate is key to the appropriate management of inventory. In this context, the inventory should consist of a list of all the items that could be classified by end-of-life management options. There should be information on the source of waste, the type of waste and the quantity of waste, and should track an item from purchase through to use and disposal. It can be confusing to an organization to know what is classified and tracked under end-of-life management options. Therefore, all the relevant departments need to have a complete list of all types of e-waste product generated in the organization. Suitable software could ensure complete tracking of the material, and identification of material which reaches the end of its life. Such software can help in maintaining the status of each item. Items which are bonded should be identified through the pasting of an appropriate sticker, with relevant details in terms of date and number.

   IT asset management solutions help organisations manage their IT assets from procurement to retirement. Such tracking mechanisms do exist within large organizations and can be leveraged to achieve end-of-life reporting and management requirements.

3. Where do we store e-waste?

   A suitable storage space is required which is sufficiently large to store all the e-waste safely. Storage norms are required for each category of e-waste. For example, CFLs and fluorescent lamps which are fragile should be safely placed in drums or returned to the original packing. Similarly, a dedicated bin is required for printer cartridges. This storage space should be separate from space allocated for other scrap, including old chairs and other metal scrap.

4. What permissions are to be sought?

   Companies who have independent facilities and are registered under current and applicable legislation have to apply to the Pollution Control Board(PCB) or similar regulatory body for registration to allow them to store hazardous waste (e-waste) as per relevant local and federal laws. This may vary from country to country. Typically, country-specific norms have to be adhered here.

5. How to provide end-of-life management solutions?

The company must identify a suitable e-waste recycler who is authorized to recycle e-waste, and enter into an agreement with this recycler. Groups of companies located with a common collection center can use such a facility to dispose of EOL products. Alternative options, such as upgrades on existing machines, or reuse of electronic equipment in different departments before final disposal, could be encouraged. A process to ensure which equipment can be reused before recycling is a good way to extend the life of the product. Used printer cartridges can be handed over for remanufacturing. This ensures that the entire shell of the cartridge is used again, instead of being crushed and recycled.

6. Documentation

   The e-waste that is collected needs to be documented. This documentation is available from the recycler. The documentation is evidence of the total quantity of products handed over for recycling. A copy of this document is then also handed over by the company to the Pollution Control Board or relevant regulatory body. Relevant documentation varies from country to country. End- of-life reporting is now an added regulatory burden for most organisations worldwide.

   The recycler would need to keep track of processes, volumes, and origin of the EOL products for routine regulatory check-up. It would be good practice for recyclers to share this report with the client company, separate to its reporting to the regulatory authorities. Companies could request the recycler to share the report for final destination of e-waste. This could be coupled with site visits at the recycling facility to ensure that proper e-waste handling and disposal is put into practice by the recycler.

2.3.2 From High-Technology Business Districts

In several IT-intensive parts of the world, such as India and China, governments have set up Special Economic Zones (SEZ) or Hi-Tech parks or business districts. SEZs enjoy special status which facilitates the exports of goods manufactured in these areas. Due to this status, all electronic goods which are purchased for use inside the SEZ are bonded. When they have to be disposed of, they need to undergo a process of de-bonding which is a cost to the company in the form of excise duty. This is an additional step that organizations operating out of an SEZ would need to adopt into their EOL management practices.

2.3.3 From a donations receptor perspective

Donations of used electronic equipment are carried out worldwide, thereby extending the life of these goods. Organisations that accept donations (donation receptor) need to understand how to responsibly dispose of these goods at the end of their life. It would be a good practice for the donor and receptor to mutually agree on the disposal of these goods through an authorised recycler. Keeping track of donated goods and received goods would therefore be required to ensure tracking and avoiding leakages.

2.4 End-of-life management: stages and waste hierarchy

In order to aim for the best goals and results when thinking of waste prevention and waste management, the principle of “waste hierarchy” provides the steps to follow based on waste desirability. This principle aims to minimize the generation of waste by using alternatives such as waste prevention, reduction, reuse, recycling and recovery of equipment before considering the possibility of disposal, which can have an environmental impact. Other principles such as environmental sustainability should also be considered when considering best environmental solutions for End- of-life management of ICT equipment.

Sometimes it is necessary to deviate from the hierarchy in order to achieve better environmental results. This, however, should be in line with the life-cycle approach and other principles such as prevention of waste and environmental sustainability.

In some cases, it is environmentally, socially and financially feasible to develop an EOL management procedure that follows the hierarchy principle. Other procedures can be customized to the EOL management according to global circumstances which can bring positive impacts on environmental as well as social and economic aspects of the EOL management for ICT equipment.

For instance, when equipment waste is generated in a location where there are no environmentally sound solutions for dismantling or recycling of the specific components, be they plastics, or metals, some argue that it would be advisable to transport them to a location where waste legislation is in place and the service provider delivers the service according to the national environmental legislation and international standard requirements. It is recommended that companies comply with the requirements of national legislation and global standards.

Understanding the goals of environmentally sound management of EOL ICT equipment will help us to highlight the importance of the different stages individually, to demonstrate how they are linked together, to identify their risks, limitations and opportunities as well as the legal requirements associated with the process. A general example that provides an overview of the different stages of EOL is presented in Figure 1: EOL Management for computing equipment[10].

2.4.1 General legal framework

There are international, regional and national regulatory regimes (e.g. global treaties, multilateral environmental agreements (MEAs), statutes, laws, regulations, international standards) that regulate the interaction between activities associated with the environmentally sound EOL management of ICT equipment with the purpose of reducing the adverse impacts of these activities. They aim to provide an appropriate protection to human health and the environment from unsound practices as well as to support the economic performance of the EOL management.

Given the global focus of this study, a full definitive list of laws, regulations and directives is not only unreasonable but also not practical. Annex III provides guidance for the general legal framework that applies to the process of EOL management. The list of documents contained in the annex is not exhaustive and it is recommended to regularly verify for amendments or revised documents ANNEX III: List 1: General References to the legislation, international standards and guidance documents

It is strongly recommended that when making use of this guidance and especially when consulting Annex III, the reader establish the documents applicable to the specific case and follow the indications according to the type of material (e.g. mobile phones, batteries, monitors, others, location, volumes and required documentation with regard to transport, storage and reporting procedures to the respective environmental authority, etc.).

2.4.2 Asset management

Asset management is understood as a practice that aims for a maximum return on obsolete or excess ICT equipment designated for the end-of-life. This is the stage where the owner of the equipment intends to recover value through requesting and approving the procurement process of life cycle extension before dismantling and EOL management processes, or when the owner intends to send the equipment directly to EOL processes (e.g. recycling, refinery and disposal).

Asset management involves the administration of the physical components of ICT equipment such as parts of computers and networks for acquisition as well as software asset management, which is a similar process, focusing on software assets, including licenses, information and prototypes.

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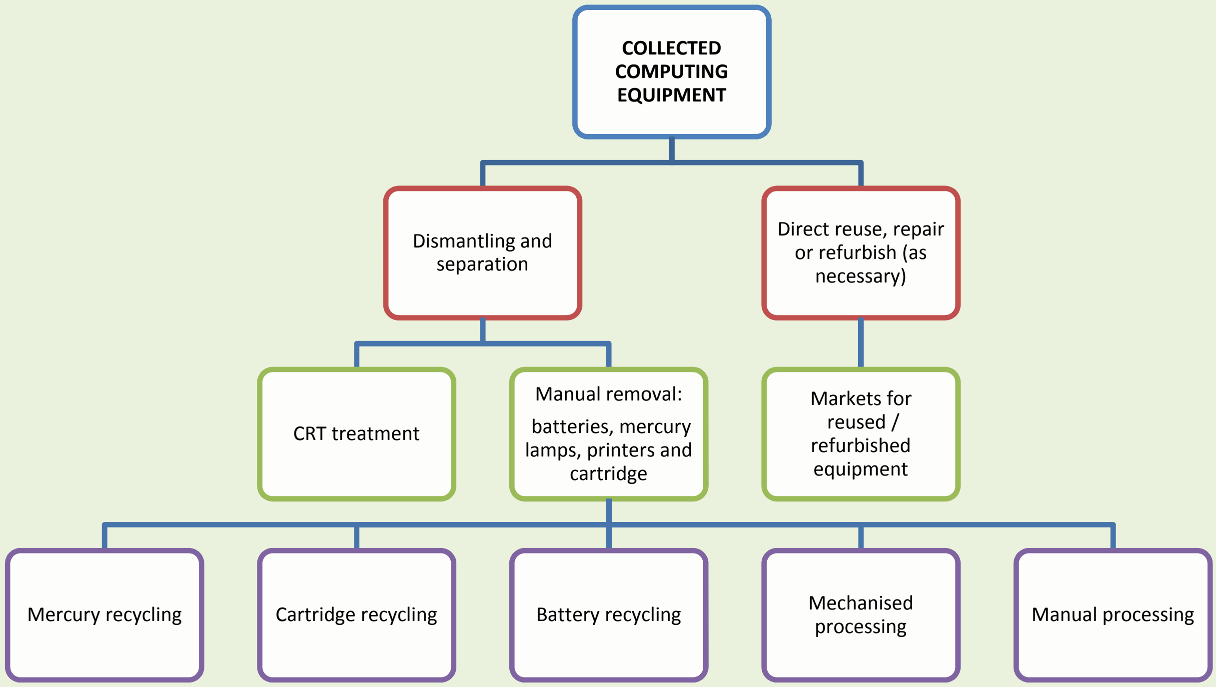
[10] Based on figure 1 in the Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment, PACE, 2011.

Figure 1: EOL management for computing equipment



2.4.3 Secure information management

In relation to data security, it is the duty of organizations under the local data protection acts which require all information collected by an organization to be destroyed when the media (in this case computer hard drives) in which it is stored comes to the end-of-life. Organizations and individuals within these organizations must ensure that all confidential data is dealt with at the time when the storage media is disposed of and non-compliance can lead to significant fines as well as the risk to damage the organization brand image. There are two sure-fire methods to ensure that there is no data leakage at this point and these are either a data destruction software package or degaussing. Preferably utilizing Communications-Electronics Security Group and Ministries of Defence approved software, these data destruction packages offer certification per hard drive giving organizations a guarantee that all data has been dealt with in a speedy and appropriate manner. At this point, the asset can be redeployed into another area of business activity, sold for reuse or donated for charitable use. The other method of secure data destruction is by means of degaussing. This method utilizes electromagnetic fields that disrupt the surface area of the part of the hard drive where the data is stored making it unrecoverable. Computer hard drives cannot be reused after degaussing and should the equipment be offered for reuse, new hard drives need to be installed.

Asset management is a key element in the end-of-life cycle as it helps the organization in making business decisions based on meaningful and measurable financial objectives. However, financial decisions cannot lift in any way the responsibility with regard to finding an optimal environmental solution to ICT equipment at this stage.

Specialized facilities around the world deal with this type of equipment achieving outstanding solutions in both areas, financial and environmental, making sure that the problem is not being shifted to other locations generating uncontrolled socio-environmental effects as well as risking the waste generator’s brand management image either on the local or global scale.

2.4.4 Reverse logistics

In this phase, appliances are transported from different locations to the warehouses where they are stored (in case logistics optimization is needed for further transport) or pre-processed (including segregation, dismantling and preparation for reuse).

There is a fundamental difference between consumer products and professional equipment. Usually consumers bring discarded products to municipal collection points or to retailer shops, which means that the equipment can be collected in large quantities and picked up in full loads by logistics providers. In case of professional equipment, when companies decide to discard equipment, a request is made to the logistics providers for a pick-up so that waste can be collected at user's premises.

In both cases, it would be advisable to test the equipment in order to evaluate the possibility for its reuse from technical and cosmetic characteristics.

In some countries, the informal sector will collect used or end-of-life ICT equipment either directly from consumers or from informal stockpiles, as used and end-of-use equipment have value for reuse. In some countries, formal collection takes place by municipal authorities where there are "bring" or "take-back" schemes to effect collection of used and end-of-life ICT equipment. In some cases these are funded through extended producer responsibility schemes. Collection of used ICT equipment from business, commerce and public sector organizations is important because of the large numbers that may be involved; this equipment may be a particularly good source of used, end-of-use and end-of-life equipment for refurbishment as well as for material recovery.

It is possible to run specific software on a personal computer or laptop that wipes or purges the hard drive to Ministry of Defence acceptable standards. Care should be taken that workers at refurbishment facilities are trained in wiping hard drives before the computing equipment is tested, so that no information stored on the hard drive is accessed inappropriately. If the hard drive cannot be successfully wiped or purged, then the drive should be destroyed physically.

In the case of mobile phones, collection of used mobile phones through telecom operators, retailers or manufacturer distribution channels should be a key element in an efficient collection system. Other collection methods may also be considered. In the case of collection by mail, postage may also be paid by the collection system, especially where a large number of used mobile phones are being sent in shipping packages. Manufacturers, telecom operators and mobile phone distributors should consider the possibility of sharing, as part of Extended Producer Responsibility (EPR) systems, the physical and/or financial obligations entailed by the collection and management of used mobile phones. This is particularly necessary and should be implemented as soon as possible in countries where the legislation and infrastructure for the collection of used mobile phones is lacking.

During handling and transportation, the equipment should be handled with care to avoid damaging and reducing their reuse and refurbishment potential or increasing the need of cosmetic refurbishing. Some of the aspects that need to be taken into account when thinking of reverse logistics are volumes, collection points and transboundary movements as well as the final destination of the collected items.

ICT equipment usually contains large percentages of plastics with a large volume but very little economic value, making the collection of equipment expensive even before the real value of such equipment can be determined by specialized companies.

Preparation for reuse typically involves disassembly, inspection and cleaning, electrical safety and function testing, component retrieval, component repair, component exchange, software installation and reassembly (see more detailed information in section 2.2.6).

2.4.5 Dismantling and segregation

The next step in the life cycle approach is dismantling and segregation. Careful manual separation of equipment components such as cathode ray tube (CRT) monitors, LCD displays, printers, laptops and desktops is a necessary first step. Each type of equipment will then be further segregated for separate recycling and material recovery processing, following the procedures that are appropriate for that type of equipment. For example, processing of printers will begin with the manual removal of ink and toner cartridges, so that these cartridges can be recycled in their own way, e.g. by refilling and rebuilding. CRTs require unique handling and attention to their vacuums, phosphors and lead. Some particularly problematical contents must be carefully manually removed from laptops, LCD screens and some older scanners: e.g. batteries, and mercury lamps. This is important because these components may complicate other material recovery streams if not removed at the start, and/or are likely to release hazardous substances into the remaining electronics, the workplace, and/or the environment during subsequent material equipment recovery processes.

This initial dismantling and removal of certain components from computing equipment may also be required by law, such as the EU WEEE Directive.

Removal of problematic components can be potentially possess hazardous for human health and environment. For example, removal of mercury lamps from LCD monitors is very likely to cause breakage, and release of mercury. The lamps are located along the sides of and behind LCD screens, and are long thin fragile glass tubes. Some lamps will almost certainly break during removal and handling; as a result, the dismantling operation should be well prepared to test its working atmosphere for mercury vapour, and to clean up visible mercury spills. Some facilities have decided not to remove the mercury lamps because of fear of breakage, and decide to send the entire LCD screen to licensed mercury treatment facilities, which have special expertise.

After the removal of the problematic components, the equipment should be further disassembled, sorted into various material streams, e.g. steel, aluminium, circuit boards, and plastics. These streams should then be sent to specialized material recovery processes.

Disassembly and separation can be done by continued use of manual labour, or by mechanized processes, or by both.

The decision of which methods to use depends primarily upon the economics, taking into account the initial cost of the machinery, the cost of manual labour, the availability of downstream processors with proper, environmentally sound recovery techniques, and the available market value of the components and equipment produced. Avoidance of high hazardous waste disposal costs can also be an economic incentive. In developing countries and in countries with economies in transition, if the costs of manual labour are low, the manual disassembly path is often taken. In industrialized countries, too, manual disassembly is often used, because it can produce more reusable computing equipment and very clean separated equipment for efficient further material recovery.

Disassembly by manual labour does not require significant technological skills, although worker training to safely carry out specific manual tasks is always important. It provides employment for workers, and can produce clean sorted material components that can be sold. It can also facilitate a careful removal of working components for additional value.

Careful separation to avoid losses is important for environmental reasons, because the recovery and recycling of metals requires significantly less energy and ecosystem disruption than in the extraction of these metals from ores. For example, the energy required to produce aluminium from scrap is only 5% of the energy required for production from ore. Gold is present in many computer circuit boards at a 40-70 times higher concentration than ore, and does not have to be mined at very low concentrations, e.g. as low as one gram of gold per tonne of rock, with great use of energy and chemicals such as cyanide.

To summarize, as ICT equipment represents a broad range of devices, dismantling and pre-processing activities mainly focus on:

- removal of hazardous components, such as ink cartridges (where present), printed circuit boards (PCBs) containing capacitors, mercury containing switchers and batteries (NiCd, NiMH Li-ion and Li-Polymer);
- removal and recovery of valuable or reusable components like HDs or fractions, e.g. PCBs.

ICT appliances do not present critical issues with regard to occupational health and safety during the pre-processing steps as long as massive exposure to dust is avoided. Consequentially, manual dismantling could be a very effective and efficient way to recover the economic and environmental value in such an e-waste stream.

Section highlights

Figure 2: Understanding dismantling and segregation

Issue	Dismantling and segregation
Definition	Careful manual separation of equipment parts and components. Tools such as electric or pneumatic screwdrivers can be applied to accelerate the speed of dismantling
Actors	Authorized recyclers, specialized authorized refurbishment company
Scope	Local to global
Equipment	EEE : obsolete, excesses and end of life
Challenges	• Effectiveness and efficiency of manual/mechanized processes • Removal of hazardous components, and batteries • Removal and recovery of value or reusable components avoiding value lost • Health and safety employee and facilities requirements • Technical knowledge and training • Legal compliance according to facility operations
Risk / Opportunities	• Time/cost efficiency and effectiveness of manual/mechanized processes • Facilities labour legal requirements • Reduction of energy demand and raw material
Best practices	• Well-trained labour to minimize value lost • Endure clean sorted material components that can be sold • Careful removal of working components • Licensed treatment facilities

2.4.6 Refurbishment

The process of refurbishment of ICT equipment is twofold. The first step in the refurbishment process is to verify hardware functionality through initial testing, removal of old data and software, and instalment of new hardware (parts), as needed. During this preparatory process, digital data destruction software might also remove all software including the basic set of instructions called an operating system. It is helpful to imagine equipment at this point as a polished mirror, awaiting a new set of instructions. The second step is to install the required instruction sets (software, both the operating system and applications) that control the hardware and provide the desired user functionality.

Refurbishment facilities should ensure that components and other equipment removed from ICT equipment, which are destined for reuse, are handled in a suitable manner that preserves their value. It is encouraged to minimize the landfilling of ICT components and equipment and arrange for an appropriate recovery and recycling where practicable.

In the case of domestic movements, refurbishment facilities should ensure that ICT equipment and its components (e.g. batteries) and residuals destined for recovery and recycling are prepared for shipment and transported in a safe and secure manner that complies with applicable hazardous equipment and/or dangerous goods transport regulations of the country and/or region.

In the case of transboundary movements, refurbishment facilities should ensure that ICT equipment and its components (e.g. batteries) and residuals destined for material recovery are prepared for shipment and transported in full compliance with the Basel Convention. Where refurbishers or other parties are exporting refurbished equipment, care should be taken to ensure compliance with all applicable laws governing equipment trade.

Refurbishment facilities dealing with equipment that is potentially hazardous to the health and safety of their workers or the environment are required to have processes in place, documented or otherwise, to ensure that this equipment is regularly inspected and monitored as required by the regulatory authorities of their country. For example, refurbishers of printers are often exposed to toner dust and therefore appropriate safety measures need to be applied.

If equipment and materials to be refurbished are defined as “waste” by the country in which they are being refurbished, the refurbishment facilities must hold all relevant waste management permits, licenses or other authorizations required by the regulatory authorities of their country. Also, refurbishment facilities should be in compliance with all applicable local regulations and permits or other authorizations that are related to the environment or human health and safety.

In developing countries, refurbishing of all types of electrical and electronic equipment, including ICT equipment, is an important economic activity in providing consumers with lower priced equipment. In some countries, the refurbishing sector has become the sector that provides income for thousands of small, partly informal enterprises in urban areas. Workers engaged in refurbishing of used electrical and electronic equipment often have a comparably high education and most of them went through a sector-specific apprenticeship system. It is worth noting that many of these enterprises are registered with the local authorities and pay taxes to local and regional administrations. In Africa and some countries in Asia in contrast the collection and recycling of e-waste is almost exclusively carried out by non-registered individuals commonly referred to as “scavengers”, the refurbishing sector operates partly under formal conditions.

As for the adverse health and environmental effects from refurbishing, in addition to the safety measures described above, refurbishers in the context of a developing country not connected to a stable electricity supply are dependent on generators, which are often placed in such a way that exhaust emissions negatively affect the air quality of the workplace.

Section highlights

Figure 3: Dealing with refurbishment	
Issue	**Refurbishment**
Definition	Any operations to allow and EEE considered as waste to work again includes both hardware and software operations
Actors	Refurbishment companies Manufacturer's authorized repair centers, authorized recyclers and specialized test centers. Informal sector (in emerging countries) Distributors (for collection)
Scope	Global
Equipment	EEE : obsolete, excesses and end- of-life
Challenges	• Refurbishment company to be authorized and hold: waste management permits, licenses or equivalent authorization required by the regulatory authorities of the country. • Identify minimum global requirements for equipment's second life: complete technology, components. • Responsible and traceable contribution to digital gap reduction in emerging countries • Reporting schemes in develop countries to control leakages • Capacity building in emerging countries • Close the loop and reduce natural resources demand (metals, rare earth)
Risk / opportunities	• EEE programmed obsolescence (limited software upgrade)
Best practices	• Secure information management • Actors environmental and legal compliancy (e.g. hazardous, permits, local authorizations, traceable processes)

2.4.7 Reuse

Reuse of ICT equipment, described as the extension of the life of the equipment or its components to be used for the same purpose for which it was initially conceptualized, may or may not involve change of equipment ownership, or support its life cycle towards a more optimal use of environmental and economic resources. However, it does not constitute a solution to the e-waste problem in its own whilst reducing the amounts of waste generated. Generally, it also involves a combination of specific after-use services like data destruction and environmental compliance certification.

The functionality tests should be performed for used ICT equipment to confirm that the equipment is fully functional and is suitable for reuse. From a sustainable point of view, the reuse of ICT equipment brings benefits by not only extending its life cycle and reducing waste generation and creating an income for the owner once the equipment reaches the market, but also by reducing e-waste by not shifting geographically to locations where its negative impacts will be maximized in the long run either due to the lack of control and legislation or the infrastructure for specialized treatment. Successful reuse operations should be completed in accordance with the General Material Recovery and Recycling Facility Guidelines described later on in this document.

There is also a need to review reuse and recycling rates of ICT proposed by some directives such as the European directives Restriction of Hazardous Substances (RoHS) and the Registration, Evaluation, Authorization and Restriction of Chemical substances (REACH) regulation, allowing not only the possibility of lower human health risk and environmental impact.

Section highlights

Figure 4: Handling reuse	
Issue	**Reuse**
Definition	Equipment or its components' life extension for the same purpose for which it was initially conceptualized, may or may not involve change of equipment ownership. Aims to support a more optimal use of environmental and economic resources
Actors	Manufacturers, equipment owner, refurbished authorized recyclers
Scope	Global
Equipment	EEE : obsolete, excesses and end of life
Challenges	• Standardized functionality tests to identify optimal second life spam • Limited solution for EEE waste streams according to technological needs • Report and traceable processes • Second life market must have e-waste management capabilities
Risk / opportunities	• Waste generation reduction • Lack of environmental legislation in developed countries may shift e-waste problematic to other geographical locations where no legislation or infrastructure is in place
Best practices	• Successful reuse operations should be completed in accordance with the General Material Recovery and Recycling Facility Guidelines described later on in this document • Governments shall maximize efforts to develop and enforcement of legislation from local to global (e.g. hazardous, permits, local authorizations, traceable processes)

2.4.8 Recycling and recovery

Recycling is responsible for the recovery of equipment; manual and semi-manual dismantling can be efficient to further disassemble the components including power supply, hard discs and disc drivers. Tools such as electric or pneumatic screwdrivers can be applied to accelerate the speed of dismantling.

The benefit of carrying out manual dismantling is that after the disassembly of the equipment, it can be easily grouped into different fractions in its complete and intact forms, which could reduce the separation effort in the end-processing phase and enable the reclaim of the reusable parts. For example, printed circuit boards which are not mixed with any other fractions can give a higher metal yield during the end-processing. A stream line assigning a specific dismantling division to different workers would greatly improve the dismantling efficiency. This approach is eco-efficiently preferable in areas with a lower labour cost and abundant workforce.

Notwithstanding eco-efficiency in manual dismantling, preprocessing and even automated processes for treating these items based on shredding, followed by a mechanical separation, have been developed. Such processes use multiple stage shredding steps to reduce the equipment in size. Different metal fractions are then extracted from the shredded equipment using a magnetic belt to remove ferrous metals followed by an eddy current separator which removes non-ferrous metals.

The non-ferrous material is further separated into copper, aluminium, brass, etc., using optical sorting, density separation, eddy current separation or vibration separation among other methods. The remaining non-metallic material is then processed in order to separate circuit boards and wire, while the other remaining fractions are landfilled. It must be emphasized that from a resource perspective it is better to recover the high-grade printed wiring boards (PWBs) prior to shredding to avoid high losses of precious metals. Furthermore, extensive shredding of PWBs and plastics can generate dust containing (brominated) flame retardants as well as dioxins within the hot shredder equipment. Exposure of the workers to these substances can be avoided by removing the PWBs before shredding and by taking adequate occupational hygienic measures.

Recycling of batteries

Battery recycling aims to minimize the environmental impact generated by the heavy metals and toxic chemicals found in batteries that are disposed of as municipal solid waste. This practice has dramatically increased the risks of soil contamination and water pollution.

According to DEFRA (the UK Department for Environment, Food and Rural Affairs) in its document *Battery Waste Management Life Cycle Assessment* published in 2006, the ten most commonly used batteries in America and Europe are recycled through three specialized processes including: Cryogenic, Pyrometallurgical and Hydrometallurgical recycling routes as shown in Figure 5: Common recycling processes for batteries in America and Europe.

In computing and mobile telecommunication equipment, batteries are of two types; both are based on lithium chemistry.

There is a very small lithium battery in the primary circuit board (the "motherboard"), about the size of a coin and sometimes called a "coin cell" or "button cell." There is a much larger rechargeable lithium-ion battery in a laptop/notebook/netbook computer that provides operating electrical power. Older computers used rechargeable nickel metal hydride (NiMH) batteries (and occasionally also NiCd), which will also be found in end-of-life computers. This larger battery must be removed and not shredded, unless the shredding equipment has the necessary pollution control equipment to manage such operations, and is licensed and permitted to do so. If this large battery remains in the equipment when it is shredded, it will break and will leak caustic electrolyte, causing a risk to the workers, a risk of fire, damage to the equipment, and contamination of other materials. Batteries may also still contain an electrical charge, and if their handling brings them into contact with a conducting metal, they will rapidly discharge (a "short circuit"), causing heat and possibly a fire.

Batteries have different compositions depending on their type, as shown in Table 2 Battery composition. These differences would require different processes, hence the difficulty and cost variations.

For recyclers the main difficulties regarding battery recycling are finding built-in batteries in ICT equipment and the high cost to process batteries due to very limited cost-effective methods developed in the industry.

This problem will be minimized by promoting the use of rechargeable batteries as they are made of more valuable material and the methods for recycling them are more effective in recovering valuable metals for reuse.

Figure 5: Common recycling processes for batteries in America and Europe

Battery type	Typical use	Current Battery Recycling routes
Silver Oxide (AgO)	Cameras, pocket calculators	Mercury distillation and silver recovery UK
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Pyrometallurgical and Hydrometallurgical
Lithium Manganese (LiMn)	Pocket calculators	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Lithium (Li)	Photographic equipment, remote controls and electronics	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe

Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Lithium Ion (Li-ion)	Mobile phones, lap- and palmtops	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Nickel Cadmium (NiCd)	Emergency lighting Cordless phones, power tools	Pyrometallurgical EU
Nickel Metal Hydride (NiMH)	Mobile and cordless phones	Pyrometallurgical EU
Lead Acid (PbA)	Hobby applications	Pyrometallurgical EU
Source: www.epbaeurope.net/090607_2006_Oct.pdf – June 2011		

Recovery of metals

ICT equipment contains many substances, many of which are metals. Some of these metals are used in the equipment in relatively large amounts, e.g. steel in millions of desktop computer cases, while some metals are used only in very small amounts, e.g. indium in the inside coating of LCD display screens. There are ways in laboratory science to recover every type of metal contained in computing equipment, but the actual recovery of useful amounts is more difficult, especially from complex substances, and recovery of all metals is simply not possible. Recovery of some metals will cause inevitable losses of others. Furthermore, recovery of any metal, especially with environmentally sound management, costs of course money.

There may be many steps required for final recovery, and it is necessary for a metal recovery facility to pay for equipment, pollution control systems, labour, supplies and operating expenses, etc. If the amount of a specific metal in ICT equipment is small, and/or the market price of that metal is low, that metal is usually not recovered. For example, although indium has a fairly high current market price, the amount in an LCD display screen is very small, and the cost of recovery is high; as a result, indium has traditionally not been recovered from end-of-life computing equipment. Lithium does not currently have a market price high enough to pay for the costs of recovery, and so the lithium contained in batteries, although available in relatively high amounts, has traditionally not been recovered, even if this is technically possible in the current battery recycling processes.

On the other hand, although the amount of gold and silver in a circuit board is quite small, the current market price of gold is much higher, and it has traditionally been recovered. In some cases, alloys can be recycled directly back into the same alloys, which improves the economic return and can be important with critical metals.

The decision of which metals to recover is thus traditionally commercial – if a specific metal can be fully recovered by a facility and sold for a profit, it will be recovered. As key and strategic metals from environmental and resource perspective are present in ICTs, perspectives different than the pure economic ones should be considered, especially by policy makers. Final metal recovery from ICT equipment has been done only by the private industry for more than fifty years, always on this commercial profit basis. Participants in the business of metal recovery should be aware of the metals in their equipment and the sound environmental management of those metals, and should also be aware of their commercial options, and should consider metal recovery processes and business partners who, while using environmentally sound management, will efficiently recover those metals.

Figure 6: Battery composition

Battery type	Alkaline manganese	Zinc carbon	Mercuric oxide	Zinc air button	Lithium button	Alkaline button	Silver oxide	Lithium manganese	Nickel cadmium	Nickel metal hydride	Lithium ion	Lead acid
Component	Percentage											
Silver							31.0%					
Iron and steel	24.8%	16.8%	37.0%	42.0%	60.0%	37.0%	42.0%	50.0%	35.0%	20.0%	22.0%	
Aluminium											5.0%	
Manganese	22.3%	15.0%	1.0%		18.0%	23.0%	2.0%	19.0%		10.0%		
Mercury			31.0%	1.0%		0.6%	0.4%					
Nickel	0.5%		1.0%		1.0%	1.0%	9.0%	1.0%	22.0%	35.0%		
Zinc	14.9%	19.4%	14.0%	35.0%		11.0%				1.0%		
Lead		0.1%										65.0%
Lithium					3.0%			2.0%			3.0%	
Cadmium									15.0%			
Cobalt										4.0%	18.0%	
$H2SO_4$ + water												16.0%
Alkali	5.4%	6.0%		4.0%		2.0%	1.0%		2.0%	4.0%		
Carbon	3.7%	9.2%	1.0%	1.0%	2.0%	2.0%	0.5%				13.0%	
Paper	1.0%	0.7%										
Plastic	2.2%	4.0%	3.0%	4.0%	3.0%	3.0%	2.0%	7.0%	10.0%	9.0%		10.0%
Water	10.1%	12.3%	3.0%	10.0%	6.0%	2.0%	5.0%	8.0%				
KOH			2.0%									
Other metals	1.3%	0.8%					4.0%			10.0%	11.0%	4.0%
Other non- metals	14.0%	15.2%		3.0%	13.0%	14.0%	4.0%	19.0%	11.0%	8.0%	28.0%	
Other material			7.0%									5.0%

Taken from: www.epbaeurope.net/090607_2006_Oct.pdf – June 2011.

Recovery of substances and components

Cathode ray tube (CRT) and non-leaded glass management and recovery

Some CRTs removed from ICT equipment can still be used as CRTs in rebuilt computer monitors, or can be used as CRT components of television displays. If a CRT monitor cannot be reused as a monitor or other display screen, it may still be recycled for its copper and glass. There is still some manufacturing of new CRTs, where the recovered glass can be used, although it is limited and diminishing and the market will be replaced in the future by other screen technologies, i.e. LCDs.

Plastics management and recovery

As with metals contained in ICT equipment, recovery of plastics involves an economic question – will the value of the recovered plastics exceed the costs of recovery, and provide a profit? Some types of plastics used in ICT equipment are high value engineered thermoplastics, types which can be repeatedly softened by heat and hardened by cooling, and hence are valuable to recycle. If these engineered thermoplastics can be recovered in a consistent, steady stream of raw material, they can be sold for a profit. However, it is necessary to also separate plastics that contain flame retardants, such as the plastics commonly used in CRT cases, and especially brominated flame retardants (BFRs) such as tetra-, penta-, octa- and deca-brominated biphenyl ethers from plastics that do not. Many buyers will not accept plastics with BFRs, and those buyers who can accept them must use processes that will not release the BFRs or create substances such as brominated dioxins and furans. There may still be some markets for plastics that contain BFRs, where they will be used in the same way, as flame retardants. Nevertheless, it should be noted that some BFRs are prohibited in some countries, e.g. pentabrominated diphenyl ether and octabrominated diphenyl ether, and in those countries should not be reused in the production of new plastics, and must be disposed of in an environmentally sound manner. The plastic recovery processing described below may create exposures to BFRs, and perhaps dioxins in low temperature processing, and precaution is necessary.

Manual disassembly of some ICT equipment can produce reasonably well-separated streams of plastics in the cases of laptop/notebook computers and peripheral equipment. Mechanized disassembly can also produce high volumes of plastics separate from other components, and is commonly used to recover large volumes. After removal, the plastic pieces may need to be further cleaned, particularly of contaminating substances such as paints, labels, and imbedded metal pieces.

To maximize resale value, plastics must then be sorted by polymer type (e.g. HIP, ABS thermoplastic), and by colour (e.g. white, black). Identification of polymer type can be difficult, especially for older computing equipment. The United States coding ISO 11469 system may be useful for some plastic, using a 'Recycle Triangle' with numbers and letters, but many plastic parts in the computing equipment are not identified. In addition, some plastics are made up of more than one type, or may have a fibre added for strength. In mechanized recovery operations, there are increasingly sophisticated scientific techniques for polymer recognition and separation.

If plastic types cannot be separated by type, a mix of different types of plastics may have little if any economic value, although some mixed plastics may be used for materials such as lumber or pallets. If no use or market as plastic can be found, smelters with appropriate emission control systems may use a limited volume of plastics in the metal recovery process, where they serve as a source of heat and substitute for other hydrocarbon fuels and as a reducing agent. Alternatively, incinerators with energy recovery systems, as well as appropriate emission control systems, may recover energy content from plastics.

Mercury lamp management and recovery

Monitors that use flat screen liquid crystal display (LCD) technology contain one or more small lamps for illumination, usually located along the outside edge of the screen. While new technology sometimes uses light emitting diodes (LEDs) for these lamps, most LCD screens contain fluorescent mercury vapour lamps. These mercury lamps will often break during the handling and mechanized processing, and will release their mercury vapour. Therefore they must be carefully removed, by manual labour, and must undergo mechanized processing such as shredding, provided the shredding equipment has the necessary pollution control equipment to manage such operations, and is licensed and permitted to do so, such as at mercury treatment facilities. Even with careful removal, some breakage is very likely to occur, and engineering controls or personal protective equipment to prevent inhalation of mercury vapour should be used at all times. Some facilities may decide not to remove the mercury lamps, of fear of breakage, and decide to send the entire LCD screen directly to mercury treatment facilities.

Once removed, mercury lamps (as well as spill collection and cleaning residues) should be sent to mercury recovery facilities. These specialized facilities will heat the lamps and mercury-bearing residues, in a closed furnace (a retort), driving the mercury vapour into a cooling chamber where it will be condensed and collected as pure mercury.

After removal of mercury lamps, LCD screens are generally not hazardous, and can be safely disposed of, such as by state-of-the-art incineration techniques. The critical metal indium is used in small amounts to coat the inside of these screens, and research is being undertaken to see if efficient recovery, now or later, may be achieved.

Ink and toner management and recovery

Printer cartridges from end-of-life printers consist of an outer plastic case and typically contain residual amounts of ink or toner, plastic and metal parts, and integrated print heads or smart chips. Some contain circuit boards. These printer cartridges are recyclable and in some cases may be reusable or refillable. Opinions differ as to how many times a cartridge can be reused, with some people saying that the quality of printing will deteriorate after the original use, and others saying that a cartridge may be reused up to six times. Some commercial cartridge remanufacturing companies will only accept OEM cartridges that have never been previously recycled. Because some inks and toners (and therefore cartridges) contain materials of concern, cartridge remanufacturing should only be undertaken by specialized companies that utilize environmentally sound management techniques and provide occupational and environmental protections. In all cases of intended reuse, a cartridge should be washed, examined for cracks or worn parts, and key parts that are defective affecting quality and performance should be replaced with new components. Only compatible ink should be used for a refill. After refilling, they should be tested individually for print quality.

2.4 A guide to best practice

The checklist provided below aims to guide the user suggesting the best way to approach each sub-stage within the EOL of ICT equipment assessing considerations that must not be overlooked. The checklist is based on the life-cycle assessment methodology. It intends to help asset management and recycling companies involved in the management of EOL ICT equipment ensure consistency and completeness of their operations by carrying out the evaluation of environmental impacts during the EOL phase of ICT' life cycle.

This checklist is complemented by a list of "General references to legislation" that includes international standards and guidance documents as well as examples of local or regional legislation that the reader could refer to. The list is intended as guidance and it is not exhaustive. Readers are recommended to check for the latest updates or revised versions of the references. See Annex III: General references to the legislation, international standards and guidance documents.

Figure 7: Check-list of EOL considerations

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
Deployment, asset management, life extension, disposal	Information – security	Has the company managing your ICT equipment developed a secure policy to protect your information?			
		Has your organization been informed about the information security policy for asset management and end-of-life processes?			
		Is there an action plan for the implementation of that security policy?			
		Is access to details of asset management and end-of-life processes of ICT equipment being controlled?			
	Risk management	Is asset management minimizing the risk for your organization in regards to brand management and environmental performance a priority?			
		Is strategic decision-making being supported by asset management?			
		Has efficiency on inventory controls been improved for strategic decision making?			
		Has the life cycle of your organization's ICT equipment been improved by the practice of asset management?			
	Environmental performances	Is the ICT life cycle of the equipment being improved?			
		Has the ICT equipment life cycle been extended (tractability of destination, brand management)?			
		Are the environmental impacts being reported?			
		Are any losses of ICT assets being identified?			
		Are processes being documented for equipment life cycle improvements?			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
Reverse logistics	Operations	Is the equipment well packaged in order to avoid damages in case it is collected for reuse or refurbishment?			
		Is the transport company administering the required documentation and authorization requested by law to transport the equipment?			
		Is the equipment being directed towards a company authorized to manage it?			
	Environmental performances	Has the equipment been classified according to waste legislation?			
		Is it an authorized waste management facility?			
		Does the facility provide a complete solution for the equipment type?			
		Would the equipment need to be redirected to a third location to finalize treatment?			
		Does transport means used to move the equipment, support and encourage the reduction of CO_2 emissions and pollution control?			
	Reporting	Have notifications been sent to environmental authorities?			
		Has the movement being authorized or notified, as applicable?			
Reverse logistics	Operations	Is the equipment well packaged in order to avoid damages in case it is collected for reuse or refurbishment?			
		Does the transport company comply with requirements and have the necessary authorization requested by law to transport the equipment?			
		Is the company to which the equipment is transported authorized by law to carry out EOL operations?			
		In case of transboundary movements, will the Basel Convention prior notice and prior consent procedures apply to a shipment?			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
	Environmental performances	Has the equipment been classified according to international and national waste legislation?			
		Is it an authorized waste management facility?			
		Does the facility provide an environmentally complete and sound solution for this type of equipment?			
		Would the equipment need to be redirected to a third location to finalize treatment (e.g. recycling, disposal)?			
		Does the transport mode that was used to transport equipment, support and encourage the reduction of CO_2 emissions and pollution control?			
Reverse logistics	Reporting/ compliance	Have notifications been sent to environmental authorities?			
		In case of transboundary movements, did the generator (of waste) (e.g. ICT company) conclude a contract with the disposer (e.g. waste management facility) for the disposal of wastes in an environmentally sound manner?			
		Did the generator (of waste) or exporter (e.g. ICT company, asset management company) inform the Basel Competent Authority of the country of export of this proposed movement?			
		Have notifications been sent by the Basel Competent Authorities of the country of export to the Basel Competent Authorities of the concerned countries (countries of transit and import)?			
		Did the Basel Competent Authorities of the concerned countries (countries of transit and import) express their consent to the proposed movement? Did the Competent Authority of the country of export issue the movement document which contains detailed information about the shipment and authorize the shipment to proceed?			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
Dismantling and segregation	Operations	Time spent vs. value of equipment recovered?			
		Cost of manual working hour vs. value recovered?			
		% of equipment recovered.			
		Quality and marketability of equipment recovered.			
		Commodity markets and economic value of the equipment recovered.			
		Different categories of equipment at the end (of the operation?)			
		Have the goals been set in a measurable and tractable manner?			
	Environmental performances	% of contaminated equipment removed?			
		% of non-contaminated equipment recovered?			
	Reporting	Has the process been documented?			
		Is the reported data comparable and measurable?			
Reuse	Operations	Has any information contained in any memory/hard disk been wiped?			
		Do the reuse percentage rates meet the requirements of the national and regional legislation?			
		Is benchmarking development according to volumes processed (models, brand)?			
		Is the system economically feasible?			
	Environmental performances	Does the reuse market have environmental policies to deal with the end-of-life of the extended life of ICT equipment?			
		Does it contribute to the minimization of waste generation?			
		Is the reporting and tractability of equipment possible according to national/regional legislation?			
	Reporting	Is the reporting and tractability of equipment possible according to national/regional legislation?			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
Recycled and recovered equipment	Operations	Can percentages be met according to the national, regional or local policy on waste management?			
		Is the information contained in any memory/hard disk being wiped?			
		Do the reuse percentage rates meet the requirements of the national legislation?			
		Benchmarking development according to volumes processed (models, brand)?			
		Is the system economically feasible?			
	Environmental performances	% of the equipment weight/volume landfilled in compliance with requirements of the national legislation?			
		% of the equipment weight/volume incinerated in compliance with requirements of the national legislation?			
		% of equipment weight/volume being recovery in compliance with requirements of the national legislation?			
	Reporting	In accordance with the WEEE directive in the European Union or in accordance with ITU-T L.1410?			
		Is traceability possible for the report?			

3 General material recovery and recycling facility guidelines

EOL ICT equipment will generally be treated by facilities that engage in raw material recovery and recycling, which requires compliance with existing requirements contained in national and international legislation as these operations are associated with environmental risks. Environmental management systems become an important aspect of these operating facilities.

To be able to comply with the legislation and employ the best technology available for environmental sound management of the EOL ICT equipment, facilities need to bear the expenses that some actors active on the market, such as traders, middle-men and even service providers which are neither certified nor legalized, do not always incur. It would be important to keep in mind that offers which provide attractive financial returns may not always reflect the true costs as they dismiss environmental responsibilities.

It is of critical importance to ensure that service providers, middlemen and traders are capable of supporting the financial gain as well as offering a sustainable solution for the e-waste problem. By looking at the aspects described below, the waste producer needs to ensure that its decision with regards to waste management is to be made responsibly towards the environment as well as to social issues, while unsupportive of unethical practices and illegal traffics.

Although the EOL management in most cases adds a positive financial value to generators' revenues, they should not seek EOL management as a main profitable stream for their businesses, unless their companies have a commercial objective to deliver such services.

3.1 Environmental management system, licences and permits

The recovery and recycling facility should possess and maintain a documented environmental management system to ensure adequate control over impact on the environment. The environmental management system may be based on, ISO 14001 or ITU-T L.1410 and the other formally recognized standards for environmental management systems prevailing in specific countries or regions, e.g. BS 7750 in the U.K. and EMAS (Environmental Management and Audit Scheme) in Europe.

In case no formally recognized standards are used, the system should also incorporate record-keeping of shipping documents, bills of lading and chain-of-custody information in the form of audits on equipment destined for downstream markets.

The facility should operate pursuant to written standards or procedures regarding operating methods for the plant and equipment, systems for management, control of site activities, site safety rules and requirements and methods for ensuring observation and monitoring (i.e. an overall operating, systems and safety manual).

The facility must comply with all applicable environmental regulations and standards (international, regional, local or municipal):

- material recovery and recycling facilities should be licensed by all appropriate governmental authorities;
- facilities should be required to operate according to best available technologies, while taking into consideration the technical, operational and economic feasibility of doing so. Licensing and permits should be consistent with governmental, regional and local regulatory requirements;
- specific permits required could be: storage permit, air emission permit, water permit, hazardous waste permit, and those required to meet landfill and other disposal regulations. Processes should be in place to ensure continued compliance with the requirements of the permits.

Legal requirements such as authorizations, licenses, permits or standards should address facility operations, workers' health and safety, control of air emissions, land and water as well as waste management. The licence or permit should describe and authorize specific facility capacities, processes and potential exposures.

3.2 Monitoring and record keeping

Material recovery and recycling facilities should develop adequate monitoring, recording and reporting programmes. Such programmes should be maintained to track:

- key process parameters;
- hygiene-risk elements such as beryllium;
- compliance with applicable regulations;
- generation of any emissions or effluents;

- movement and storage of waste, especially hazardous waste.

The facility should have adequate record-keeping systems to ensure compliance and have records of employee training, including health and safety leaflets, bills of lading and chain-of-custody of all equipment, emergency response plans, closure plans in case a plant or operation closes, record-keeping policies, fire prevention and suppression procedures, equipment failure backup plan, and security plans.

3.3 Emergency planning

The facility should have a regularly updated emergency plan that provides guidelines on how to react to emergencies such as fires, explosions, accidents, unexpected emissions and weather-related emergencies. The emergency plan should also indicate what reporting and monitoring is required in specific instances.

The plan should be communicated to the local emergency response authorities.

3.4 Occupational health and safety: best practices to ensure workers' safety

The facility must comply with all applicable health and safety regulations and must ensure occupational health and safety of employees by:

- providing continuous health and safety training of personnel;
- providing ergonomic work areas with safe and effective tools;
- avoiding heavy lifting, where possible, and training employees to lift in a safe manner. in some cases lifting tools may be required;
- making available and enforcing the use of personal protection equipment;
- labelling all hazardous materials;
- safeguarding dangerous mechanical processes;
- avoiding exposure to unacceptable occupational risks such as airborne dust and fumes through the use of process dust collection systems;
- periodic air monitoring to monitor elements of risk including but not limited to lead, cadmium and beryllium;
- providing process fire suppression equipment and systems where appropriate;
- considering policies that prohibit eating food or smoking in processing areas;
- providing for worker health benefits or insurance and long-term disability and death benefits;
- providing liability compensation for accidents;
- encouraging the development and implementation of an environmental liability regime for recycling facilities to prevent environmental damage.

3.5 Personal protective equipment

Plant personnel should be provided with the appropriate personal protective equipment (PPE) to ensure employee safety. The level of PPE required will depend on the level of potential risk to which the employee is exposed and the type of equipment with which the employee works. The assessment and decision on occupational health and safety measures, including the selection of appropriate PPEs should be under the supervision of a competent occupational health and safety (OHS) specialist.

- Eye protection: Safety glasses should be worn to prevent eye injuries. Eye washing stations should be available in areas easily accessible by employees and as regulated by local legislation.

- Head protection: Hard hats may be required in certain areas, such as in proximity to overhead racks and around automatic dismantling machines and smelting furnaces.
- Hand protection: When opening boxes, using safety knifes, handling sharp objects or using pallet jacks, gloves may be required. When manually dismantling equipment or handling chemicals, gloves should be also be worn. Gloves help protect hands from cuts, scrapes, chemical burns and infection by blood-borne pathogens.
- Skin protection: In certain conditions, such as working in proximity to furnaces, chemical equipment and some types of automated equipment, a fire-resistant work smock may be necessary to protect exposed skin from burns or chemicals.
- Foot protection: Steel-toed shoes should be worn to prevent foot injuries from falling objects, pallet jacks, chemical spills, etc.
- Hearing protection: Earplugs should be worn in work areas where prolonged noise exposure would lead to hearing damage.
- Respiratory protection: Dust masks or face masks should be worn in areas where there is a risk of dust inhalation. Where indoor pollutants other than dusts or particles, such as toxic gases and vapours known to affect employees at a work place, proper respirators should be made available and worn by the employees. Working in confined spaces where there is oxygen deficiency, may require the use of air supply apparatus.

3.6 Employee training

The facility should provide employees with periodic training to safeguard their occupational health and safety. The training should address safe work practices, required safety precautions and required personal protective equipment. Employees should be trained in the proper identification and handling of any hazardous material that may be present in the equipment to be recycled. Training should be documented, recorded and updated as conditions merit.

3.7 Financial guarantees

Material recovery and recycling facilities should establish an appropriate plan for closure and aftercare which ensures that the financial means for such closure are available. A financial mechanism should be maintained that will ensure that the facility is properly cleaned up in the event:

- of major pollutant releases or gross mismanagement of end-of-life electronics equipment, components, and scrap;
- of closure of the facility.

Figure 8: Material recovery and recycling guidelines					
Life cycle phase	**Facet**	**Considerations**	**Comply Y/N**	**Aspect(s) impacted**	**Description of impact, unconformity or improvement actions to be taken**
General material recovery and recycling facility guidelines	Environmental management system				
	Licensing and permits	Material recovery and recycling facilities should be licensed by all appropriate governmental authorities.			
		Require that facilities operate according to best available technologies, while taking into consideration the technical, operational and economic feasibility of doing so.			
		Licensing and permits should be consistent with governmental, regional and local regulatory requirements.			
	Monitoring and record keeping	Specific permits required could be: storage permit, air emission permit, water permit, hazardous waste permit, and those required to meet landfill and other disposal regulations.			
		Processes should be in place to ensure continued compliance with the requirements of the permits.			
		Key process parameters.			
		Hygiene-risk elements such as beryllium.			
	Emergency planning	Compliance with applicable regulations.			
		Generation of any emissions or effluents. Movement and storage of waste, especially hazardous waste.			
	Occupational health and safety: best practices to ensure workers' safety	Provide continuous health and safety training of personnel.			
		Provide ergonomic work areas with safe and effective tools.			
		Avoid heavy lifting where possible and train employees to lift in a safe manner. In some cases, lifting tools may be required.			
		Make available and enforce the use of personal protection equipment.			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
General material recovery and recycling facility guidelines		Label all hazardous materials.			
		Safeguard dangerous mechanical processes.			
		Avoid exposure to unacceptable occupational risks such as airborne dust and fumes through the use of process dust collection systems.			
		Periodic air monitoring to monitor elements of risk including but not limited to lead, cadmium and beryllium.			
		Provide process fire suppression equipment and systems where appropriate.			
		Consider policies that prohibit eating food or smoking in process areas.			
		Provide worker health benefits or insurance and long-term disability and death benefits.			
		Provide liability compensation for accidents.			
		Encourage the development and implementation of an environmental liability regime for recycling facilities to prevent environmental damage.			
	Personal protective equipment	Eye protection: Safety glasses should be worn to prevent eye injuries. Eye washing stations should be available in areas easily accessible by employees and as regulated by local legislation.			
		Head protection: Hard hats may be required in certain areas, such as in proximity to overhead racks and around automatic dismantling machines and smelting furnaces.			
		Hand protection: When opening boxes, using safety knifes, handling sharp objects or using pallet jacks, gloves may be required. When manually dismantling equipment or handling chemicals, gloves should be also be worn. Gloves help protect hands from cuts, scrapes, chemical burns and infection by blood-borne pathogens.			

Life cycle phase	Facet	Considerations	Comply Y/N	Aspect(s) impacted	Description of impact, unconformity or improvement actions to be taken
General material recovery and recycling facility guidelines		Skin protection: In certain conditions, such as working in proximity to furnaces, chemical equipment and some types of automated equipment, a fire-resistant work smock may be necessary to protect exposed skin from burns or chemicals.			
		Foot protection: Steel-toed shoes should be worn to prevent foot injuries from falling objects, pallet jacks, chemical spills, etc.			
		Hearing protection: Earplugs should be worn in work areas where prolonged noise exposure would lead to hearing damage.			
		Respiratory protection: Dust masks or face masks should be worn in areas where there is a risk of dust inhalation.			
	Employee training	Is employee training, being recorded, signed and tracked?			
	Financial guarantees	Has the company acquired the insurances needed to protect, assets, employees and equipment handled including during transportation?			

4 Clean supply chain and conflict minerals

The demand of the ICT equipment manufacturing processes for rare metals such as tin, tungsten, gold and others can help support developing countries in their economic growth and lead the way out of poverty. However¸ it is necessary to introduce a responsible global supply chain management code to encourage industry suppliers and other stakeholders to be responsible and sympathetic towards conflict-affected and high-risk issues.

The ICT industry in general and, specifically, companies can ensure a proactive respect for human rights and contribute to the environmental protection by avoiding putting the ever increasing demand on the limited natural mineral resources which sometimes come from small–scale mining using artisanal practices without proper safety and risk control measures.

From the point of view of asset management and recycling industry, closing the loop on e-waste by introducing or reinserting precious and rare metals recovered or recycled from the unwanted ICT equipment to the supply chain represents an opportunity for manufacturers to:

- ensure a clean supply chain and reduce the demand on limited natural resources, which is auditable, measurable and tractable;

- reduce production costs of brand new product and the possibility to influence customer's purchasing power by offering a product that is verifiable conflict-free;
- manufacturers can support the effort that recyclers make to recover material by:
  - ◊ designing products that through their different life cycle stages reduce environmental impact and waste generation;
  - ◊ designing, producing, labelling and commercializing equipment that has a reasonable extensive life and that once it reached the end of life, it can easily be repaired or dismantled for reuse or its value recovered via recycling or its life finalized in the best environmental possible manner without influencing economic growth.

According to U.S. Environmental Protection Agency[11], the following factors illustrate the advantages of waste prevention through recycling and support the "closed loop" initiative through the use of recycled material over raw material production energy demands.

Aluminium

- Aluminium can be recycled using less than 5% of the energy used to make the original product.
- Recycling one aluminium beverage can save enough energy to run a 100 watt bulb for 20 hours, a computer for 3 hours, or a TV for 2 hours.

Plastic

- Producing new plastic from recycled material uses only two-thirds of the energy required to manufacture it from raw materials.
- Plastics require 100 to 400 years to break down at the landfill.
- Five 2-litre recycled PET bottles produce enough fibrefill to make a ski jacket.

Glass

- Producing glass from raw materials requires 30% more energy than producing it from crushed, used glass.
- The energy saved from recycling one glass bottle will operate a 100-watt light bulb for four hours.
- It takes approximately 1 million years for a glass bottle to break down at the landfill.

Steel

- Tin cans contain 99% steel.
- Recycling steel and tin cans save between 60 and 74% of the energy used to produce them from raw materials.
- According to the Steel Recycling Institute, steel recycling in the United States saves the energy equivalent to electrical power for about one-fifth of American households for one year.
- One tonne of recycled steel saves an energy equivalent of 3.6 barrels of oil and 1.49 tonnes of iron ore over the production of new steel.

Paper

- Producing recycled paper requires about 60% of the energy used to make paper from virgin wood pulp.
- Manufacturing one tonne of office and computer paper with recycled paper stock can save between 3 000 and 4 000 kilowatt hours over the same tonne of paper made with virgin wood products.

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11 www.epa.gov/osw/partnerships/wastewise/wrr/factoid.htm.

- Preventing 1 tonne of paper waste saves between 15 and 17 mature trees.

Copper

- Recycling a tone of copper uses 15% of the energy that would be used to mine and extract the same copper.

Many substances in the ICT equipment present little or no special hazard or concern particularly in the early steps of recycling such as manual dismantling of steel in the cases of CPUs, or copper in wire.

Some substances, however, may be quite hazardous, and facilities should obtain and maintain current Material Safety Data Sheets. Some materials can present a hazard when the ICT equipment is broken, crushed, shredded, melted, incinerated or land filled, unless environmentally sound management practices are used.

> The Organization of Economic Cooperation and Development, OECD, introduced *Due Diligence Guidance for Responsible Supply Chains of Mineral* as a voluntary proactive initiative in which companies can ensure that they respect human rights, assess their potential risks of contributing to conflict, make sure they comply with domestic laws, including those governing the illicit trade in minerals and United Nations sanctions.
>
> Amongst the challenges that the guidance may face for its use according to OECD are industries' flexibility, cooperation and participation, switching costs and integration to existing internal policies (for more information on the guidance, please see www.oced.org).

For example, beryllium in copper-beryllium connectors poses little or no risk when computing equipment is manually dismantled, but if beryllium is reduced to fine airborne dust, especially if it is melted, it creates a fume that is not controlled and is inhaled by workers; thus, it can permanently scarring the lungs, leading to serious health problems and death. In addition, it is not only the substances in ICT equipment, such as those listed above, that are of concern. Other substances may be used in recycling, or may be produced or arise as emissions. For example, poly vinyl chloride insulation in wires is not hazardous in normal handling, but if it is burned to recover copper without proper emission control equipment and systems, it may create dioxins, furans and other combustion emissions.

Three main groups of substances that may be released during recycling, incineration or landfilling, that should be of concern are:

i) original substances that are constituents of ICT equipment, such as lead, mercury, cadmium, etc.;

ii) added substances that are used in recycling processes, such as cyanide or strong acids; and

iii) new substances that may be formed (sometimes unintentionally) by recycling processes, such as dioxins.

One group of chemicals which should be mentioned in specific is persistent organic pollutants (POPs). POPs share four properties:

- they are highly toxic and can cause serious health problems such as cancer and birth defects in humans;
- they are persistent, lasting for many years before degrading into less dangerous forms;
- they evaporate and travel long distances through air and water, and
- they accumulate in fatty tissues.

The combination of these properties makes POPs highly dangerous. The international regime regulating POPs is the Stockholm Convention on Persistent Organic Pollutants which is a global treaty aiming to protect human health and the environment from the negative effects of POPs by restricting and ultimately eliminating their production, use, trade, release and storage. The list of chemicals currently controlled under the Stockholm Convention contains 21 POPs.

Three groups of POPs are of concern in relation to ICT equipment:

1) **Brominated flame-retardants** Hexabromobiphenyl, tetra- and pentabromodiphenyl ethers (components of commercial pentabromodiphenyl ether), and hexa and heptabromodiphenyl ethers (components of commercial octabromodiphenyl ether). Hexabromobiphenyl and commercial octabromodiphenyl ether have been extensively used in components of ICT equipment made of plastic (e.g. computer and television casings made of acrylonitrile-butadiene-styrene) and in circuit boards. Commercial pentabromodiphenyl ether has been commonly used in rigid polyurethane elastomers in instrument casings and in epoxy and phenolic resins in electrical and electronic equipment.

   Under the Stockholm Convention, the production and use of listed brominated diphenyl ethers (BDEs) are prohibited for all applications with the exception that Parties may recycle articles containing these chemicals. The production of listed BDEs has ceased in the developed countries but may still occur in other parts of the world. Furthermore, other brominated flame-retardants, such as decabromodiphenyl ether, remains widely used and may have the potential to be converted into listed BDEs.

2) **Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F)** These chemicals are considered to be critical for a number of applications in the ICT equipment industry such as photo resistant and anti-reflective coatings and etching agent for semi-conductors, photo masks in the semiconductor and liquid crystal display (LCD) industries and electric and electronic parts for some colour printers and colour copy machines. The Stockholm Convention allows the production and use of PFOS, its salts and PFOS-F for these applications until alternatives are identified or are phased-in.

3) **Polychlorinated dioxins and furans** These chemicals are among the most toxic chemicals known, and cause cancer in humans. These chemicals have no industrial use but are released from thermal processes and from industrial processes such as the production of polyvinyl chloride and other chlorinated substances. They may also be unintentionally formed and released from other sources such as uncontrolled burning of materials which contains halogenated organics and hydrocarbon (e.g. cables with PVC sheets), open burning of waste, fossil fuel-fired utility and industrial boilers, and special chemical production processes. The Stockholm Convention requires that governments identify sources of these POPs and apply measures to reduce their levels. To that end, best available techniques (BAT) and best environmental practices (BEP) should be implemented.

The Convention does not allow for recovery, recycling, reclamation, direct reuse or alternative uses of POPs, with the exception of the recycling of articles containing listed BDEs. Nevertheless, the convention requires that this recycling is carried out in an environmentally sound manner. However, a technical review of the implications of recycling listed BDEs indicated that preventing POPs from contaminating the general recycling stream remains technically challenging, especially in developing countries. The improper treatment of BDE-containing wastes can generate toxic brominated dioxins and furans. The technical review of the implications of recycling listed BDEs revealed that more information is urgently needed on BAT and BEP for preventing the release of dioxins and furans from the treatment of BDE-containing wastes. The ongoing use of PFOS, its salts and PFOS-F for critical applications, results in the generation of PFOS-containing wastes from industrial processes and from articles that reach the end of their useful life. Managing these wastes in an environmentally sound manner is important to minimize the risks posed by the continued use of PFOS.

Recycling rare metals in ICT equipment

ITU-T Study Group 5 identified the recycling of ICT rare metal components as an area demanding attention, and has responded with the new Recommendation ITU-T L.1100 detailing the procedures to be employed when recycling these metals. The Recommendation outlines key considerations in all phases of the recycling process, and provides guidelines as to how organizations may fairly and transparently report on rare metal recycling.

Rare metals are essential to the high-end functionality of ICT equipments, and the ICT industry has reached the point where it is not possible to omit these metals from product design. To further illustrate the need of recycling rare metals; let us take the case of mobile phones which contain no less than 20 rare metals. A tonne of gold ore yields 5 g of gold, compared to a staggering 400 g yielded from a tonne of used mobile phones.

It is well known that natural stocks of some semiconductor-compounds such as CIGS (copper, indium, gallium, selenide) or CdTe (cadmium, tellurium) will be depleted in the near future. The inelastic supply of these metals necessitates recycling from an environmental perspective, but it is their rarity and consequent value that provides ample economic incentives for such recycling. It is one of the rare cases where environmental and economic concerns are aligned precisely, and the need to recycle rare metals is surely one that will find support in all economic sectors.

The ICT equipment also contains “critical materials” or “special materials” such as platinum group metals, gallium, indium, rhenium, “rare earths”, cobalt and antimony. There has also recently been an increasing interest in the recovery of these metals. Because of their unique properties, these materials have an important role in modern applications and manufacturing, including ICT equipment. There is concern, however, that commercial access to these materials may become limited or even unavailable, for geological, economic and political reasons, and modern industry may thus be seriously disrupted. In some cases, e.g. platinum group metals, high market prices lead to profitable recovery. However for other metals, such as the rare earth elements for which recovery is technically very challenging, these concerns of scarcity have not caused market prices to rise to the point where a profit can be made from recovery. For the mix of metals contained in ICT equipment, some steps taken to recover precious metals enable the more efficient recovery of other “critical metals” in subsequent processing steps, with advanced technology, but not all of the “critical metals” contained in ICT equipment are recovered. However, there is ongoing research to more efficiently recover these materials, their market prices are currently rising, and there are proposals to subsidize their recovery, so there may be opportunities in the future to further broaden the scope of recovery from computing equipment.

5 Socio-economic issues

There is a wide range of social aspects that ought to be considered when thinking of the EOL management of ICT equipment. Their effect over the development of communities all around the world, and especially in developing countries, can be both positive and negative, depending on whether the EOL management of ICT equipment is managed responsibly or not.

Some developing countries are facing challenges in relation to e-waste imported under the disguise of second-hand equipment as well as generated domestically. It seems important for developing countries to adopt policies, legislation and standards in support of the creation of sustainable jobs and technology for environmentally sound management of EOL ICT equipment.

Even though refurbishing and reuse could be seen as a risk for manufacturers or traders, the regulated practices can support the protection of our global community and held to limit the operations of unlawful players on the market. One should be cautious of traders who call themselves “recyclers” and offer impressive economic benefits as a solution for the EOL management of ICT equipment by exporting equipment to places with low environmental and labour standards, low wages, and which render a relatively high value of recovered raw materials (achieved using such practices as burning of copper wires).

Uncontrolled disassembly, burning, and disposal cause a variety of environmental problems such as erosion of land, high water demands and contamination of ground sources and air pollution with carcinogens and neurotoxins. Fumes include dioxins and furans. Inappropriate methods of processing waste could lead to deforestation and the inevitable relocation of communities, animal life as well as the disappearance of ecological habitats. In addition, it could lead to health problems, including occupational health and safety issues, affecting the workers who are either directly or indirectly involved in processing waste.

Hard-rock mining of copper, silver, gold and other materials extracted from electronics is considered to have important damaging effects over different environmental aspects that can be considerably reduced when recycling that equipment.

The main problems recyclers face on a regular basis are items such as metal inserts in plastic, non-compatible plastic labels attached to plastic casings, rubber grommets and pads glued to plastic casings. All those items make it very difficult to economically recycle plastic. If those items are handled differently, then a variety of plastics would be recycled rather than land filled, especially plastics which contain a high proportion of fire retardants.

The time spent to dismantle the small piece of plastic from the component, whatever it may be, is not sometimes worth the labour as it has a very low value commodity.

One of the other areas that recyclers encounter in the disassembly process is the number of fixing to hold parts in place, especially battery fixings. It can make a huge difference on how the equipment is handled for best practice in reuse and recycling or simply plain shredding. Batteries need to be recovered easily, e.g. by a clip.

Sometimes, it is advisable for designers of new ICT equipment to work with future recyclers to understand how their products would be or are actually disassembled and recycled in the work place.

These are of course different concerns, depending on the type of materials used in manufacturing sustainable products, where designers can also play a crucial role:

- plastics: in particular the minimization of the number of polymers used and the marking of small pieces in order to facilitate identification;
- mercury containing backlights: work on easy and safe dismantling design, especially when fully-automated recycling solutions are available;
- provide easy removal for batteries, avoiding built-in batteries which are time consuming during the dismantling processes.

Ghana case study: social and environmental impacts of used ICT equipment and its end- of-life in developing countries with economies in transition

Social and environmental issues related to ICT, in particular used and end-of-life ICT equipment have a different dimension in the context of developing countries. The recently completed socio-economic assessment and feasibility study on sustainable e-waste management in Ghana which is a part of the E-waste Africa project coordinated by the Secretariat of the Basel Convention, suggested that the current e-waste management in Ghana leads to significant social and economic impacts on the informal workers.

Employment in the refurbishing and end-of-life of electronic and electrical equipment recycling sector involves exposure to rigorous and insecure working conditions and severe health hazards. Even children, sometimes as young as 5 years old, were observed to be involved in the recovery of materials from end- of-life of electronic and electrical equipment, earning less than USD 20 per month. Most of the people employed in the end-of-life of electronic and electrical equipment recycling, aged between 14 to 40 years, worked for 10 to 12 hours a day.

Despite the long working hours, most of the people employed in the refurbishing and end-of-life of electronic and electrical equipment recycling sector continue to live in extreme poverty. Monthly incomes of collectors were between USD 70 and 140, refurbishers between USD 190 and 250, and recyclers between USD 175 to 285. Expert opinion suggested that these incomes could go lower, in case regular supply or collection of end-of-life of electronic and electrical equipment was hindered. Hence, considering the partial or full dependency of family members – in urban areas of up to 6 people – on such incomes, it could be concluded that most of these workers lived below nationally and internationally defined poverty lines.

This is a significant revelation, especially considering that most of these workers originate from the northern part of the country where the majority of the poor live. Thus, even though engaging in the informal end-of-life of electronic and electrical equipment recycling did not necessarily ensure higher incomes, the workers preferred that sector as they had access to a regular income in the form of rapid cash flow – in contrast to agriculture-driven households in northern Ghana.

Valuing the recycling sector

In total, the informal refurbishing and end of life of electronic and electrical equipment recycling sector sustained between 121 800 to 201 600 people in Ghana. That represented about 1.04% to 1.72% of the total urban population, or 0.50% to 0.82% of the total population.

Due to the informal nature of refurbishing and end-of-life of electronic and electrical equipment recycling sector, its true value was not reflected in the national GDP. Nevertheless, based on the data of the total number of people employed in the refurbishing and WEEE recycling sector and their average salaries, the sector was estimated to contribute between USD 105 to 268 million indirectly to the national economy.

As for environmental impacts, during the informal e-waste recycling activities, high amounts of hazardous substances are released, with no thoughts given to the safety of the workers and the protection of the environment. This leads to significant negative impacts on the soil, air and water as well as on the human health.

The recycling activities at numerous small workshops within the scrap yard often take place directly on unfortified ground. Harmful substances released during dismantling therefore lead directly to discharges in the soil. Within the burning areas, scrap yard workers use numerous temporary fires to burn plastics, mainly from copper cables and wires and other mixed fractions.

The burning operations create an accumulation of ash and partially burned materials. Insulating foam from dismantled refrigerators, primarily polyurethane, or old car tyres were the main fuels used for the fires, contributing to acute chemical hazards and longer-term contamination at the burning sites. In order to quantify soil and ash as well as sediment contamination in Agbogbloshie, Greenpeace Research Laboratories carried out a small sampling campaign. The two soils and ash samples with the highest contamination showed copper, lead, tin and zinc concentrations over one hundred times higher than typical background levels. Concentrations of antimony and cadmium exceeded typical background soil levels by around fifty times and five times, respectively.

In addition to heavy metals, the samples also contained organic chemicals such as halogenated chemicals (e.g. polybrominated diphenyl ethers (PBDEs), used as flame retardants (mainly used in monitor and TV casings) and polychlorinated biphenyls (PCBs, often found in old condensers) as well as phthalates (commonly used as plasticizers in flexible PVC). The burning of PVC, in addition to releasing chemical additives including heavy metals and phthalates, can generate many organic chemicals itself. Dioxins and furans (PCDD/F) are formed as products of incomplete combustion of chlorinated organic materials, including PVC coated wires, with the reaction being catalysed by the presence of metals such as copper.

The Agbogbloshie market is situated on a flat ground alongside the Odaw River. During periods of heavy rainfall much of the site becomes flooded and it is likely that surface dusts and soils, along with any chemical contaminant they may contain, are carried into the adjacent, lower-lying lagoons and the Odaw River which ultimately flows into the ocean.

Although end-of-life treatment operations of e-waste give rise to further employment and income opportunities for a large group of people, they are also associated with severe environmental and health hazards, hence diluting the overall potentials and benefits to a large extent. Thus, the e-waste problem in emerging economies and developing countries needs a twofold approach:

- improvement of the local e-waste management capacities;
- better regulation of transboundary movements of used and obsolete ICT equipment.

6 Offsetting opportunities and mitigation

6.1 *Corporate social responsibility (CSR)*

Corporate social responsibility (CSR) is about how businesses align their values and behaviour with the expectations and needs of stakeholders – not just customers and investors, but also employees, suppliers, communities, regulators, special interest groups and society as a whole. CSR describes a company's commitment to be accountable to its stakeholders.

CSR demands that businesses manage the economic, social and environmental impacts of their operations to maximize the benefits and minimize the downsides.

Key CSR issues include governance, environmental management, stakeholder engagement, labour standards, employee and community relations, social equity, responsible sourcing and human rights.

CSR is not only about fulfilling a duty to society; it should also bring competitive advantages.

Through an effective CSR programme, companies can:

- improve access to capital;
- sharpen decision-making and reduce risk;
- enhance brand image;
- uncover previously hidden commercial opportunities, including new markets;
- reduce costs;
- attract, retain and motivate employees.

6.2 *CO_2 management*

The proliferation of e-waste legislation worldwide, as well as the actual momentum in the debate around climate change and the Kyoto Protocol, could lead to the opportunity of establishing market-based links between different environmental measures aiming at addressing at multinational level different societal problems and further promote and pave the road towards sustainable development and sustainable consumption and production. While global carbon markets are growing year-by-year, e-waste bills are in force in an increasing number of countries globally. Unfortunately, in the great majority of policy bills only a few types of products are covered by legislation. Specific targets on different WEEE categories are missing, particularly for those having a huge impact on the environment. All appliances are regarded as “equivalent” from an environmental perspective, while environmental priorities exist.

End-processing has neither specific targets, for instance, for ensuring proper recovery of precious and special metals from those appliances containing printed circuit boards, nor for ensuring a proper recovery of other relevant metals (iron, copper and aluminium particularly). Recovery of elements is usually regarded as a “weight perspective”: those elements present in few milligrams or parts per million in devices (such as special metals) are not addressed as a priority by policy makers in e-waste bills.

As seen in Figure 9: CO_2 emissions of precious and rare metals, the estimated CO_2 emissions for the primary production of some important metals used in the EEE industry (namely copper, cobalt, tin, indium, silver, gold, palladium, platinum and ruthenium) have been calculated to an annual CO_2 emission level of 23.4 Mt, almost 1/1 000 of the world’s CO_2 emissions. This includes neither CO_2 emissions from other metals used in electrical and electronic equipment as steel or aluminium, nor other CO_2 emissions associated with the manufacturing of electrical and electronic equipment.

Recovering metals from state-of-the art recycling processes generates only a fraction of these CO_2 emissions and has also significant benefits compared to primary mining in terms of land use and hazardous emissions. For example, the production of 1 kg of aluminium by recycling uses only 1/10 or less of the energy required for primary production, and prevents the creation of 1.3 kg of bauxite residue, 2 kg of CO_2 emissions and 0.011 kg of SO_2 emissions as well as the impacts and emissions associated with the production of the alloying elements used in aluminium. For precious metals, specific emissions saved by state-of-the-art recycling are even higher.

Figure 9: CO_2 emissions of precious and rare metals

Metal	Demand for EEE [t/a 2006]	% on global Prod.	CO_2 for primary prod. [t CO_2/ t metal]	CO_2 emissions [Mt]
Copper	4 500 000	30%	3.4	15.3
Cobalt	11 000	19%	7.6	0.08
Tin	90 000	33%	16.1	1.45
Indium	380	79%	142	0.05
Silver	6 000	30%	144	0.86
Gold	300	12%	16.991	5.10
Palladium	32	14%	9.380	0.30
Platinum	13	6%	13.954	0.18
Ruthenium	6	84%	13.954	0.08
Total				**23.4**

Considerations from the previous chapters lead to the need of investigation for establishing global allowance-based transactions, as well as carbon-offset projects, and voluntary carbon markets for the electronic industry as well as for the e-waste recycling industry.

The following considerations need to be taken into account for the three different scenarios mentioned above.

- First, there are potential, positive, environmental and economic benefits in allowing the *e-waste recycling industry to actively participate in the carbon markets*, which should be further researched in depth. Opportunities are related to the creation of market based and economic incentives to promote e-waste collection, while achieving simultaneously broader environmental benefits. At the same time, the creation of new business models for the recycling industry and the promotion of downstream valorization of material fractions having a greater potential of CO_2 equivalent emissions could be achieved and fostered. Moreover, the creation of new markets for actors having the obligation of surrendering a number of CO_2 allowances, meeting demand with new, environmentally sound EOL ICT equipment processes should be encouraged. This could be the case of carbon credits resulting from the recovery of GHG of C&F appliances or of precious and special metals which have a huge impact in primary mining.
- Secondly, there is a chance of *enabling project-based offsets for different stakeholders* (e.g. producers or recyclers) for setting up a take-back scheme in a country, or specific pre-processing or end-processing facilities, without legislative obligations (JI or CDM) with the following principles in mind: proving that the reduction of potential emissions have been verified according to existing standards (i.e. ensuring that carbon credits meet some general criteria and are validated and verified by an authorized body) and ensuring the environmental integrity (i.e. any emission reduction is real, measurable and additional to any that would have occurred in the absence of the project activity, preventing any free-riding).

  For the EEE industry or e-waste recycling industry to participate in CDM projects, they need to clearly address specific issues. At first, it is crucial to ensure the reductions of creating additional emissions over and beyond the business-as-usual scenario, ensuring that such projects would not have been implemented without the funding provided by carbon credits. Furthermore, a proper check of environmental integrity should be carried out; ensuring no escape route for free-riders is created, by giving the possibility for someone else to emit more e-waste.
- Thirdly, there is the option of *participation in voluntary markets*, enabling project-based offsets for different stakeholders (e.g. producers or recyclers) for setting up a take back scheme in a country without legislative obligations and enabling such credits to be part of the voluntary markets. A project has been launched recently in Brazil by Sens International, a Swiss-based organization, by setting up a recycling plant for refrigeration appliances and ensuring that CFC gases are destroyed, placing on voluntary markets the verified emissions reductions under the name of Swiss Charter Units (SCUs). The returns on the certificates are supporting operations of the facility and could be also invested in order to build other facilities.

The three different options described in the above paragraphs are not alternatives but rather complementary. Different implications exist in a full evaluation of the potential benefits of establishing such a link between carbon markets and e-waste management, particularly ensuring environmental integrity and a proper evaluation framework. It is clear that there is a need for multiple, complementary policy tools to address the global challenge of climate change.

7 Case studies

Computers for all

On 7 June 2007, UNIDO and Microsoft announced a joint initiative that would create a bridge between companies discarding used computer equipment and small and medium enterprises in Africa that could refurbish and repair the equipment for their own use. The Refurbished Computer Initiative for Small and Medium Entrepreneurs in Africa was signed by the Director-General of UNIDO and Dr Cheick Diarra, Chairman of Microsoft Africa at the first African subregional Forum on Information and Communication Technologies (ICT) Best Practices, held in Ouagadougou, Burkina Faso.

Microsoft and UNIDO have been working together since July 2006 to promote innovative uses of ICTs that support entrepreneurship and help promote investment and create business opportunities for SMEs in Africa. According to Dr Cheick Diarra, there is a great demand for affordable computers among the SME community in Africa. The UNIDO-Microsoft initiative sets stringent quality criteria for refurbished computers, including warranties and after-sales service. Since electronic waste is a global problem, the agreement also stipulates ways for the eventual disposal and recycling of obsolete computers.

In a subsequent development on 21 September 2007, a letter of intent was signed jointly by UNIDO, the Government of Uganda and Microsoft aimed at promoting the development of local software solutions in Uganda. The letter of intent followed a July 2006 memorandum of understanding between UNIDO and Microsoft in which both partners agreed on a new strategic collaboration to tackle the root causes of poverty by promoting innovative uses of information and communication technologies. These would, in turn, support entrepreneurship and help promote investment and create business opportunities, especially for small and medium-sized enterprises in Africa. Six district business information centres will provide rural businesses and those who operate them with integrated solutions, instruction in technology and entrepreneurial skills and Internet access. Under the second phase of the project, the number of these centres will be increased to eight. Microsoft has researched rural computing in India extensively and will now apply its knowledge in Uganda.

Microsoft: voluntary recycling

Despite the fact that there are no mandatory recycling laws in the US for gaming consoles, PC peripherals, and music players, Microsoft chose to extend its sphere of responsibility into electronics recycling. It implemented three methods by which its US customers can recycle their consoles, Zunes, and PC peripherals.

First, it partnered with Dell to support the collection/recycling of electronics equipment that is collected via the *Goodwill Reconnect Program*.[12] This programme enables Microsoft's customers to drop off their unwanted electronics at any of the 1 000+ participating collection points throughout the US.

Second, Microsoft began offering its customers the option of returning electronics to its brick and mortar stores. Like the Reconnect programme, Microsoft Stores accepts all brands of electronics, not just Microsoft branded equipment, to ensure that they are properly recycled.

There is also a third option for those customers who do not live near a participating Reconnect Goodwill drop-off location or Microsoft Store – customers can contact the company via email at: eRecycle@microsoft.com and Microsoft will provide a prepaid UPS label to send Microsoft branded equipment directly to the recycle station. All of the company's recyclers are ISO 14001 certified and have been audited by Microsoft and third party auditors to ensure they meet the company's standards to responsibly and completely recycle all equipment and follow all contractual guidelines.

GlaxoSmithKline: USD 1.8 million gain

"How often can you say that an IT department is generating revenue – seven-figure revenue – for its company?" asks Armin Jahromi, Service Development Manager, GlaxoSmithKline.

Like most large companies, GlaxoSmithKline (GSK) had ever-increasing amounts of outdated equipment (used computers, old printers, and abandoned scanners) cluttering its offices and – when that equipment

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[12] Visit the site at: http://reconnectpartnership.com for more information.

remained plugged-in – consuming electricity. But unlike most large companies, GSK decided to do something about it. Working with PlanITROI, a commercial refurbisher, GSK launched an eCycling programme that removed the unwanted equipment, netted it USD 1.8 million in asset value recovery activities over two years, and reduced its carbon footprint by 143 tons.

Verizon Wireless' HopeLine Programme

HopeLine puts Verizon's technology to work in communities by turning no-longer-used wireless handsets and accessories into support for the victims of domestic violence, all while helping to protect the environment by disposing of phones in an environmentally sound way.

Since the HopeLine reuse and recycling programme was launched in 2001, Verizon Wireless has:

- collected more than 8 million phones through our stores and other points nationwide,
- awarded more than USD 14 million in cash grants to domestic violence agencies and organizations throughout the U.S.,
- distributed more than 123 000 phones with more than 406 million minutes for free wireless service to be used by victims of domestic violence,
- properly disposed of nearly 1.72 million phones in an environmentally sound way and refurbished the remaining units,
- kept more than 210 tons of electronic waste and batteries out of landfills.

Wireless phones given to HopeLine are refurbished and sold for reuse, generating proceeds for the programme. Refurbished phones, complete with 3 000 minutes of wireless service, are provided to local domestic violence prevention organizations or local law enforcement agencies for use with their domestic violence clients. If donated phones are unsalvageable, they are recycled in an environmentally sound way under a zero landfill policy.

8 Checklists

8.1 *An internal prospective*

For successful E-waste management it is necessary that each organization not just understands what types of wastes it generates but also streamlines the processes for its safe reuse, recycling or disposal. Here are 6 steps that will nudge organizations to grapple with the challenge of responsible e-waste disposal.

Who is responsible for end-of-life within the organization?

Identifying departments which will be responsible is very important. Typically within large corporates e-waste like computers monitors and telecommunication will be generated and will come under the IT department's responsibility. These assets will be tagged and inventory available with IT department. Other types of electrical and universal wastes like fans, coffee machines, and printer cartridges could come under the jurisdiction of facilities. Universal wastes like batteries, compact fluorescent lamps (CFL) mercury containing lamps, would also come under the jurisdiction of facilities. It is necessary to identify the departments who will deal with e-waste. There may be more than one department responsible for different types of e-waste such as facilities, housekeeping, purchase and accounts etc. Clear responsibilities with respect to End-of-life management options assigned to each department. Person with defined roles and responsibilities must be identified for each department.

What do we track?

Understanding the types of end-of-life management options that the organization will generate is the key to the inventory. Inventory is a list of all the items that could be classified as end-of-life management options. Inventory will have information of source of waste, the type of waste and the quantity of waste. Inventory of e-waste and tracking from purchase – use – disposal is vital step for managing end-of-life management options. Organizations departments and business enable functions may sometimes be confused what is classified under end-of-life management options. Therefore all the responsible departments will need to have a complete list of all types of e-waste product generated in the organization. Suitable software could ensure a complete tracking of the material and identification of material which reaches its end-of-life. This software will help in maintaining the status of each item. Items which are bonded should be identified through pasting of an appropriate sticker with relevant details in terms of date and number.

IT Asset management solutions help organizations manage their IT assets from procurement to retirement. The first step of e-waste management is therefore in the inventory of retired assets. Such tracking mechanisms do exist within large organizations and hence could be leveraged to achieve end-of-life reporting and management requirements.

Where do we store the e-waste?

A suitable storage space is required which is sufficiently large to store all the e-waste safely. Storage norms are required for each category of e-waste. For example CFLs and fluorescent lamps which are fragile should be safely placed in drums or put in the original packing. Likewise a dedicated bin is required for printer cartridges. This storage space should be separate from space allocated for other scrap including old chairs and other metal scrap.

What permissions are to be sought?

Registration with the environmental authority companies is needed. These companies have independent facilities and are registered under the current and applicable legislation, and have to apply to the pollution control board (PCB) or regulatory body for registration which allows them to store hazardous waste (e-waste) as per relevant local and federal laws. This may vary from country to country. Typically country specific norms have to be adhered here.

How can we provide end-of-life management solutions?

The company must identify a suitable e-waste recycler who is authorized to recycle e-waste. The organization must enter into an agreement with this recycler. Groups of companies located with the common collection centre can use this facility to dispose of end-of-life products. Alternative options such as upgrades on existing machines, or reuse of electronic equipment in different departments before final disposal could be encouraged. A process to ensure which equipment can be reused before recycling is a good way to extend the life of the product.

Remanufacturing of printer cartridges: used printer cartridges can be handed over for remanufacturing. This ensures that the entire shell of the cartridge which is made up of plastic is used again instead of being crushed and recycled.

What documentation do we need to collect?

The e-waste collected is documented, which will be handed over to the company by the recycler. This document is evidence of the total quantity of products handed over for recycling. A copy of this document is usually also handed over by the company to the pollution control board or relevant regulatory body. Relevant documentation varies from country to country. End-of-life reporting is now an added burden for most organizations worldwide.

The recycler would need to keep track of processes, volumes, and origin of the end-of-life products for routine regulatory check-up. It would be good practice for recyclers to share this report with the client company as well as the regulatory authorities.

1. Identification of responsibility for end-of-life within the organization	☐
2. End-of-life inventory, and tracking of items from the time of purchase	☐
3. Storage facilities for e-waste	☐
4. Sourcing end-of-life management solutions from recycler companies	☐
5. Registration with the relevant environmental authority, plus permissions	☐
6. Definition of documentation needed from recycler	☐
7. Flow of end-of-life and e-waste information into management systems	☐

8.2 The perspective of high-technology business districts

In several parts of the world which are IT-intensive, such as India and China, governments have set up special economic zones (SEZs). SEZ's enjoy a special status which facilitates the export of goods manufactured in these areas. Due to this status, all electronic goods which are purchased for use inside the SEZ are bonded and when they have to be disposed of, they need to undergo a process of de-bonding which is a cost to the company in form of excise duty. This is an additional process that organizations operating out of an SEZ would need to adopt into the end-of-life management.

8.3 The perspective of a donation receptor

The donation of used electronic equipment is practiced worldwide, thereby extending the life of these goods. Organizations that accept donations (donation receptor) need to understand how to responsibly dispose these goods at their end of life. It would be a good practice for the donor and receptor to mutually agree to dispose these goods through an authorized recycler. Keeping track of donated goods and received goods would therefore be required to ensure tracking and avoiding leakages.

9 Conclusions

As a general principle, ICT equipment management should follow a life cycle approach. This includes reuse, refurbishment, recycling and environmentally sound disposal operations as described in this document.

The scale of success of the ICT industry worldwide coupled with its regular refreshing of its product lines means that the quantities of end-of-life ICT assets is huge, and continues to grow. Organizations throughout the world need to set an enforce end of life policies, and build collaborative links with the recycling industries.

This is not just a problem within companies – consumers too need to understand and be aware of the issues surrounding end-of-life ICT assets. Clearly, ICT companies can play a significant role here in helping their customers gain such an understanding so that they act appropriately in this regard.

Ultimately, end-of-life management is about identifying and sticking to good quality processes regarding asset management, information management, reverse logistics, dismantling, refurbishing, reuse, recycling and recovery. The good news for organizations is that companies that do this well will meet their corporate responsibilities while acting as efficiently as possible in the context of business performance. Clearly, this should be a strong driver for more organizations buying into end- of-life management.

9.1 Suggestions to ITU-T SG 5

The suggestions listed below cover the areas where there is an opportunity to develop further work in order to achieve superior end-of-life performance development within the ICT sector, and are presented to ITU-T SG 5 for its perusal:

1. ICT product design issues

Clean supply chain; reduction of the demand on limited natural resources, which is measurable and tractable; designing products that through their different life cycle stages reduce environmental impact and waste generation; designing, producing, labelling in compliance to the requirements of legislation in place, commercialization of products that have a reasonable extensive life and that once they achieved the end of life, can easily be repaired or dismantled for reuse or its value recovered via recycling or its life finalized in the best environmental possible manner without impacting economic growth.

2. Technical guidance applicable to refurbishment and repair facilities as well as marketing of used ICT equipment

Risk prevention and minimization; processing and management of equipment and components destined for reuse; management of materials, components and residuals destined for recycling or disposal; and, record keeping and performance measurement (partly covered here).

3. Environmental and socio-economic aspects

Uncontrolled burning, disassembly, and disposal causes a variety of environmental problems affecting directly or indirectly human health such as erosion of land, high water demands and contamination of ground sources, air pollution with carcinogens and neurotoxins. Fumes include dioxins and furans. Inappropriate method of processing waste could lead to, deforestation and the inevitable relocation of communities, animal life as well as the disappearance of ecological habitats. In addition, this could lead to health problems including occupational health and safety issues, affecting those who are either directly and indirectly involved, due to the methods of processing the waste; etc. (partly covered here).

There must be a direct guidance to the industry in order to help governments and communities to end bad practices such us uncontrolled burning and to secure that material is being handled properly. This industry movement needs to take into account the micro-economics that have been developed around those practices harmful as they are to society and the environment, because they represent are the only income for thousands of families who cannot be excluded from employability access in the world.

4. Principles for donors of ICT equipment

Ensure that products are functional and that appropriate products are provided; availability of technical support in the country of destination; and, ensure full transparency, contract and notification and consent prior to delivery.

5. Development of national ICT policies

Ensure that the life-cycle approach is used for developing national ICT policies. This means that such issues, as, *inter alia*, green design, collection, recycling, disposal should be considered in the policy.

6. Map guidance document on ICT applicable standards and legislation

Develop a map or guidance document that lists all different end-of-life standards currently available around the world, highlighting the aim, resources needed, pros/cons, boundaries, expectations, possible overlapping or relation with others, as well as the differences among them. This document, which would need to be updated regularly, will be of help to the user to identify, differentiate, and make an independent decision over which standard to use according to the needs and objectives of the stakeholder on its specific role within the recycling chain.

7. Development of a global CO_2 – equivalent market

Developing a market for CO_2 trading will help to directly control and incentivize reduction on pollution emissions through the use of best practices available and technology, as well as making use of economic incentives and fees over the direct effect of the environmental impacts generated by inappropriate ICT disposal, locally or overseas.

8. Recovery of rare metals and green ICT supply chain

In the effort to achieve a green supply chain within the ICT sector, it is recommended that ITU-T SG 5 actively includes and facilitates access to the recycling and precious metals industry in the discussions and possible developments that aim to return such metals to the industry with the physical and technical characteristics needed to satisfy new equipment production requirements. It is this industry that has the practical knowledge on the technical aspects and feasibility opportunities and limitations of the recovery process.

10 Glossary

BAT	Best Available Technique
BDE	Brominated Diphenyl Ether
BEP	Best Environmental Practice
BFR	Brominated Flame Retardants
BS	British Standards
BSI	British Standards Institute
C&F	Cargo and Freight
CFL	Compact Fluorescent Lamps
CO_2	Carbon Dioxide
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSR	Corporate Social Responsibility
DEFRA	Department for Environment, Food and Rural Affairs (UK)
EC	European Commission
EEE	Electrical and Electronic Equipment
EMAS	Environmental Management and Audit Systems
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EU	European Union
GHG	Greenhouse Gas
GHGP	Green House Gas Protocol (of the WRI)
ICT	Information and Communication Technologies
ISO	International Standards Organization
ITU	International Telecommunication Union
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LED	Light Emitting Diode
Li-ion	Lithium ion (battery)
MEAS	Multilateral Environmental Agreements
NGO	Non-Governmental Organization
NiCd	Nickel Cadmium
NiMH	Nickel-Metal Hydride (battery)
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer

OSH	Occupational Health and Safety
PCB	Pollution Control Board
PCB	Printed Circuit Board
PFO	Perfluorooctane Sulfonic Acid
PFOf	Perfluorooctane Sulfonyl Fluoride
PFOs	Perfluorooctane Sulfonic Acid Salt
POP	Persistent Organic Pollutants
POST	Power on Self-Test
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
PWB	Printed Wiring Board
REACH	Restriction, Evaluation and Authorization of Chemicals
RoHS	Restriction of certain Hazardous Substances
SCUs	Swiss Charter Units
SEZ	Special Economic Zone
SG 5	Study Group 5 (of the ITU-T)
SOx	Sulfur Oxides (various forms)
UK	United Kingdom
WEEE	Waste Electrical and Electronic Equipment (European Union Directive)

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12 Annexes

Annex I[13]

Table 1: Example of functionality tests for used computing equipment

Computing equipment	Functionality tests	Test results
Central processing units (CPUs), including desk top PCs	**Power on self test (POST)*** Switching on the computer and successfully completing the boot up process. This will confirm that the principal hardware is working, including power supply and hard drive. • A working monitor would need to be used if none present • Ensure that cooling fans are functioning • Remove dust as much as possible (e.g. delicately using a vacuum cleaner is possible), in order to ensure better cooling and stable operation	**Computer** should boot up successfully **Computer** should respond to keyboard and mouse input **Cooling fans** should operate normally. No strong mechanical sound denoting end-of-life of fans
Laptops/notebooks	**Power on self test (POST)*** Switching on the laptop and successfully completing the boot up process. This will confirm that the principal hardware is working, including power supply and hard drive. • Test screen • Test battery functionality and safety • Ensure the display is fully functional • Ensure cooling fan(s) is functional	**Laptop** should boot up successfully **Laptop** should respond to keyboard and mouse input **Display** turns on during boot up. Image should be clear and colours contrast and brightness correct with no screen burned images, scratches or cracks (see also below for display devices). **Laptop battery** able to retain a minimum of 1 hour[14] of run time; or battery tested to determine the full charge capacity in watt-hours also with a minimum of 1 hour remaining (see laptop batteries section below, paragraph 120). Check if connections are clean, no deformation due to heat on the battery pack, no hotspots during charge/discharge test
Keyboards	Connect to computer and ensure they successfully interface Test keys for functionality	Computer should respond to **keyboard** input **Keyboard** should have no missing or non-functioning keys

[13] For more information, see PACE Guidance Document on the Environmentally Sound Management of Used and End-of-Life Computing Equipment, 2011.

[14] One hour is a minimum charge a battery should hold, although some users of laptops may request more useable runtime. It should be noted that some end users will also be able to make use of batteries with less capacity. For example, a battery able to hold a 40-minute capacity need not be discarded, and can have use for those principally connecting the laptop to a reliable electricity supply using the charger. However, for the purposes of this document and for export, batteries must hold at least a one-hour charge.

Computing equipment	Functionality tests	Test results
Mice	Assess mouse casing, cable and parts Plug into computer or laptop to assess functionality	**Mouse** should have all parts present (e.g. the roller ball). Computer should respond to **mouse** input. Visible cursor on screen should not judder
Cables and power cords	Assess cable insulation and inspect plugs	**Cabling and plugs** should be complete and free of damage, e.g. has no cracked insulation Any detachable cable with damage should be replaced by a new one to avoid electric shocks or premature failures
Display devices	Plug in display and test the picture quality for pixels, colour, contrast and brightness. Software based diagnostic testing for display devices are readily available on line[15], and should be used Visual inspection for screen burn (CRTs) or "image persistence" (flat screens), scratches or other damage to screen or housing Cabling should be inspected and present	**Display devices** The picture should not be fuzzy, or have damaged pixels, or be too dark. LCD backlights should all function. Colours, brightness, hue and straightness of lines should be considered The software diagnostic test should be positive Cabling should be free from damage. Any detachable cable with damage should be replaced by a new one to avoid electric shocks or premature failures
Laser and inkjet printers	A test page can be successfully printed This can be standalone but also from a computer or local area network to assess connectivity For inkjet printers, check that the ink heads are not clogged with dry ink	**Printers** should successfully print a test page and not jam, or produce a smudged or incomplete copy
Components (removed from equipment) including mother boards, other circuit boards, sound cards, graphics cards, hard drives, power supplies and cords/ cables	Components should be gently wiped from dust to improve thermal exchange and allow better cooling Components should be tested for functionality either before removal from the host computer or laptop, or by insertion in a test bench computer using diagnostic software, or a known working device as applicable	**Components** should be fully functional **Power supplies and cords / cables** should be complete and free of damage, e.g. has no cracked insulation. Any detachable cable with damage should be replaced by a new one to avoid electric shocks or premature failures

15 See for example: www.softpedia.com/progDownload/Nokia-Monitor-Test-Download-464.html.

Annex II

Disposal operations

(Annex IV of the Basel Convention)

A. Operations which do not lead to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative uses

Section A encompasses all such disposal operations which occur in practice.

D1	Deposit into or onto land, (e.g. landfill, etc.)
D2	Land treatment, (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D3	Deep injection, (e.g. injection of pumpable discards into wells, salt domes of naturally occurring repositories, etc.)
D4	Surface impoundment, (e.g. placement of liquid or sludge discards into pits, ponds or lagoons, etc.)
D5	Specially engineered landfill, (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D6	Release into a water body except seas/oceans
D7	Release into seas/oceans including sea-bed insertion
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A
D9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A, (e.g. evaporation, drying, calcination, neutralization, precipitation, etc.)
D10	Incineration on land
D11	Incineration at sea
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)
D13	Blending or mixing prior to submission to any of the operations in Section A
D14	Repackaging prior to submission to any of the operations in Section A
D15	Storage pending any of the operations in Section A

B. **Operations which may lead to resource recovery, recycling reclamation, direct reuse or alternative uses**

Section B encompasses all such operations with respect to material legally defined as or considered to be hazardous wastes and which otherwise would have been destined for operations included in Section A.

R1	Use as a fuel (other than in direct incineration) or other means to generate energy
R2	Solvent reclamation/regeneration
R3	Recycling/reclamation of organic substances which are not used as solvents
R4	Recycling/reclamation of metals and metal compounds
R5	Recycling/reclamation of other inorganic materials
R6	Regeneration of acids or bases
R7	Recovery of components used for pollution abatement
R8	Recovery of components from catalysts
R9	Used oil re-refining or other reuses of previously used oil
R10	Land treatment resulting in benefit to agriculture or ecological improvement
R11	Uses of residual materials obtained from any of the operations numbered R1-R10
R12	Exchange of wastes for submission to any of the operations numbered R1-R11
R13	Accumulation of material intended for any operation in Section B

Annex III

General references to the legislation, international standards and guidance documents

- Basel Convention: Control of Transboundary Movements of Hazardous Wastes and Their Disposal – adopted 1989, with amendments;
- Regulation (EC) No 1418/2007 of 29 November 2007 concerning the export for recovery of certain waste listed in Annex III or IIIA to Regulation (EC) No 1013/2006 of the European Parliament and of the Council to certain countries to which the OECD Decision on the control of transboundary movements of wastes does not apply;
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- Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste – applicable since 12 July 2007.
- Regulation (EC) No 1379/2007 of 26 November 2007 This regulation includes in particular a revision of the forms for notification and movement documents and for the information to accompany shipments of green-listed waste.
- Special provisions for waste shipments to new Member States: Transitional rules are now contained in Article 63 of Regulation 1013/2006. Before, they were laid down for 7 new Member States in the respective Acts of Accession:
- Latvia: Annex VIII to the Act of Accession of 2003, chapter 10.
- Poland: Annex XII to the Act of Accession of 2003, chapter 13(B).
- Slovakia: Annex XIV to the Act of Accession of 2003, chapter 9(B).
- Bulgaria: Annex VI to the Act of Accession of 2005, chapter 9(B)(at p. 16).
- Romania: Annex VII to the Act of Accession of 2005, chapter 9(B)(at p. 21).
- Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste – applicable since 12 July 2007.
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General specifications and key performance indicators

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Table of contents

General specifications and key performance indicators

Executive summary

Environmental management is becoming an important part of every company's working methods, particularly in the ICT sector where there are negative environmental impacts like in any other sector, but whose products play an important role in enabling organizations of other industries improve their sustainability performance. The ICT industry needs excellent procedures and processes to deal with environmental data so that ICT organizations can improve their own sustainability tracking, management and performance.

This document, part of the ITU Toolkit for environmental sustainability for the ICT sector, focuses on environmental key performance indicators (KPIs) that can be of assistance to an ICT organization to quantify and evaluate performance in this area. Identifying and working with environmental KPIs is not new. Many organizations have already identified a number of common environmental KPIs between them. The objective here is to create a common set of environmental KPIs that together help an organization meet its regulatory, commercial and societal challenges.

There are five main groups of environmental KPIs that are tracked by ICT organizations: energy, GHG emissions, waste, water and others that are usually more specific to the operation of a company.

There are already a number of standards and methodologies in place that can provide a framework for environmental management. This document explores such standards from a number of these providers, including global standards organizations, and ICT industry networks and initiatives.

The starting point in the selection of an environmental KPI isn't picking and choosing a KPI from a global menu, but to define a target based on the organization's business strategy. First order priorities (lowering an organization's own impacts) usually provide economic and environmental benefits, but other priorities may be driven by business objectives, investor demand for information, better internal decision-making, etc.

The reason for building standardized processes with KPIs is to ensure that the metrics are as comprehensive, useful and insightful as possible. In choosing KPIs, this document suggests that issues such as relevance, measurability, and uniformity of data units/boundaries are important to ensure that time and resources are not wasted chasing after the wrong data.

Once the KPIs are chosen, there are good practices that need to be put in place to ensure that the data is collected, and once collected, is verified and validated.

While most of the KPIs covered in this analysis are focused on carbon and energy management, there are plenty of gaps that need to be explored in terms of other environmental KPIs, particularly relating to e-waste. Setting environmental targets supports effective environmental load reduction by the organization. In addition, it could help with compliance regarding environmental regulations whenever they emerge, even if they do not currently exist.

1 Introduction

This document establishes the necessary procedures that ICT companies should use to define environmental key performance indicators (KPIs) for decision making. KPIs are environmental tools used commonly for:

- environmental data management;
- eco-efficiency measurement (energy, water, waste and CO_2);
- environmental target setting and follow-up.

Environmental management is becoming an important part of every company and especially in the information and communication technology (ICT) companies, whose products and services are addressed to deal with tomorrow's needs of a more environmentally sustainable world. It is important to have standard procedures and processes to deal with environmental data management. This document draws from ICT's best practices and intends to help ICT organizations improve their environmental tracking, management and performance.

1.1 Target audience and scope

This document is focused on information and communication technology (ICT) organizations and companies.[1] It is aimed at:

- The management of ICT organizations, from the business functions as well as the environment/sustainability functions.
- The management of non-ICT organizations who want to account for improvements in environmental impacts enabled through the use of ICT.

An ICT organization's core activity is directly related to the design, production, promotion, sales or maintenance of ICT goods, networks or services. ICT companies and organizations have several differentiated sub-sectors that must be considered in order to identify individual KPIs. Note that a company could orient its business to one or more of these sub-sectors:

- **ICT telecom operators**: Networks operation and provision of telecommunication services such as telephony or data communication accesses, e.g. Telefónica, Vodafone, AT&T, China Mobile, etc.
- **ICT manufacturers**: ICT technology and infrastructure developers and distributors, e.g. ALU, Nokia, Samsung, Sony, Ericsson, Nokia Siemens Networks, IBM, Huawei, Toshiba, etc.
- **ICT software developers**: Software programing for distribution and customer use from mobile or home devices, e.g. Google, Apple, Microsoft, etc.

The intensity of these different environmental indicators will differ regarding the ICT sub-sector, and the nature of the impact that can also vary from one sub-sector to another, e.g. network energy consumption is one of the most important impacts from telecom operators while production and material usage creates the largest impact for manufacturing companies. In this sense, it is not possible to make a specific, individual list of KPIs for ICT companies to follow. Instead, it is better to clarify terms and provide general guidance.

[1] ICTs are a combination of devices and services that capture, transmit and display data and information electronically. These include personal computers (PCs) and peripherals, broadband telecom networks and devices, and data centers. ITU-GeSI – Using ICTs to Tackle Climate Change (2010).

1.2 ICT environmental impacts

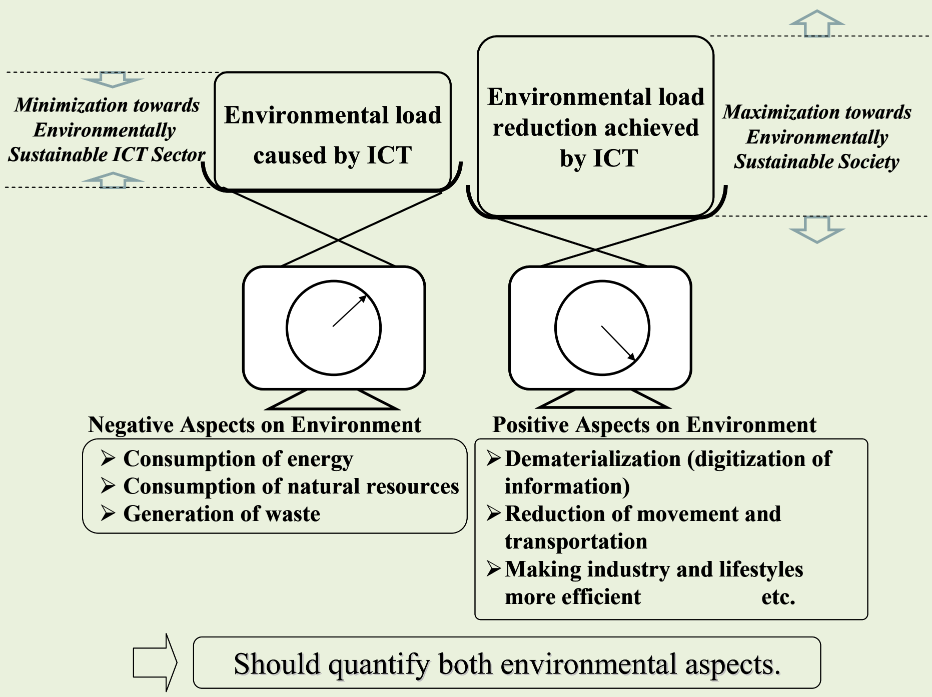
ICT organizations have a double-edged nature regarding environmental impacts. There are mainly two orders of effect regarding environmental impacts of ICTs[2]:

1. **First order effects** (or the environmental load of ICTs): the impacts created by the physical existence of ICT and the processes involved, e.g. GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources, which together represent the environmental load related to ICT goods, networks and services over their life cycle.

2. **Second order effects** (or the environmental load reduction achieved by ICTs): the impacts and opportunities created by the use and application of ICTs. This includes environmental load reduction effects which can be either actual or potential, e.g. travel substitution, transportation optimization, working environment changes, use of environmental control systems, use of e-business, e-government, etc. In this sense, it is important to mention the "Enabling Effect" which represents the possible greenhouse gas (GHG) emissions reduction by five major opportunities: dematerialization, smart motor systems, smart logistics, smart buildings and smart grids[3].

Figure 1: Positive and negative impacts of ICTs describes a schematic approach of the environmental impacts of ICTs on the environment. First order effects are directly related to negative effects on the environment by ICTs, and second order effects are identified with the positive ones. It is important to calculate these positive impacts as well as the negative ones, if possible, to achieve an assessment with a fuller perspective. For both effects, environmental KPIs should be used to account for both impacts.

Figure 1: Positive and negative impacts of ICTs[4]



[2] Recommendation ITU-T L.1410 – Methodology for environmental impact assessment of information and communication technologies goods, networks and services (2012).

[3] SMART 2020 – Enabling the low carbon economy in the information age (2010).

[4] Recommendation ITU-T L.1410 (2012) – Methodology for environmental impact assessment of information and communication technologies goods, networks and services.

1.3 Definition of an environmental KPI

A key performance indicator, or KPI in terms of this document's usage, is a metric or measure used to quantify and evaluate organizational performance in relation to the meeting of targets and objectives. KPIs are also used to set measurable objectives, evaluate progress, monitor trends, make improvements, and support decision making.

The defined KPIs are quantitative and periodically measure values that concern the environment as a result of ICT business operations. They can be used to measure the level of eco-efficiency, a term based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution.

Commonly used environmental KPIs are:

- energy consumption, from fuel use or electricity consumption, or use of renewable energy;
- GHG emissions depending on the scope, or by type of gas;
- waste generated;
- waste recycled;
- water used; and
- recycled, hazardous materials used, etc.

2 Environmental KPIs for ICT organizations

The intention of this section is to review existing environmental KPIs suggested or asked for by global environmental initiatives, or defined in ICT-specific guidelines or initiatives. The treatment and management of environmental KPIs is not new. Some organizations have already identified a number of common environmental KPIs between them. This document helps identify which KPIs might be relevant to a particular organization.

There are five main groups of environmental KPIs that are usually identified by different ICT and non-ICT institutions: energy, GHG emissions, waste, water, and others. The environmental KPIs in this document are organized in these same categories.

2.1 Environmental KPIs by global organizations or initiatives

The following organizations[5] are globally recognized as providing support to all sectors of the economy in defining comparable environmental KPIs. These KPIs are usually part of environmental reporting indices, investor indices, or environmental standards and methodologies.

Reporting or investor indices provide external bodies with an opportunity to make an evaluation regarding the sustainability and environmental performance of companies. KPIs on standards or methodologies provide a framework for environmental matters that help organizations measure their own performance and improve internal environmental management capabilities.

2.1.1 Carbon Disclosure Project (CDP)

The Carbon Disclosure Project is an organization that works with shareholders and corporations to foster, in particular, the disclosure of greenhouse gases emissions and climate change strategies of major

[5] This is a non-exclusive list in alphabetical order.

corporations.[6] CDP has developed a general questionnaire, and in 2012 included an ICT-specific questionnaire. Some of the KPIs required by the general CDP questionnaire are:

Energy (usually denominated in megawatt hours or MWh):

- fuel;
- electricity;
- heat;
- steam;
- cooling.

GHG emissions (Tonnes CO_2eq):

- total gross scope 1;
- total gross scope 2;
- total gross scope 3;
- scope 1 and 2 per type of gas;
- scope 1 and 2 per country;
- scope 1 and 2 per type of business;
- (scope 1 and 2)/revenues;
- (scope 1 and 2)/employee;
- (scope 1 and 2)/(normalized company intensity figure);
- kg CO_2-e per unit of good/service.

Other:

- Amount of emissions traded in carbon markets.

Sector-specific question module (ICT)

The sector specific module is divided in sub-sectors. Here are some examples:

- Data centers
  - ◊ power usage effectiveness (PUE) value;
  - ◊ utilization rate.
- Scope 1 and 2 emissions in in metric tonnes CO_2eq/Terabyte of network traffic
- Electricity use/terabyte
- Hardware
  - ◊ % of products that meet energy-efficiency requirement.
- Business services
- Scope 1 and 2 emissions per square metre.

[6] Carbon Disclosure Project: www.cdproject.net (2012).

2.1.2 Dow Jones Sustainability Index (DJSI)

DJSI is an index that evaluates the performance of the world's leading companies in sustainability; it is the longest-running global sustainability benchmark worldwide.[7] The KPIs DJSI requires from ICT companies are:

Energy (MWh):

- Electricity purchased (MWh)
- Renewable energy: per type, number of units and MWh output.

GHG emissions (Tonnes CO_2eq):

- Metric Tonnes CO_2eq (scopes 1 and 2)
- Carbon intensity: relative indicator per unit of product or other KPI.

Waste:

- Total waste generated.

Water (million m^3):

- Total water withdrawal
- Total salt/brackish water withdrawn
- Total municipal water supplies (or from other water utilities)
- Total water from all other sources
- Water returned to the source of extraction at similar or higher quality as raw water extracted.

Others:

- Volume of oil lost
- Direct volatile organic compounds emissions.

2.1.3 GHG Protocol corporate standard

The GHG Protocol is an accounting tool that gives standards and guidance regarding corporate greenhouse gas accounting and reporting to companies.[8] Note that the GHG Protocol provides numerous tools for GHG calculation, including several for specific sectors, but none specifically for ICTs. Due to the huge amount of possible KPIs, only a top-level selection has been made, with the intent of showing how GHG emissions are analysed in the GHG Protocol. The suggestions on how to organize KPIs for GHG emissions by this initiative are as follows:

- GHG emissions from stationary combustion (scope 1)
- GHG emissions from mobile combustion (scope 1)
- GHG emissions from air conditioning and cooling (scope 1)
- GHG indirect emissions from own consumption of purchased electricity (scope 2)
- Other indirect emissions (scope 3), e.g. extraction and production of purchased materials transportation of purchased fuels; and use of sold products and services.

[7] Dow Jones Sustainability Index. www.sustainability-index.com/ (2012).

[8] Greenhouse Gas Protocol. www.ghgprotocol.org (2012).

2.1.4 Global Reporting Initiative (GRI)

GRI is a multi-stakeholder organization that produces a comprehensive sustainability reporting framework for the mainstreaming of disclosure on environmental, social and governance performance, producing standards for sustainability reporting.[9] General guidelines are to be used by companies of all types. A pilot version of a telecommunication sector supplement is also available. Some of the quantitative environmental KPIs suggested by GRI are:

Energy:

- Direct energy consumption by primary energy source
- Indirect energy consumption by primary source.

GHG emissions:

- Total direct and indirect greenhouse gas emissions by weight
- Other relevant indirect greenhouse gas emissions by weight.

Waste:

- Total weight of waste by type and disposal method
- Weight of transported, imported, exported, or treated waste deemed hazardous
- Percentage of transported waste shipped internationally.

Water (million m^3):

- Total water withdrawal by source
- Percentage and total volume of water recycled and reused
- Total water discharge by quality and destination.

Materials and waste:

- Materials used by weight or volume
- Percentage of materials used that are recycled
- Total weight of waste by type and disposal method.

Others:

- Emissions of ozone-depleting substances by weight
- NOx, SOx, and other significant air emissions by type and weight.

The sector supplement asks for the following environmental indicators:

- Volume/Weight of banned, restricted of scheduled waste for phase out in markets where the organization operates
- Volume/Weight of critical material.

[9] Global Reporting Initiative – Telecommunication Sector Supplement. 2003. www.globalreporting.org/GRI Telecommunications Sector Supplement.

2.1.5 ISO 14031

ISO 14031 gives guidance on the design and use of environmental performance evaluation, and on identification and selection of environmental performance indicators, for use by all organizations, regardless of type, size, location and complexity.

Energy:

- Energy consumed per year or per unit of output
- Energy consumed or customer service
- Quantity of each type of energy consumed
- Energy generated by-products or process flows
- Number of units of energy saved through energy conservation programmes
- Area of land used to produce one unit of energy
- Average fuel consumption of vehicle fleet
- Total product lifetime energy consumption.

Waste:

- Waste per year or per unit of output
- Hazardous waste, recyclable and omnipresent produced per year
- Total waste for final disposal
- Amount of waste stored at the site
- Controlled amount of waste permits
- Waste converted into reusable materials per year
- Hazardous waste removed due to material substitution.

Water:

- Amount of water per unit of product
- Amount of reused water.

Others:

- Number of vehicles in the fleet that have the technology to reduce pollution
- Number of hours of preventive maintenance of equipment per year
- Number of products introduced to the market with reduced hazardous properties
- Number of products that can be reused or recycled
- Percentage of reusable or recyclable content of a product
- Proportion of defective products
- Number of units of products generated per unit of output
- Number of units of energy consumed during product use
- Product life
- Number of products with instructions for use and safe disposal to the environment.

2.1.6 ISO 14064-1

ISO 14064-1 provides governments, businesses, regions and other organizations with principles and requirements for the design, development and management of GHG inventories and their presentation. The norm establishes, in general terms, three main groups for GHG KPIs and each of these groups can be broken down individually by type of GHG gas (CO_2, CH_4, N_2O, HFC, PFC and SF_6), fuel, business area, etc.

GHG emissions:

- Direct GHG emissions, coming from fuel consumption for electricity, heat or steam generation.
- Indirect emissions from electricity, heat or steam generated externally and consumed by the company.
- Other indirect emissions: employee mobility, business travel, products transportation, GHG emissions coming from leasing companies, etc.

ISO 14064-1 covers the same approach for GHG accounting as the GHG Protocol. Other ISO 14064 family norms are ISO 14064-2 and ISO 14064-3 for GHG reduction projects and verification details, respectively.

2.2 Environmental KPIs by ICT organizations or initiatives

In addition to the global initiatives, there are a number of organizations directly related to ICT which also provide environmental KPIs covering reporting guidelines, standards and methodologies.

2.2.1 European Telecommunications Network Operators' Association (ETNO)

ETNO is a policy group for European telecommunications network operators.[10] ETNO has defined a group of KPIs that are collected every year from its members for its Annual Report.[11] These KPIs are:

Energy:

- Total annual consumption of electricity from the grid
- Total annual consumption of electricity directly purchased from renewable sources
- Total annual consumption of electricity from CHP (combined heat and power)
- Total annual consumption from own production of electricity (e.g. fuel cells, own CHP, etc.)
- Diesel consumption
- Petrol leaded consumption
- Petrol unleaded consumption
- LPG (liquefied petroleum gas) consumption
- CNG (compressed natural gas) consumption
- Total annual automotive fuel savings (via energy efficiency actions) compared with previous year
- Total annual heating oil demand
- Total annual natural gas demand
- Other fuels/sources (e.g. coal, etc.)
- District heating
- Amount of energy.

[10] European Telecommunication Network Association. ETNO. www.etno.be (2012).

[11] ETNO: Sustainability reports questionnaire 2010.

GHG emissions:

- Total CO_2 emissions from electricity consumption
- Total CO_2 emissions from heating fuel consumption.

Materials:

- Paper demand by the employees
- Paper used for telephone directories
- Total paper demand (including demand by the employees but not directories)
- Percentage of paper recycled.

2.2.2 European Telecommunications Standards Institute (ETSI)

ETSI produces globally applicable standards for information and communication technologies including fixed, mobile, radio, broadcast, Internet, aeronautical and other areas. It provides technical specific standards for ICTs in the field of measurement methods for energy efficiency of wired and wireless[12] access. KPIs are defined as:

Wired access:

- The power consumption of broadband telecommunication network equipment:

  PBBline = PBBeq/Nsubscrib-lines

  The indicator needs to be evaluated in different conditions of traffic to take into account low power mode.

- Global network power performance is proposed as normalized power consumption

  NPC = 1 000 × PBBport/bitrate [mW/Mbit/s]

Wireless access:

- Network level efficiency is based on coverage (more indicative for rural cases):

$$EE_{coverage} = \frac{A_{coverage}}{P_{site}} : \text{km}^2/\text{W}$$

- Network level performance indicator based on data traffic (more indicative for urban cases). Two metrics are defined, one for GSMA and other for WCDMA/LTE/WIMAX technology.

$$\text{GSMA} \qquad EE_{capacity} = \frac{N_{busy\_hour}}{P_{site}}$$

Nbusy_hour is the number of subscribers based on average busy hour traffic demand by subscribers and average RBS busy hour traffic.

[12] European Telecom Standardization Institute. ETSI. ETSI TS 102 706 V1.2.1 (2011-10), Environmental Engineering (EE), Measurement Method for Energy Efficiency of Wireless Access Network Equipment.

WCDMA LTE WIMAX	$$EE_{equipment} = \sum_{ALx=1}^{l}\left(c_{ALx} \cdot EE_{equipment}^{ALx}\right)$$ $$EE_{equipment} = \sum_{ALx=1}^{l}\left(c_{ALx} \cdot EE_{equipment}^{ALx}\right)$$ (Kbit/J)	$EE_{equipment}^{ALx}$ takes into account data traffic and energy consumption during an activity of the cell. It is defined as average data traffic and distance between user equipment and radio network equipment. C_{ALx} is a weighting factor that considers traffic distribution during a day.

In November 2011, ETSI published an LCA (Life Cycle Analysis) standard[13] containing detailed requirements beyond ISO 14040/ISO 14044 and EU ILCD Handbook for LCA of ICT Equipment, Networks, and Services.

Several useful KPIs can be derived through the use of LCA techniques, including *resource productivity,* where:

- Resource productivity = material input per unit service.

LCA provides a quantitative index with which to compare applications, e.g. similar ICT systems. As a result, it can be used to calculate resource productivity. ICT systems of higher resource productivity are those that deliver higher performance (e.g. lower CO_2 emissions) with lower resource consumption.

Another possible LCA based KPI applicable to ICT systems is carbon efficiency, defined as the "output of functionality/CO_2eq per ICT system providing the functionality". So the more functionality provided with less CO_2eq emissions, the higher the carbon efficiency of the ICT system. For example, the provision of services such as fibre to the home (FTTH) or fibre to the building (FTTB) differs, based on the results of this analysis.

FTTH 100 [Mb/s]/120 kgCO_2e = 0.83

FTTB 50 [Mb/s]/130 kgCO_2e = 0.38.

So, in the case of this LCA study, the carbon efficiency KPI is 116% better for FTTH than FTTB.[14]

2.2.3 The Green Grid

The Green Grid is a non-profit, open industry consortium of end users, policy-makers, technology providers, facility architects, and utility companies collaborating to improve the resource efficiency of data centers and business computing ecosystems. They have developed two useful energy efficiency metrics for IT equipment:[15]

Energy in data centers:

- power usage effectiveness (PUE) = total facility power/IT equipment power;
- data center infrastructure efficiency (DCiE) = 1/PUE = IT equipment power/total facility power × 100%.

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[13] European Telecom Standardization Institute. ETSI . ETSI TS 103 199. V1.1.1 (2011-11), Environmental Engineering (EE). Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements.

[14] [G. Griffa, L. Radice, C. Bianco *et al.* (2010): Carbon footprint of next generation fixed networks. 32nd International Telecommunications Energy Conference, INTELEC 2010, June 6-10, Orlando, FL, US].

[15] The Green Grid. www.thegreengrid.org – Green Grid Data Center Power Efficiency Metrics: PUE and DCiE (2008).

2.2.4 GSMA

The GSM Association (GSMA) is an association of mobile operators and related companies devoted to supporting the standardizing, deployment and promotion of the GSM mobile telephone system. The following KPIs are proposed in the GSMA Methodology for Assessing the Environmental Impact of Mobile Networks.[16]

Energy:

- energy consumption per mobile connection;
- energy consumption per unit mobile traffic;
- energy consumption per cell site;
- energy consumption per unit of mobile revenue;
- mobile network electrical energy usage and diesel energy usage.

Others:

- number of physical cell sites and number of technologies;
- percentage coverage (geographic, population);
- number of mobile connections, mobile revenues;
- minutes of mobile voice traffic, bytes of mobile data traffic.

2.2.5 International Electrotechnical Commission (IEC)

The International Electrotechnical Commission is a non-profit, non-governmental international standards organization that prepares and publishes International Standards for all electrical, electronic and related technologies. In its document on smart electrification[17], IEC suggests the following KPIs for efficient electricity generation:

Energy (smart grids):

- efficiency of generation = GE(generated energy)/IE (input energy);
- efficiency of transmission = TE (transmitted energy)/IE.

GHG emissions:

- CO_2 at generation = CO_2/IE

2.2.6 International Telecommunication Union – Study Group 5 (ITU-T SG 5)

ITU and its Telecommunication Standardization Bureau (ITU-T) have the mandate to lead and develop a set of methodologies to assess the environmental impact of ICTs. This objective is carried out by ITU-T Study Group (SG 5) which is responsible, inter alia, for studies on methodologies for evaluating ICT effects on climate change. Other efforts and activities of this study group are e-waste, electromagnetic fields, protection of telecommunication equipment from electromagnetic disturbances; supply chains aspects, conflict minerals, energy efficiency, etc.

Within the framework of SG 5, some KPIs for environmental management have been defined in several methodologies applicable to the whole ICT sector.

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[16] GSMA Association. www.gsm.org A Methodology for Assessing the Environmental Impact of Mobile Networks (2011).

[17] Coping with the Energy Challenge The IEC's role from 2010 to 2030: Smart electrification.

Recommendation ITU-T L.1410 – Methodology for environmental impact assessment of information and communication technologies goods, networks and services

This methodology provides assessment on the environmental impact coming from ICT goods, networks and services. The following KPIs have been extracted from different relevant parts of Recommendation ITU-T L.1410.

Energy:

The following KPIs are considered as inputs established in clause I.2: Methodological Framework, for handling of Life cycle Inventory (LCI) results for electricity and energy. Types of fuel extracted from Annex I: Elementary Flows.

- electricity;
- fuels: oil, diesel, petrol, jet fuel, LPG, LNG, coal, gas, other forms of delivered energies: district heating (water and steam), district cooling.

GHG emissions:

The KPIs considered in clause I.3 as a recommendation for reporting inventory are:

- total CO_2eq per ICT good, network and service;
- direct GHG emissions.

Water:

Annex H deals with the modelling of unit processes, where a unit process is a facility where a product is produced, an office or a store, an activity or a place where a service is produced and a vehicle or a "mobile facility" that transports products. Apart from considering energy inputs, this annex describes KPIs for water:

- water consumption [measured in litres];
- water discharge to municipal sewage or recipient.

Waste:

Waste fractions (residual waste fractions or waste fractions that needs further treatment, also including material recycling and energy recovery).

Others:

The following KPIs are considered as "additional impact categories" in clause I.2.4: Life cycle impact assessment (LCIA):

- human toxicity [kg 1,4-DB eq.];
- resource depletion [kg Sb-eq.];
- acidification [kg S02-eq.];
- eutrophication [kg PO4-eq.]; and
- ozone layer depletion [kg CFC 11-eq.].

Recommendation ITU-T L.1420 – Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations

This methodology presents the requirements and recommendations which an organization needs to comply with when assessing the ICT-related energy consumption and greenhouse gas (GHG) emissions.

Energy:

In clause 8.3.4.2, “Evaluation of energy consumption and GHG impact of ICT organizations”, the methodology addresses several sources of energy that can be considered for environmental KPIs:

- electricity from renewable sources produced within the organization’s boundaries;
- electricity imported by the organization for its own consumption;
- heat or steam imported by the organization for its own consumption;
- fossil fuel (for instance coal, gas or oil) consumed by fixed equipment owned by the organization;
- fossil fuel (for instance coal, gas or oil) consumed by mobile equipment (for instance, cars) owned by the organization.

GHG emissions:

The approach is the same as the GHG Protocol and ISO 14064. It also addresses metrics for the emission factors , which complement the metrics in the other two standards:

- Scope 1: GHG emissions in kg CO_2eq per litre of fuel used for ICT power supply backup systems
- Scope 2: GHG emissions, in kg CO_2eq per kWh consumed, mentioning the country and/or the energy provider considered.

And for indirect emissions, clause 8.7.1 reviews in detail different indirect GHG emission sources, which can be used as well as KPIs:

GHG emissions from supply chain: Purchased goods and services, capital goods, leased assets (upstream), fuel- and energy-related activities not included in scope 1 or 2, transportation and distribution (upstream).

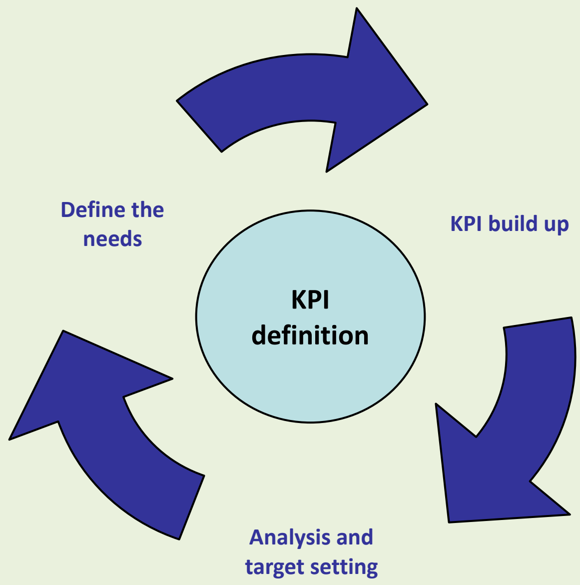
GHG emissions from own activities: Transportation and distribution (downstream) business travel, employee commuting, leased assets (downstream) and others, franchises.

- GHG emissions from operation of products: Processing of sold products, use of sold products, leased assets (downstream)
- GHG emissions from end-of-life treatment (EoLT): Waste generated in operation, EoLT of sold products.

3 A suggested process for KPI definition

Before selecting any environmental KPI, it is important that ICT companies have clear business strategies and target definition. After this, a process of KPI definition should be established. Figure 2 represents a schematic way of a KPI definition process.

Figure 2: Environmental KPI process scheme



3.1 Defining the needs

First of all, the needs of the organization must be clear, in order to identify KPIs to satisfy those needs and drive the process in the right path. First order priorities are of an economic and environmental nature, but other specific needs can be based on business objectives and priorities, investor demands, control of processes, efficiency, better decision making, investment indices, etc.

3.2 Listing relevant KPIs

In order to build up KPIs based on organizational needs, it is important to consider three things. The first issue is being clear about the types of KPIs desirable for the organization. The second issue is identifying the process for collecting the inputs needed for the KPIs. Finally, the third issue is putting in place verification to ensure that the KPIs meet quality expectations in terms of decision-making, In addition, is important to establish adequate internal processes to guarantee the availability and reliability of the primary data required to build them.

3.2.1 Types of KPIs

Prior to data collection, it is necessary to define the KPIs that are going to be managed. Several suggestions and examples have been made thus far, but it is important to know the characteristics that an environmental KPI must have in order to make the right choice.

These are important **characteristics** that apply when choosing KPIs:

Relevance: This is an important characteristic not only to the environment but also to company priorities, objectives or data management. If the company is going to spend time and money on managing data, that data needs to be relevant; otherwise, it would be a waste, or at least not efficient. It is appropriate at this point to consider the needs of other stakeholders as well. For example, KPIs for reporting under the GRI scheme could be different from those needed for internal environmental management or communication to executive committees.

Measurability: Not every KPI is easily quantifiable. As a result, it helps to be precise in the definition of the ones which are not, to avoid confusion.

Uniformity: Standard processes require standard KPIs: all data collected should have the same units and boundaries; this will save time in normalization processing. Being clear about data boundaries is important – this accounts for which data have been taken into account, or not, to build specific KPIs. At the same time, it must be very clear where assumptions and/or estimations have been made. If part of the data is missing, it is necessary sometimes to carry out an estimation to cover the data gap.

KPIs can be **constructed** in different ways, including the following:

Absolute/relative: A KPI can be defined in absolute terms (e.g. total electricity consumed during a year) or in relative terms (e.g. electricity consumed per employee). The latter forms of KPIs are intensity values, and these are necessary when comparing data from different companies. Absolute data is usually not comparable, because it depends too much on the size of the company, company growth, or changes in boundaries. Intensity KPIs can be more equitably compared between different companies or different divisions of the same company. They can also better reflect changes in the organization's size and performance. Usual intensity denominators are: employees, revenues, and products manufactured.

Since the main objective of using relative KPIs is homogenization, the key is to homogenize the intensity denominators, e.g. if a company decides to use the KPI "Volume of CO_2 per unit of product manufactured" during a certain period, it should take into consideration the fact that different products need different amounts of energy. To manage a KPI like this, an algorithm needs to be put in place so that all products are denominated in terms of energy, which is directly related to CO_2 spent.

Here's an example.

> *Product A costs 1 energy unit to be produced, and Product B costs 2 energy units. If the company produces 100 A and 100 B, it spends 300 energy units in both products, so the resulting KPI is 300 energy units/200 products = 1.5 energy units/product. If the company has a target in reducing the energy per product manufactured, an increase of demand of product A to 200 units (and no increase in the production of B) requires 400 energy units to produce both, and the resultant KPI = 400 energy units/300 products = 1.33 energy units/product. While the company is reducing its KPI (energy units per units of product) in absolute terms, but managing this value as an internal target can be confusing, because the KPI target was met without recourse to any energy efficiency measures. However, a change in demand favouring Product B next year could result in the KPI target being completely missed, again with no change in energy efficiency measures.*

Direct/indirect: Especially in carbon accounting and reporting, the difference between indirect or direct KPIs has its importance, in order to meet the requirements of standards such as ISO or GHG Protocol. Investment indices also require reporting in these terms. A direct KPI would relate to resources spent directly by company-owned buildings or their employees. Indirect KPIs would represent third parties such as leasing companies.

Positive/negative: The positive and negative effects of different KPIs have been explained and are related to first and second order effects.

Local/global: KPIs can be managed locally or globally according to company needs. Note that some indicators can be global by nature: CO_2 emissions affect climate change globally, no matter the department, zone or country where they are generated, while water pollution, for example, is locally focused.

3.2.2 Data collection process

The establishment of an internal standard process to gather all the relevant information relative to environmental performance is essential to manage the data and build KPIs. Data gathering is periodical, and without a standard process the data could well be incomplete, wrong or late. Having a data collection process reduces uncertainty risk when the data has to be published in an external report or index.

1. **Identify a responsible group and/or dashboard:** This group will be responsible for the management of the KPI data, and the boundaries applicable to the data. It will also make the internal decisions to ensure that the data is correct, internally verified and, where relevant, verified externally as well.
2. **Identifying the organizational and geographical boundaries:** The data will be collected from different departments or subsidiaries inside the company. The first step is to identify them, so there can be an effective communication between the KPI data group and the rest of the organization. Documents and databases need to be accessible to all the subsidiaries and companies.
3. **Identifying key actors:** The data gathering group will need to identify and have contact with the data providers, and ensure that they are aware of and understand the mechanism of the data gathering process and its importance. The units of the data collected and sent must be the same for each category.
4. **Having a reliable database or data storing software to store and/or manage the data:** There needs to be an internal database to store the relevant information, and provide management of access permissions. There a growing number of software solutions available to manage such tasks.
5. **Establishment of a period of data gathering:** In order to meet company objectives and compare the data across time periods, it is essential to define time boundaries and compile the information in blocks. This can be done monthly, quarterly, or annually. Theoretically, the shorter the time period is, the better, but sometimes the only effective way is to gather it annually. The reporting bodies and indices too ask for environmental information based on specified time periods.
6. **Identify data/KPIs and their boundaries:** Some of the KPIs coincide with the stored data, but most of them are a combination of different units, or a result of a calculation or conversion. It is important to differentiate and identify them. Estimating the degree of confidence in the measures helps in estimating and verifying future numbers.

Note: Do not expect the data to be perfect the first year!

3.3 Third-party verification of data collected for all environmental indicators

Data verification is essential in the process to reduce data uncertainty and minimize errors in data gathering, which leads to a more accurate control of the processes, better decision making and control. Ultimately, this also helps meet investor expectations. Verification can be done internally and/or externally. Third-party verification is important in order to have data accounting certified for environmental reporting and compliance with possible local environmental regulations and policies.

3.3.1 Common verification process

It is recommended that there are parallel internal and external (third party) verification processes The internal verification process should emerge as a natural consequence of the data collection process, and should be carried out right after finishing data collection with a standard process. This should also clear the path for the third party verification team. Ideally, this third party should be a certification company with expertise and competence in environmental data assurance.

The verification process should comply with ISO 14001 which establishes audit procedures that provide for the planning and conduct of an audit of an environmental management system. Specifically for GHG emissions, ISO 14064-3 specifies principles and requirements and provides guidance for those conducting or managing the validation and/or verification of greenhouse gas (GHG) assertions.[18]

3.4 Analysis and target setting

Once the data are registered and stored, there are KPIs to measure the performance of a determinate period of time. Once the data and KPIs have been internally and externally verified, the organization should be prepared to set the targets, according to company needs. The evolution through time of specific data to meet specific targets can drive the company to redefine the needs to build up KPIs to better achieve targets. As a result, the KPI definition process ends up being cyclic.

The definition of targets and a correct analysis of KPIs allows ICT companies to identify gaps and facilitate their own decision-making. Examples of different types of targets are discussed in the next section.

4 Target definition

One of the objectives of quantifying environmental performance through KPI definition and accounting is the establishment of environmental targets. Once a company is able to reduce the uncertainty relating to the measurement of periodical change, it can measure periodical and percentage changes in specific KPIs, which can become the basis for target setting.

4.1 Types of environmental targets

In general, there are three main types of ICT-related environmental targets: eco-efficiency targets, ICT enabling effect targets, and targets for external communication.

4.1.1 Eco-efficiency targets

Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. It focuses on business opportunities and allows companies to become more environmentally responsible and more profitable. It fosters innovation and therefore growth and competitiveness. In short, it is concerned with creating more value with less impact.[19]

According to eco-efficiency principles, improved environmental efficiency behaviour in businesses leads to economic benefits at the same level. The easiest example is that " less electricity usage means less money spent on that electricity".

Eco-efficiency target setting requires those who set environmental KPIs to have a real understanding of the environmental performance of the company, and its evolution over time, in order to make for more accurate forecasts. If this understanding does not match reality, it will probably lead to wrong target setting, which could result in negative reputational and economic impacts, among other effects. It is also important to establish a baseline date, and make sure that the KPI inventory for that time period is complete and accurate enough to set an appropriate environmental quantitative target.

Relative and intensity KPIs are specially related to eco-efficiency because they measure the best input-output ratio instead of the absolute values – e.g. MWh per employee, volume of CO_2 per unit of company

[18] International Standards Organization. www.iso.org/ (2012).

[19] World Business Council for Sustainable Development – Eco-efficiency: creating more value with less impact (2000).

revenue, etc. Such KPIs better reflect efficiency with more resilience to company changes, such as changes in the size of the company or variation in demand.

It is important to note that, in most cases, efficient services rely on efficient products, so producing more efficient products leads to more efficient behaviour. The ETSI EE Technical Committee provides efficiency specifications and metrics for IT products that can help in this task.

4.1.2 ICT enabling effect targets

The ICT enabling effect, described thoroughly in the SMART 2020 report, allows non-ICT sectors to become more efficient through the use of ICT goods and services, contributing to the creation of smart buildings, smart grids, smart logistics and smart industry processes, allowing dematerialization and efficient use of resources.

Due to the nature of this effect, located as it is on the customer side, it is more difficult to quantify with specific values, but it is recommended to estimate the savings of resources by the use of products and services, to successfully targets set within ICT companies.

Targets and KPIs that demonstrate the enabling effect of ICTs on the environment should be developed based on standard methodologies.

4.1.3 Communication targets

There is a difference between targets being internal or external in terms of communication. There are targets that are relevant for publication in Corporate Responsibility reports and others for reporting to investment indices. , These are the external targets. There also exists the need for control of internal processes, which can be improved by the establishment of internal corporate targets, directly addressed to relevant managers and employees. These are more relevant to the working of the company, and give direct value to the company to improve its environmental performance.

4.2 Examples of corporate ICT environmental targets

A number of examples of corporate ICT environmental targets are listed below. The intention is not to make a comparison of best practices in this area. Instead, the examples given below show several targets proposed by different companies. Also, not all targets for every company have been listed. This is only a sample of measurable targets. The past achievements, or targets which have been accomplished, have been omitted, as well as those that are not clear targets or have no clear baseline.

Some examples[20] of real environmental targets established by ICT companies are:

Alcatel-Lucent (2010 CR Report)

- Reduce absolute carbon footprint (CO_2 equivalent) by 50%, of 2008 baseline, by 2020
- Reduce water consumption by 20%, of 2010 baseline, by the end of 2013
- Achieve a 40% increase in the number of base stations deployed with alternative energy powering solutions (relative to 2010 baseline) by end of 2011.

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[20] This is a non-exclusive list in alphabetical order.

AT&T[21]

- Reduce electricity consumption relative to data growth in 2011 (energy intensity metric) on the network by 17% from year 2010
- Reduce Scope 1 emissions (direct) by 14% by 2014, using 2008 baseline.

Belgacom (CSR Report 2010)

- Reduce the CO_2 emissions by 70% (period 2007-2020)
- Reach an average of 120 g CO_2/km for new company cars by 2012
- Monitor and improve energy efficiency in buildings by 2020.

Cogeco Cable[22] (2011 Corporate Social Responsibility Report)

- Air travel: Decrease air travel by 10% per RGU over 5 years
- Facilities: Decrease energy consumption by 2% per RGU over 5 years
- Vehicles: Decrease total vehicle emissions by 500 tons of CO_2 over 5 years.

France Telecom Orange

- Reduce its greenhouse gas emissions (CO_2 equivalent) by 20% by 2020 (2006 baseline).
- Reduce its energy consumption by 15% by 2020 (2006 baseline).
- Install solar stations: By the end of 2010, 1 554 solar stations have been installed, including 922 radio stations (BTS) in 14 African and Middle Eastern countries. Annual production of solar energy of all sites is estimated to be 8.6 GWh, corresponding to the equivalent of 45 000 tonnes of CO_2 emissions and 16.8 million litres of fuel being saved.

Huawei (CSR Report 2010)

- Reduce average energy consumption per unit business volume of shipments by 35% of the consumption level in 2009, by the end of 2012
- Reduce CO_2 emissions per unit sales revenue by 9% by 2011 relative to 2010 in China region.

Nokia[23]

Energy:

- Reduce energy used in production by 20% per unit produced compared to year 2008 by the end of 2012
- Reduce the average charger's no-load power consumption by 75% from 2006 level by the end of 2012.

Emissions:

- Reduce greenhouse gas emissions per person working in Nokia offices and R&D by a minimum of 23% compared to the year 2006 level by the end of 2012
- Reduce the offices, R&D and manufacturing facilities greenhouse gas emissions by a minimum of 30% compared to the year 2006 by the end of 2012
- Reduce greenhouse gas emissions per sales package produced by 20% compared to the year 2008 by the end of 2012.

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[21] www.att.com/gen/landing-pages?pid=7735.

[22] www.cogeco.ca/export/sites/cogeco/corporate/files/others_en/COGECO_CSR_Report_2011.pdf.

[23] http://ncomprod.nokia.com.

NSN (CSR Report 2010)

- Improve the energy efficiency of GSM/EDGE and WCDMA/HSPA base station products by up to 40% by 2012 (2007 baseline)
- Reduce CO_2 emissions from buildings by 30% by 2012, from the 2007 baseline
- Reduce CO_2 emissions from IT operations and use of IT products by 10% by the end of 2010, from the 2008 baseline
- Improve the energy efficiency of buildings to reduce associated energy use by 34.3 GWh by 2012
- Increase the use of renewable energy in company operations to 50% by the end of 2010 (2007 baseline)
- Reduce emissions from new cars in service fleet in Europe to 120 g/km by 2010.

Microsoft[24]

- Reduce carbon emissions per unit of revenue by 30% (compared with 2007 levels) by 2012.

Swisscom[25]

- Reduce absolute carbon footprint (scope 1 and 2) by yearly 3% by 2015 (2010 baseline)
- Increase the value of the ratio of traffic over energy consumption measured in bit/joule by 15% in 2011 compared with 2010 (i.e. 1 950 bit/joule compared with 1 699 bit/joule).

Telefónica (CSR Report 2010)

- Reduce energy consumption in networks per equivalent access (intensity figure) by 30% in 2015 with 2007 year baseline
- Reduce absolute energy consumption in office buildings per employee by 15% in 2015 with 2007 year baseline

Verizon (CR Report 2010-2011)

- Improve carbon-intensity efficiency year-over-year by 15% in 2011
- Increase the percentage of alternative-fuel vehicles in the fleet toward our target of 15% by 2015
- Implement our energy efficiency standards programs at 75% of our facilities with 200 or more people
- Expand Green Team membership to 5 000 employees
- Expand the "smart building" programme to a total of 250 facilities.

5 Checklist

This entire document has focused on the kinds of metrics that can be used to manage environmental and sustainability performance. Most of the KPIs are defined in the context of methodologies and guidelines, which can act as checklists.

However, the recommendation of this document is to match environmental KPIs to the needs and objectives of the business. The definition of environmental KPIs and targets in an ICT companies has to follow a structure. On that basis, a checklist for actions to standardize procedures that would help ICT companies improve their environmental performance through the definition of environmental KPIs and targets is described as follows:

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24 www.microsoft.com/environment/our-commitment/our-footprint.aspx.

25 http://2010.swisscom-report.ch/en/gri.

1.	Alignment of environmental and business strategies in the short and long term	☐
2.	Definition of environmental aspects to be assessed (waste, energy, materials, GHG, etc.)	☐
3.	Identification of primary input value of the environmental aspect identified	☐
4.	Establishment of relevant KPIs for environmental performance management	☐
5. 5.1 5.2 5.3 5.4 5.5	Creation of a standardized process for data gathering and KPI build up Identify a responsible KPI data group to carry out the process. Identify organizational and geographical boundaries Identify key data managing actors. Have a reliable database or data software to store and/or manage the data. Establish time periods for data gathering.	☐
6.	Definition of environmental targets	☐
7.	Definition of activities and programs to meet the targets	☐
8.	Follow up targets and improve your environmental performance	☐

6 Conclusions

The need for sustainable and efficient management of ICT environmental data grows in every company. It is necessary to agree on standard processes in order to manage them effectively, not only for efficiency reasons, but also to have an appropriate way to compare similar companies.

Environmental KPIs and targets have to be aligned with corporate policies and should give value to the company in terms of facilitating decision making and effective resource allocation. It has been already said that defining the needs of an organization is very important, and one of the reasons to do so is to set targets that will actually help the company; otherwise, they would only be a waste of resources.

ICT companies should consider that the definition of environmental targets has to include a plan to achieve them. The main reason for target setting is to improve the performance and efficiency of an organization, and one of the definitions of environmental efficiency is to reduce costs while reducing negative environmental effects. Once a target is set, there must be measures taken to achieve it. Some of the measures might have already been expected or planned, but others may be unexpected, or even created after defining targets in order to meet objectives.

Most of the KPIs reflected in this analysis include energy and carbon related management aspects and there are some gaps that should be evaluated in terms of other environmental issues. There is a need for information on KPIs to manage electric and electronic waste (e-waste) in ICT companies, and also in the provision of ICT products to final customers. These information gaps are worth investigating and evaluating.

Apart from the business implications of setting a target, not achieving the goal could have reputational consequences. The organization will give the impression of setting targets just for “face-lifting” purposes, and that reduces trust regarding its environmental performance. Setting achievable targets is very important, and preferable to setting impressive ones.

Setting environmental targets supports effective environmental load reduction of the different ICT facilities and processes. In addition it could help to comply with environmental regulations whenever they emerge, even if they do not already exist.

The variety of environmental KPIs and targets defined by several ICT companies suggests that the ICT sector should work in defining standards and methodologies that could help them improve their environmental performance. Within the framework of ITU-SG 5 activities and methodology development, different KPIs should be included as global suggestions for ICT companies.

KPIs are required to really put a value to the environmental benefits that ICT could bring to the world economy.

7 Glossary

CDP	Carbon Disclosure Project
CR	Corporate Responsibility
CSR	Corporate Social Responsibility
DCiE	Data Center infrastructure Efficiency
DJSI	Dow Jones Sustainability Index
EDGE	Enhanced Data rates for GSM Evolution
EoLT	End of Life Treatment
ETNO	European Telecommunications Network Operators’ Association
ETSI	European Telecommunications Standards Institute
GHG Protocol	Greenhouse Gas Protocol is an accounting tool to quantify and manage greenhouse gas emissions
GRI	Global Reporting Initiative
GSM	Global System for Mobile Communications
GSMA	GSM Association
HSPA	High Speed Packet Access, a mobile telephony protocol
IEC	International Electrotechnical Commission (IEC)
KPIs	Key Performance Indicators
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MWh	Mega Watt hours, usually defining the quantity of electricity purchased
PUE	Power Usage Effectiveness
PUE	Power Usage Effectiveness value
RGU	Revenue Generating Unit
Scopes 1, 2 and 3	Categorization of direct and indirect emissions, as defined by the Greenhouse Gas (GHG) protocol
SG 5	International Telecommunications Union Study Group 5
Tonnes CO_2eq	Greenhouse gas emissions denominated in tonnes of carbon dioxide equivalents
WBCSD	World Business Council for Sustainable Development
WCDMA	Wide-band Code Division Multiple Access, a 3G technology to increase GSM transmission rates

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Assessment framework for environmental impacts of the ICT sector

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Table of contents

Assessment framework for environmental impacts of the ICT sector

Executive summary

There are a number of standards and guidelines to manage energy, GHG and waste aspects for ICT products, organizations, and projects. They have been created by various standards development organizations (SDOs). Some of them are sector-neutral and some of them are sector-specific.

This document summarizes the scope and purposes of the different energy and GHG management standards and guidelines. In particular, it examines the relationships between assessment targets and assessment criteria in order to understand:

- their application;
- their inter-dependencies;
- where they are complementary;
- where they supplement each other, and
- how they might be competitive.

The initial task is to map and review all the relevant standards and guidelines. Nine different sources of standards are examined, including:

- ISO TC 207
- GHG Protocol
- ITU-T
- IEC TC 111
- BSI
- EC-JRC handbooks
- JRC-IES methodologies
- ETSI
- IAASB

This review is used to map all the standards and guidelines across two dimensions. One dimension covers *assessment targets*, including product, organization, project, city and country. The second dimension covers *assessment criteria*, including inventory, carbon footprint, LCA, ICT enablement accounting, product eco-design, labelling, and validation/verification.

The resulting mapping of the standards provides insight to organizations on how they can use the various standards and guidelines to create their own sustainability assessment framework.

1 Introduction

This document reviews environmental management standards and guidelines of ISO TC 207, ITU-T SG 5, IEC TC 111, BSI, ETSI, EC-JRC, IAASB and WRI/WBCSD, and establishes an assessment framework for energy/greenhouse gas intensity and environmental impacts of the ICT sector according to various assessment criteria and assessment targets.

The assessment framework focuses on helping the ICT sector understand:

- the various environmental management standards and guidelines that could apply to it;
- the purpose and scope of these standards and guidelines;
- the interaction of these standards and guidelines when applied to the same assessment target and criteria, and
- the relationships between the standards and guidelines when viewed as part of an assessment framework table.

1.1 Objectives

This assessment framework aims to provide:

- an overall view of most assessment targets and assessment criteria, and
- a description of the relationships between assessment targets and assessment criteria to help understand:
  - ◊ their application;
  - ◊ their inter-dependencies;
  - ◊ where they are complementary;
  - ◊ where they supplement each other;
  - ◊ how they might be competitive.

A single diagram cannot include all these views. However a table can be used as a way of describing them, and the table's matrix format is shown in Figure 1.

Figure 1: Matrix of inter-relationships between standards regarding assessment criteria

Assessment criteria	Products	Organizations	Projects
Inventory			
Carbon footprint			
LCA			
ICT enablement accounting			
Labelling			
Product eco-design			
Validation and verification			

Most of the ISO, ITU-T, IEC, BSI, ETSI, EC-JRC, WRI/WBCSD and IAASB and assessment methodology standards and guidelines are included in Figure 2: Inter-relationships between standards and guidelines in the assessment framework, which focuses on assessment targets and assessment criteria.

1.2 Target audience

This document provides an overall perspective on energy and GHG assessment standards and guidelines for ICT elements, such as goods, networks, services, organizations, projects, facilities and wastes, to the following target audience:

- Designers and developers of ICT goods, including manufacturers of ICT goods
- Management of environment and sustainability functions in telecommunication service providers, ICT service providers, and ICT organizations
- Management of environment and sustainability functions of non-ICT organizations who want to account for improvements in environmental impacts enabled through the use of ICT.

2 Review of relevant standards and guidelines

This section reviews relevant standards and guidelines to the assessment framework in summary. Detailed information is available in each standard and guideline.

2.1 ISO TC 207 standards

ISO TC 207 has developed various base standards for the assessment of environmental impacts of every industry sector. Most of its standards may be classified into the following three categories: environmental labels and declarations; life cycle assessment, and the management of greenhouse gases.

ISO TC 207 has developed the following standards on environmental labelling and declarations:

- ISO 14021:1999, "Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)" specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. It further describes selected terms commonly used in environmental claims and gives qualifications for their use. This international standard also describes a general evaluation and verification methodology for self-declared environmental claims, including specific evaluation and verification methods for the selected claims in this standard. Self-declared environmental claims may be made by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such claims. Such claims made in regard to products may take the form of statements, symbols or graphics on product or package labels, or in product literature, technical bulletins, advertising, publicity, telemarketing, as well as digital or electronic media, such as the Internet.
- ISO 14024:1999, "Environmental labels and declarations – Type I environmental labelling – Principles and procedures" establishes the principles and procedures for developing Type I environmental labelling programmes, including the selection of product categories, product environmental criteria and product function characteristics, and for assessing and demonstrating compliance. This international standard also establishes the certification procedures for awarding the label. Type I labels are awarded to products by a third party, either governmental or private organizations. Products meeting a set of predetermined criteria earn the label. Criteria are established for distinct product categories by the labelling body and deal with multiple environmental aspects of the product. These labels are sometimes directed at specific types of products, such as the Environmental Choice label[1] for paints and surface coatings, or Energy Star for lighting and appliances. These labels indicate that a

[1] Environmental Choice recognizes genuine moves made by manufacturers to reduce the environmental impact of their products, and provides an independent guide for consumers who wish to purchase products that are better for the environment. See www.environmentalchoice.org.nz.

product is environmentally preferable, in order to increase the demand for environmentally preferable products. These labels are usually represented by a logo on the product or product packaging.

- ISO 14025:2006, "Environmental labels and declarations – Type III environmental declarations – Principles and procedures" establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations, which provide environmental data about a product. These declarations are produced by the organization making the product, and are often certified by a third party. They usually take the form of brochures, rather than a simple label or logo. The declaration is typically based on a life cycle study with the use of ISO 14040 and 14044. The declaration contains quantified data from various life cycle stages of the product, including: material extraction, production, transportation, use and end-of-life disposal or recycling. The declaration may also contain qualitative data about the product and the organization. Type III declarations allow consumers to compare products based on all of their environmental impacts and make their own decision about which product is preferable. Competition among organizations on environmental grounds is encouraged by this kind of declaration.[2]

ISO TC 207 has developed the following standards on life cycle assessment (LCA):

- ISO 14040:2006, "Environmental management – Life cycle assessment – Principles and framework" describes the principles and framework for life cycle assessment including:
  a) the goal and scope definition of the LCA;
  b) the life cycle inventory analysis (LCI) phase;
  c) the life cycle impact assessment (LCIA) phase;
  d) the life cycle interpretation phase;
  e) reporting and critical review of the LCA;
  f) limitations of the LCA;
  g) relationship between the LCA phases, and
  h) conditions for use of value choices and optional elements.
- ISO 14044:2006, "Environmental management – Life cycle assessment – Requirements and guidelines" has the same specification scope with ISO 14040 but specifies requirements and provides guidelines for LCA. It includes the methodological framework for LCA and reporting of LCA results which is described in a standardized format specified in ISO/TS 14048:2002.[3]

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2 The ICT sector needs to refer to ISO 14025 to utilize Product Category Rules (PCR) development guidelines. The ICT sector has a variety of ICT products, e.g. laptop computers, modems, set-top boxes, facsimiles, cell phones, smart phones, and routers/switches, so no single specification can cover every type of ICT product. ISO 14025 provides guidance on developing category-specific documentation for the environmental assessment. ISO 14025 is a sector-neutral standard. As a consequence, the ICT sector needs sector-specific information to incorporate into the standard which covers "Product Category Rules (PCR)." In effect, the ICT sector may utilize ISO 14025 to specify PCRs for ICT product categories.

3 ISO/TS 14048:2002 ("Environmental management – Life cycle assessment – Data documentation format") defines the requirements and structure of a data documentation format for the transparent and unambiguous documentation and exchange of Life Cycle Assessment (LCA) and Life Cycle Inventory (LCI) data. The use of a data documentation format permits consistent documentation of data, reporting of data collection, data calculation and data quality, through the specification and structuring of relevant information. Such a format specifies requirements on the categorization of data documentation into data fields, each with an explanatory description. The description of each data field is further specified by the structure of the data documentation format. The Technical Specification is applicable to the specification and structuring of questionnaire forms and information systems. However, it can also be applied to other aspects of the management of environmental data. It does not include requirements regarding completeness of data documentation. The data documentation format is independent of any software or database platform for implementation. The Technical Specification does not require any specific sequential, graphic or procedural solutions for the presentation or treatment of data, nor does it describe specific modelling methodologies for LCI and LCA data.

ISO TC 207 has developed the following standards on the management of greenhouse gases (GHG):

- ISO 14064-1:2006, "Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals" specifies detail principles and requirements for designing, developing, managing and reporting organizational or company-level GHG inventories. It includes requirements for determining organizational boundaries, GHG emission boundaries, quantifying an organization's GHG emissions and removals, and identifying specific organization actions or activities aimed at improving GHG management. It also includes requirements and guidance on inventory quality management, reporting, internal auditing and the reporting organization's responsibilities in verification activities. Part 1 is consistent with best practice established in the Corporate Accounting and Reporting Standard developed by the WRI/WBCSD.
- ISO 14064-2:2006, "Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements" focuses on GHG projects or project-based activities specifically designed to reduce GHG emissions or increase GHG removals. It includes principles and requirements for determining project baseline scenarios and for monitoring, quantifying and reporting project performance relative to the baseline scenario and provides the basis for GHG projects to be validated and verified.
- ISO 14064-3:2006, "Greenhouse gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions" details principles and requirements for verifying GHG inventories and validating or verifying GHG projects. It describes the process for GHG-related validation or verification, and specifies components such as validation or verification planning, assessment procedures and the evaluation of organization or project GHG assertions. ISO 14064 Part 3 can be used by organizations or independent parties to validate or verify GHG assertions.
- ISO 14065:2007, "Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition" specifies requirements to accredit or otherwise recognize bodies that undertake GHG validation or verification using ISO 14064, or other relevant standards or specifications.
- ISO 14066:2011, "Greenhouse gases – Competency requirements for greenhouse gas validation teams and verification teams" specifies personal attributes, knowledge and skill (competency) requirements, required levels of proficiency and methods to evaluate competencies for GHG validation and verification teams by areas of competence.
- ISO 14067, "Greenhouse gases – Carbon footprint of products" specifies principles and requirements for the quantification and communication of greenhouse gases associated with the whole life-cycle (Carbon Footprint of a Product, CFP) or specific stages (partial CFP) of the life cycle of products, based on existing LCA (ISO 14040 series) and environmental claims, labels and declaration (ISO 14020 series) standards. ISO 14067 provides for the development of CFP-product category rules (CFP-PCR), or the adoption of PCRs that have been developed in accordance with ISO 14025 and that are consistent with ISO 14067. It is intended to promote the monitoring, reporting, and tracking of progress in the mitigation of GHG emissions. The carbon footprint may show quantitative comparisons between different products and affect consumers when they choose products with the lowest climate impacts. While GHG emissions are reported at global, national or company levels, ISO 14067 addresses emissions that arise from processes which constitute the life cycle of a product, in different organisations and independent from national boundaries.
- ISO/TR 14069, "Greenhouse gases – Quantification and reporting of GHG emissions for organizations (Carbon footprint of organization) – Guidance for the application of ISO 14064-1" describes guidance in the use of ISO 14064-1 to analysis the GHG inventory of organizations. Since ISO 14064-1 specifies only generic processes of the GHG inventory analysis and relevant requirements, its specification seems quite vague for applying to GHG inventory analysis. The purpose of ISO 14069 is to produce more specific guidance to ISO 14064-1.

2.2 GHG Protocol standards

WRI/WBCSD has developed the following standards under the GHG Protocol initiative:

- The GHG Protocol Corporate Standard, "A Corporate Accounting and Reporting Standard" (referred to as the Corporate Standard) provides standards and guidance for companies and other types of organizations preparing a GHG emissions inventory. This standard covers the accounting and reporting of the six greenhouse gases covered by the Kyoto Protocol. The standard, and related guidance, was designed with the following objectives to:
  - ◊ help companies prepare a GHG inventory that represents a true and fair account of their emissions, through the use of standardized approaches and principles;
  - ◊ simplify and reduce the costs of compiling a GHG inventory;
  - ◊ provide business with information that can be used to build an effective strategy to manage and reduce GHG emissions;
  - ◊ provide information that facilitates participation in voluntary and mandatory GHG programmes;
  - ◊ increase consistency and transparency in GHG accounting and reporting among various companies and GHG programs.

This standard is consistent with ISO 14064-1, as stated above.

- "Corporate Value Chain (Scope 3) Accounting and Reporting Standard – Supplement to the GHG Protocol corporate accounting and reporting standard" (referred to as the Scope 3 Standard) complements and builds upon the Corporate Standard to promote additional completeness and consistency in the way companies account for and report on indirect emissions from value chain activities. The Corporate Standard classifies a company's direct and indirect GHG emissions into three "scopes," and requires that companies account for and report all scope 1 emissions (i.e. direct emissions from owned or controlled sources) and all scope 2 emissions (i.e. indirect emissions from the generation of purchased energy consumed by the reporting company). The Corporate Standard gives companies flexibility in whether and how to account for scope 3 emissions (i.e. all other indirect emissions that occur in a company's value chain). Often, the majority of total corporate emissions come from scope 3 sources, which means many companies have been missing out on significant opportunities for improvement. This is the reason why the Corporate Value Chain Accounting and Reporting Standard was developed. This standard provides requirements and guidance for companies and other organizations to prepare and publicly report a GHG emissions inventory that includes indirect emissions resulting from value chain activities (i.e. scope 3 emissions). The primary goal of this standard is to provide a standardized step-by-step approach to help companies understand their full value chain emissions impact in order to focus company efforts on the greatest GHG reduction opportunities, leading to more sustainable decisions about companies' activities and the products they buy, sell, and produce.
- "The GHG Protocol for project accounting" (referred to as the Project Protocol) provides specific principles, concepts, and methods for quantifying and reporting GHG reductions – i.e. the decreases in GHG emissions, or increases in removals and/or storage – from climate change mitigation projects (GHG projects). This standard aims to:
  - ◊ provide a credible and transparent approach for quantifying and reporting GHG reductions from GHG projects;
  - ◊ enhance the credibility of GHG project accounting through the application of common accounting concepts, procedures, and principles, and
  - ◊ provide a platform for harmonization among different project-based GHG initiatives and programmes.
- "Product Life Cycle Accounting and Reporting Standard" (referred to as the Product Standard) provides requirements and guidance for companies and other organizations to quantify and publicly report an inventory of GHG emissions and removals associated with a specific product during its life cycle. The

primary goal of this standard is to provide a general framework for companies to make informed choices to reduce GHG emissions from the products (goods or services) they design, manufacture, sell, purchase, or use. In the context of this standard, public reporting refers to product GHG-related information reported publicly in accordance with the requirements specified in the standard. This standard builds on the framework and requirements established in the ISO LCA standards and PAS 2050, with the intention of providing additional specifications and guidance to facilitate the consistent quantification and public reporting of product life cycle GHG inventories. In other words, this Product Standard corresponds to an LCA methodology and is supplementary to ISO LCA standards.

- "ICT Sector Guidance to support the GHG Protocol Product Standard" is sector guidance for the carbon footprinting of ICT products (including goods and services) based on the Product Standard. Focusing on the three areas of desktop managed services, telecommunications networks, and remote collaboration, this ICT sector guidance deals with:
  - ◊ overview section providing general guidance;
  - ◊ guidance related to ICT infrastructure (covering areas such as networks, data centers, hardware and software);
  - ◊ guidance related to ICT Service Applications (this refers to a combination of infrastructure guidance and, in some cases, the enablement effect of the ICT application), and
  - ◊ supporting default data, secondary emissions factors, references and glossary;
  - ◊ the goal of this standard is the same to that of IEC/TR 62725. That is, there are two competitive standards for the same targets.

2.3 ITU-T standards

ITU-T has developed the following methodology standards:

- ITU-T L.1410, "Methodology for environmental impact assessment of ICT goods, networks and services" is based upon ISO LCA standards. This standard aims at:
  - ◊ providing ICT specific requirements, in addition to those of ISO LCA standards;
  - ◊ ensuring a minimum quality of LCA studies of ICT goods, networks and services;
  - ◊ ensuring the credibility of LCAs of ICT goods, networks and services;
  - ◊ increasing the transparency and facilitating the interpretation of LCA studies of ICT goods, networks and services;
  - ◊ facilitating communication of LCA studies of ICT goods, networks and services, and
  - ◊ providing a methodology for telecommunication operators and service providers to assess the environmental load of one or more services which are carried by their ICT networks.
- ITU-T L.1420 (02/2012), "Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies within organisations" provides a methodology to assess GHG emissions and energy consumptions generated from the use of ICT in non-ICT organizations, based on ITU-T L.1410. Also this standard provides a supplement to ISO 14064-1 and the GHG Protocol Corporate Standard for ICT organizations intending to assess their own organizational energy consumption and GHG related impacts.
- ITU-T L.1430, "Methodology for environmental impact assessment of ICT projects" specifies principles, concepts, requirements and methods with guidance for quantifying, monitoring and reporting GHG emission reductions or removal enhancements, and/or energy consumption savings and/or energy efficiency improvements from an ICT project as a supplement to ISO 14064-2 and the Project Protocol. This standard provides requirements and guidance for:
  - ◊ planning an ICT project and its baseline scenario;
  - ◊ identifying and selecting GHG sources, sinks and storages relevant to the ICT project and baseline scenario;
  - ◊ identifying and selecting energy consumption sources, generators and storages relevant to the ICT project and baseline scenario;

- ◊ managing data quality;
- ◊ monitoring, quantifying, documenting and reporting ICT project performance, and
- ◊ validating and/or verifying the ICT project plan and/or report.

- ITU-T L.1440, "Methodology for environmental impact assessment of ICT within cities" recommends ways in which ICT may be used to reduce the rate of GHG accumulation in the atmosphere by optimizing the use of energy. This work is still in the initial stages, as of the beginning of 2012.
- ITU-T L.1450, "Methodology for environmental impact assessment of ICT within countries" focuses on how ICT may be used across nations to reduce the rate of GHG accumulation in the atmosphere by optimizing use of energy. This work is still in the initial stages, as of the beginning of 2012.

2.4 IEC TC 111 standards

IEC TC 111 has dealt with the following items:

- IEC/TR 62725, "Analysis of quantification methodologies for greenhouse gas emissions for electrical and electronic products and systems" provides guidance to understand methodologies to evaluate carbon footprint of products, by quantifying greenhouse gas emissions for electrical and electronic products and systems based on life-cycle thinking (LCT). This technical report is applicable to any type of electrical and electronic products, which are new or modified (e.g. reconditioned, upgraded, etc.). It is intended to be used by those involved in design and development of electrical and electronic products, and their supply chains regardless of industry sectors, regions, types, activities and sizes of organizations. It may also be used as guidance to prepare a Product Category Rule (PCR) of each product category in the sector of electrical and electronic products and systems.
- IEC/TR 62726, "Guidance on quantifying greenhouse gas emission reductions from the baseline for electrical and electronic products and systems" is a Technical Report which addresses GHG reductions contributed by the supply of electric and electronic products. Consequently, it aims at providing practical guidance for the quantification of carbon reduction effects achieved by an electric and electronic product-related GHG project, with reference to ISO 14064-2 and the Project Protocol of WRI/WBCSD.
- IEC 62430:2009, "Environmentally conscious design for electrical and electronic products" aims at the reduction of adverse environmental impacts of a product throughout its entire life cycle. This can involve balancing the environmental aspects of the product with other factors, such as its intended use, performance, cost, and quality, and choosing methods to meet legal and regulatory requirements in the most environmentally friendly way. Environmentally conscious design is not a separate design activity; rather, it is an integral part of the existing design process.

2.5 BSI standard

BSI released the following standard to support the carbon footprinting of products:

- PAS 2050:2011, "Specification for the assessment of the life cycle greenhouse gas emissions of goods and services" builds on existing ISO LCA methods by specifying requirements for the assessment of GHG emissions within the life cycle of goods and services. These requirements further clarify the implementation of these standards in relation to the assessment of GHG emissions of goods and services, and establish particular principles and techniques, including:
  - ◊ cradle-to-gate and cradle-to-grave GHG emissions assessment data as part of the life cycle GHG emissions assessment of goods and services;
  - ◊ the scope of greenhouse gases to be included;
  - ◊ criteria for global warming potential (GWP) data;
  - ◊ treatment of emissions and removals from land use change and biogenic and fossil carbon sources;
  - ◊ treatment of the impact of carbon storage in products and offsetting;

◊ requirements for the treatment of GHG emissions arising from specific processes, and,
◊ data requirements and accounting for emissions from renewable energy generation.

BSI published the following standard to facilitate carbon neutrality in various entities (e.g. organizations, governments, communities, families, and individuals):

- PAS 2060:2010, "Specification for the demonstration of carbon neutrality," specifies a consistent set of measures and requirements for entities to demonstrate carbon neutrality for a product, service, organization, community, event or building.

2.6 EC-JRC handbooks

In March 2010, the Joint Research Centre of the European Commission (EC-JRC) released the International Reference Life Cycle Data System (ILCD) Handbook[4] to provide practical guidance on how to conduct a Life Cycle Assessment, in order to calculate a product's total environmental impact in terms of GHG emissions, resources consumed and the pressures on the environment and human health that can be attributed to it. Consisting of a number of separate handbooks, the ILCD Handbook is based on, and conforms to, ISO LCA standards (ISO 14040 and ISO 14044) which provide the indispensable framework for Life Cycle Assessment (LCA). The ISO LCA framework, however, offers the individual practitioner a range of choices, which can affect the legitimacy of the results of an LCA study. While flexibility is essential in responding to the large variety of questions addressed, further guidance is needed to support consistency and quality assurance. As a result, the ILCD Handbook has been developed to provide guidance for consistent and quality-assured LCA data and studies. The ILCD Handbook is a series of technical documents providing guidance for good practice in LCA in business and government as follows:

- ILCD Handbook: Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment
- ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance
- ILCD Handbook: General guide for Life Cycle Assessment – Provisions and action steps
- ILCD Handbook: Framework and requirements for Life Cycle Impact Assessment models and indicators
- ILCD Handbook: Review schemes for Life Cycle Assessment
- ILCD Handbook: Specific guide for Life Cycle Inventory data sets
- ILCD Handbook: Reviewer qualification for Life Cycle Inventory data sets.

2.7 JRC-IES methodologies

The Institute for Environment and Sustainability (IES) is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC). As of June 2012, it is developing the following two methodologies:

- Environmental footprint of products[5]: it aims at providing a methodology for the calculation of the environmental footprint of products (including carbon footprint). This methodology will be developed building on the ILCD Handbook, as well as other existing methodological standards and guidance documents.
- Environmental footprint of organizations[6]: it aims at providing technical guide for the calculation of the environmental footprint of organizations (including carbon). As with the product footprint

[4] EC-JRC, "ILCD (International Reference Life Cycle Data System) Handbook: General guide for Life Cycle Assessment – Detailed guidance", http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-General-guide-for-LCA-DETAIL-online-12March2010.pdf.

[5] Refer to http://ec.europa.eu/environment/eussd/product_footprint.htm.

[6] Refer to http://ec.europa.eu/environment/eussd/corporate_footprint.htm.

methodology, this too will build on the ILCD Handbook, as well as other existing methodological standards and guidance documents.

2.8 ETSI standard

The European Telecommunications Standards Institute Environmental Engineering (ETSI EE) group developed the following methodology standard:

- ETSI TS 103 199 (2011-11), "Environmental Engineering; Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements" aims to:
  - ◊ harmonize the LCAs of ICT equipment, networks and services;
  - ◊ increase the quality of the LCA by adding ICT specific requirements to those of ISO 14040 and ISO 14044;
  - ◊ facilitate communication of LCAs of ICT equipment, networks and services, and
  - ◊ increase the credibility of LCAs of ICT equipment, networks and services.

Since this standard refers to the ISO LCA standards as normative references, it establishes generic and specific requirements for LCA of ICT equipment, networks and services. In effect, it provides practical guidance for an LCA study. This goal is identical to that of ITU-T L.1410-Part 1, which means there are two standards which are similar and compatible.

2.9 IAASB standard

The International Auditing and Assurance Standards Board (IAASB) is developing the International Standard on Assurance Engagements (ISAE) 3410[7], as follows:

- ISAE 3410, "Assurance Engagements on Greenhouse Gas Statements," defines two levels of assurance on GHG statements: Reasonable Assurance and Limited Assurance. The assurance procedures covered in the standard include inspection, observation, confirmation, recalculation, re-performance, analytical procedures, and inquiry. This standard corresponds to ISO 14064-3.

3 Assessment framework

This assessment framework explores a summary view of most assessment targets and assessment criteria, and also describes their relationships in order to identify:

- how to apply them;
- where they are competitive with each other;
- their inter-dependencies;
- where they are complementary;
- where they supplement each other, and
- how they might be competitive.

3.1 Assessment targets

ISO TC 207 identified only three assessment targets: product, organization and project. Additionally ITU-T SG 5 identified two more assessment targets: cities and countries.

[7] IAASB, "ISAE 3410, Assurance Engagements on Greenhouse Gas Statements," IFAC, January 2011, www.ifac.org/publications-resources/proposed-international-standard-assurance-engagements.

3.1.1 Product

ISO 14040 includes the definition of "product"[8] as "any goods or service[9]". But ITU-T, with its expertise in telecommunications, identified "networks" and "services" as additional assessment targets. Thus, in ITU-T's definition, "product" covers any goods, networks and services.

3.1.2 Organization

ISO 14064-1 defines "organization" as a company, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration. This definition is valid in other standards and guidelines.

3.1.3 Project

Here a "project" is referred to as a GHG project which is defined by ISO 14064-2 as an activity or activities that alter the conditions identified in the baseline scenario which cause GHG emission reductions or GHG removal enhancements. Based on this definition, ITU-T has defined "ICT project" as a GHG project using mainly ICT goods, networks and services, aiming at GHG emission reductions or GHG removal enhancements, and/or a GHG project using mainly ICT goods, networks and services, aiming at energy consumption savings and energy efficiency improvement.

3.1.4 City and country

Two further methodologies, ITU-T L.1440 and L.1450, aim at providing relevant methodologies to assess impacts from the use of ICT goods, networks and services on cities or countries, exploiting the ways ICT can help save energy consumption and improve energy efficiency.

3.2 Assessment criteria

The standards and guidelines of various standards development organizations (SDOs) may be classified into the following assessment criteria:

- **Inventory**: this is a type of inventory developed for a variety of GHG sources and sinks in order to account for the total GHG emissions of an organization. This terminology applies usually to organizations. But, in this instance, GHG projects for GHG reductions and removal enhancements are also located in the inventory area of the assessment framework table, as GHG reductions and removal enhancements should be quantified from a GHG inventory supported by various project activities.
- **Carbon footprint**: defined as the total sum of GHG emissions and GHG removals during the life cycle phases of a product. It may be expressed as net global warming impact in CO2e. In this definition, carbon footprinting is based on a life cycle assessment.
- **Life cycle assessment (LCA)**: a methodology for compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle. A life cycle assessment

[8] The product can be categorized as services, software, hardware or processed materials.

[9] Services have tangible and intangible elements. Provision of a service can involve, for example, the following:

- an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired);
- an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return);
- the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission), and
- the creation of ambience for the customer (e.g. in hotels and restaurants).

Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.

Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic.

applies to a particular product, defined broadly to include goods, networks or services. It deals with all the stages of a product's life from raw material extraction through materials processing; transportation in all the phases; production; use; repair and maintenance, and disposal or recycling. By this life cycle assessment, an inventory of all relevant energy and material inputs and environmental releases (i.e. outputs) is compiled; potential impacts associated with identified inputs and releases are evaluated, and then the assessment results may help manufacturers recognize where are weak points along with all the life cycle stages in terms of GHG emission and energy consumption. Through such LCA work, manufacturers can carry out improvements where a product proves to be weak. The assessment of the entire life cycle stages of a product may be the base of other environmental impacts assessment.

- **ICT enablement accounting**: accounting for the positive impacts enabled by using ICT and the negative impacts caused by using ICT.
- **Product eco-design**: the requirements and procedures to integrate environmental aspects into design and development processes of products, including the combination of products, and the materials and components from which they are made. It requires manufacturers to demonstrate how they have integrated life cycle thinking into the product design and development process in order to minimize the significant environmental impacts of the product across its life cycle stages.
- **Labelling by evaluation**: this covers any claims which indicate environmental aspects of a product. An environmental label may take the form of a statement, symbol or graphic on a product or package label, in product literature, in technical bulletins, in advertising or in publicity, amongst other things.
- **Validation and verification**: the process by which GHG assertions may be evaluated against agreed validation and verification criteria. Typically, validation is an ex-ante process and verification is an ex-post process.

3.3 Assessment framework

3.3.1 Overall assessment framework

The assessment standards and guidelines for environmental impacts of products, organizations and projects, as discussed above, may be analysed for their inter-relationships using the following assessment framework:

Figure 2: Inter-relationships between standards and guidelines in the assessment framework

Criteria	Products	Organizations	Projects	Properties
Inventory	-	ISO 14064-1	ISO 14064-2	General procedure and requirements
	-	ISO 14069	-	Practice guidance for ISO 14064-1
	-	ITU-T L.1420	-	Sectoral guidance for ISO 14064-1 and the Corporate Standard
	-	Environmental footprint of organizations	-	General procedure and requirements
	-	-	ITU-T L.1430	Sectoral guidance for ISO 14064-2 and the Project Protocol
	-	-	IEC/TR 62726	

Criteria	Products	Organizations	Projects	Properties	
	-	GHG Protocol corporate accounting (Scope 1 and Scope 2) and reporting standard (called Corporate Standard)	GHG Protocol for project accounting (called Project Protocol)	General procedure and requirements	
	-	GHG Protocol corporate value chain (Scope 3) accounting and reporting standard (called Scope 3 Standard)	-	Life cycle assessment (LCA) required	General procedure and requirements; and a supplement to the Corporate Standard
Carbon footprint	ISO 14067 and Part of ISO 14025 (Product Category Rules)	-	-		General procedure and requirements
	GHG Protocol product accounting and reporting standard (called Product Standard)	-	-		General procedure and requirements
	Environmental footprint of products	-	-		General procedure and requirements
	ICT sector guidance to support the GHG Protocol Product Standard	-	-		ICT-sector guidance to support ICT and EE products; not complementary but competitive
	IEC 62725	-	-		
LCA	ISO 14040	-	-		General procedure and requirements
	ISO 14044	-	-		
	ILCD Handbook	-	-		Practice guidance for ISO 14040 and 14044
	PAS 2050	-	-		Practice guidance for and supplement to ISO 14040 and 14044
	ITU-T L.1410 Part 1	-	-		ICT-sector guidance for ISO 14040 and 14044; Compatible and complementary each other
	ETSI TS 103 199	-	-		

<table>
<tr><th>Criteria</th><th>Products</th><th>Organizations</th><th>Projects</th><th colspan="2">Properties</th></tr>
<tr><td>ICT enablement accounting</td><td colspan="3">ITU-T L.1410 Part 2</td><td rowspan="2"></td><td>General procedure and requirements; not complementary but competitive</td></tr>
<tr><td rowspan="3">Labelling</td><td>ISO 14025 (Type III)</td><td>-</td><td>-</td><td>General procedure and requirements, and 3rd party evaluation required</td></tr>
<tr><td>ISO 14021 (Type II)</td><td>-</td><td>-</td><td colspan="2">General procedure and requirements, and self-declaration purpose</td></tr>
<tr><td>ISO 14024 (Type I)</td><td>-</td><td>-</td><td rowspan="2">Life cycle thinking (LCT) required[10]</td><td>General procedure and requirements, and 3rd party evaluation required</td></tr>
<tr><td>Product eco-design</td><td>IEC/TR 62430</td><td>-</td><td>-</td><td>General procedure and requirements</td></tr>
<tr><td rowspan="4">Validation and verification</td><td>-</td><td>ISAE 3410</td><td>-</td><td rowspan="4">3rd party evaluation required</td><td rowspan="2">Validation/ verification procedure and requirements</td></tr>
<tr><td colspan="3">ISO 14064-3</td></tr>
<tr><td colspan="3">ISO 14065</td><td>Evaluation for validation and verification bodies</td></tr>
<tr><td colspan="3">ISO 14066</td><td>Competency evaluation for validation and verification teams</td></tr>
</table>

[NOTE 1] Where "-" means there are no relevant standards.

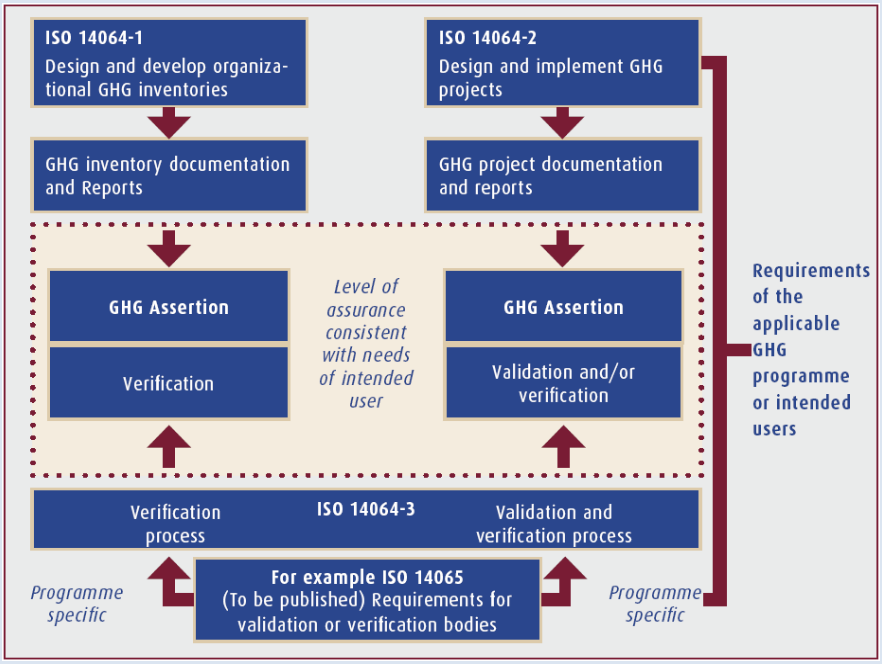
[NOTE 2] Various combination cases may be derived from the above table. Identified features and properties using any combination are valid. For example, ISO 14044 is an LCA methodology which applies to products, covers the entire life cycle of a product and specifies the general assessment procedure and execution requirements.

3.3.2 Standards map of ISO 14064-1, 14064-2, 14064-3, 14065 and 14066

The following diagram, published as part of ISO TC 207, shows the relationships between relevant standards.

[10] IEC 62430:2009 is based on the Life Cycle Thinking (LCT) which provides consideration points of all relevant environmental aspects during the entire life cycle of products (refer to http://lct.jrc.ec.europa.eu/index_jrc for detailed information on the LCT).

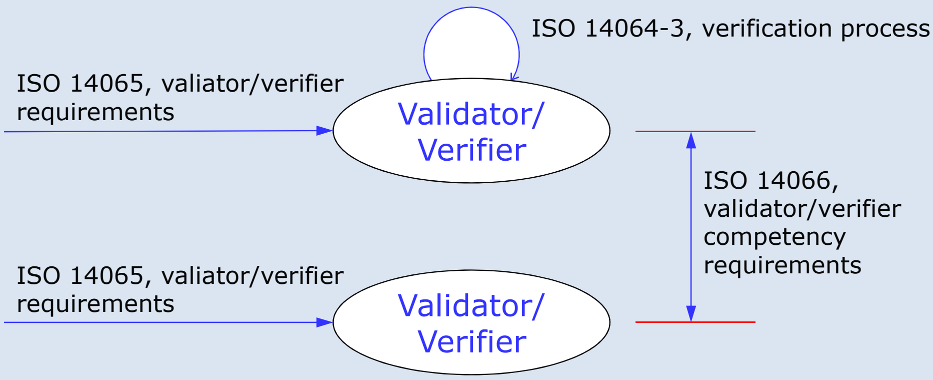
Figure 3: Relationships between standards in ISO TC 207



For example, an organization uses ISO 14064-1 to develop and report its GHG inventory and a project initiator would use ISO 14064-2 to quantify and report GHG reductions and removal enhancement for a GHG project.

The relationship between validation and verification standards is shown below:

Figure 4: Relationships between validation and verification standards



ISO 14064-3 specifies principles and requirements and provides guidance for those conducting or managing the validation and/or verification of GHG assertions.

ISO 14065 specifies principles and requirements for GHG validators and verifiers that undertake validation and/or verification of GHG assertions.

ISO 14066 specifies personal attribute, knowledge and skill (competency) requirements, required levels of proficiency and methods to evaluate competencies for GHG validators and/or verifiers by areas of competence.

3.3.3 Standards map of GHG standards and programmes in terms of type, compliance, voluntary, and geographic scope

ISO released an introductory report, “GHG schemes addressing climate change: How ISO standards help.” Clause 5 of the report describes an overview of GHG standards and programmes with a comparison table for type, compliance, voluntary and geographic scope. This table depicts another view of the assessment framework as follows:

Figure 5: Compliance and geographical scope of standards and guidelines

Standards/programmes and their scope		Type	Compliance	Voluntary	Geographic scope
National GHG emissions	UNFCCC	programme	X		International
Organization/ entity-wide GHG emissions	EU ETS	programme	X		European
	ISO 14064-1	standard		X	International
	GHG Protocol, Corporate Standard	standard		X	International
	Chicago Climate Exchange	programme		X	Mostly US
Corporate disclosure on climate change	Climate Disclosure Standards Board	standard		X	International
	Carbon Disclosure Project Questionnaire	guidelines		X	International
	PAS 2060 Carbon Neutrality	guidelines		X	UK, international
GHG offset projects	Clean Development Mechanism	programme	X		Non-Annex 1
	Joint Implementation	programme	X		Annex 1
	Regional Greenhouse Gas Initiative	programme	X		North-east US
	ISO 14064-2	standard		X	International
	GHG Protocol, Project Protocol	standard		X	International
	Climate Action Reserve	programme		X	Mostly US
	Voluntary Carbon Standard	programme		X	International
	Gold Standard	programme		X	International
	Chicago Climate Exchange	programme		X	Mostly US
	Climate Community and Biodiversity Standards	co-benefit add-on		X	International
	Social Carbon	co-benefit add-on		X	Non-Annex 1
	American Carbon Registry	programme		X	Mostly US
	Alberta Offsets System	programme		X	Alberta, Canada
	Pacific Carbon Trust	programme	X		British Columbia, Canada

Standards/programmes and their scope		Type	Compliance	Voluntary	Geographic scope
Product-specific/ supply-chain GHG emissions	PAS 2050	standard		X	UK, international
	ISO 14067	standard		X	international
	GHG Protocol, Scope 3 Standard	standard		X	international
Validation and verification (auditing) of GHG emissions and reduction claims	ISO 14064-3	Standard		X	international
	ISO 14065	standard		X	international
	ISO 14066	standard		X	international
	ISAE 3000	standard		X	international
	ISAE 3410	standard		X	international
	Validation and Verification Manual CDM	guidance document	X		Non-Annex 1
	Validation and Verification Manual IETA	guidance document		X	Non-Annex 1

The standards and programmes above are briefly explained in the ISO report. Comparison factors are quoted as follows:

- **Programmes** are defined as GHG schemes, including compliance and voluntary programmes, under which GHG emissions or emissions reductions can be certified by third parties, and may be traded. As a result, programmes usually have bodies that certify projects, verifiers, and specific protocols and/or programmes that are accredited under that programme. Under a compliance regime, entities are required by law to report and/or reduce their GHG emissions. Such compliance regimes include, but are not limited to, cap-and-trade systems, such as the Kyoto Protocol and the European Union Emissions Trading System (EU ETS). However, other standards and programmes are used by companies and institutions on a purely voluntary basis. The motivation for reporting GHG emissions and purchasing carbon offsets varies: it may be driven by corporate public relations or a code of ethics, a desire to go beyond what is mandated in terms of emission reductions, or to prepare for expected compliance action, such as the future introduction of a cap-and-trade system. As demand is driven by purely voluntary action, the voluntary markets for carbon offsets are much smaller than the compliance markets, such as the Clean Development Mechanism (CDM), a flexibility mechanism defined in the Kyoto Protocol. The distinction between programmes and standards can be confusing, since several of the programmes call themselves “standards”, such as the Voluntary Carbon Standard or the Gold Standard.
- **Standards** in the context of the table in Figure 5: Compliance and geographical scope of standards and guidelines include protocols, methodologies and guidance, and provide guidance and/or specifications on GHG quantification, monitoring, reporting and assurance. “International Standards” are those produced by ISO following specific principles and procedures. Most standards typically stand alone and do not have a body directly associated with them that accredits projects, protocols and/or verifiers. Typically, standards themselves do not have registration and enforcement systems to track and ensure legal ownership as is necessary, for example, in the case of emissions reductions from offset projects. The choice of a standard is typically voluntary, as long as it is not part of a compliance programme. That means an organization can decide which standard to use for its GHG emissions inventory or to implement an offset project, if it is not under a mandatory scheme of a compliance programme. Nevertheless, if a company chooses a particular standard under which to implement its GHG management system, that standard may state the requirements in a legally binding way (e.g. “the project proponent “shall” use a third-party auditor”) or as a recommendation or guideline (e.g. “the project proponent “should” use a third party auditor”).

- **Co-benefits** refer to environmental and social benefits that can be achieved in addition to carbon reductions. Standards that ensure such co-benefits are usually used in offset markets.
- **Guidance documents** provide specific process guidelines on how to apply a standard or a protocol. The use itself of such guidance documents can be voluntary or mandatory. For example, the CDM provides numerous mandatory guidance "methodological tools" such as the "Tool for the assessment and demonstration of additionality".
- **Geographic scope** refers to situations where activities are implemented under that programme or standard. For example, CDM activities and approved methodologies for offset projects are applied in Non-Annex 1 Countries unless adopted by the Voluntary Carbon Standard (VCS) programme for application in other jurisdictions.

4 Conclusions

For the ICT organization that wishes to manage its energy and GHG performance, there are a number of different sources of standards and guidelines it can draw upon. The difficulty in using these standards is understanding how they fit together, and how an organization can create its own sustainability assessment framework based on these standards.

What this document does is provide the insight that the way to understand how these various standards and guidelines fit an organization's purposes (or not, as the case may be) is through the use of two separate dimensions: the assessment targets that an organization might choose to meet, and the assessment criteria that an organization uses to better understand its performance.

What we find is that the standards and guidelines that are extant, when mapped using these dimensions, show up as meeting different needs of organizations. However, they also emerge as inter-related, inter-dependent, complementary, supplementary or even just competitive with each other.

This means there is no single assessment framework that meets the needs of ICT organizations around the world. Instead, each organization needs to map the standards and guidelines to their own requirements, in terms of business strategy and environmental performance, in order to create an assessment framework that meets their own business challenges, and is right for them.

5 Glossary

Additionality	criterion applied to GHG or ICT projects, stipulating that GHG emission reductions and/or removal enhancements should only be quantified if the project activity (or the same technologies or practices it employs) would not have been implemented in its baseline scenario and/or the project activity emissions are lower than baseline emissions. In effect, GHG/ICT projects shall be those that are intended only for GHG emission reductions and/or removal enhancements without regulatory enforcement and economic advantages. For example, if a technology employment project is caused by regulation, its GHG emission reductions do not have to be taken into account. However, if a project reduces emissions more than would have occurred in the absence of the project, it can be considered as additional. As a result, its GHG emission reductions can be rewarded with an economic incentive program like GHG emission allowances within GHG emission trading systems.
Annex 1 countries	Defined in the International Climate Change Convention as those countries taking on emissions reduction obligations: Australia; Austria; Belgium; Belarus; Bulgaria; Canada; Croatia; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Italy; Japan; Latvia; Liechtenstein; Lithuania; Luxembourg; Monaco; Netherlands; New Zealand; Norway; Poland; Portugal; Romania; Russian Federation; Slovakia; Slovenia; Spain; Sweden; Switzerland; Ukraine; United Kingdom; USA. [The Corporate Protocol]
baseline scenario	a hypothetical reference case that best represents the conditions most likely to occur in the absence of a proposed GHG project[11] [ISO 14064-2]
carbon dioxide equivalent (CO2e)	unit[12] for comparing the global warming impact of a GHG to carbon dioxide [ISO 14064-2]
Certified Emission Reductions (CERs)	A unit of emission reduction generated by a CDM project. CERs are tradable commodities that can be used by Annex 1 countries to meet their commitments under the Kyoto Protocol [The Corporate Protocol]
Certification	procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements [ISO 14024]
Clean Development Mechanism (CDM)	mechanism established by Article 12 of the Kyoto Protocol for project-based emission reduction activities in developing countries. The CDM is designed to meet two main objectives: to address the sustainability needs of the host country and to increase the opportunities available to Annex 1 Parties to meet their GHG reduction commitments. The CDM allows for the creation, acquisition and transfer of Certified Emission Reductions (CERs) from climate change mitigation projects undertaken in non-Annex 1 countries. [The Corporate Protocol]
direct GHG emissions	Emissions from sources that are owned or controlled by the reporting company [The Corporate Protocol]
energy consumption source	physical unit or process that consumes energy [ITU-T L.1430]
energy generator	physical unit or process that generates energy [ITU-T L.1430]

[11] The baseline scenario concurs with the GHG project timeline.

[12] The carbon dioxide equivalent is calculated using the mass of a given GHG multiplied by its global warming potential.

energy storage	physical unit or component that has the capability to store or accumulate energy produced by an energy generator or energy captured from an energy consumption source [ITU-T L.1430]
environmental aspect	element of an organization’s activities or products that can interact with the environment [ISO 14021]
environmental claim[13]	statement, symbol or graphic that indicates an environmental aspect of a product, a component or packaging [ISO 14021]
environmental impact	any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities or products [ISO 14021]
environmental label; environmental declaration	claim which indicates the environmental aspects of a product or service [ISO 14025]
global warming potential (GWP)	a relative measure of how much heat a greenhouse gas traps in the atmosphere [ISO 14064-2]
greenhouse gas[14] (GHG)	gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds [ISO 14064-2]
greenhouse gas assertion	declaration or factual and objective statement made by the responsible party [ISO 14064-2]. The GHG assertion may be presented at a point in time or may cover a period of time. When provided by a responsible party, it should be clearly identifiable, capable of consistent evaluation or measurement against suitable criteria by a validator or verifier. The GHG assertion could be provided in the form of a greenhouse gas report or GHG project plan.
greenhouse gas emission	total mass of a GHG released to the atmosphere over a specified period of time [ISO 14064-2]
greenhouse gas emission reduction	calculated decrease of GHG emissions between a baseline scenario and the project [ISO 14064-2]
GHG programme; GHG program	a generic term for: (1) any voluntary or mandatory, government or non-government initiative, system, or program that registers, certifies, or regulates GHG emissions; or (2) any authorities responsible for developing or administering such initiatives, systems or programs. [The Project Protocol]
greenhouse gas project (GHG project)	an activity or activities that alter the conditions identified in the baseline scenario which cause GHG emission reductions or GHG removal enhancements [ISO 14064-2]
greenhouse gas project proponent	individual or organization that has overall control and responsibility for a greenhouse gas project [ISO 14064-2]
greenhouse gas removal	total mass of a GHG removed from the atmosphere over a specified period of time [ISO 14064-2]

[13] An environmental claim may be made on product or packaging labels, through product literature, technical bulletins, advertising, publicity, telemarketing, as well as through digital or electronic media such as the Internet.

[14] GHGs include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6).

greenhouse gas removal enhancement	calculated increase in GHG removals[15] between a baseline scenario and the project [ISO 14064-2]
greenhouse gas sink	physical unit or process that removes a GHG from the atmosphere [ISO 14064-2]
greenhouse gas source	physical unit or process that releases a GHG into the atmosphere [ISO 14064-2]
greenhouse gas storage	physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a GHG removed from the atmosphere by a greenhouse gas sink or a GHG captured from a greenhouse gas source [ISO 14064-2] The total mass of carbon contained in a GHG storage at a specified point in time could be referred to as the carbon stock of the storage. A GHG storage can transfer greenhouse gases to another GHG storage. The collection of a GHG from a GHG source before it enters the atmosphere and storage of the collected GHG in a GHG storage could be referred to as GHG capture and storage.
ICT project	GHG project using mainly ICT goods, networks and services, contributing to GHG emission reductions or GHG removal enhancements, and/or a GHG project using mainly ICT goods, networks and services, contributing to energy consumption savings and energy efficiency improvement [ITU-T L.1430]
indirect GHG emissions	Emissions that are a consequence of the operations of the reporting company, but occur at sources owned or controlled by another company [The Corporate Protocol]
Inventory	A quantified list of an organization's GHG emissions and sources [The Corporate Protocol]
life cycle	consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal [ISO 14040]
life cycle assessment (LCA)	compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14040]
life cycle inventory analysis (LCI)	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle [ISO 14040]
life cycle impact assessment (LCIA)	phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product [ISO 14040]

[15] GHG removal enhancement corresponds to quantified GHG removal achieved by an activity or set of activities intended for GHG capture and closure. The usage of ICT may result in some GHG removals.

Product	any goods or service [ISO 14040] [NOTE 1] The product can be categorized as follows: • services (e.g. transport); • software (e.g. computer program, dictionary); • hardware (e.g. engine mechanical part); • processed materials (e.g. lubricant). [NOTE 2] Services have tangible and intangible elements. Provision of a service can involve, for example, the following: • an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired); • an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return); • the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission); • the creation of ambience for the customer (e.g. in hotels and restaurants). Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures. Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic.
product category rules (PCR)	set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories [ISO 14025]
Scope 1	A reporting organization's direct GHG emissions [The Corporate Protocol]
Scope 2	A reporting organization's emissions associated with the generation of electricity, heating/cooling, or steam purchased for own consumption [The Corporate Protocol]
Scope 3	A reporting organization's indirect emissions other than those covered in scope 2 [The Corporate Protocol]
Validation	systematic, independent and documented process for the evaluation of a greenhouse gas assertion in a GHG project plan against agreed validation criteria[16] [ISO 14064-2]
Verification	systematic, independent and documented process for the evaluation of a greenhouse gas assertion against agreed verification criteria[17] [ISO 14064-2]

[16] In some cases, such as in first-party validations, independence can be demonstrated by the freedom from responsibility for the development of GHG data and information.

[17] In some cases, such as in first-party verifications, independence can be demonstrated by the freedom from responsibility for the development of GHG data and information.

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