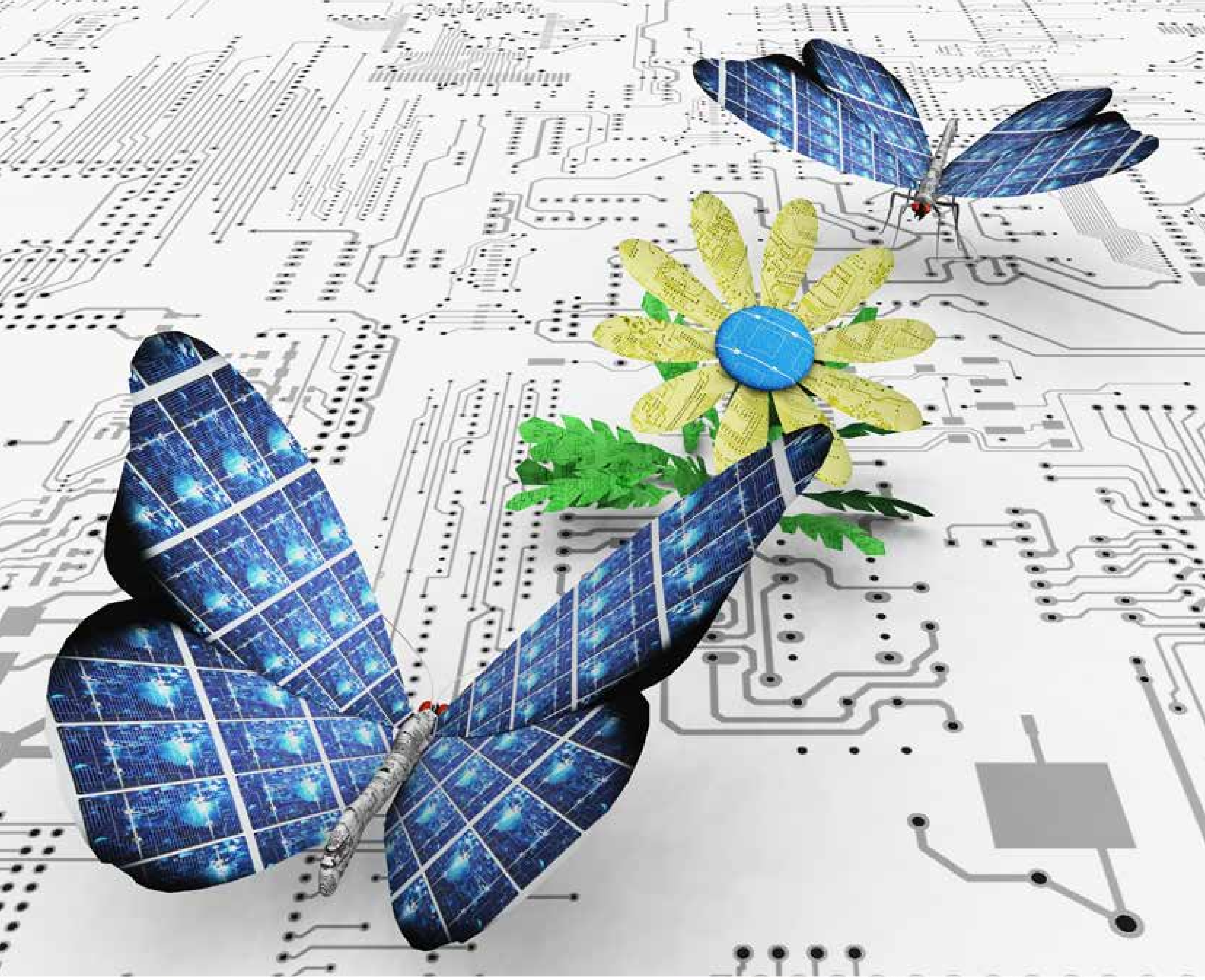

Sustainable products

itu.int/ITU-T/climatechange/ess

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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

If you would like to provide any additional information, please contact Cristina Bueti at tsbsg5@itu.int..

Sustainable products

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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.

The toolkit

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

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

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

1 Introduction

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

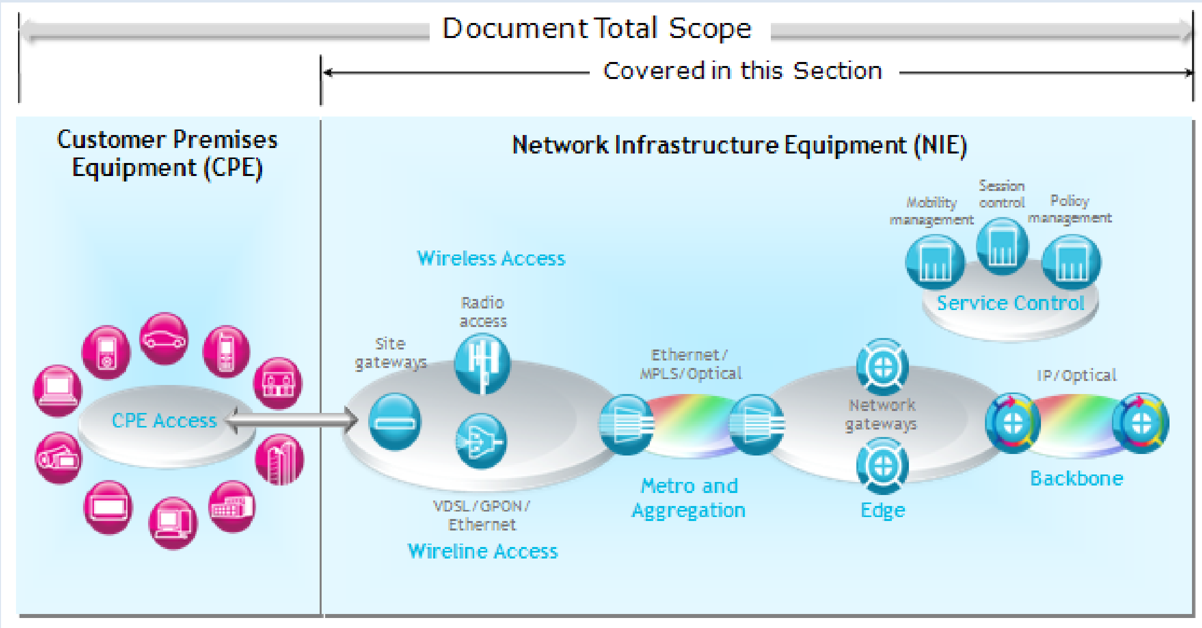
This document provides an overall perspective on environmentally-conscious design and development to the following target audience:

- 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.

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[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.

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[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)

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[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.

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[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.

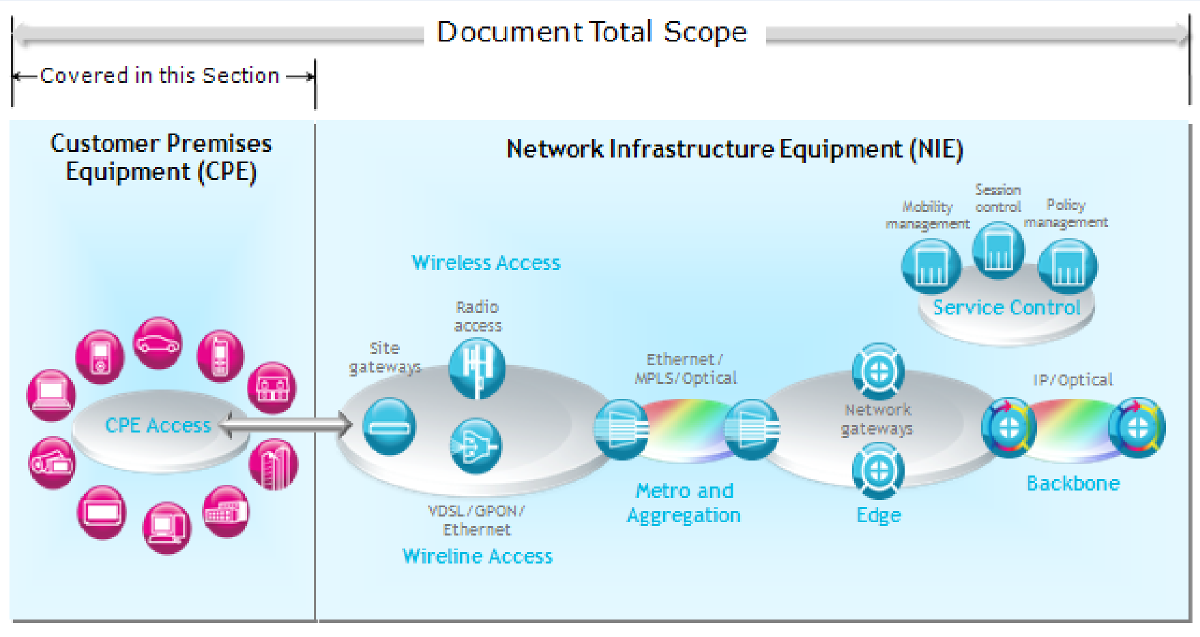
2.4.2 Best environmental practices

- 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.

[18] British Standards Institute – Publicly Available Specification, "Specification for the assessment of the life cycle greenhouse gas emissions of goods and service", BSI PAS 2050:2008, online: www.bsigroup.com/upload/Standards%20.../Energy/PAS2050.pdf.

[19] European Telecommunications Standards Institute: www.etsi.org.

[20] International Telecommunication Union: www.itu.int.

[21] World Resources Institute (WRI). Publications at: www.wri.org/publications/climate.

Background data and assumptions made for an LCA on creosote poles: www.ivl.se/webdav/files/B-rapporter/B1865.pdf.

- Inga Gurauskien, Visvaldas Varžinskas. Eco-design Methodology for Electrical and Electronic Equipment Industry. Environmental research, engineering and management, 2006. No. 3(37), P.43-51.
- C. Herrmann, M. Spielmann: Methods and Overview on Activities on Carbon Footprints. EGG Conference – September 2008; Berlin, Germany.
- C. Herrmann, A. Saraev, L. Scheidt, P. Brands, J. Sly: APPEAR: ADVANCED PLATFORM FOR PRODUCT ENVIRONMENTAL ASSESSMENT AND REPORTING. CARE Conference – November 2010; Vienna, Austria.
- C. Herrmann, A. Saraev, M. Held: TUTORIAL: Green Electronics – Pathway beyond Compliance Product Differentiation Today and Tomorrow. CARE Conference – November 2010; Vienna, Austria.
- C. Herrmann, P. Canepa: Guide for Product Carbon Footprints. How to calculate Product Carbon Footprints (PCF) for Electronic Products: www.pe-international.com/uploads/media/PCF_for_Electronic_Products.pdf.
- T. Higgs et al.: Review of LCA methods for ICT products and the impact of high purity and high-cost materials. This paper appears in: Sustainable Systems and Technology (ISSST), 2010 IEEE International Symposium on Sustainability.
- T. Joyce, T.A. Okrasinski, W. Schaeffer: Estimating the carbon footprint of telecommunications products: a heuristic approach. ASME Journal of Mechanical Design – Special Issue on Sustainable Design, September 2010.
- T. Künniger, K. Richter: Life Cycle Analysis of utility poles. A Swiss case study: www.uswag.org/2002/empa.pdf.
- J. Malmodin et al.: Life Cycle Assessment of Third Generation (3G) Wireless Telecommunication Systems at Ericsson: www.ecestudents.ul.ie/course_pages/btech_es/modules/et4407/Supplementary%20Material/9.ericsson%20LCA%20paper.pdf.
- T. Okrasinski, J. Malian: A Framework for Estimating Life Cycle Eco-impact for Information and Communications Technology Products. CARE Conference – November 2010; Vienna, Austria.
- Scharnhorst, Wolfram; Hilty, Lorenz M.; Jolliet, Olivier. Life cycle assessment of second generation (2G) and third generation (3G) mobile phone networks. Environment International 32 (2006) 656-675.
- M. Stutz et al.: Carbon Footprint of a Typical Business Laptop from Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-laptop-carbon-footprint-whitepaper.pdf.
- M. Stutz et al.: Carbon Footprint of a Typical Business Desktop from Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-desktop-carbon-footprint-whitepaper.pdf.
- M. Stutz et al.: Carbon Footprint of a Typical Rack Server from Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-server-carbon-footprint-whitepaper.pdf.
- M. Stutz et al.: Carbon Footprint of the Dell Streak Tablet: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-carbon-footprint-streak.pdf.
- Winco K.C. Yung, H.K. Chan, Danny W.C. Wong et al.. Eco-redesign of a personal electronic product subject to the energy-using product directive. International Journal of Production Research. http://dx.doi.org/10.1080/00207543.2011.571941.
- Winco K.C. Yung; H.K. Chan; Joey H.T. So et al. A life-cycle assessment for eco-redesign of a consumer electronic product. Journal of Engineering Design 22(2) 69-85, 2011.

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

8 Bibliography

"Circular Economy" at: www.ellenmacarthurfoundation.org/about/circular-economy.

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: Background data and assumptions made for an LCA on creosote poles: www.ivl.se/webdav/files/B-rapporter/B1865.pdf

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

British Standards Institute – Publicly Available Specification, "Specification for the assessment of the life cycle greenhouse gas emissions of goods and service", BSI PAS 2050:2008, online: www.bsigroup.com/upload/Standards%20.../Energy/PAS2050.pdf.

C. Herrmann, A. Saraev, L. Scheidt, P. Brands, J. Sly: APPEAR: Advanced Platfo for Product Environmental Assessment and Reporting. CARE Conference – November 2010; Vienna, Austria.

C. Herrmann, A. Saraev, M. Held: TUTORIAL: Green Electronics – Pathway beyond Compliance Product Differentiation Today and Tomorrow. CARE Conference – November 2010; Vienna, Austria.

C. Herrmann, M. Spielmann: Methods and Overview on Activities on Carbon Footprints. EGG Conference – September 2008; Berlin, Germany.

C. Herrmann, P. Canepa: Guide for Product Carbon Footprints. How to calculate Product Carbon Footprints (PCF) for Electronic Products: www.pe-international.com/uploads/media/PCF_for_Electronic_Products.pdf.

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

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

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.

European Telecommunications Standards Institute: www.etsi.org.

Inga Gurauskien, Visvaldas Varžinskas. Eco-design Methodology for Electrical and Electronic Equipment Industry. Environmental research, engineering and management, 2006. No. 3(37), pp. 43-51.

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: www.iso.org/iso/store.htm.

J. Malmodin *et al.*: Life Cycle Assessment of Third Generation (3G) Wireless Telecommunication Systems at Ericsson: www.ecestudents.ul.ie/course_pages/btech_es/modules/et4407/Supplementary%20Material/9.ericsson%20LCA%20paper.pdf.

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

M. Stutz *et al.*: Carbon Footprint of a Typical Business Desktop From Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-desktop-carbon-footprint-whitepaper.pdf.

M. Stutz *et al.*: Carbon Footprint of a Typical Business Laptop From Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-laptop-carbon-footprint-whitepaper.pdf.

M. Stutz *et al.*: Carbon Footprint of a Typical Rack Server from Dell: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-server-carbon-footprint-whitepaper.pdf.

M. Stutz *et al.*: Carbon Footprint of the Dell Streak Tablet: http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/dell-carbon-footprint-streak.pdf.

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

Scharnhorst, Wolfram; Hilty, Lorenz M.; Jolliet, Olivier. Life cycle assessment of second generation (2G) and third generation (3G) mobile phone networks. Environment International 32 (2006) 656-675.

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

T. Higgs *et al*.: Review of LCA methods for ICT products and the impact of high purity and high cost materials. This paper appears in: Sustainable Systems and Technology (ISSST), 2010 IEEE International Symposium on Sustainability.

T. Joyce, T.A. Okrasinski, W. Schaeffer: Estimating the carbon footprint of telecommunications products: a heuristic approach. ASME Journal of Mechanical Design – Special Issue on Sustainable Design, September 2010.

T. Künniger, K. Richter: Life Cycle Analysis of utility poles. A Swiss case study: www.uswag.org/2002/empa.pdf.

T. Okrasinski, J. Malian: A Framework for Estimating Life Cycle Eco-impact for Information and Communications Technology Products. CARE Conference – November 2010; Vienna, Austria.

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

Winco K.C. Yung; H.K. Chan; Joey H.T. So *et al*.: A life-cycle assessment for eco-redesign of a consumer electronic product. Journal of Engineering Design 22(2) 69-85, 2011.

Winco K.C. Yung, H.K. Chan, Danny W.C. Wong *et al.*: Eco-redesign of a personal electronic product subject to the energy-using product directive. International Journal of Production Research. http://dx.doi.org/10.1080/00207543.2011.571941.

World Resources Institute (WRI). Publications at: www.wri.org/publications/climate.

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