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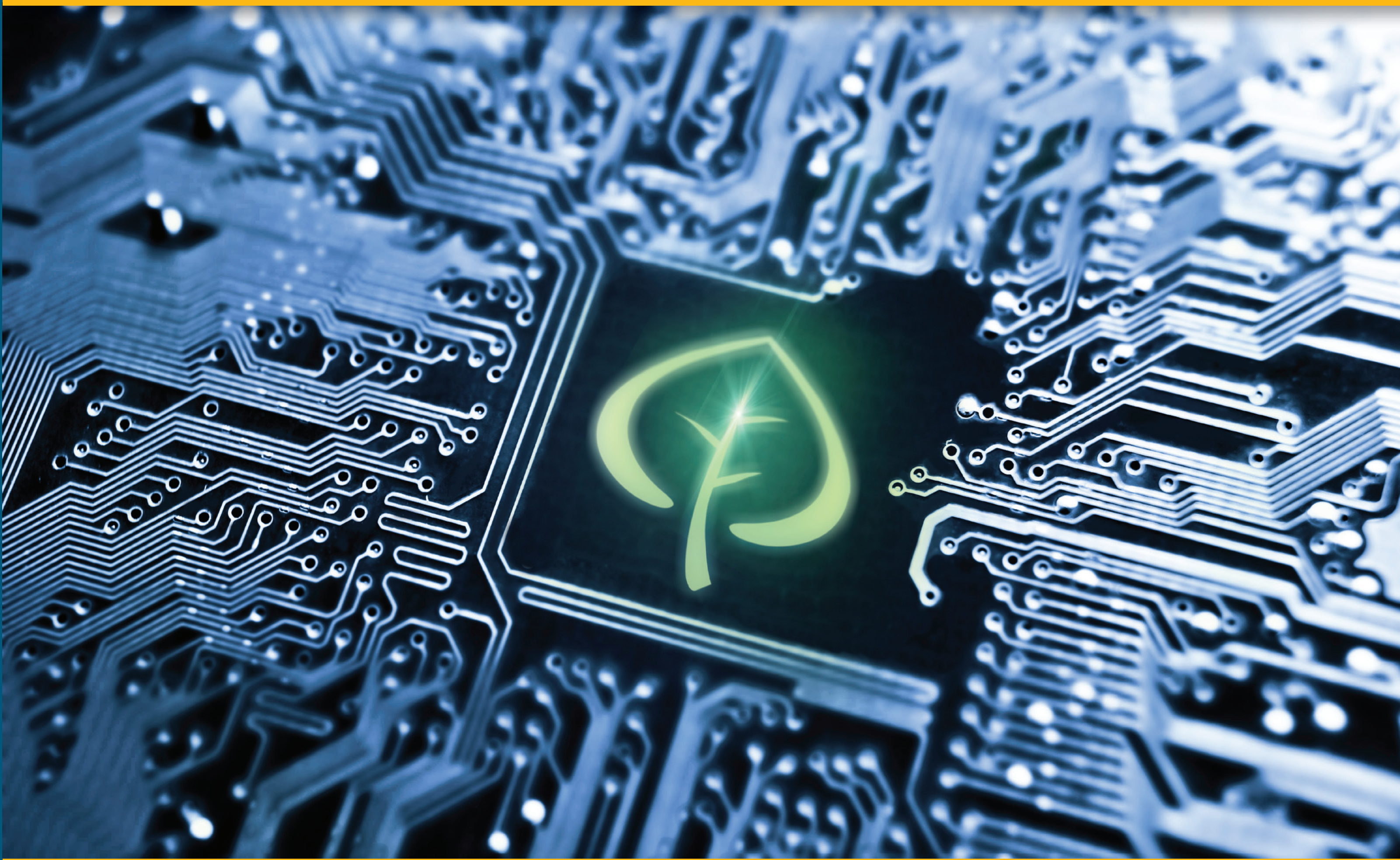

White paper

GREEN COMPUTING

ILNAS
Institut luxembourgeois de la normalisation, de l'accréditation, de la sécurité et qualité des produits et services

ANEC
AGENCE POUR LA NORMALISATION ET L'ÉCONOMIE DE LA CONNAISSANCE

Acknowledgments

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Executive Summary:

This document surveys, from a holistic perspective, various topics and technologies in the area of sustainability and Information Technology (IT), also known as Green Computing or Green ICT. An investigation is made regarding questions on the environmental impact of current IT usage, energy efficiency of IT products and how IT can contribute to business sustainability. The aim of the document is therefore to present a comprehensive review of the state-of-the-art approaches to help companies in developing sustainable and environmental friendly products and services which are supported or enabled by IT. In this context, standardization is presented as the cornerstone to guide and support organizations to achieve sustainability. A thorough review is conducted on the most relevant standards related to the topic of Green Computing from different standardization bodies such as ISO, IEC, CENELEC, ETSI, and ITU and consortia such as ECMA and IEEE. Finally, the Eco-management and Audit Scheme (EMAS) is surveyed as an environmental management system which enables organizations to assess, manage, and continuously improve their environmental performance. Because the requirements of ISO 14001 "Environmental management systems" are an integral part of EMAS, organizations that comply with EMAS automatically comply with the requirements of such standard.

Foreword

The "*Institut Luxembourgeois de la Normalisation, de l'Accréditation, de la Sécurité et qualité des produits et services*" (ILNAS) is an administration, under the supervision of the Minister of the Economy in Luxembourg. ILNAS is the national standards body, and, in this frame, has developed, in partnership with the University of Luxembourg, a certificate on "Smart ICT for Business Innovation" (lifelong learning framework) at the end of 2014. The current White Paper has been carried out in the context of this university certificate. Its aim is to support the development and to strengthen the standardization culture at the national level, specifically in an economically meaningful field like Smart Information and Communication Technology (Smart ICT). This initiative is *de facto* in line with the Luxembourg's Policy on ICT Technical Standardization 2015-2020 in the context of education about standardization.

The university certificate offers a broad view of cutting-edge Smart ICT concepts and provides various tools to the students in order to develop their sense of innovation. The economic interest grouping ANEC GIE is supporting ILNAS in raising awareness, training, and monitoring activities in the field of standardization and metrology, as well as applied research. ILNAS commissioned ANEC GIE standardization department to implement yearly the university certificate, and to carry out its development. In this framework, ANEC GIE is actively contributing to the creation of pedagogical materials related to the Smart ICT topics addressed and covered by the university certificate.

Overall, the pedagogical program has been developed based on a common-thread that describes the role of technical standardization as an enabler of innovation. In this context, ICT is considered as a dynamic horizontal sector that supports the development of other economic sectors (vertical convergence). In the intersection between the horizontal and the vertical sectors, technical standardization can be considered as an enabler to allow the interoperability between them. All in all, technical standardization is not only a specific module in the academic program, but it is present in each module as a reference and as a key factor to trigger innovation. In other words, technical standardization represents the general keystone of the university certificate.

With the aim of providing the students with a reliable source of information and of recent breakthroughs, the different standardization committees involved in Smart ICT developments are considered like a basis for the certificate. They represent the unique ecosystem gathering both the public (Ministries, administrations, etc.) and private sectors (manufacturers, researchers, business innovators, and other stakeholders…), making them the beating heart of the ICT progress, and thus creating a conducive common technical "platform" for the students of the certificate. More in detail, the focus of the certificate relies on important aspects of Smart ICT and their applications, including development of smart cities, smart grid, big data and analytics, cloud computing, Internet of Things and digital trust. Moreover, ICT governance and environmental issues related to ICT are likewise addressed.

This document, which is used as a basis for the development of the Green ICT lecture in the context of the university certificate, tackles the later topic (environmental issues related to ICT) from the holistic perspective of Green Computing in which both aspects, Green IT and Green by IT, are equally treated as well as their relation with sustainability. The aim is to provide a comprehensive survey of relevant related literature, to introduce various technologies in these areas, and also to present some perspectives regarding new Smart ICT technologies. The document does not only investigate the concerns on the environmental impact of current ICT usages and energy efficiency of ICT products, but also addresses how Green ICT contributes overall to ICT organizations. Moreover, the document highlights related standards and standardization activities as key enablers for the economy.

Jean-Marie REIFF, Director
Jean-Philippe HUMBERT, Deputy Director
ILNAS

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Abbreviations

CE	Consumer Electronics
CPU	Central Processing Unit
DVD	Digital Versatile Disc
ECMA	European Computer Manufacturers Association
EEE	Electrical and Electronic Equipment
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
EPE	Environmental Performance Evaluation
EPEAT	Electronic Product Environmental Assessment Tool
ERP	Enterprise Resource Planning
ETC	Emission Test Chamber
ETSI	European Telecommunications Standards Institute
GHG	Greenhouse Gas
HRM	Human Resource Management
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IS	Information System
ISO	International Organization for Standardization
IT	Information Technology
ITU	International Telecommunication Union
KPI	Key Performance Indicator
MIS	Management Information System
MP3	MPEG-1 or MPEG-2 Audio Layer III
NRBV	Natural-Resource-Based View
SCI	Smart Community Infrastructures
SCM	Supply Chain Management
TR	Technical Report

1. Introduction

Over the last few years, there is a raising awareness on the impact that modern societies have on the environment. Many environmental issues, such as energy consumption or e-waste, are caused due to usage of Information Technologies (IT) but some other environmental issues may also be solved by IT. Green Computing refers to a collection of technologies and codes of best practices which provide a holistic perspective of IT systems considering both aspects: reducing the environmental impact of IT, hardware or software, throughout its life cycle (in an approach that is usually known as **Green IT**) and developing and using information systems (IS) to reduce the environmental impact of products that require IT (in an approach called **Green IS** or Green by IT).

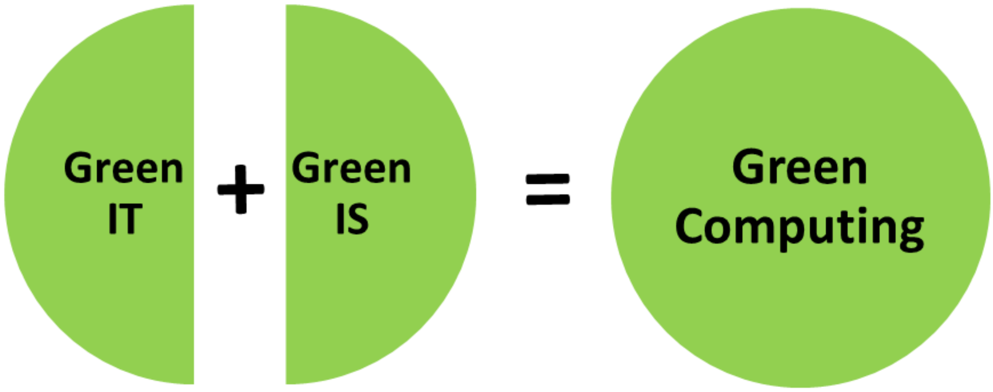

Figure 1 Holistic vision of Green Computing integrating Green IT and Green IS as key components

This document leverages on this integrative vision of Green Computing (see Figure 1) to discuss the business opportunity that computational sustainability can represent to companies and organizations, either in terms of efficiency improvements on the business processes (eco-efficiency) or as an added value on the way organizations and companies are perceived by society (eco-branding). Overall, the aim of this document is to help companies in the process of developing sustainable and environmentally friendly products and services which are supported or enabled by IT. More specifically:

- The focus of "**Green IT**" is on reducing the environmental impact of IT (hardware and software) throughout its life cycle. It addresses waste associated with the use of hardware and software and energy consumption.
- The focus of "**Green IS**" is on developing and using information systems to reduce the environmental impact (e.g. energy savings) of products and services that require IT. Green IS concerns the possible contributions of information systems to support or enable sustainable initiatives (such as sustainable buildings) and practices across the entire firm (Watson et al. 2010) and can also be described as IS-enabled organizational change (Kalsheim and Beulen, 2014).

In order to introduce this integrative perspective of Green Computing, the remaining of this document is organized as follows:

- **Green Computing**. This section aims at emphasizing the relevance of Green Computing as an added value for companies and organizations. Respective value models are presented for both, Green IT and Green IS. The Green IT model dissects in different steps the mechanisms to assist an organization to reach the goal of environmental sustainability, going from a preliminary stage of raising awareness to a final one in which the Green IT value is created. On the other hand, the Green IS model is built from the scope of coercive and mimetic pressures that regulations and customers exert on organizations, and how such pressures can be transformed into an added value, resulting in an improved corporate image and performance of the business processes.

- **Green Technologies**. This section aims at summarizing different technologies and capabilities (i.e. "green practices") that are frequently employed to achieve environmental sustainability in or by IT usage. The scope of such recommendations encompasses a wide spectrum of disciplines including some simple codes of good practices, such as teleconferencing and telecommuting, or more advanced technological aspects, such as the sustainable design of a data center.

- **Green Frameworks**. Despite the lack of an ultimate framework that guarantees environmental sustainability in IT, some researchers have started to consider the orchestration of best "green practices" into coherent strategies to foster the environmental sustainability of organizations. This section presents two of these strategies in the form of orchestrated "Green frameworks".

- **Standardization**. Given that environmental standards can trigger innovations that lower the total cost of a product and improve its value, this section presents an extensive survey about standardization for companies to adopt Green IT and Green IS practices. Previously introduced technologies are therefore guided and supported with various international, national, industry and other standards. Special relevance is given to ISO standards 14001 and 50001 which respectively tackle environmental and energy management systems.

- **EU regulation: eco-management and audit scheme (EMAS)**. This section discusses a specific environmental management tool that was proposed by the EU as a voluntary tool for companies to achieve sustainability. EMAS is no longer limited to EU member states and has become globally applicable. Additionally, this audit scheme is strongly based on the standard ISO 14001 "Environmental management system" which is also reviewed in the previous section.

- Finally, in the last section of this document, **conclusions and a general outlook** on the innovative potentials of Green Computing are provided.

2. Green Computing

The concept of Green Computing dates from 1992, when the United States Environmental Protection Agency launched the 'Energy Star' program. Energy Star was first applied to various products such as computer monitors, television sets and air conditioners. A well-known initial result of green computing was the sleep mode option of computer monitors that puts the device in a low energy consumption mode when no user activity is detected after a certain period of time. Nowadays green computing includes many more concepts such as consolidating computer hardware using virtualization software, cloud computing or, improving the energy efficiency of data centers (Watson et al, 2008).

Businesses are increasingly beginning to comprehend that Green Computing initiatives – including both, Green IT and Green IS - are possible while at the same time making a solid return on the investment (Bose and Luo, 2011). In fact, Porter and Van der Linde (1995) argued already two decades ago that companies should treat environmental investments as "*an economic and competitive opportunity, not as an annoying cost or an inevitable threat*". The three primary drivers of such initiatives are to:

1. reduce costs due to increased completion and budget cuts,
2. reduce consumption due to resource restrictions and higher energy prices,
3. comply with law and regulations.

2.1 Green IT value model

This section presents a Green IT value model that can assist an organization to reach the goal of environmental sustainability. This conceptual model consists of four components (Figure 2): Awareness, Translation, Comprehension, and Green IT value. This will ultimately lead to environmental sustainability.

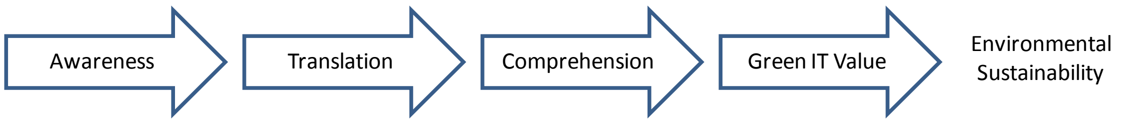

Figure 2 Green IT value model (Chou and Chou, 2012)

- Awareness - The recognition of the potential value and opportunities of environmental, economic and social benefits offered by Green IT must first be identified before a Green IT initiative will be adopted. Molla (2009a) found that the main reasons not to adopt Green IT were costs and an unclear business value.
- Translation - During this stage organizations must create a Green IT strategy that should be embedded into their overall strategies. Derived policies must be operationalized, possibly by means of a number of Green IT projects. Therefore sufficient resources (both human and financial) must be available for hiring subject matter experts for project implementations,

training employees, buying new technologies and preparing organizational changes due to new Green IT initiatives (e.g. an Environmental Management System such as ISO 14000[1]).

- Comprehension - In this stage organizations should proactively measure and report Green IT outcomes and check those against required results. This may include historical results of environmental performance tracking, cost-saving and energy reduction from Green IT initiatives, possible updates of Green IT policies, and recommended new Green IT initiatives or opportunities. Organizations have to remove deficiencies in performance results, for example by making use of tools from 'Energy Star', and to ensure that their Green IT meets related laws and regulation.
- Green IT value – The value for the organization can be found in more sustainability throughout the complete IT life cycle. This has both direct (e.g. less energy consumption) and indirect impacts (e.g. competitive advantage through improved corporate branding). It is likely that the organization will attract more customers that buy its environmental sustainable products and services.

Many uncertainties may affect an effective practice of Green IT. Chou (2013) expands on Green IT value model by adding various risk factors that may affect each component in the Green IT value model, thereby focusing on the area of environmental sustainability (Table 1). The risks range from ethic, social and knowledge issues to funding and stakeholders support.

	Awareness	**Translation**	**Comprehension**	**Green IT value**
Organization's activities	• Understanding the relationship of environmental quality and quality of life. •Recognizing the needs of Green IT by organizations, governments, and society. •Knowing that IT devices consume high energy, release pollution, and generate waste. •Identifying economic benefits of green IT. •Postulating potential value of green IT.	•Creating green IT strategies and link it to organizational strategies. •Sharing company's green IT vision with employees. •Classifying expected value of green IT. •Transforming green IT idea into operational courses. •Seeking resources and funding for green IT practice. •Developing innovative technologies for green IT implementation. •Performing organizational change and change management. •Offering training programs to employees. •Adopting knowledge management system to assist green IT mission.	•Creating measurements for assessing green IT outcome. •Monitoring performance in IT department. •Adopting suitable tools for calculating energy usage. •Creating an environmental management system (EMS) in organization. •Creating green IT performance reporting system. •Establishing green IT laws, standards, and regulations for industries and societies.	•Combining the results of the three components in Green IT value model: Awareness, translation and comprehension. •Defining the value as the measurement of satisfaction of exploiting green IT. •Collecting value from enterprise's satisfaction of implementing green IT. •Collecting value from social and environmental satisfaction of implementing green IT.
Risks in components	•Lack of the knowledge of environmental	•Insufficient support from top management. •Concern of	•Lack of knowledge of green IT metrics. •Insufficient	•Insufficient knowledge in defining the value of

[1] "Overall management system that includes organizational structure, planning activities, responsibility, practice, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy."

	sustainability. •Lack of the knowledge of green IT. •Profit-cent red managerial philosophy. •Lack of individual behavioral change. •Lack of social responsibility. •Insufficient business ethics. •Insufficient effort from government.	investment risk. •Lack of stakeholder consent and support. •Inadequate experience in Green IT. •Insufficient funding to green IT initiatives. •Lack of specific IT support. •Inadequate experience in change management. • Inadequate experience in training programs. •Lack of skill in building knowledge management system.	experience in workplace monitoring. •Selecting improper tools for calculating energy usage. •Insufficient knowledge in creating EMS. •Insufficient knowledge in crafting green IT policies and laws.	awareness, translation and comprehension. •Insufficient knowledge in calculating green IT value. •Insufficient value data to be collected in organizations. •Insufficient capability of interpreting the results of value. •Insufficient capability of communicating with the society.

Table 1 Risk in Green IT value model (Chou, 2013)

Chou (2013) concludes that "*The identification and understanding of these risk factors may allow companies preparing these threats ahead of time, so they may have better chance to achieve the goal of environmental sustainability*".

2.2 Green IS value model

Gholami et al. (2013) investigated the drivers of a company for Green IS adoption and its impact on the firm's environmental performance. Although companies are under constant pressure from regulators, customers and competitors, they found that few companies are willing to give up efficiency and effectiveness for environmental issues. Green IS investments to implement sustainable business practices are still expected to increase turnover and/or profit.

The model of Gholami et al. (2013) consists of four main elements (Figure 3):

- Macro factors: are based on coercive and mimetic pressures. Coercive pressures come from regulations, suppliers, or customers; Mimetic pressures include the perceived success of competitors, suppliers, and customers.
- Micro factors: are based on the attitude and considerations regarding immediate vs. future environmental consequences of individuals and the organization as a whole. At this level, mimetic pressures influence individuals to embrace Green IS policies.
- Action: the most effective way of Green IS adoption by an organization is to embed the initiatives into its overall strategy. Hart (1995) takes three types of strategic initiatives into consideration:
    - pollution prevention (reduce emissions, waste and hazardous materials);
    - product stewardship (relates to an environmental friendly supply chain management, both upstream and downstream);
    - sustainable development (concerns transforming businesses into sustainable ones).

  A number of technologies and techniques (such as video and teleconferencing, emission management systems) can be used to implement such strategies.
- Outcome: the measured environmental performance using the following indicators: environmental certification, reduction of waste, reduction of emissions, recycling performance, environmental compliance improvement, improved corporate image, preserved or social commitment.

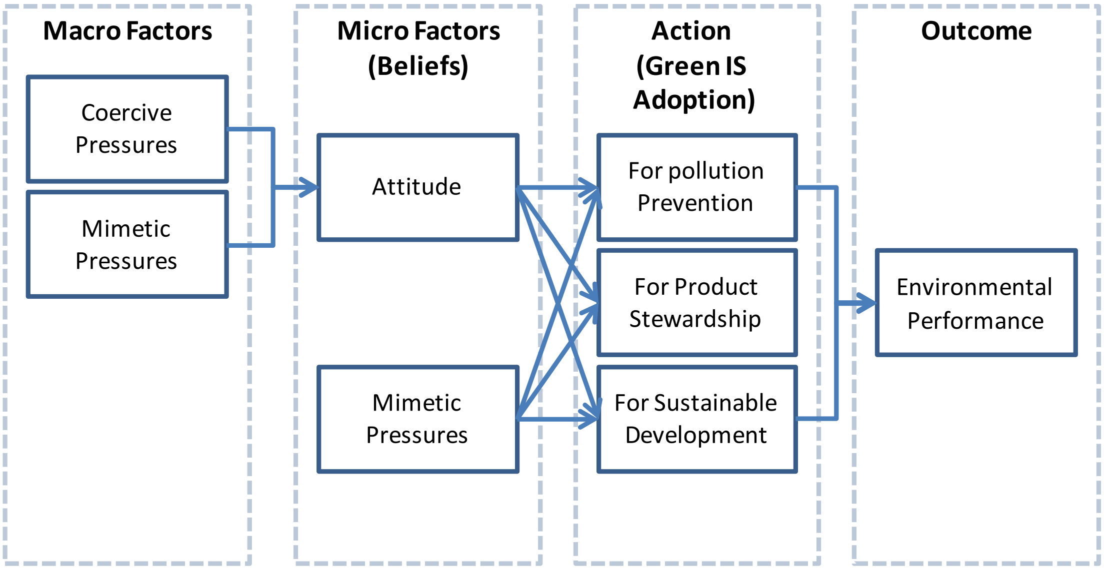

Figure 3 Research model for Green IS adoption and its impact on performance (Gholami et al., 2013)

Their results suggest that Green IS adoption contributes positively to environmental performance. But the environmental value depends on the type of Green IS adopted (i.e. adoption for pollution prevention, product stewardship or sustainable development). Short-term orientation concentrates on using Green IS for pollution prevention, whereas the strategic orientation in the long term considers using Green IS for product stewardship and sustainable development. The relationship between the long-term strategic orientation and the environmental performance is significant and positive. However, no significant relationship was found between the short-term orientation and environmental performance of the firm. Although coercive pressures from policy makers influence the attitude toward Green IS adoption, the mimetic pressures do not. This indicates, according to the authors, the importance of regulations for environmental sustainability.

3. Green Technologies

This section reviews different existing technologies which offer possibilities to reduce the negative environmental impacts in activities by producers and consumers that use IT. Leveraging on these technologies, the following section will introduce some frameworks for the orchestration and implementation of Green IT and Green IS.

3.1 Cloud computing

Many companies are considering a new computing paradigm, cloud computing, to optimize utilization and minimize cost of their computer back-end (mainframes, IT servers, etc.). This way organizations can avoid upfront costs associated with building their IT infrastructures, do not want to maintain or do not have the internal resources to maintain a data center. Cloud computing providers leverage shared infrastructure and balance IT resources for computing tasks in real-time while at the same time reduce gas emission and maintain the levels of service. Cloud computing relies on sharing of hardware and software resources, which are not only shared by multiple users but also dynamically reallocated per demand. Using this business model removes ultimately the need for a company to have an on-premise data center, which evidently has a positive effect in the natural environment and its resources. To date already many vendors provide Green IS focused cloud services and are experiencing significant growth rates per annum.

3.2 Computer power management

One of the best practices to save energy in computing is turning off equipment when not in use. The open industry standard "Advanced Configuration and Power Interface" (ACPI[2]) is an advanced Green IT practice that allows a computer operating system to directly control the power-saving aspects of its underlying hardware. It can automatically turn off components such as monitors and hard drives after specific periods of inactivity. Computer power savings modes include monitor sleep mode, hard disk sleep mode, system standby and hibernation mode, and different CPU power states.

[2] http://www.acpi.info/

3.3 Data center design

Data centers consume large amounts of energy, typically over 100 times more than standard commercial buildings. Energy efficient data center design such as recycling of waste heat, therefore, has a big positive impact on energy conservation and can be applied primarily in the following areas:

- IT systems
    - Increase hardware utilization, e.g. by means of virtualization (see subsection 3.4).
    - Enable computer power savings modes (see subsection 3.2).
    - Purchase energy efficient devices, e.g. computer power supplies, computer processors, small form factor or solid state storage devices, terminal servers.
- Main power systems
    - Power management practices (a set of hardware and software techniques to optimize performance and power).
    - Increase the use of renewable energy.
    - Use of natural light instead of electricity.
- Cooling systems
- Air management

3.4 IT virtualization

IT virtualization refers to the abstraction of IT resources, e.g. running multiple logical computer systems on one set of physical hardware (server virtualization) or pooling physical storage from multiple network storage devices into what appears to be a single storage device that is managed from a central console (storage virtualization). IT virtualization reduces costs for hardware, reduces energy consumption and physical space use. It also improves software testing and deployment and increases the flexibility of hardware investments. It can assist in distributing of work so that servers are either busy or put in a low-power sleep state. Therefore virtualization is one of the primary forces for organizations to incorporate environmental sustainability into IT practices and business.

3.5 Materials recycling and e-waste

Through proper recycling of IT equipment e-waste is cut down, harmful materials such as lead, mercury, and cadmium are kept out of the natural environment and can be reused that otherwise would need to be produced. Materials recycling is possible for almost any computing device and accessory, such as hard disks, printer cartridges, and batteries. Furthermore, businesses and individuals should try to extend the life of IT equipment by upgrading devices instead of just replacing them.

3.6 Smart grid and smart meters

A Smart Grid is a technology consisting of hardware and software that makes more efficient use of existing infrastructures for electrical generation, transmission and distribution. It is a modernized version of the utility electricity delivery system which gathers and acts automatically on information flows. The objective is to improve the efficiency, reliability and sustainability of the production and distribution of electricity by load balancing and peak load management. It makes use of digital communication between devices connected to the grid. The data relates to energy production and consuming behaviors of both suppliers and consumers. In that sense, real time information exchange between producers and consumers helps to better control energy demands and reduces the need of energy surplus during peak hours.

Devices on the network have sensors to gather data (power meters, voltage sensors, fault detectors, etc.). A Smart Meter is a device that records the energy (electricity, gas, etc.) consumption in predefined intervals and sends data at least daily back to the public utility for e.g. monitoring and pricing purposes. It can also be used to provide information about energy consumption and to set real-time energy prices to consumers. A key feature is automation technology that lets the public utility adjust and control each individual device from a central location. Benefits include handling alternative sources of electricity (e.g. solar and wind power), smart control for eco-friendly buildings and in due course integrating electric vehicles onto the grid.

3.7 Software algorithmic efficiency

The efficiency of a computer algorithm has an impact on the amount of IT resources it requires. The better the software is coded the less resource usage is required for a given functionality. The most common efficiency parameters are time (how long does the calculation take to complete), memory (how much working memory is needed for both code and data) and CPU (how much load requires the calculation). Also power-aware applications (i.e., power-aware or energy-aware schedulers) are relevant in this context. Examples are power-aware application software, middleware and operating systems. In addition advances are being made regarding modifications of the software development life cycle to facilitate environmentally sustainable software development.

3.8 Teleconferencing and telecommuting

Teleconferencing is a technology that is often implemented as a Green IS practice. It brings many advantages such as, reduction of toxic gas emissions related to travel, lowering material usage for office space and associated reductions in energy consumption for heat, air conditioning and lighting. An important social aspect is that it also adds to increase worker satisfaction. Other similar practices such as telecommuting are able to reduce the square meters per employee as companies only need to allocate space when the staff is at the office. Telecommuting also reduces work-related commuting issues such as travelling time, emissions and energy consumption.

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One of the most prominent technical challenges that relates to these technologies is the lack of commonly agreed standards. For example in cloud computing, portability is a particularly challenging issue, as moving e.g. a ERP cloud implementation from one vendor to the other is timely and costly (resulting in vendor lock-in risk). Also regarding Smart Grids there are technical challenges in the design, standardization, architecture, and operation. For example, an overwhelming number of propriety and standalone solutions in households exist for temperature regulation, and Smart Meters have to be integrated into existing infrastructures. Or concerning e-waste, a better co-design of hardware-software architectures is required to prolong the lifetime of electronic devices.

Measuring progression in greenness requires that one or more of the frameworks discussed in the following section and the above mentioned Green IT and Green IS technologies become embedded in a continuous measurement and management process.

4. Green Frameworks

There is still lacking a framework that assists organizations with initiating, implementing and managing Green IT and IS strategies which explicitly take into account technical, managerial and social aspects of environmental sustainability in a balanced and overarching manner. However, in the last decade several authors have zoomed into specific characteristics related to environmental sustainability in management, technology and/or social domains, which are presented in this section.

4.1 Generic competitive environmental strategies

Orsato (2006) proposed a framework of competitive environmental strategies based on Porter's competitive advantage theory (Porter, 1985) and the resource-based view of the firm (Wernerfelt, 1984). It consists of four components: environmental efficiency (Eco-efficiency), beyond compliance leadership, environmental branding (Eco-branding), and environmental cost leadership. The framework assists firms to define and prioritize areas to invest in Green IS. It also helps to optimize the overall economic return on such investments, and convert it into competitive advantage (see Table 2).

Competitive Advantage	Differentiation	Beyond compliance leadership	Eco-branding
	Lower costs	Eco-efficiency	Environmental cost leadership
		Processes	Products & Services
		Competitive Focus	

Table 2 Generic Competitive Environmental Strategies (Orsato, 2006)

- Eco-efficiency. For firms that are heavily dependent on their organizational processes and need to reduce environmental impact and lower its cost, this is the most suitable strategy. Companies in the food and beverage industries typically fall into this category and will develop process capabilities to continuously increase its productivity while decreasing its environmental impact.
- Environmental cost leadership. This strategy focuses on radical product innovation, such as material substitution or more efficient use of materials. However, it is difficult for firms that operate in markets with reduced scope for differentiation and also the need for radical innovations in product design makes this a difficult strategy. Especially when clients value the environmental features products, but often competitive price comes first.
- Beyond compliance leadership. This strategy holds for firms that also want the general public, and especially its customers to acknowledge their environmental improvements efforts. Such companies spend money on their Environmental Management System (EMS) certification, agree

voluntarily with environmental management business codes and invest in unprofitable environmental sustainability improvements. However since EMS certification can also be obtained by competitors, it requires companies to develop competences beyond their EMS, such as animal welfare and ethics.

- Eco-branding. This is a straightforward strategy for marketing differentiation based on the environmental attributes of products. The firm provides unique products that are valuable to buyers beyond simply offering a low price. Such companies need to observe three basic pre-requisites: 1) consumers can and want to pay for ecological differentiation costs; 2) the differentiation is not easily imitated by competitors; 3) regularly and clearly communicate to consumers and stakeholders on the product's environmental performance.

4.2 Framework for environmentally sustainable IT and IS research

Jenkin et al. (2011) developed an integrated multidisciplinary research framework that addresses environmental sustainability in management, environmental psychology, and social marketing domains. The framework consists of four main constructs and between these constructs a number of propositions have been formulated. Three of these constructs are located at the organizational level of analysis whereas an environmental oriented component can be applied also at the individual level of analysis (Figure 4). The four constructs are: 1) environmental sustainability motivating forces, 2) environmental sustainability initiatives, 3) environmental orientation, and 4) environmental impacts.

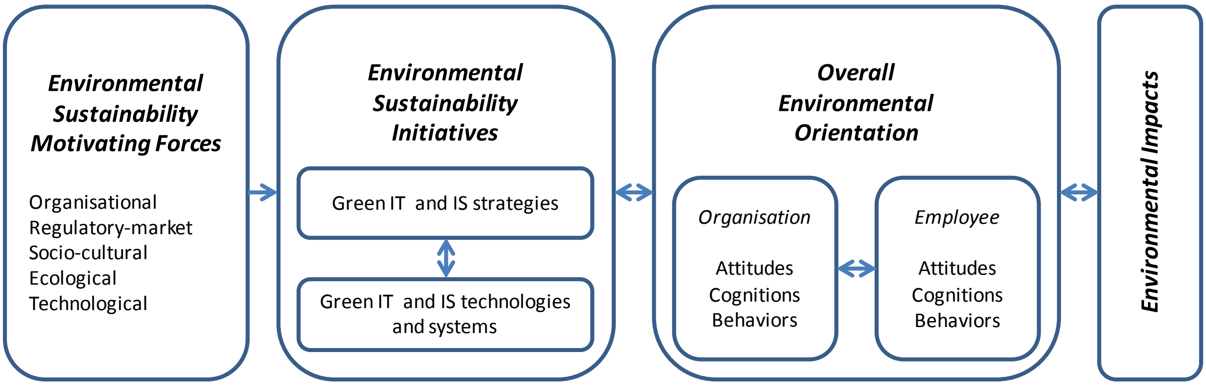

Figure 4 Framework for environmentally sustainable IT and IS research (Jenkin et al, 2011)

This framework allows managers to understand the role of Green Computing in corporate environmental initiatives and how this could fit into corporate social responsibility programs. The four constructs are described below on more detail.

1) The *environmental sustainability motivating forces* reflect how the organization's decision is affected to act in an environmentally sustainable way. These forces consist of five components: a) organizational, b) regulatory-market, c) socio-cultural, d) ecological, and e) technological.

- Organizational forces represent financial considerations, internal stakeholders, business capabilities, organizational structures, policies, leadership, as well as organizational culture;

- Regulatory-market forces reflect external standards, regulations and laws, and market pressures;
- Socio-cultural forces represent beliefs, environmental values, and trends in society;
- Ecological forces reflect the rate and amount of depletion of natural resources;
- Technological forces represent the technologies that can facilitate environmentally sustainable business practices.

2) The *environmental sustainability initiatives* category is composed of strategies based on the organization's support towards a sustainable environment and the resulting technologies and systems to support the organization's Green IT and IS strategies. It includes energy savings and waste reduction across the company and ecological sustainable development. Based on Hart (1995), Jenkin et al. (2011) identified four Green strategy types (Table 3).

- Type 0 strategies deal with the image of the organization by portraying it as taking genuine case about the environment. Environmental policies and practices are publicly communicated but implementation is not carried out because of insufficient resources such as lacking financials or specific skills of staff. Intentions may be authentic of even fake "green-washing".
- Type 1 strategies focus on the efficient use of natural and firm resources to reduce negative impact on the natural environment. Implementation often occurs as incremental changes to business operations. Examples of Green IT initiatives include reducing energy consumption by procuring energy efficient computer monitors, or consolidating computer servers by making use of virtualization technology. Examples of Green IS include the implementation of information systems to reduce paper consumption or reduce the need for daily commuting by means of teleworking.
- Type 2 strategies involve initiatives to balance the firm's and society's short and long term needs for natural resources by minimizing environmental impacts throughout a product's life cycle. These strategies relate to redesigning IT for environmental production processes or product life cycles.
- Type 3 strategies are of all types the largest in scope and in its most extreme form involves a fundamentally rethinking how firms operate throughout all activities and interactions. The goal is to achieve environmental sustainability and ultimately stopping environmental degradation altogether. Examples are conducting business transactions through e-commerce and completely eliminating paper-based workflows.

Strategy type	Description	Example
No 0: Image-oriented only	Portrays an image of caring about the environment by publicly announcing environmental policies and practices that subsequently are not implemented.	Announce a strategy to reduce energy use in the organization's supply chain by using IT/S. Subsequently there are insufficient resources for implementation.
No 1: Prevent, control, eco-efficiency	Efficiency oriented to reduce negative environmental impacts. Focus is on resource efficiency, waste prevention and control.	Introduce the objective or energy savings and then reduce power consumption across the company through energy efficient servers (e.g. server virtualization).
No 2: Product stewardship, eco-equity	Includes type 1 strategy and involves attempts to achieve balancing the firm's and society's short and long term needs for natural resources by strictly reducing the environmental impacts throughout a product's life cycle.	Develop a Green IS strategy to help reduce the environmental impact of organization's products. For example by capturing environmental data during product distribution, use and maintenance for product design improvements.
No 3: Sustainable development, eco-effectiveness	Comprises of type 1 and 2 strategies and extends sustainability considerations throughout all of the firm's activities and interactions.	Introduce the goal to substantially reduce business travel using information technology. Then implement videoconferencing and collaboration tools as travel substitutes.

Table 3 Green IT and IS strategy types and examples (Jenkin et al., 2011)

3) The overall environmental orientation consists of three factors: a) attitudes, b) cognitions, and c) behaviors related to environmental sustainable solutions. Attitudes include the culture of the organization or favorableness towards environmental sustainability by employees. Cognitions relate to the shared understanding at the organization level or values, beliefs and expectations by employees. Behaviors concern organizational routines and individual actions of employees. These three factors also play an important role at the employee level. Examples are an employee with a positive attitude towards reducing his own paper consumption by following a new procurement process or an organization culture that does not value supporting environmental sustainability.

4) The e*nvironmental impacts* are the bottom line of the Green IT or Green IS initiatives and range from specific measures such as reducing IT waste of computer hardware to more comprehensive results such as reducing the consumption of oil and gas by changing production processes or obtaining environmental certifications.

Jenkin et al. (2011) point out that the overall ownership of sustainability initiatives is an important point of attention. Selection and implementation of environmental friendly technologies and systems are typically carried out by IT departments whereas the provision of power, cooling, and management of energy costs, often fall under the domain of Facilities Management. The overall success of Green IS initiatives may depend on the proper alignment at group-level between the IT and Facilities Management departments.

5. Standardization

There exist various international, national, industry and other standards that assist companies in reducing their environmental footprint. These standards are being developed by Standards Developing Organizations (SDO), which can consist in:

- Formal standards bodies, meaning an organization benefiting from a broad recognition and complying with the principles set out in annex 3 of the World Trade Organization (WTO) Technical Barriers to Trade (TBT) Committee agreement *Code of Good Practice for the preparation, adoption and application of standards*. Their primary activities are to develop, coordinate, promulgate, and produce *de jure* (formal) standards. At the international level, there are three formal standards bodies broadly recognized: ISO, IEC and ITU. There are also different regional formal standards bodies; for the European Union, the three recognized standards bodies are CEN, CENELEC and ETSI.
- Private standards bodies, commonly called "*consortia*" or "*fora*" for the ICT sector. In the standardization context, they are organizations regrouping individuals, companies, associations or governments with a common objective of participating in the creation of technical specifications or *de facto* standards, meaning these standards benefit from a widely recognition of the market. The main difference with formal standards is that these organizations are not necessarily seeking to engage with all interested parties and the specifications they produce are not systematically made available for public enquiry.

The standards developed by those SDOs are instrumental for companies that embark on the Green IT and Green IS journey. The most important ones related to the topic of IT and environmental sustainability come from the following ones:

1) ISO - International Organization for Standardization
2) IEC - International Electrotechnical Commission
3) ETSI - European Telecommunications Standards Institute
4) ITU - International Telecommunication Union
5) CENELEC - European Committee for Electrotechnical Standardization
6) ECMA - European Computer Manufacturers Association
7) IEEE - Institute of Electrical and Electronics Engineers

Porter and van der Linde (1995) already pointed two decades ago that "*Properly designed environmental standards can trigger innovations that lower the total cost of a product or improve its value. Such innovations allow companies to use a range of inputs more productively – from raw materials to energy to labor – thus offsetting the costs of improving environmental impact and ending the stalemate. Ultimately, this enhanced resource productivity makes companies more competitive, not less*". In the next subsections the most important standards from these organizations are presented shortly.

5.1 Formal standards bodies

5.1.1 ISO

ISO[3] is an independent, non-governmental international organization developing high quality voluntary International Standards for products, services, processes, materials and systems, and for conformity assessment, managerial and organizational practice. ISO is the world's leading developer of International Standards composed of a global network of national standards bodies[4], the most representative of standardization in each country, from all regions of the world. Through its members, it brings together experts, from industry government, consumer organizations, academia, non-governmental organizations and more to share knowledge and develop voluntary, consensus-based, market-relevant standards that support innovation and provide solutions to global challenges facilitating international exchange of goods and services, support sustainable and equitable economic growth, promote innovation and protect health, safety and the environment.

The ISO 14000 family of environmental management standards offers frameworks and practical tools to organizations that allow systematizing and continuously improving their environmental management efforts.

ISO 14001:2015, ISO 14004:2004, ISO 14005:2010 and ISO 14006:2011 focus on environmental management systems whereas other standards in this family deal with a variety of environmental aspects such as performance evaluation, water footprint, life cycle assessment, and environmental communication. As with ISO 9000, ISO 14000 does not deal with environmental impact of products and services rather with the processes that create it. Also, certification is performed by third-party organizations and the ISO 19011 audit standard (Audit Protocol) must be used when auditing an environmental management system (EMS).

There are 27 published ISO standards in this family categorized in: 1) Environmental management systems; 2) Environmental auditing and related environmental investigations; 3) Environmental labelling; 4) Environmental performance evaluation; 5) Life cycle assessment; 6) Greenhouse gas management. For this survey the following standards in the ISO 14000 family are described in more detail:

- ISO 14001:2015, Environmental management systems — Requirements with guidance for use;
- ISO 14004:2004, Environmental management systems — General guidelines on principles, systems and support techniques;
- ISO 14005:2010, Environmental management systems — Guidelines for the phased implementation of an environmental management system, including the use of environmental performance evaluation;
- ISO 14006:2011, Environmental management systems — Guidelines for incorporating ecodesign;

[3] http://www.iso.org/iso/home.htm

[4] In this context, ILNAS is the national standards body of Luxembourg, and represents Luxembourg's interests in the European standardization organizations (CEN, CENELEC and ETSI) and the international organizations (ISO, IEC). For further information, please visit http://www.portail-qualite.public.lu/fr/index.html

- ISO 14031:2013, Environmental management — Environmental performance evaluation — Guidelines.

The environmental management system (EMS) standards in the 14000 family are intended to provide organizations an effective management system that can be integrated with other management system standards, thereby balancing economic and environmental interests. It allows to identify and control environmental impacts and to continuously improve organizations' environmental performance. In the context of this study, an effective EMS helps organizations to achieve compliance with applicable legal regulations and other requirements and to avoid, reduce or control adverse environmental impacts of its products (Green IT) or activities and services (Green IS).

An effective EMS can help organizations to assure interested parties that management commitment exists to meet the requirements of its policy, objectives, targets and regulatory compliance. In addition the EMS design incorporates the process of continual improvement and emphasis is placed on prevention rather than resolving environmental issues. Next to economic benefits that can be gained from an EMS and improved environmental performance, the potential benefits associated with an effective EMS are according to ISO 14001:2015:

- protecting the environment by preventing or mitigating adverse environmental impacts;
- mitigating the potential adverse effect of environmental conditions on the organization;
- assisting the organization in the fulfilment of compliance obligations;
- enhancing environmental performance;
- controlling or influencing the way the organization's products and services are designed, manufactured, distributed, consumed and disposed by using a life cycle perspective that can prevent environmental impacts from being unintentionally shifted elsewhere within the life cycle;
- achieving financial and operational benefits that can result from implementing environmentally sound alternatives that strengthen the organization's market position;
- communicating environmental information to relevant interested parties.

In addition ISO has also developed other standards that can be applied in order to take in place a sustainable development:

- ISO/TR 37150:2014, Smart community infrastructures — Review of existing activities relevant to metrics;
- ISO 50001:2011, Energy management systems — Requirements with guidance for use.

a) ISO 14001

This international standard specifies requirements and provides guidance for an EMS to enable organizations to develop and implement a policy of measurable objectives with regard to environmental sustainable goals. "*The overall aim of this International Standard is to support environmental protection and prevention of pollution in balance with socio-economic needs*", (ISO 14001, 2004). It applies to environmental aspects that an organization identifies as those which it can influence and control. It takes legal requirements into account and offers to determine the environmental impact of organizational activities, its products and services. It also assists in checking, corrective actions, and management review of the environment management aspects but does state any specific environmental performance criteria itself.

ISO 14001 is generic and flexible enough to be used by all types and sizes of organizations producing any product or service anywhere in the world. It is typically applied by organizations wishing to:

- establish, implement, maintain and improve an environmental management system,
- assure itself of conformity with its stated environmental policy,
- demonstrate conformity by: a) making a self-determination and self-declaration; b) seeking confirmation of its conformance by parties having an interest in the organization; c) seeking confirmation of its self-declaration by a party external to the organization; d) seeking certification and registration of its environmental management system by an external organization.

The body of the document consists of EMS requirements related to policies, planning, implementation, operation, checking and management review. ISO 14001:2004 is the standard against which organizations are assessed and contains only requirements that can be objectively audited. As a side note, ISO 14001 has been recently reviewed into a new version in 2015. However, the eco-management and audit scheme (EMAS) has not yet incorporated this new version of the standard into the recommendation.

This standard is based on the well-known Plan-Do-Check-Act (PDCA) method (see Figure 5)

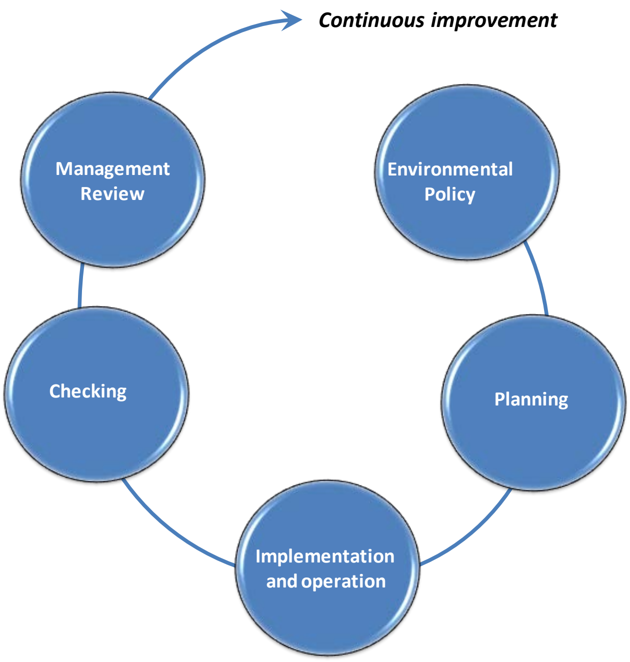

Figure 5 Environmental management system model of ISO 14001

b) ISO 14004

Organizations that require more detailed guidance on various environmental management system issues can make use of to 14004:2004. It is not intended for self-declaration or other conformity assessment purposes. This standard provides a structured approach to set environmental objectives and targets and to establish and monitor operational controls. It includes examples, descriptions and options that assist in the implementation of an EMS and in strengthening its relation to the overall management of an organization.

It can also be used by organizations of all types, sectors, sizes and levels of maturity and special needs for small and medium-sized enterprises (SMEs) are included as well. Key tasks for setting-up and managing an EMS include the need to (ISO 14004, 2004, page VI):

- recognize that environmental management is among the highest organizational priorities,

- establish and maintain communication and constructive relations with internal and external interested parties,
- identify the environmental aspects of the organization's activities, products and services,
- identify the legal requirements and other requirements to which the organization subscribes, that relate to the organization's environmental aspects,
- ensure the commitment of management and all persons working for or on behalf of the organization to the protection of the environment, with clear assignment of accountability and responsibility,
- encourage environmental planning throughout the product or service life cycle,
- establish a process for achieving environmental objectives and targets,
- provide appropriate and sufficient resources, including training, to comply with applicable legal requirements and with other requirements to which the organization subscribes, and to achieve environmental objectives and targets on an ongoing basis,
- evaluate environmental performance against the organization's environmental policy, objectives and targets and seek improvement where appropriate,
- establish a management process to audit and review the environmental management system and to identify opportunities for improvement of the system and resulting environmental performance,
- encourage contractors and suppliers to establish an environmental management system.

c) ISO 14005

The purpose of this standard is to encourage and guide organizations to develop, implement, maintain and improve an EMS that meets the requirements of ISO 14001. ISO14005:2010 includes advice on the integration and use of environmental performance evaluation techniques. Again, it is applicable to any organization, regardless of its maturity, nature of its activities or the location and gives special attention to SMEs. It uses a phased approach to implement an EMS that can grow to meet the requirements of ISO 14001.

A phased development approach offers several advantages. It gives the opportunity of early evaluations of how EMS investments provide a return and allows tracking EMS benefits, while it is being implemented step by step. It shows how environmental improvements supports customer expectations, helps to reduce costs, improves relations, and assists in demonstrating legal compliance.

d) ISO 14006

This standard offers guidance and assistance to organizations to establish a systematic and structured approach to incorporate and implement green design[5]as part of an EMS such as ISO 14001. Green design is a process that aims to reduce adverse environmental impacts and to continuously improve the environmental performance of products and services. This can be achieved through a balance between environmentally friendly aspects with other factors, such as intended use, performance, cost, marketability and quality, and by choosing methods that meet legal and regulatory requirements. It is not to be seen as a separate design activity but should be an integral part of an existing design process. In general, a three phased approach is foreseen to incorporate green design into the processes and under the umbrella of a management system of an organization:

[5] The term used in ISO 14006 for "green design" is "ecodesign", also known as "environmentally sustainable / conscious design" or "design for environment"

1. assess the impact of the organization products and services on the environment;
2. identify appropriate green design measures to reduce adverse effects on the environment;
3. incorporate the ecodesign process into the existing design and development process make and make it an integral part the EMS.

ISO 14006:2011 is also applicable to all organizations, regardless of size, type, product or service provided. The body of the standard consists of three clauses that provide guidance to the incorporation of green design into the design and development process and an EMS. It also clarifies the potential benefits of an integrated green design process and addresses the role of top management.

This standard for green design advocates an implementation using three knowledge areas required for ecodesign within an EMS using other international standards[6]:

- ISO 14001 as it relates to management of organization processes with environmental impacts;
- ISO 9001 as it deals with the design management process itself;
- ISO/TR 14062 and/or IEC 62430 as these standards assist with incorporation into the design and development process of environmental issues.

e) ISO 14031

This standard provides guidance on the design and use of a process, called environmental performance evaluation (EPE) within an organization. ISO 14031:2013 is applicable to small and large enterprises regardless of type, location and complexity. EPE is an ongoing process of collection and assessment of environmental data in order to provide both the current performance and performance trends and can be used independently or to support an EMS.

The EPE process facilitates measurements, evaluations and communication of the organization's environmental performance by means of performance indicators (KPIs) which are related to the environmental impact of its activities, products and services. When an EMS is available the organization can assess its environmental performance against its environmental performance policy, objectives, targets and compliance with legal or other requirements. The ISO 14031 standard has been recommended in 2012 by the European Commission as part of the eco-management and audit scheme (EMAS)[7] selection and use of environmental performance indicators.

f) ISO/TR 37150

This technical report (TR) is not a standard, but an informative document that provides a review of present (technical) activities which have been published, implemented or discussed relevant to metrics for Smart Community Infrastructures (SCI). Examples of community infrastructures (also known as public utilities) are energy (electricity, gas, fuel), water (supply, sanitation, reuse), transportation (road, railroad, air, water), waste and recycle, and information and communications technology (ICT). Potential stakeholders for this technical report include governments, city planners, investors, consumer groups and planners, operators and vendors of community infrastructures.

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[6] ISO 9001:2015, *Quality management systems – Requirements*; ISO/TR 14062:2002, *Environmental management — Integrating environmental aspects into product design and development*; IEC 62430 - *Environmentally conscious design for electrical and electronic products*

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

Community infrastructures can play an important role in sustainable development in order to balance economic, social and environmental aspects. Such infrastructures are called "smart" if these are more effective and efficient in terms of economic, quality of life and environmental impact. Functions of community infrastructures are fundamental to support more advanced functions in community facilities (commercial buildings, hospitals, schools, etc.) and community services (tourism, healthcare, education, etc.) Because products and services of SCI are more technology-oriented and more internationally-tradable these are, therefore, appropriate for international standardization.

The intention of ISO/TR 37150:2014 is to disseminate information about leading-edge SCI technologies and to establish harmonized product standards to evaluate its sustainability performance. Although this technical report provides directions for further standardization, it should not be considered as a recommendation document for best practices. It lists a number of desirable features of, and identifies gaps and possible future directions for SCI metrics. These metrics should be selected with consideration for synergies and trade-offs of multiple issues or aspects that a community faces, such as environmental impacts and quality of community service. The focus should be on advanced features of community infrastructures such as interoperability and efficiency.

g) ISO 50001

This standard specifies requirements for an energy management system[8]. With ISO 50001:2011 organizations are able to set up the necessary processes and systems in order to improve their energy performance, including efficiency, use and consumption. It also specifies requirements related to design measurement, documentation, reporting, and procurement practices for equipment, systems, processes and personnel that contribute to energy performance. Implementation of this standard is to lead to reductions in carbon dioxide (CO_2) and toxic exhaust gas emissions including carbon monoxide (CO), hydrocarbons (C_xH_y), nitrogen oxides (NO_x) and ozone (O_3).

This standard is applicable to organizations of all kinds and sizes that wish to ensure that it conforms to its stated energy policy. By using this standard, organizations can demonstrate this to others, either by self-evaluation and self-declaration, or by certification of the energy management system by third parties. The standard can be used independently, but it can be integrated with other management systems.

5.1.2 IEC

The International Electrotechnical Commission (IEC)[9], also a non-profit, non-governmental international standards organizations, is the world's leading organization that prepares and publishes International Standards and manages conformity assessment systems for all electrical and electronic products, systems and services, and related technologies collectively known as "electrotechnology". IEC supports all forms of conformity assessment and administers 3rd party conformity assessment systems. The IEC members(like for ISO) come from all around the world representing the entire range of electrotechnical interests in their country, companies and business, industry associations, educational bodies, governmental and regulatory bodies. All stakeholders are brought together through the country's member National Committee. The IEC provides a global platform where thousands of experts are able to cooperate to develop the International Standards or conformity

[8] ISO 50001:2011 defines an energy management system as a set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve those objectives.
[9] Please visit the IEC website at http://www.iec.ch/about/for further information.

assessment services that are needed by industry, regulators and policy makers, testing or research laboratories, academia, investors or insurers.

The following standards developed by the IEC are of importance for Green IT because these relate to green design. These two standards, which will be described shortly in the next subsections, deal with the equipment itself whereas ISO 14006 relates to incorporating green design into the environmental management system (EMS) of an organization.

- IEC 62075:2012, Audio/video, information and communication technology equipment – Environmentally conscious design
- IEC 62430:2009, Environmentally conscious design for electrical and electronic products

As mentioned in the subsection describing ISO 14006, the goal of green design is to reduce adverse environmental impacts of a product or service throughout its entire life cycle (i.e. raw-material acquisition, manufacture, distribution, use, maintenance, re-use and end of life). Design in this context includes the activities related to the processes of product or service planning, development and decision-making and the creation of organizational green design policies.

a) IEC 62075

This standard specifies requirements and recommendations for the design of environmentally sound products for the ICT & CE industries and was originally developed by ECMA in 2003 as ECMA-341. It provides pragmatic advice on how to reduce the environmental footprint of products by taking the right decisions at the design stage. IEC 62075:2012 primary applies to audio, video, and ICT products, although it can also be used for its individual components and subassemblies. Requirements and recommendations for e.g. consumables include:

- chemical emissions,
- energy efficiency,
- hazardous substances/preparations,
- life cycle aspects,
- material efficiency,
- noise emissions,
- product packaging.

The scope of this standard is restricted to criteria directly related to the environmental performance of the product.

b) IEC 62430

This standard specifies requirements and procedures to integrate environmental aspects into design and development processes of electrical and electronic products, including combination of products, and the materials and components of which they are composed. It is intended for use by all stakeholders involved in the design and development of electrical and electronic products, including those in the supply chain.

5.1.3 ISO/IEC

ISO and IEC created a joint technical committee, ISO/IEC JTC 1[10], to provide a single comprehensive standardization committee in which to address international Information Technology and Information and Communications Technology standardization for business and consumer applications. The JTC 1 Committee is one of the largest and most prolific technical committees in international standardization. It is globally recognized as the focal point of formal standardization in ICT, which encompasses all technologies for the capture, storage, retrieval, processing, display, representation, organization, management, security, transfer, and interchange of data information.

In development of ICT standards, ISO/IEC JTC 1 recognizes the importance of addressing environmental concerns (e.g., climate change, energy conservation, and impact on the environment), also recognizes that the ICT sector has a responsibility to minimize impact on the environment and that it is a mean to promote application of ICT technology to other sectors to encourage reduction in environmental impact by those sectors.

ISO and IEC have also published, in collaboration through the ISO/IEC JTC 1, some other "Green IT" standards, including:

- ISO/IEC 16317:2011, Information technology -- Telecommunications and information exchange between systems -- proxZzzy for sleeping hosts;
- ISO/IEC 19395:2015, Information technology -- Sustainability for and by information technology -- Smart data center resource monitoring and control;
- ISO/IEC 28360:2015, Information technology -- Office equipment -- Determination of chemical emission rates from electronic equipment.

They are also currently developing new International Standards concerning the energy efficiency of computing systems and data centers:

- ISO/IEC 30132 Information technology -- Information technology sustainability -- Guidance for the development, evaluation and application of energy efficient computing systems;
- ISO/IEC TR 30133, Information technology -- Data centers -- Guidelines for resource efficient data centers;
- ISO/IEC 30134 series of standards on Key Performance Indicators (KPI) for data centers.

This section details only the standards already published by ISO/IEC JTC 1.

a) ISO/IEC 16317

ISO/IEC 16317 was prepared by Ecma International (as ECMA-393) and was adopted by ISO/IEC as an International Standard. Because many electronic devices are always fully powered-on (instead of sleep modes) solely for the purpose of maintaining network connectivity a lot of energy is wasted. By using so-called "network proxy" for devices like notebooks, printers and game consoles much energy could be saved. This network proxy is a device that maintains network presence for a sleeping device (host) that does not necessary need to be powered-on all the time. The ISO/IEC 16317:2011 standard specifies the capabilities that a proxy may expose to a host, and the information that must be exchanged between a host and a proxy. It also specifies required and optional behavior of a proxy

[10] The reader is invited to visit the ISO/IEC JTC 1 webpage for additional information at http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/jtc1_home.htm

while it is operating, such as network packets handling and waking a host, next to the proxy behavior for 802.3 (Ethernet) and 802.11 (WiFi).

b) ISO/IEC 19395

The ISO/IEC 19395:2015 standard has originally been published by ECMA as ECMA-400. In many data centers management of IT, electrical power and cooling are still separate activities. The isolation of such "Resources" may result in sub-optimal solutions. This standard specifies "Messages" that are sent back and forth from a data center "Management function" to the data center "Resources".

The Messages facilitate integrated ("smart") monitoring and control of the Resources. The Resources consist of "Resource Components" that are grouped into IT, power and fluid domains. Messages can consist of commands, responses or events which are encoded in XML and exchanged in HTTP. The bottom-line objective of this standard is to minimize power consumption and thus contribute to environmental sustainable IT (Green IT).

c) ISO/IEC 28360

This standard specifies methods to determine the chemical emission rates from *Electronic Equipment* (such as consumer electronics and other ICT products) during intended operation in an Emission Test Chamber (ETC). The methods consist of preparation, sampling/monitoring in a controlled ETC, storage and analysis, calculation and reporting of emission rates.

Examples of consumer electronics that can be tested on its chemical emission rates are:

- Home video systems (TVs sets, satellite receivers and video recording equipment);
- Home audio and portable audio systems (amplifies, blue ray players, MP3 players);
- Computer systems (Monitors, computers, laptops and tablets).

The determined emission rates can be used to compare equipment in the same class and subsequently rank its Green IT-ness.

5.1.4 CENELEC

CENELEC[11], the European Committee for Electrotechnical Standardization, is a non-profit organization responsible for standardization in the electrotechnical engineering field and its members are national Electrotechnical Standardization Bodies from almost all European countries and a number of affiliates outside Europe. Together with the European Committee for Standardization (CEN) and ETSI, it forms the European system for technical standardization. CENELEC prepares voluntary standards, which help facilitate trade between countries, create new markets, cut compliance costs and support the development of a Single European Market.

The "EN 50600" series of standards on data centers, by the technical committee CLC/TC 215, are important for the Green IT topic.

In 2012, EN 50600-1 has been published, which deals with the issues to be addressed from a business risk and operating cost perspective. It makes a classification of data centers possible, based on "availability", "security" and "energy-efficiency" criteria. This European standard defines common

[11] For further information about CENELEC please visit http://www.cenelec.eu/aboutcenelec/whoweare/index.html

aspects of data centers including terminology, parameters and reference models and describes aspects required to support the effective operation of telecommunications within data centers. Furthermore EN 50600-1:2012 describes general design principles for data centers upon which requirements of the other EN 50600 series are based. The other standards in this series relate to construction, power distribution and environmental control topics. Six other standards in this series are under development (Table 4). They particularly concern the adoption of ISO/IEC 30134 series of International Standards that will define key performance indicators for data centers and the transformation of the "Best practices" document in support of the EU CoC on Data Centers into a Technical Report.

Reference.	Name	Status
EN 50600-1:2012	Part 1: General concepts	Published
EN 50600-2-1:2014	Part 2-1: Building Construction	Published
EN 50600-2-2:2014	Part 2-2: Power distribution	Published
EN 50600-2-3:2014	Part 2-3: Environmental control	Published
EN 50600-2-4:2015	Part 2-4: Telecommunications cabling infrastructure	Published
EN 50600-2-5	Part 2-5: Security systems	Approval stage
EN 50600-3-1	Part 3-1: Management and operational information	Approved
EN 50600-4-1	Part 4-1:Overview and general requirements for key performance indicators	Enquiry stage
EN 50600-4-2	Part 4-2: Key performance indicator PUE	Enquiry stage
EN 50600-4-3	Key performance indicator REF	Enquiry stage
EN TR 50600-99-1	Recommended practices for energy management	Enquiry stage

Table 4 Data center facilities and infrastructures

5.1.5 ETSI

The European Telecommunications Standards Institute (ETSI)[12] is officially recognized by the European Union as a European Standardization Organization. It produces globally applicable standards for ICT including fixed, mobile, radio, and broadcast networks and internet technologies. ETSI[13] is an independent, non-profit, standardization organization in the telecommunications industry. In particular, ETSI is involved in Smart ICT standardization with activities regarding, for example, Internet of Things, Smart Cities, Cybersecurity or Green ICT. Furthermore, ETSI is in charge of developing all standards related to spectrum management and electromagnetic computability used in European law.

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[12] Since 2015, ETSI has become a partner of the ILNAS-UL university certificate Smart ICT for Business Innovation (we refer the reader to http://www.portail-qualite.public.lu/fr/normes-normalisation/education-recherche/projets-phares-dans-l_education-a-la-normalisation/index.html or http://smartict.uni.lu for more information)

[13] Please visit ETSI website at http://www.etsi.org/ for further information.

ETSI is working to define the best environmental practices for telecommunication equipment and infrastructures in different situations. For example, many of the standards and specifications produced by the ETSI Environmental Engineering committee (TC EE) are aimed at improving the energy efficiency and the environmental impact of ICT equipment. ETSI has also been defining the complete life cycle for ICT goods, networks and services. This definition is useful in making assessments of the environmental aspects of a product in the various phases of its life cycle.

Recently, ETSI focused on the development of standards in support of European Commission (EC) Mandate 462 on energy efficiency in fixed and mobile information and communication networks. The work has been carried out in cooperation with ETSI Technical Committee "Access, Terminals, Transmission and Multiplexing (ATTM)" and CEN and CENELEC. This is in addition to standardization in support of the regulations related to EC Directive on energy-related products such as the regulation on network standby mode power consumption.

The ES 205 200 series of standards from ETSI, are of interest given the subject of Green IT. They have been produced by ATTM and cover operational energy management and sustainability of broadband access networks and its data centers.

In order to bring energy consumption down, telecommunication actors should implement measures to monitor and act upon energy usage of broadband networks and sites related to those networks (operator sites, operator data centers, customer data centers, etc. These standards will assist in defining metrics (KPIs) that enable energy usage to be managed more effectively. The intention of these documents is to:

- create operational infrastructure architectures and network implementations that consume energy more efficiently;
- define and realize objectives for other environmental aspects of sustainability for operational broadband networks and its data centers.

The series consists of three parts:

No.	Part	Details
ETSI ES 205 200-1	Part 1: "General requirements	Sub-part 1, a guidance document is in preparation to explain the purpose of the series to non-experts
ETSI ES 205 200-2	Part 2: "Specific requirements";	Sub-part 1: Data centers, Sub-part 2: Fixed (excluding cable) access networks; Sub-part 3: Mobile access networks; Sub-part 4: Cable Access Networks.
ETSI ES 205 200-3	Part 3: "Monitoring of sustainability";	Several parts are in preparation and will define actions for monitoring sustainability

Table 5 The ETSI ES 205 200 series of standards

Part 1 describes general requirements, and specifies Key Performance Indicators (PKI) and its usage in relation to the common objectives of operational energy management. The common objectives relate to energy consumption, task efficiency, energy re-use and renewable energy. The general requirements for all KPIs deal with the infrastructure scalability and infrastructure evolution; formulae and definitions of terms; and measurement points and procedures. Part 2 defines the KPIs and describes how these KPIs are to be applied, including the support for future regulatory objectives. Part 3 deals with monitoring of sustainability for the above mentioned infrastructure, and is in preparation.

Moreover, ETSI has launched in 2011 an Industry Specification Group (ISG) on "Operational energy Efficiency for Users" (OEU) with the goal to create Global Efficiency Indicators for environmentally efficient ICT, e.g. infrastructure, equipment and software within data centers and networks taking into account at least power consumption and greenhouse gas emission. This group has already published several Group Specifications[14] and is always working on several deliverables:

Reference.	Name	Status
ETSI GS OEU 001 V2.1.1 (2014-12)	Operational energy Efficiency for Users (OEU); Global KPIs for ICT Sites	Published
ETSI GS OEU 002 V1.1.1 (2015-06)	Operational energy Efficiency for Users (OEU); Energy Consumption Measurement of Operational Technical Equipment of Copper and Optical Fixed Access	Published
ETSI GS OEU 006 V1.1.1 (2015-06)	Operational energy Efficiency for Users (OEU); Referential specification to define sustainable levels of ICT Sites	Published
ETSI GS OEU 008 V1.1.1 (2013-09)	Operational energy Efficiency for Users (OEU); Global KPI for Information and Communication Technology Nodes	Published
ETSI GS OEU 012 V1.1.1 (2015-10)	Operational energy Efficiency for Users (OEU); Technical Global KPIs for Fixed Access Networks	Published
ETSI GS OEU 017 V1.1.1 (2015-10)	Operational energy Efficiency for Users (OEU); Referential specification to define sustainable levels of Fixed Broadband access networks	Published
ETSI GS OEU 003	Operational energy Efficiency for Users (OEU); Energy Consumption Measurement of Operational Information Technology Servers	Technical Board adoption of the Work Item
ETSI GS OEU 005	Operational energy Efficiency for Users (OEU); Monitoring of Global KPI of Green Data Centers	Early draft
ETSI GS OEU 009	Operational energy Efficiency for Users (OEU); Global KPI Modelling for Green Smart Cities	Early draft
ETSI GS OEU 014	Operational energy Efficiency for Users (OEU); Storage in ICT sites; Fire extinguishing & Alarm systems; Issues & proposal of efficient solutions	Early draft
ETSI GS OEU 016	Operational energy Efficiency for Users (OEU); Energy Consumption Measurement of Operational Information Technology memory units	Early draft
ETSI GS OEU 018	OEU Management of end of life of ICT equipment	Stable draft

Table 6 ETSI Group Specifications - Operational energy efficiency for users

5.1.6 ITU-T

The International Telecommunication Union (ITU)[15] is the United Nations specialized agency for information and communication technologies and is also working in the field of sustainability and IT. ITU-T is the standardization branch of ITU and develops standards called ITU-T recommendations.

[14] These ETSI Group Specifications are freely available on the ETSI website: http://www.etsi.org/

[15] More information is available at http://www.itu.int/en/ITU-T/about/Pages/default.aspx

It is also responsible for studies on methods to evaluate the effect of IT on climate change. By raising awareness of the role of IT in tackling environmental challenges, the ITU-T Study Group 5 (SG5) promotes innovative ICT solutions to environmental issues. It develops Green IT standards for using ITs in an eco-friendly way in order to support a sustainable future in a number of areas, including:

- Assessment of environmental impact of IT
- Climate change adaptation and mitigation
- Energy efficiency
- E-waste
- Smart Sustainable Cities
- Smart Water Management

Examples are to promote the reuse with universal chargers for mobile phones and to reduce effects of e-waste through of recycling IT. In Table 7 the current recommended Green IT standards of ITU are listed[16].

Rec. No.	Title	Status and approval date
L.1000	Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices	Approved 2011-06-13
L.1001	External universal power adapter solutions for stationary information and communication technology devices	Approved 2012-11-29
L.1002	External universal power adapter solutions for portable information and communication technology devices	Consented / Determined Not yet approved
L.1005	Test suites for assessment of the universal charger solution	Approved 2014-02-13
L.1010	Green battery solutions for mobile phones and other hand-held information and communication technology devices	Approved 2014-02-13
L.1100	Procedure for recycling rare metals in information and communication technology goods	Approved 2012-02-22
L.1101	Measurement methods to characterize rare metals in information and communication technology goods	Approved 2014-03-22
L.1200	Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment	Approved 2012-05-29
L.1201	Architecture of power feeding systems of up to 400 VDC	Approved 2014-03-01
L-1202	Methodologies for evaluating the performance of an up to 400 VDC power feeding system and its environmental impact	Approved 2015-04-22
L.1300	Best practices for green data centers	Approved 2014-06-29
L-1301	Minimum data set and communication interface requirements for data center energy management	Approved 2015-05-07
L.1310	Energy efficiency metrics and measurement methods for telecommunication equipment	Approved 2014-08-22
L.1320	Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centers	Approved 2014-03-22
L-1321	Reference operational model and interface for improving energy	Approved

[16] Details can be found at (http://www.itu.int/net/ITU-T/lists/standards.aspx?Group=5&Domain=28).

	efficiency of ICT network hosts	2015-03-01
L-1330	Energy efficiency measurement and metrics for telecommunication networks	Approved 2015-03-01
L.1340	Informative values on the energy efficiency of telecommunication equipment	Approved 2014-02-13
L.1400	Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies	Approved 2011-02-22
L.1410	Methodology for Environmental Life Cycle Assessment (LCA) of information and communication (ICT) goods, networks and services	Approved 2014-12-07
L.1420	Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations	Approved 2012-02-06
L.1430	Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects	Approved 2013-12-13
L-1440	Methodology for environmental impact assessment of information and communication technologies at city level	Approved 2015-10-23
L.1500	Framework for information and communication technologies and adaptation to the effects of climate change	Approved 2014-06-22
L.1501	Best practices on how countries can utilize ICTs to adapt to the effects of climate change	Approved 2014-12-22

Table 7 Green IT standards of ITU

The ITU-T also published a Green IT Toolkit on environmental sustainability for the ICT sector (ITU, 2012). By means of international standards and guidelines it supports ICT companies on how to build sustainability into their operations and management. The Toolkit consists of six documents that cover the following topics (see Table 8).

Topic	Details
Sustainable ICT in corporate organizations	Focuses on the main sustainability issues that ICT 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	Focuses on building sustainable products through the use of environmentally-conscious design principles and practices, covering development and manufacture, through to end-of-life treatment.
Sustainable buildings	Focuses on the application of sustainability management of buildings for as ICT companies through the stages of construction, lifetime use and de-commissioning.
End-of-life management	Covers the various end-of-life stages and the accompanying legislation and provides support in creating a framework for environmentally-sound management of end-of-life ICT equipment.
General specifications and key performance indicators	Focuses on matching environmental KPIs to an organization's specific business strategy and targets, and creating standardized processes to ensure KPI data is useful to management.
Assessment framework for environmental impacts	Explores how various standards and guidelines can be mapped in order for an organization to create a sustainability framework relevant to its business objectives and desired sustainability performance.

Table 8 Green IT Toolkit on environmental sustainability for the ICT sector (ITU, 2012)

Each document focuses per topic on the available standards, guidelines and methods. It also includes a checklist for sustainability practitioners to assist them throughout the Green IT endeavor.

5.2 Fora and Consortia

5.2.1 ECMA

ECMA (European Computer Manufacturers Association) International [17] is an industry consortium that is dedicated to standards in ICT and Consumer Electronics (CE). For the subject of Green IT the standards from the category of "Energy Efficiency and Environmental Conscious Design" are the most relevant[18].

In Table 9 the standards of this category are listed and some have been adopted under a "fast-track procedure", by ISO/IEC or IEC.

No.	Name	Short description	Version
ECMA-328	Determination of Chemical Emission Rates from Electronic Equipment	Specifies methods to determine chemical emission rates from ICT & CE equipment during intended operation in an Emission Test Chamber (ETC). *Note: has been adopted as ISO/IEC 28360:2015*	6th edition (December 2013)
ECMA-341	Environmental Design Considerations for ICT & CE Products	Specifies requirements and recommendations for the design of environmentally sound products. *Note: has been adopted as IEC 62075:2012*	4th edition (December 2010)
ECMA-370	"THE ECO DECLARATION - TED".	Specifies environmental attributes and measurement methods for ICT and CE products according to know regulations, standards, guidelines and currently accepted practices.	4th edition (June 2009)
ECMA-383	Measuring the Energy Consumption of Personal Computing Products	Complements ECMA-341 by defining a method on how to measure energy consumption of products and provides categorization criteria to allow energy consumption comparisons of similar products.	3rd edition (December 2010)
ECMA-389	Procedure for the Registration of Categories for ECMA-383	Specifies the procedure to be followed by the Registration Authority in preparing, maintaining and publishing International Registers of desktop, notebook and Ultra Low Energy computer categories for use with ECMA-383	2nd edition (December 2009)
ECMA-393	proxZzzy™ for sleeping hosts	Specifies maintenance of network connectivity and presence by proxies to extend the sleep duration of electronic devices for maintaining network connectivity. *Note: has been adopted as ISO/IEC 16317:2011*	2nd edition (June 2012)
ECMA-400	Smart Data Centre Resource Monitoring and Control	Models IT & facility equipment, systems and components in Smart Data Centre as Resources, organizes the resources in a graph, and specifies the semantics of messages for commands, responses and events. *Note: has been adopted as ISO/IEC 19395:2015*	2nd edition (June 2013)

Table 9 ECMA "Energy Efficiency and Environmental Conscious Design" standards

[17] http://www.ecma-international.org/

[18]These are freely available at: http://www.ecma-international.org/publications/standards/Stnindex.htm

5.2.2 IEEE

Also the Institute of Electrical and Electronics Engineers (IEEE, a not-for-profit professional organization)[19] has a number of standards that cover the theme of sustainability and IT.

It has 19 active *Green and Clean Technology Standards*, guides and practices of which the IEEE Std 1680 "Environmental Assessment of Electronic Products " and IEEE Std 1888 "Ubiquitous Green Community Control Network Protocol" are the most relevant (Table 10). In this group of standards also includes Std IEEE 2030, which provides alternative approaches and best practices for achieving Smart Grid interoperability.

1680-2009 - Environmental Assessment of Electronic Products • 1680.1-2009 - Environmental Assessment of Personal Computer Products, Including Notebook Personal Computers, Desktop Personal Computers, and Personal Computer Displays • 1680.2-2012 - Environmental Assessment of Imaging Equipment • 1680.3-2012 - Environmental Assessment of Televisions
1888-2014 - Ubiquitous Green Community Control Network Protocol • 1888.1-2013 - Ubiquitous Green Community Control Network: Control and Management • 1888.2-2014 - Ubiquitous Green Community Control Network: Heterogeneous Networks Convergence and Scalability • 1888.3-2013 - Ubiquitous Green Community Control Network: Security
2030-2011 - Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads

Table 10 The Green IT standards of IEEE

In the remainder of this subsection some specifics on the IEEE standards 1680 and 1888 will be provided:

- IEEE Std 1680 gives guidance and implementation procedures for the IEEE 1680 family of standards. It also provides methods by which manufacturers may declare their products as conforming with these standards and by which such conformance may be verified. These standards provide consistent performance criteria for the design of the products in scope. This allows gaining market recognition for efforts to reduce the environmental impact of these electronic products. Stakeholders of these standards include, next to product manufacturers, government, institutional, and corporate purchasers.

- IEEE Std 1888 is also a family of standards that cover a number of areas in facility networking infrastructure. The base standard defines the architecture and exchange protocols over IPv4/v6 based networks, whereas the other standards are extensions and describe network gateway access, control, and management; specify the requirements of network convergence; and enhance the network security management capabilities. The IEEE 1888 family of standards is called "Green" as these allow securely and efficiently interoperation with heterogeneous access networks and improve the flexibility, scalability and manageability of IEEE 1888 systems.

[19] https://www.ieee.org/about/index.html

6. EU regulation: Eco-management and Audit Scheme (EMAS)

An important environmental management tool for organizations to prove their commitment to sustainability (and application of Green IT and/or Green IS) is the *Eco-Management and Audit Scheme* (EMAS). EMAS [20] is an EU regulation developed by the European Commission which enables organizations to assess, manage and continuously improve their environmental performance. The objective of EMAS is twofold: 1) organizations can improve their environmental and financial performance, and 2) organizations can communicate their environmental achievements to stakeholders and society in general. Although EMAS is an official EU regulation, it is binding for those organizations only that voluntarily decide to implement this scheme.

The first EMAS regulation, originally restricted to companies in industrial sectors, was adopted in 1993 and became operational in 1995. In 2001 a second version was launched that integrated the environmental management system requirements of ISO 14001. In addition, indirect effects were included such as ones related to planning decisions and finance. The current revision of EMAS (version 3) dates from January 2010 and has introduced obligatory Key Performance Indicators (KPI) to harmonize reporting on environmental performance. EMAS is no longer limited to EU member states only and is globally applicable.

Because the requirements of ISO 14001:2004 "Environmental management systems" are an integral part of EMAS, organizations that comply with EMAS automatically comply with the requirements of ISO 14001. But organizations that meet the EMAS requirements go even beyond the scope of ISO 14001, as EMAS takes into account additional elements to support organizations in continually improving their environmental performance (see Figure 6).

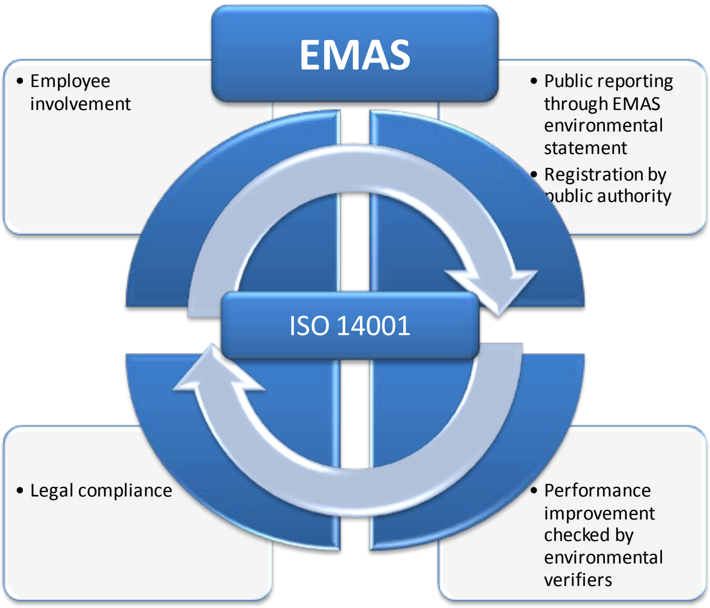

Figure 6 Scope of EMAS

[20] Source: http://ec.europa.eu/environment/emas/about/summary_en.htm

In addition, EMAS registered organizations can relatively easy apply for the ISO 50001 certification "Energy management systems". EMAS already fulfils most of the formal and content requirements, and organizations have to make only minor changes and additions to their EMS as to comply with ISO 50001. These changes relate to specific additions of energy management topics in their EMS and a few structural adaptations.

7. Conclusions and outlook

The combination of sustainability and IT is promising and is getting more and more attention at governments, businesses, individuals and the society as a whole. Sustainability involves a development that meets human needs today in the broader social-economic and environmental context, without compromising the ability of future generations to meet their own needs. Information technology can be used to reduce the environmental footprint of the IT industry (Green IT) and is a means to reduce the environmental impact of products and services that require IT or also those that can benefit from IT (Green IS).

Examples of Green IT include:

- Lower energy consumption throughout the life cycle of IT hardware;
- Software algorithmic efficiency improvements to minimize the amount of IT resources required;
- E-waste reduction (including toxic materials) by using materials that can be easily recycled and have low environmental impact.

Examples of Green IS include:

- Collaboration software and teleconferencing systems to reduce negative environmental impacts associated with commuting;
- Information systems to track and trace environmental variables such as waste, emissions, toxicity, energy and water consumption;
- Supply chain systems to optimize product routing in to reduce the amount of consumed fuel when transporting products.

Pressure and drivers that apply to organizations originate from legislative bodies, value chain partners and customers. However, companies should treat environmental investments as an economic and competitive opportunity, not as an annoying cost or an inevitable threat. Recognizing the potential value and opportunities of sustainability benefits from Green IT and IS should first be identified before such an initiative will be adopted unequivocally. Subsequently, the Green IT/IS strategy must be embedded into overall strategies.

Four Green IT and IS strategy types were discussed, in increasing order of ambitions: 1) eco-image: company image-oriented only; 2) eco-efficiency: control and prevent; 3) eco-equity: product stewardship; 4) eco-effectiveness: sustainable development. Organizations have to proactively measure and report their Green IT/IS outcomes and check those against required results. Ideally these are a combination of:

- Economic benefits, such as product and service differentiation, cost reduction and corporate brand enhancement;
- Environmental benefits, such as lower energy and water consumption, improved materials recycling and pollutant reduction;
- Social benefits, such as increased worker satisfaction, improved work-life balance, and higher life quality.

To achieve the goals of sustainability, such as energy and waste reduction, pollution prevention environmental protection, a number of IT technologies are available, such as Cloud Computing, sustainable Data Centre design, Smart Grids, Teleconferencing and Telecommuting. These technologies are guided and supported with various international, national, industry and other standards. The most important ones related to the topic of IT and environmental sustainability are available from the following organizations:

- ISO - International Organization for Standardization
- IEC - International Electrotechnical Commission
- ETSI - European Telecommunications Standards Institute
- ITU - International Telecommunication Union
- ECMA - European Computer Manufacturers Association
- IEEE - Institute of Electrical and Electronics Engineers

Most prominent are the Environmental Management System (EMS) standard ISO 14001, the Energy Management System standard ISO 50001, the Green IT standards for power adapters and chargers of the International Telecommunication Union and the IEEE standard 1680 "Environmental Assessment of Electronic Products". In addition there exist environmental management tools for organizations to prove their commitment to sustainability and application of Green IT and/or Green IS. For example, the Eco-Management and Audit Scheme (EMAS) is an EU regulation of voluntary application developed by the European Commission that enables organizations to assess, manage and continuously improve their environmental performance.

Although EMS standards or Environmental Management audit schemes can bring many benefits to companies today; it will be a matter of time until such practices will become a "license to operate". As firms within an industry sector adopt Green practices, the "beyond compliance" frontier moves further, and what was once a differentiator (such as a certified EMS) becomes a given. Nevertheless, a cleaner environment and more sustainable growth has then been established which was the objective of Green IT and IS in the first place.

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ANEC

AGENCE POUR LA NORMALISATION ET L'ÉCONOMIE DE LA CONNAISSANCE

CONTACT:

ILNAS / ANEC

Southlane Tower I

1, avenue du Swing

L-4367 Belvaux

Phone: (+352) 24 77 43 70

Email: anec@ilnas.etat.lu

www.portail-qualite.lu