EcoSoft: Proposition of an Eco-Label for Software Sustainability

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Abstract. There is an increasing interest in corporate sustainability and how companies should include it to satisfy user's requirements concerning social, economic, and environmental impacts. Research about sustainability in computer science aims to offer methods, techniques and tools to lessen the impact of new technologies on the environment, to offer a better world, a smarter life, to the next generations. Information systems must participate in the collective effort to move towards sustainable development, and software and application companies must lead a CSR strategy to achieve this aim. Moreover, beyond an individual company approach, sustainability should be seen as an integral quality of any software (as well as safety, performance or reliability). All of this seem obvious at a time when applications and programs of all kinds are ubiquitous in everyday life. Nevertheless, the challenges of sustainable development have still not been considered in certain key sectors such as the development of information technology. A lot of ecolabels exist for a lot of different products, although not for software sustainability. We propose in this work an ecolabel for software sustainability, based on a set of relevant criteria found in different works.

Keywords: Sustainability · Ecolabel · Software

1 Introduction

The 21st century is a period of new technologies and could be called the digital age. It is also a period that is very affected by sustainable development issues that apply to all aspects of our society. Information technologies, because of their importance, do not escape preoccupations and questions as to their role and responsibility in developing a more respectful and sustainable economic model. As defined for the first time in 1987 in the Brundtland Report, «humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. This involves a gradual transformation of the economy and society across the spectrum of sustainability.

As a result, international communities have become aware of the need to control greenhouse gas emissions, which are the main drivers of climate change, and therefore to reduce energy consumption and carbon footprint globally [2]. In this context, information technologies have an ambivalent role: they reduce the impact on the

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environment in certain contexts of use, notably through virtualization or business process optimization. However, in other cases they are themselves responsible for negative effects on the environment, such as the very energy-intensive use of data centers [3]. This global dematerialization continues, particularly with the transition to the cloud, making IT responsible for 10% of global electricity consumption in 2017 [4]. Information technology must therefore be fully considered in sustainable development actions and more particularly in companies social and environmental responsibility (CSR) strategies. It is therefore essential to be able to provide models, methods and tools which allow, first, to measure and assess the impact of technologies on the environment, and then, second, to be able to apply tools in the development process of these technologies in order to improve their sustainability.

Research on information technology and computer science in general aims to make technologies more efficient and efficient, to create a smarter planet [5]. In this new business model, the sustainability aspect is more rarely considered. Sustainable development efforts in the information technology sector have so far focused on infrastructure (data centers) and the manufacturing of hardware [6]. The data centers are particularly targeted by the objectives of reducing energy consumption in the IT sector, considering both their importance in the infrastructure of enterprises and their data, and their considerable energy requirements. In 2012, the European Union even took the lead by launching a project called GAMES (Green Active Management of Energy in IT Service centers), which aims to develop a set of tools, methods and techniques for managing the energy performance of next-generation data centers [7]. For both data centers and other information technology infrastructure and services, the source of energy consumption is in the software layer [8]. As a result, a reduction in the resource consumption of software components leads to a reduction in the electricity consumption of computer equipment. The software layer is therefore an important if not crucial lever in reducing ICT energy consumption.

Since 2010, there has been growing interest in research on the concept of sustainability in computer engineering, but sustainable development applied to information technology remains a less important topic [9]. Nevertheless, the ever-increasing number of scientific publications on the subject shows that researchers are interested in defining and developing concepts for sustainability in software engineering. This includes characterizing models, methods and tools to reduce the life cycle impact of software products and their development.

The definition of sustainability in software engineering brings together several possible characterizations but we will retain the following one for the continuation of this work. "Sustainable Software is software, whose impacts on economy, society, human beings, and environment that result from development, deployment, and usage of the software are minimal and/or which have a positive effect on sustainable development." [10].

In this paper, we will focus on the environmental sustainability framework. The impact of new technologies on the environment is rather ambiguous because, as stated earlier, they can be both a benefit and a harm. For a more in-depth analysis of their impact, it is also necessary to consider the different phases of their life cycle and the effects associated with them: the effects due to the production of information technology, effects due to their use and systemic effects.

- Production effects consider the use and consumption of natural resources, as well as pollution associated with the extraction of raw materials and end-of-life electronic waste.
- The effects of use concern the positive indirect effects of their use, such as process optimization and product virtualization and simulation, and thus the conservation of natural resources.
- The systemic effects concern the long-term indirect effects resulting from the use of information technology, such as changing lifestyles that encourage stronger economic growth leading to a rebound effect as resource consumption increases.

These effects on the environment, in order to be controlled, must be measured and evaluated and therefore monitored by companies. It is the commitment of these companies to contribute to the sustainable development of their information systems and technologies that is crucial.

Companies and organizations, by their place in society, have social responsibility for their practices and the effects they have on society [11]. Their activities and decisions directly influence the economy, making their commitment to sustainable development all the more important in reducing the digital environmental footprint. To help and encourage companies to become more involved in social responsibility, ISO 26000 was created in 2014 to provide guidelines for the implementation of sustainable practices. Sustainability is approached in a multidimensional way around 7 areas of action: communities and local development, human rights, relations and working conditions, consumer issues, the loyalty of practices and the environment. On the occasion of the Horizon 2020 program for research and innovation, the European Commission has also launched a platform providing information technology companies with a set of tools and methodologies to assess the energy consumption and the carbon footprint associated with technologies they use and develop[1]. This initiative aims to encourage companies to move towards eco-design by developing software solutions that use fewer resources and have a longer lifespan. Companies, in particular software publishers, must be responsible for the management of their information systems and the programs they sell to their customers.

The sustainable development strategy for companies is increasingly an important competitive advantage for their growth, particularly because of the influence it has on their brand image. In addition to financial gains, such as reducing energy bills, this gives them an image of responsibility that is increasingly important for consumers. The benefits of a sustainability policy convince an increasing number of structures to integrate CSR objectives into their business models [12]. In particular, new technology companies are a real lever for reducing the consumption of energy resources, and even more for reducing the environmental impacts of ICT [13].

So, the problem today is the lack of clear consensus and definitions about sustainability in software engineering. In order to move towards sustainable development, information systems must participate in the collective effort and software and application companies must pursue a CSR strategy geared to the sustainability of software development. So how can sustainability be integrated into software development?

[1] https://ictfootprint.eu/.

More specifically, how can ecodesign be integrated into software and application development?

We will be looking at the concept of software eco-design as a way to make the software layer of new technologies more environmentally friendly. It will be a question of how digital players, whether government, organizations, businesses or users, can make software and applications more sustainable, particularly in terms of energy efficiency.

This work will first look at the related works in the field of ecolabeling. Then, the proposed EcoSoft label is presented with all the defined criteria in Sect. 2. We conclude in Sect. 3.

2 Related Works

More and more consumers are considering the ecological dimension of the products they buy and use in line with the growing interest in environmental issues [13]. Eco-labels were then introduced to meet this demand, with more than 450 consumer labels worldwide awarded by governments, organizations or consumer associations in 2016 [14]. These labels help consumers to identify more responsible products and to choose according to criteria that integrate environmental quality. Labels, especially if assigned by official authorities, are a guarantee of consumer confidence and credibility [15].

An eco-label is a quality label that certifies that a product or service has a reduced impact on the environment. It aims to “promote the design, production, marketing and use of products with less impact on the environment throughout their life cycle” and “better inform consumers of the effects of products on the environment, without compromising the safety of the product or workers, or significantly affecting the qualities that make the product suitable for use”[2].

An eco-label may certify products and services of different categories which comply with certain ecological criteria. For example, we find labels for food (Organic Agriculture label), textile (GOTS label[3]), tourist accommodation (Panda Gîte label[4]), electronic devices (Energy Star label[5]), wood (FSC label[6]) or cosmetics (label Cosmebio[7]).

The award of an eco-label is usually based on a balance record and a life cycle analysis of the product carried out by a national or international public entity, or delegated to an independent accredited entity. It may be evidenced by a distinguishing sign such as a pictogram on the product, a label or a name in order to be easily identified by the public and consumers.

[2] http://www.ecolabels.fr/fr/espace-consommateurs/les-ecolabels.

[3] https://www.global-standard.org/fr/.

[4] https://ecotourisme.gites-de-france.com/notre-demarche-panda.html.

[5] https://www.energystar.gov/.

[6] https://fr.fsc.org/fr-fr.

[7] https://www.cosmebio.org/en/.

There are a multitude of labels related to ICT products. The multiplicity of products and the complexity of production chains make it difficult to create a single label. Labels are classified according to their type, that is to say to which organization they come from, by which standards they are regulated. There are currently three different types of labels that can attest to the ability of products to comply with a sustainability approach by certifying that the environmental impacts of the labelled products are low compared to those of other products on the market.

Type 1 brings together official labels, that is to say they are proposed by local authorities (state, European Union), public interest groups (AFNOR – the French standards association, for example) or self-reported by an ONG. These labels under ISO 14024 meet strict specifications and their certification is regularly reviewed by independent certifiers. They consider the entire product life cycle (LCA approach). The best-known type 1 ecolabels are the European ecolabel, the NF French environment label, the Blue Angel of German origin (focuses on health, climate, water, and resources) and the International Energy Star, for the energy efficiency of products. The TCO label adds a humanitarian aspect to the environmental aspect since it certifies the creation of products minimizing the impact on human health.

The self-declarations correspond to the Type 2 eco-labels. They fall under ISO 14021 and are developed under the responsibility of companies alone. In general, they concern only part of a product's life cycle or relate to a single environmental characteristic of the product. The associated standard frames self-declarations by specific criteria: it must not be misleading, be clearly presented, be verifiable, etc. The best known is the EPEAT label created in the United States by the Green electronic Council which allows companies to evaluate IT equipment according to their eco-characteristics. This label is now used worldwide by a large number of companies. The ECMA-370 standard provides a system of measures and environmental features to help companies in the ICT sector in the creation of self-declarations.

Ecoprofiles are type 3 eco-labels, covered by ISO 14025. Their allocation is the result of a LCA and allows a comparison between products of the same category at the level of resource consumption, greenhouse gas emissions, and waste.

In the field of new technologies, labelling is difficult to achieve because of the virtual dimension of products (software, applications, websites) which makes users believe that they have no impact on the environment. It is therefore important to add value to software that is developed in a sustainable way, and labeling is a way to give them more visibility. By engaging in the implementation of digital technology certifications and labels, governments, particularly at European and global levels, would help legitimise software eco-design in the eyes of users. Companies that make the effort to achieve a sustainable strategy in the development of their products also gain credibility compared to their competitors when this approach is formally recognized [16]. A sustainability label for digital software and services such as EcoSoft would therefore serve this objective of bringing more visibility and therefore credibility to ecodesign in the software field. [17] proposes a discussion about the labelisation of sustainable software products and websites and list a set of possible criteria that can be applied by separating them in different types. Criteria for green web content management systems and web applications can be found in [18].

3 EcoSoft, an Eco-Label for Software Sustainability

We propose the establishment of a sustainability label for software that would allow users to choose programs and applications based on their impact on the environment. This label would be a way for consumers to easily identify the most durable software and thus be able to limit their carbon use as users. It is also an approach that helps to make the company aware of the environmental impacts of digital software and services and to be able to implement a commitment to sustainable development. The company reduces its software footprint and at the same time promotes its image through this eco-design approach.

Like the Energy Star label on energy-efficient electronic devices, the EcoSoft label would serve to inform about the voluntary commitment made by designers on the energy efficiency of software on a computer, a tablet or smartphone according to several criteria. It would be valid for a period of 2 years, maximum duration given the many developments and updates that occur in the life of a software or application. The software or web application would be given a distinctive logo to make its certification visible. There is a similar project for eco-design of websites in particular called Green Code Label[8] which labels websites developed according to web design methods. However, there is no European or international label that certifies the sustainability of an application service. Indeed, the official eco-label of the European Union[9] does not certify digital products and services, which would make the EcoSoft label a reference in the field of sustainable software certification.

A software labeled EcoSoft must meet sustainability criteria. It must have been developed in accordance with software ecodesign techniques by integrating the tools and methods of sustainable management of the complete product life cycle. EcoSoft is a multi-criteria label, that is to say that its awarding is based on the respect of a set of predefined criteria, and therefore it could not be granted on the basis of a single criterion. Digital softwares, applications and services of all categories and types can be certified. There are also no restrictions on the source of the program.

Following the Greensoft model [19], a software can be analyzed according to the three phases of its life cycle: the development phase, the usage phase, the end-of-life phase. Our EcoSoft label will use criteria than can be classified following these three phases, as shown in Table 1. However, on the contrary of the Greensoft model, our eco-label will only specifically address criteria concerning software. It will not take into account the criteria relating to the energy consumption of computers and other hardware machines, as well as the energy required for the company's infrastructure. In this work, we have choose criteria into the two facets of sustainability defined by [20]: the sustainability BY the software (ICT4Green) and the sustainability IN the software (GreenIT).

[8] https://label.greencodelab.org/.

[9] Site officiel écolabel européen: http://ec.europa.eu/environment/ecolabel/eu-ecolabel-products-and-services.html.

Table 1. EcoSoft criteria.

Development phase	
Sustainable documents	Download size
Sustainable specification	Hardware requirements
Code optimization	Green analysis efficiency
Usage phase	
Accessibility	Material resource consumption
Usability	Backup size
Energy efficiency at running time	
End of life phase	
Data conversion to the future	Long-term data storage
Software or application	Packaging and manuals

This section presents all the criteria listed in Table 1. Each criteria is described with two possible values, the first one indicates that efforts have been done to obtain a sustainable software, although the second one indicates the contrary. The awarding of the label should mean that all criteria of the list are respected.

3.1 Development Phase

The criteria for the conception and design phase are the following.

Sustainable documents {up-to-date and integrating sustainable techniques; outdated or not sustainable}
The creation and/or provision of reference documents in ecodesign to stakeholders have to be taken into account. This criterion comes before the start of the project. In the design phase, it is a question of being able to provide project stakeholders with reference material enabling them to integrate sustainable design techniques in the form of good practices, recommendations, checklists, examples of implementation, etc. It also take into account the maintainability of the software in order to analyse and change files in an effective and efficient way, regarding the source code but also the content [17]. This relates also to the modifiability criteria proposed in [21].

Sustainable specification {eco-designed specifications; no good practice application}
The software ecodesign is also based on a specification writing directed towards sustainability with precise functional specifications without unnecessary functionalities and without unnecessary data production [22]. The expression of adapted functional needs determines the quality of the software and in particular its efficiency. Indeed, every feature of the program consumes CPU and memory resources during use even if they are in the background [22]. The preliminary draft of the specifications should then include the drafting of a complete specification consisting of functional and technical specifications that comply with ecodesign standards, including clear modelling of the

program [19], for instance by using clear and precise UML specifications. As said in [23] a new form of requirements 'Environment Requirements' need to be added to the non functional usual requirements.

Code optimization {optimized; not optimized}
Programming of the software must be carried out in accordance with good ecodesign practices. Software ecodesign focuses on functional, graphic, ergonomic and technical design. In case of a software, we recommend that at least 2/3 of the techniques provided by the software ecodesign referential (in constant evolution)[10] should have been applied in order to value the criteria as 'optimized'. We propose to use a checklist to identify the used techniques. In case of an application, we recommend that at least 65 of the 115 best practices proposed [24] have been applied in order to value the criteria as 'optimized'. We propose to use the Opquast checklist[11] to work.

Download size {optimized; not optimized}
More and more software products are nowadays downloadable. We recommend that the size of the downloaded software should be optimized to the maximum [19]. Many techniques exist to reduce download size so they should be used to do it.

Hardware requirements {average configuration; powerful configuration}
End-user influence is high as nearly 90% of the energy used by ICT hardware can be attributed to the application software running on it [25]. As a result, it is necessary to maximize the hardware lifetime by its actual physical durability rather than forcing its obsolescenc by software platform requirements [21]. If the requirements needs too powerful hardware, it will induce the buying of new material to be able to run the software. It then must be able to operate with hardware that is at an average configuration compared to current standards to avoid replacement and new hardware purchases [19, 26]. This can be related to the Portability criteria of [21].

Green analysis efficiency
[27] proposes to add a green analysis stage to promote energy efficiency. It determines the greenness of each increment of the system that is developing. This stage acts like a testing stage but for energy efficiency. Metrics are used is this stage to perform the analysis (CPU usage, Green Performance Indicators, etc.).

3.2 Usage Phase

The criteria used for the usage phase are the following.

Accessibility {improved; not improved}
Software ecodesign also addresses the social dimension such as digital accessibility. Good development practices improve the user experience, especially for people with disabilities. For people with colour blindness, for example, graphs cannot be understood if colours cannot be identified. The software or application should then be

[10] Software ecodesign referential: https://collab.greencodelab.org/.
[11] https://checklists.opquast.com/fr/eco-conception/.

designed to comply with good accessibility practices to enable navigation for all audiences. We recommend to use the standards of W3C[12].

Usability {optimized, not optimized}
The software or application should be user-friendly [21]. If the customer satisfaction if high, the support cost is low. We recommend to use 2/3 of the usability guidelines proposed by [28].

Energy efficiency at running time {optimized; not optimized}
[29] states that efficiency defines how software behaves when it comes to saving resources. We recommend that the program must not have an eco-score of less than 70/100 on the Greenspector test[13] in order for the criteria to obtain the value «optimized» . This can be related to the performance criteria of [21].

Material resource consumption {optimized; not optimized}
It is important to identify the resource consumption of the various components of the software. In [30], the authors distinguish a set of software components to be analyzed in terms of energy consumption. For example, there is the software architecture, RAM, processor (also called CPU), storage or source code to take into account. For these energy consumption measurements, the code must be analysed with diagnostic tools to determine whether the ecodesign methods have been complied with, for instance PowerAPI [31], Greenspector[14], Intel SoC Watch[15], Chisel [32]. We recommend to use Greenspector and to obtain an eco score of more than 70/100 to the test (CPU, memory, mAh deload) for classifying the criteria as «optimized».

Backup size {optimized; not optimized}
It is possible to optimize the energy consumption necessary for the backup of software data or application over the long term. Reducing the number of backups can also be a possible optimization. By eliminating the problem of constantly backing up the same copy of a file again and again, data de-duplication can decrease backup storage consumption by 10 to 50 times compared to traditional tape-based backup methods. Since less data is sent across the infrastructure, data de-duplication also can reduce the bandwidth consumed by traditional network-based backups by up to 500 times [34].

3.3 End-of-Life Phase

The criteria used for the end-of-life phase are the following.

Data conversion to the future {OpenSource format; Proprietary format}
The data of the current program must be of a format allowing easy transfer to the future software (essentially open source formats), otherwise data can causes compatibility issues and energy and material resource consumption issues [19].

[12] https://www.w3.org/WAI/.

[13] https://greenspector.com/fr/product/.

[14] https://greenspector.com/fr/.

[15] https://software.intel.com/en-us/socwatch-help-energy-analysis-workflows.

Long-term data storage (back-up) {optimized, not optimized}
The energy consumption needed to back up software data or long-term application should be optimized [19]. Sometimes, legal regulations require long-term storage data and the backup storage size will increase.

Packaging and manuals {recyclable; not recyclable}
If the software or application contains a packaging and/or user manuals in paper form, these documents must be recycled [19].

4 Conclusion

The label we propose here is at the theoretical stage and has not yet been tested on practical cases. EcoSoft is an eco-label that takes into account the involvement of stakeholders (project manager, software architects, developers) in the process of integrating sustainability into the project. The three stages of the software's life cycle, namely the development, usage and end of life, are analyzed to determine the environmental impacts they generate. We focused the analysis on the energy consumption of software components, which is an important aspect for the overall quality of the software, especially for the user experience on the mobile device, but also because digital energy consumption has a high environmental footprint.

The field of software and its technologies is constantly evolving, especially in the forms that the software can take. In this sense, the label could evolve by adapting the criteria to the type of software analyzed in order to be able to take into account its specificities (application software, web applications, system software…).

Our future work will be to validate the chosen criteria with a set of professionals. Then to test these criteria on several softwares in order to define if they can be awarded the label EcoSoft.

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