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STUDY OF SUSTAINABILITY IN SOFTWARE ENGINEERING

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ABSTRACT

While building hardware and software products, there is a huge need for resources, thus it is necessary that Information Communication Technology (ICT) does it in a sustainable manner. For achieving this, ICT/IT have been dedicated to addressing the effects of hardware on the environment but little have been done considering the effects of building software product. The growing demand of more complex software applications has had a huge negative impact on the environment due to its increasing resource and power consumption. The effect of ICT on sustainable development especially on software is a crucial topic in Green Computing. Sustainable development refers to resource use for meeting the needs of humans while taking into account the ecological, economic, and societal impacts.

Keywords: Sustainable Development, Sustainability, Sustainable Software

I. INTRODUCTION

1.1 Sustainability in Software Engineering

Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. However sustainability in software is something towards which enough work is not done. The need for sustainability in Information and Communication Technology (ICT) has risen in the few years as the power consumption of data centres in the world has increased from 58 TWh in 2000 up to 123 TWh in 2005 and is still increasing [2]. Therefore there is need to either reduce the power consumption or to develop or use these data centres in a sustainable manner.

A variety of research work on sustainable ICT has mainly focused on environmental sustainability in terms of computer hardware. Issues related to energy consumption in software must be given prior importance in achieving green computing. Software features as well as hardware components are equally responsible for negative effects on environment. Software has an indirect effect on the environment by operating and managing the underlying hardware running it. Some software based solutions can monitor and utilize resources efficiently and others can be sustainable enough to limit the need of adding more hardware due to updates. Thus, software code must be created efficiently and its building process from requirement to disposal should be carried out in a sustainable manner.

1.2 Impacts of ICT on Environment

Sustainable software can be defined as software whose direct and indirect impacts on economy, society, human beings and environment that result from development, deployment and usage of the software are minimal and/or

which has a positive impact on these [2]. Direct impacts include energy and resource demand that is necessary for production, usage and disposal of the software product. Indirect impacts are effects that result from using the software product on other processes and long term systemic effects.

Berkhout and Hertin [3]identifiedthree main impacts of Information and Communication Technology (ICT) on the environment.These impacts are: first-, second-, and third-order impacts. There are negative as well as positive effects for these.

- First-order impacts are caused due to the production and use of ICT, resource use and pollution from mining, hardware production, power consumption during usage, and disposal of electronic equipment waste. There are positive effects as well such as ICT can be used for computerised monitoring of toxic emissions, remote sensing etc. These are direct effects.
- Second order impacts result indirectly from using ICT, like incomplete substitution of existing structures and activities e.g. the use of computers have supplemented paperwork rather than decreasing it. Positive effects are production processes and design and operation of products have become more efficient and intelligent, etc.
- Third-order impacts are long term indirect effects on the environment that result from ICT usage, like changing life styles promoting faster economic growth or rebound effect . These effects do not appear sequentially and are disconnected. Second-order effects are caused by the first-order effects and third-order effects can only appear as a result of second-order effects.

1.3 Aspects of Sustainability in the Software Lifecycle

Four aspects of sustainability in the software lifecycle had been distinguished by Penzenstadler [4]. The first two focus rather on the developing company and its processes, while the latter two have the system under development in scope.

•Development process aspect - Sustainability in the initial software development process with responsible use of ecological, human, and financial resources. For example, Naumann et al. proposed guidelines for environmentally sustainable web development [5]. Lago et al. proposed to measure the environmental impact of software services by their energy consumption [6].

•Maintenance process aspect - Sustainability of the software during its maintenance period. This includes continuous monitoring of quality and knowledge management. For example, Albertao measures sustainability performance of a software project according to standard quality properties [7].

•System production aspect - Sustainability of the software system as product with respect to its use of resources for production, for example, by using sustainably produced hardware components. ISO 14001 Environmental System Management Standard [8] is anadministrative tool for strategic sustainable development, which is embedded into a framework by MacDonald [9].

•System usage aspect - Sustainability in the usage processes i.e. when software system is used as a product. The probably most important step for analysing and optimizing business processes is taken during requirements engineering, as proposed by Mahaux et al [10]. Hilty et al. propose a classification of ICT application types as starting point of such an analysis [11].

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II. STATE OF THE ART WORK

2.1 The Green Soft Model

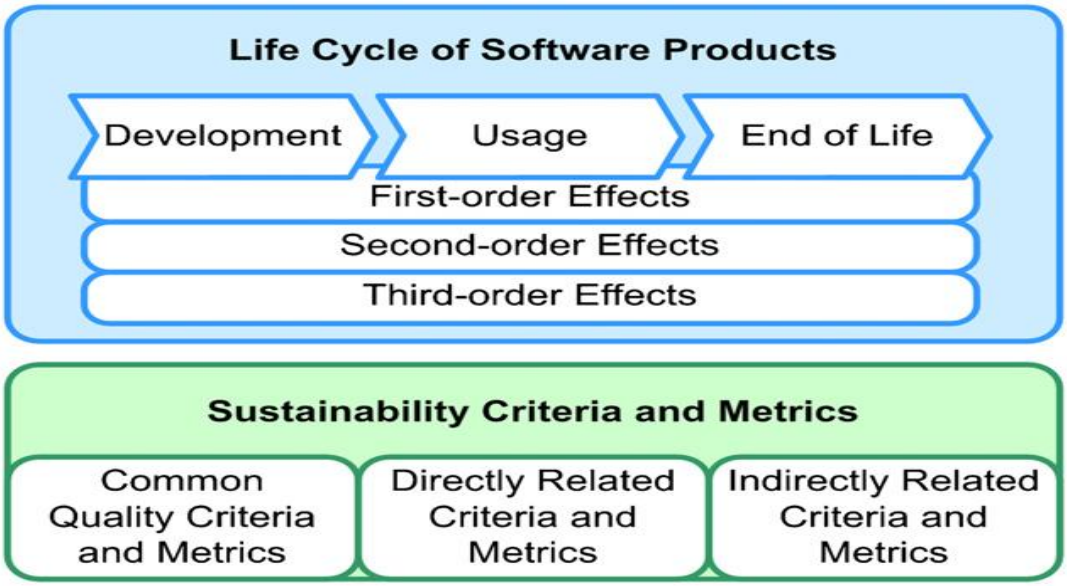
This model was introduced by Stefan Naumann, Markus Dick, Eva Kern, Timo Johann [12]. The Greensoft model support software developers, administrators, and software users in creating, maintaining, and using software in a more sustainable way. The model consists of a life cycle model for software products, sustainability criteria and metrics for software products, procedure models for different stakeholders, and recommendations for action, as well as tools (fig 1) that support stakeholders in developing, purchasing, supplying, and using software in a green and sustainable manner.

2.1.1 Life Cycle of Software Products

It begins with the early stages of product development and ends with the product's disposal.Its objective is to enable stakeholders to assess impacts on sustainable development according to the three different levels of impacts [3]. The findings gained from these assessments are used for measuring software sustainability. Various impacts that need to be considered in different phases of software development life cycle are shown in fig 2.

For example, environmental impacts to be considered in the development phaseincludeelectrical energy that is necessary to powerthe workstations, natural resources that are necessary to operate theIT infrastructure (e.g. networking devices, servers, and storages),energy that is necessary for heating and air conditioning, or energy for transportationpurposes like long distance business trips for meetingswith customers.

Similarly, environmental impacts in the distribution and disposal phase printed manuals, chosenmeans of transport, type and design of the retail and transport packagingordata medium. The Usage Phase considers impacts that result from deploying, using, and maintaining the software product.



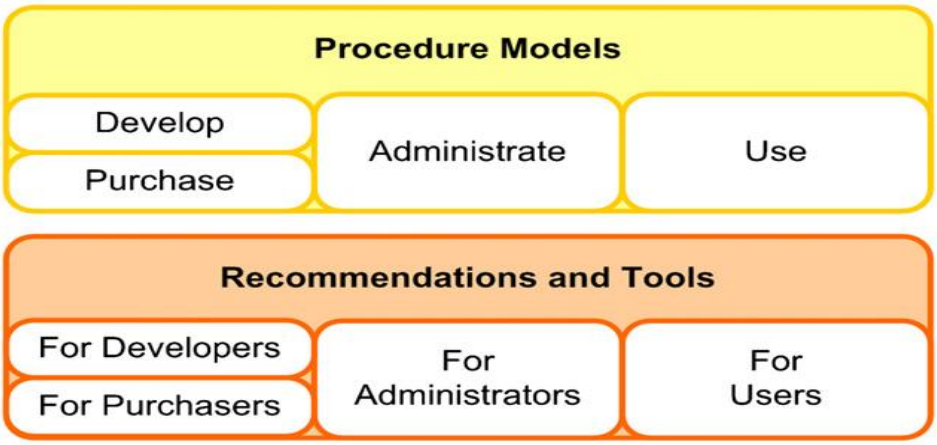


Figure1: The Greensoft Model

2.1.2 Sustainability Criteria and Metrics

This model covers metrics and criteria for the measurement of software quality and it allows a classification of criteria and metrics for evaluating a software product's sustainability.Itrepresents three categories of sustainability criteria and metrics for software products: CommonQuality Criteria and Metrics, Directly Related Criteria and Metrics, andIndirectly Related Criteria and Metrics. The first relates to commonquality criteria for software.The second comprises criteria and metrics that relate to first-ordereffects. The last includes criteria and metricsrelated to second-order and third-ordereffects. All criteria should also be classifiedaccording to the phases of our proposed software productlife cycle. Additionally, it is also necessary to classify criteria andmetrics according to the type of software.

	Development	*Usage*	*End of Life*
Third-order Effects	- ... - Changes in software development methods - Changes in corporate organizations - Changes in life style	- ... - Rebound effects - Changes of business processes	- ... - Demand for new software products
Second-order Effects	- ... - Globally distributed development - Telework - Higher motivation of team members	- ... - Smart grids - Smart metering - Smart buildings - Smart logistics - Dematerialization	- ... - Media disruptions
First-order Effects	- ... - Daily way to work - Working conditions - Business trips - Energy for ICT - Office HVAC - Office lighting - ... - Manuals - Transportation - Packaging - Data medium - Download size	- ... - Accessibility - Hardware requirements - Software induced resource consumption - Software induced energy consumption	- ... - Backup size - Long term storage of data (due to legal issues) - Data conversion (for future use) - ... - Manuals - Data medium - Packag ng
	Development *Distribution*	*Usage*	*Deactivation* *Disposal*

Fig 2 Sustainability Relevant Effects During Product Life Cycle Phases.

2.1.3 Procedure Models

It consists of sub procedural models – Develop, purchase, administrate and use. The Develop procedure model proposes several enhancements for arbitrary software development processes that enable stakeholders to recognize impacts, which result from producing and using the software product. The proposed enhancements are: Sustainability Reviews & Previews, Process Assessment, Sustainability Journal, and Sustainability Retrospective [13]. Process Assessment helps to optimize the sustainability of the production process, whereas Sustainability Reviews & Previews help to optimize the sustainability of the evolving software product. Both efforts are combined by the Sustainability Retrospective, so that finally impacts over the whole life cycle of the software product are covered. Sustainability Reviews & Previews take a look at the work done, assess outcomes according to sustainability issues, and develop measures, which are realized until the next Sustainability Review & Preview in order to optimize the sustainability of the software product under development.

A typical procurement process has the following steps: define subject matter, define requirements, select bidders, evaluate bids, and conclude contract. It is necessary to clearly state sustainability issues, i.e. ecological and social requirements in the tender's subject matter, in specifications and in contract performance clauses. This proposal for a sustainable software procurement process can be divided into two fields: the procurement of custom software products and the procurement of standard software products.

Administrate sub procedure model includes making software available by installing, configuring, and maintaining it. It also includes educating and training users, who work with the software in an organization. Configurations that can be done by users without the need for installing add-ons for browsers, configuring a word processor via its preferences dialog, etc., are covered by the sub-procedure modelUse.A minimalistic procedure model should implement a continuous improvement cycle i.e. energy efficiency, energy consumption, and resource consumption should be checked regularly in order to improve these with appropriate measures.

2.1.4 Recommendations and Tools

Recommendations and Tools support stakeholders with different skill levels in applying green and sustainable techniques when developing, administrating or using software products. Recommendations can be guidelines, checklists, best practice examples, implementation reports, etc. Tools can be software tools, but also any other tool, like paper-based data collection sheets.

III. CONCLUSION

Software has a great effect on the environment just as hardware even though the effect is indirect. Not only should software be written efficiently to not over use the underlying hardware, its engineering building process from requirements to disposal should be carried out in an energy efficient manner and a sustainable software engineering process should be introduced to fulfil the constraints of energy efficiency. This will reduce the negative effects of ICT on sustainable development and the environment. It is also important to take advantage of software tools that monitor resources in an energy efficient manner. This paper discusses the various impacts of software development on the environment and metrics that can be measured to measure the sustainability of software. A reference model has also been discussed which shows how sustainability can be applied to various

phases of software development cycle and how this model will help in developing a software in a sustainable manner.

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