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Green IT

Sustainable software sourcing

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ABSTRACT:
Because of constantly changing environment, sustainability and sustainable development has become a topical subject in today's organizational environment, that cannot be ignored. Pressure coming from different stakeholder groups forces organizations to meet their responsibilities towards environment and that is why environmental sustainability nowadays reaches to all aspects of the operation in many organizations. As the use of information technology is continuously growing, its share from global greenhouse gases is also increasing at the same time. This issue drives towards making information technology greener and it is also why this thesis studies the methods of how software and its supplier can be evaluated during the software sourcing process in environmentally sustainable way. These methods should support the concept and principles of green information technology, which core is in the efficient use of information technology at the same time when environmental impacts are minimized.

Thesis was carried out by studying already existing research about the topics of software sourcing and environmentally sustainable information technology from the perspectives of software and its supplier. Thesis also utilized interviews that were held during this study. Interviews were targeted to organizations and their representatives that in addition to their own profession have high interest as well as insight for matters of environmental sustainability. Through the findings made from previous research and interviews, best practices were analyzed and formed as a set of recommendations that combine both perspectives studied in this research, evaluating greenness of software, and evaluating green actions of software supplier. Forming of the guidelines was done by utilizing the design science method as well as its process model steps and guidelines.

As a result of this study, guidelines that consist of eight recommendations were formed for software sourcing process that take the environmental sustainability into consideration. Guidelines consist of four recommendations for evaluating software that is considered to be purchased and four recommendations for evaluating supplier of the software. Even though recommendations are designed keeping in mind large organizations where sourcing process is typically more structured, the recommendations are applicable to almost any size of organization willing to utilize those, as recommendations can be adapted to varying needs. Recommendations work as high-level guideline to help consider green values in software sourcing process. Recommendations are also easily understandable without deeper knowledge of software development, and they should act as motivation to organization utilizing them. To have more detailed and precise insight about the use of these recommendations, more practical experience would be needed, which opens an opportunity for further development of the recommendations. In addition, recommendations could benefit studying methods that would be suitable for rating the evaluation criteria presented in the guidelines.

KEYWORDS: sustainability, green IT, sourcing, software, supplier

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TIIVISTELMÄ:
Elinympäristömme muuttuessa jatkuvasti, kestävästä kehityksestä on tullut ajankohtainen aihe tämän päivän liiketoimintaympäristössä. Aihetta ei voida organisaatioissa enää ohittaa, sillä eri sidosryhmien mukanaan tuoma paine pakottaa organisaatiot kantamaan oman vastuunsa ympäristön hyväksi. Tästä syystä ympäristön kestävä kehitys on tullut hyvin laajasti osaksi monien organisaatioiden jokapäiväistä toimintaa. Informaatioteknologian käytön jatkaessa kasvuaan, myös sen osuus globaaleista kasvihuonepäästöistä kasvaa samanaikaisesti. Tämä ongelma on osaltaan ajamassa eteenpäin ratkaisuja, joiden tavoitteena on tehdä informaatioteknologiasta vihreämpää. Sen vuoksi tämä Pro Gradu -tutkielma tutkii niitä menetelmiä, joiden avulla ohjelmistoa sekä sen toimittajaa voidaan arvioida ohjelmiston hankintaprosessin aikana ympäristön kannalta kestävästä näkökulmasta. Näiden menetelmien tulee tukea vihreän informaatioteknologian käsitettä ja sen periaatteita, jonka keskiössä on informaatioteknologian tehokas käyttö, samanaikaisesti kuitenkin minimoiden sen vaikutukset ympäristöä kohtaan.

Tämä tutkielma on toteutettu tutkimalla jo olemassa olevaa tutkimustietoa niin ohjelmistohankinnasta, kuin ympäristön kannalta kestävästä informaatioteknologiasta niin ohjelmiston, kuin sen toimittajankin näkökulmasta. Lisäksi tutkielmassa hyödynnettiin haastatteluja, jotka kohdennettiin sellaisiin organisaatioihin ja niiden edustajiin, joilla oman ammatillisen erityisosaamisen lisäksi on kiinnostusta sekä näkemyksiä liittyen ympäristön kestävään kehitykseen. Näiden aikaisemmista tutkimuksista sekä haastatteluista saatujen tietojen pohjalta analysoitiin parhaat käytänteet ja niiden avulla laadittiin ohjeistukset, jotka yhdistävät molemmat tutkielman keskiössä olevat näkökulmat, ohjelmiston vihreyden arvioinnin, sekä sen toimittajan ympäristötekojen arvioinnin. Ohjeistusten laatimisessa käytettiin avuksi suunnittelutieteellistä menetelmää, mukaan lukien sen prosessivaiheita sekä muita suosituksia.

Tutkielman tuotoksena laadittiin ohjeistukset, jotka ottavat huomioon ympäristön kestävän kehityksen. Ohjeistukset koostuvat neljästä suosituksesta itse ohjelmiston arvioinnin avuksi, sekä neljästä suosituksesta ohjelmiston toimittajan arviointia varten. Ohjeistukset on laadittu lähtökohtaisesti suurten organisaatioiden näkökulmasta, sillä niissä hankintaprosessi on usein strukturoidumpi. Tästä huolimatta ohjeistuksia voidaan käyttää hyväksi lähes minkä tahansa kokoisessa organisaatiossa, jossa niitä ollaan halukkaita hyödyntämään, sillä ohjeistuksia on mahdollista soveltaa täyttämään erilaisia tarpeita. Ohjeistukset toimivat ikään kuin ylätason ohjeistuksina, jotka auttavat huomioimaan vihreät arvot hankintaprosessin aikana. Lisäksi ohjeistukset ovat helposti ymmärrettävät, eikä niiden käyttäminen vaadi erityistä osaamista ohjelmistokehityksen puolelta, minkä lisäksi niiden tulisi toimia motivaation lähteenä niitä käyttävälle organisaatiolle. Jotta ohjeistusten toiminnasta saataisiin tarkempi kuva, niiden käytöstä todellisessa ympäristössä tarvittaisiin lisätietoa, mikä avaakin mahdollisuuden ohjeistusten jatkokehitykselle. Lisäksi ohjeistukseen soveltuvien arviointikriteerien tutkiminen voisi olla hyödyllistä niiden monipuolisemman käytön mahdollistamiseksi.

AVAINSANAT: kestävä kehitys, vihreä IT, hankinta, ohjelmisto, toimittaja

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Abbreviations

CPU	Central processing unit
CRAC	Computer room air conditioning
CRM	Customer relationship management

DBMS	Database management system
EMS	Environmental management system
ERP	Enterprise resource planning
GDPR	General Data Protection Regulation
ICT	Information and communication technology
IT	Information technology
I/O	Input/output
JVM	Java virtual machine
KPI	Key performance indicator
LCA	Life cycle assessment
PC	Personal computer
R&D	Research and development
TCO	Total cost of ownership
UPS	Uninterruptible power supply

1 Introduction

Sustainability and sustainable development are topics that cannot be ignored in today's organizational environment. Social pressure from different stakeholder groups, such as customers, government, and society are urging organization to meet their responsibility requirements concerning sustainability matters (Loeser, 2013). One widely used definition to sustainable development is from World Commission of Environment and Development (1987) where it is said that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition highlights well the fact how versatile topic sustainability is, and that it reaches to all aspects of our surroundings as well as information technology.

Information technology is part of our daily life in social communication as well as in business organizations (Hiekkanen, Seppälä & Ylhäinen, 2021). Nevertheless, energy efficiency of the technologies used in information technology sector in business environment, have not been able to be developed in the same phase than fixed data and mobile data. Therefore, energy efficiency is one of the key elements of sustainable information technology infrastructure (Loeser, 2013). Use of electricity has been increasing continuously and one reason for it, is the expansion of data centers, which are resulting a significant part of environmental impacts of IT (Harmon & Auseklis, 2009). This then also makes data centers used by organizations a remarkable overall source of greenhouse gases among all the other sources of pollution. In information-intensive organizations, carbon footprint of data centers can cover more than 50% of organization's total greenhouse gas emissions and for service organizations, data centers can be even a main source of the emissions. In total worldwide electricity consumption, the relative share of ICT products has increased from about 3.9% to 4.6% between 2007 and 2012 (Van Heddeghem, Lambert, Lannoo, Colle, Pickavet & Demeester, 2014). Dastbaz, Pattinson and Akhgar (2015, p. 7) state that ICT ecosystem is approaching to 10% of world's electricity generation. Based on all the information, it is obvious that IT cannot be excluded when considering actions that needs to be done to support environmental sustainability.

In addition, IT can also be seen as enabler for transformation towards more sustainable economy and society which is why it is in important position when thinking actions supporting sustainability (Loeser, 2013).

In addition to increasing energy usage and financial costs related to it, risks of climate change have become to a national as well as global issue driving green computing (Harmon & Auseklis, 2009). That is why governments increasing regulations are driving adaption of sustainable IT investment and practices more and more in the future (Harmon & Auseklis, 2009). For organization, investing to green technology has a potential to even save money, increase efficiency, and boost growth opportunities which can make it even more tempting (Wilbanks, 2008).

Harmon and Auseklis (2009) have defined “green computing” and its alternative “green IT” as the “practice of maximizing the efficient use of computing resources to minimize environmental impact”. This definition includes minimizing the use of environmentally harmful materials, energy, water, and other resources as well as minimizing waste from manufacturing and supply chain process. Sustainable IT can be defined more broadly; in addition to environmental criteria, it also includes economic and social responsibility for defining organizations success. Green computing can be then seen as a part of sustainable IT service strategies and process definitions. In this research, the focus will be only in environmental aspects of sustainable IT, which means that economic and social responsibility will not be part of this research scope. Because green IT seems to be more common and preferable term for environmentally sustainable IT than green computing, it will be used in this research as well.

In order to implement green IT practices to business activities, an organization must understand that it has an impact to a wide range of its processes. Loeser (2013) has differentiated green IT to three functions: IT sourcing, IT operations and IT disposal. This research will consider IT sourcing and its two sub-categories, supplier relationships, and sourcing of IT products and services, such as hardware, software, and external

computational and storage capacities. This division of IT sourcing will be used as a structure for this research when examining environmentally sustainable software sourcing. In supplier relationships focus will be in sustainable supplier selection and what comes to sourcing of IT products and services, focus will be in the selection of sustainable software. This means that evaluation and selection of hardware as well as external computational and storage capacities and their suppliers are not considered in this research.

There is already existing research about sustainable software design and sustainable supplier selection. For example, Luthra, Govindan, Kannan, Mangla and Garg (2017) have researched sustainable supplier selection evaluation criteria whereas Madan, Sangwan and Bhatia (2019) have identified the software metrics that are contributing to sustainable and green software development. Those metrics are still rather complicated to be used as they are in software sourcing without deeper knowledge about software development and many studies about sustainable supplier selection, such as already mentioned Luthra et al. (2017), are discussing about all aspects of sustainability, including economic and social responsibility, in addition of environmental point of view. It seems that there is a lack of research about environmentally sustainable software and supplier selection combined to a simple guideline which can be utilized in sustainable software sourcing process and that is to which this research seeks to answer.

1.1 Research aim and research methodology

The aim of the thesis is to find best practices for evaluating software and its supplier in sourcing process in a way that it supports green IT thinking. Through these findings, this research formulates recommendations that can be utilized in sustainable sourcing process, in order to help the evaluation and selection of software and its supplier from environmentally sustainable point of view. The overall aim is formulated to one research question where this thesis seeks to answer: which are the best practices for evaluating software and its supplier from environmentally sustainable aspect?

This research will be primarily made from the perspective of large organizations, as it is a belief that in large organizations sourcing process is in most cases more controlled than in smaller organizations, even though the recommendations can be applied in smaller organizations as well. Recommendations that are designed through this research should be easy to apply to the evaluation and selection process of software and its supplier without too much investigation to technical details. In additions, recommendations should be simplified enough to motivate to take environmental aspects into consideration in software sourcing process. As the research aims to create recommendations that support green IT principles, focus will be only in environmental sustainability, not in other sustainability aspects like economic and social, which both will be excluded from this research.

Research is carried out by utilizing design science research method, where the aim is to create artifact, which solves a defined problem (Hevner, March, Park & Ram, 2004). Recommendations created through this research can be seen as a method, which is a one form of artifact that "range from formal, mathematical algorithms that explicitly define the search process to informal, textual description of 'best practice' approaches, or some combination". Design science research method is therefore seen as compatible method for designing the recommendations for sustainable software sourcing.

1.2 Research structure

After introduction, relevant literacy will be reviewed to establish proper theoretical framework and understanding about research background, previous research and essential findings impacting to objectives and execution of this research. Literature review will focus on sourcing and green IT, the topics that form the basis for this research. About sourcing, it is important to explain what it is, what are the stages of sourcing process, and which stages will be in focus in this research. It is also necessary to clarify how sustainability is connected to sourcing. As for green IT, there is a need to explain what it is and what are the green IT principles that will guide the research. Theoretical framework

then continues by focusing to tie these two concepts together as environmentally sustainable software sourcing. There it will be explained what are the characteristics that make software green and the ways to evaluate supplier's sustainable performance from environmental perspective.

After literature review, research methodology used in this research will be presented and discussed. Design science research and its process model as well as interview method used to collect data to support design science research process are introduced. After presenting interview results, research will focus to actual artifact, recommendations, which are formulated through the findings from literature review and interviews. Designing and presenting recommendations will be following the stages of design science research after which research and its results will be analyzed in discussion section that will conclude the research.

2 Sourcing

Sourcing is another word used (especially on the materials area) for purchasing and it can be defined as “finding, selecting, contracting, and managing the best possible source of supply on a worldwide basis” (Van Weele, 2010, p. 10-11). It relates to creating the best possible supplier strategy for a certain commodity as well as finding the best possible supplier.

Sollish & Semanik (2011, p. 1-2, 17) state that sourcing is a purchasing and supply management function, which is a process for locating, developing, qualifying, and employing suppliers. The main objective for sourcing is to engage those suppliers that are aligned with the organization’s strategic business and organizational goals. Day-to-day activities of acquisition are not included to sourcing as it is more strategic, long-term plan for supply chain action. Sourcing process has four main functions that are presented in figure 1: strategic planning, research, solicitation, and contract administration.

In the function of strategic planning, the sourcing strategy will be aligned with the organizations business strategy (Sollish & Semanik, 2011, p. 17). After strategic planning, research covers the analyzation of internal requirements, market analysis, and prequalification of potential suppliers. Prequalification means that supplier meets the required condition and is able to supply product or services with competitive price. Solicitation includes preparing request, evaluating responses, selecting the supplier, conducting negotiations, and forming a contract. Final step of sourcing process, contract administration, includes ongoing monitoring of selected supplier’s performance.

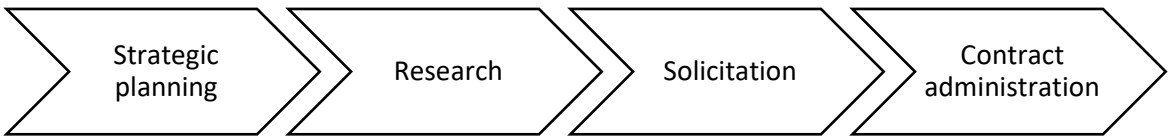

Figure 1. Sourcing process (Sollish & Semanik, 2011, p. 17).

Regarding the sourcing process, the focus in this research will be in finding potential suppliers whose software meet with the functional and environmental requirements set to it as well as supplier evaluation and selection. These focus points can be seen as part of research and solicitation functions (Sollish & Semanik, 2011, p. 17, 101). After prequalifying potential suppliers by focusing on the requirements of the product or service, solicitation stage is one of the most critical activities in strategic sourcing. How supplier is selected, is highly dependent on the criteria that is used for evaluation and how the chosen metrics are applied to it. There are several evaluation criteria that can be applied but it is important to take into account that all of those are not equally valuable and the selection needs to be done carefully in order for it to support organization's sourcing objectives.

Objectives for sourcing are specified targets, which will help to achieve the mission and add value to the organization (Sollish & Semanik, 2011, p. 4). When objectives are developed, measurements for evaluation should be considered for being able to know if the objectives are achieved. Also, objectives should be prioritized, as all goals cannot be equally important. Sustainability demands is one example among many that could influence to sourcing objectives. As sustainable objectives are in focus in this study as well, there is no need to take any deeper look to other possible focus points of sourcing objectives.

2.1 Sustainability in sourcing

Increasing customer knowledge and ecological pressure from markets and stakeholders are affecting to the demands for business organizations to make more sustainable decisions in their supply chain (Luthra et al., 2017). Veit, Lambrechts, Quintens and Sameijn (2018) have found out that perceived sustainability of organization's country of origin and its suppliers as well as organization's own sourcing strategy influence on customers perceptions about the organization itself. It was also found out that customers are not interested or even willing to buy from organization that behaves unsustainably but

however they are willing to pay more for sustainable products, even in the cases where the organization has been formerly associated to unsustainable behavior. Customers are then favorable also to organization that is improving its processes to more sustainable direction. This research gives an argument why sustainability should be taken into consideration in sourcing and that the change towards more sustainable way of operating can be done at any time.

Regarding Van Weelen (2010, s.388) sustainability in purchasing is about buying for a better future which is required by general public in the world of today. Sollish and Semanik (2011, p.153) state that in order for organization to operate sustainably, it requires commitment from the entire organization and even though it is difficult to find the best practices that are sustainable, it is still every organization's best interest to review its operations and determine what should be done to meet the needs of different quarters. This requires ability to adapt and stay ahead of the changing environment. Cooperation and attitude of suppliers can also minimize the cost of procurement as well as ensure social and economic benefits to organizations (Santosh & Shivangi, 2019).

2.2 Software sourcing

When sourcing software, client company has usually possibility to choose between options of developing software in-house or sourcing software package (Nöhren, Heinzl & Kude, 2014). In-house software is defined as customized software, which is developed internally by organization IT unit or externally by software vendor. As for packed software, Carmel and Sawyer (1998) define it as a software that is sold as a product. Companies providing packed software typically sell the product on a market, instead of specific customers.

Nowadays also Software as a Service (SaaS) has become more and more important way to source software (Gangadharan, Uden & Luttighuis, 2016). In SaaS, software is offered under service level agreement for determined price. Its advantage is that is reduces the

cost of ownership when compared to on-premises software (Santy & Sikkel, 2014). Like software that is seen more as a product, SaaS can also be decided to be made by organization themselves (insourcing) or by buying the service from external provider (outsourcing) (Gangadharan et al., 2016).

In this research software sourcing will be considered through packed software which is supplied as a product with no or very little room for customization or through SaaS, as the evaluation is done for already existing products and their suppliers. Highly customized software is entirely excluded from this research as those are build based on customer needs when also customers motivation towards sustainability aspects most likely has a great impact to the sustainability of the final result.

3 Green IT

In this section the focus will be on the concept of green IT. First some of the definitions of green IT are introduced with background of the concept and the elements where it constructs from are studied. After this, the focus will be in the sourcing function of sustainable software by introducing what are the characteristics that make software green and how it can be measured as well as what are the ways to evaluate suppliers' sustainable performance.

3.1 Definition of green IT

There are several different definitions for green IT and the one by Harmon and Auseklis (2009) already referred in introduction, "practice of maximizing the efficient use of computing resources to minimize environmental impact" is one of them. Another definition is by Wang (2008) where it is said that green IT is about supporting personal and business critical computing needs in a sustainable manner by minimizing strains and impact for environmental resources. Jenkin, Webster and MacShane (2011) have a bit more permissive definition where green IT refers to technologies and systems that directly or indirectly address environmental sustainability in organizations.

Through green IT literature review about previous research Loeser (2013) proposes that green IT can be differentiated to three aspects:

1. Consideration of environmental criteria when purchasing IT equipment and services.
2. Energy-efficient IT operations in data centers and in office environments.
3. Environmentally friendly practices referring to the disposal of IT equipment.

In the other hand Loeser (2013) also lists the characteristics where it can be seen as an enabler:

1. Reengineering of business and production processes.
2. Implementations of information system based environmental management systems.
3. Innovations for environmental technologies in end user products and services.
4. Tracking of resource demands and emissions of products and services (lifecycle analyses).

Loeser (2013) formulates that “the concept of green IT refers to measures and initiatives which decrease the negative environmental impact of manufacturing, operations, and disposal of IT equipment and infrastructure. Based on this definition and three central aspects of green IT presented earlier, Loeser proposes three aspects of which green IT is consisting of: IT sourcing, IT operations, and IT disposal. IT sourcing consists of two sub-categories: supplier relationships and sourcing of IT products and services (such as hardware, software, and external computational and storage capacities like cloud computing). IT operations sub-categories are general IT management, data center, and office environment, of which data center is further sub-categorized to servers and storage, network, cooling, and energy supply. This division is presented in figure 2.

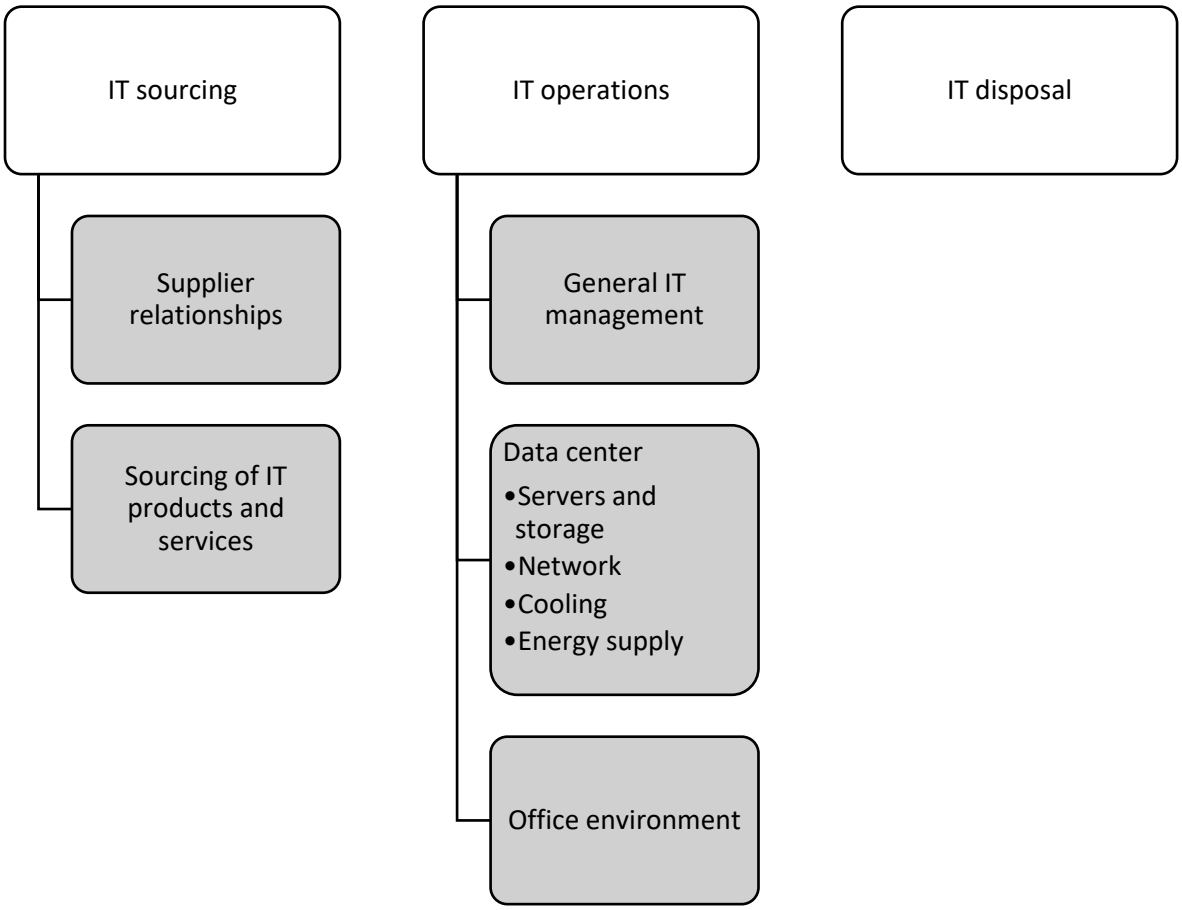

Figure 2. Green IT processes, scopes, and focus points (Loeser, 2013).

Loeser (2013) has listed measures and initiatives for IT sourcing's two sub-categories. Measures and initiatives of these two sub-categories, supplier relationships and sourcing of IT products and services, are presented in figure 3. Some of these measures and initiatives are applied in this research as well as when metrics for green software and supplier evaluation are explored.

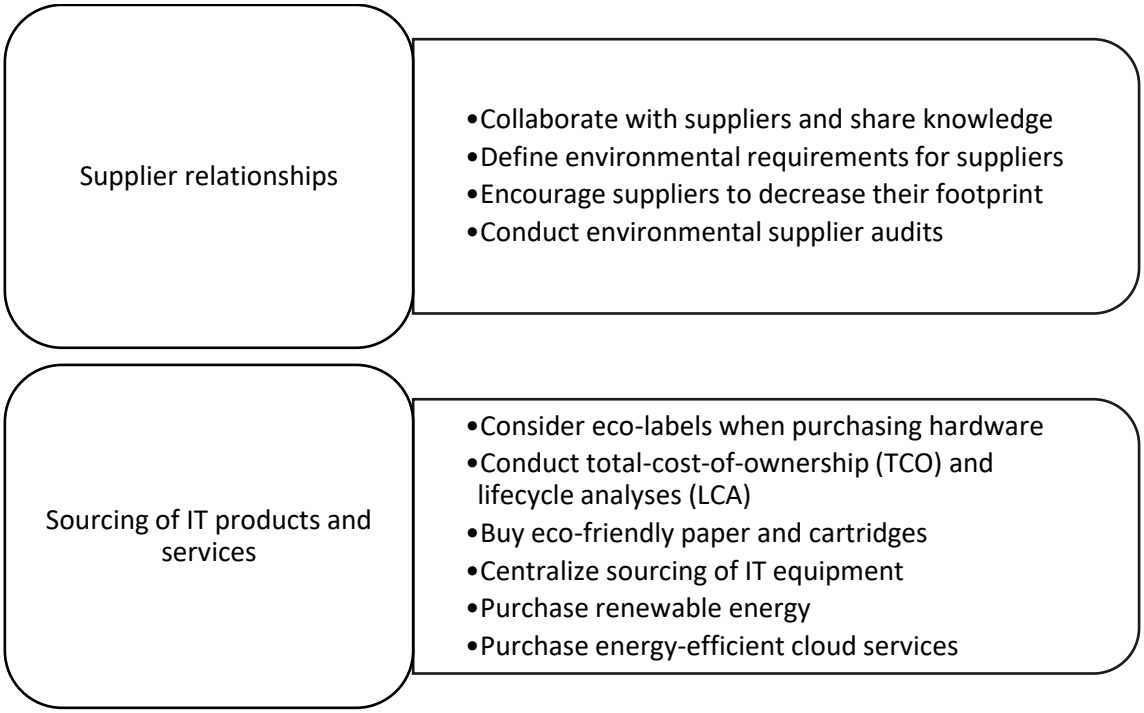

Figure 3. IT sourcing measures and initiatives (Loeser, 2013).

Even though the focus is on IT sourcing and the evaluation during the sourcing process, there are important measures and initiatives in the processes of IT operations and IT disposal, that have also a role when making the purchase decisions. For example, some general IT management measures and initiatives can as well have an effect to how the decisions in sourcing process are done. Rest of the measures and initiatives found by Loeser (2013) are presented in table 1.

Table 1. IT operations and IT disposal measures and initiatives (Loeser, 2013).

IT operations	General IT management		Develop a green IT/IS action plan
			Develop a green product and service portfolio
			Create an inventory of IT hardware
			Consolidate applications
			Manage lifecycle of stored data
			Monitor energy consumption
			Measure and analyze environmental KPIs
			Implement IT performance measurement systems
			Detailed energy monitoring of all devices
	Data center	Servers and storage	Consolidate servers
			Virtualize servers and storage
			Deploy blade servers
			Deploy energy-efficient processors
			Install energy-saving hard disk drivers
			Install dynamically adjustable fans
			Deploy energy-efficient server power supplies
			Right-sizing of server and storage capacities
			Activate energy-management functions
			Apply scheduling and workload management
			Shut down servers dynamically
			Monitor energy consumption of servers
		Network	Install intelligent switches
			Virtualize network
		Cooling	Install dynamically adjustable cooling systems
			Install modern CRAC systems
			Install in-row chillers
			Utilize liquid refrigerants for server cooling
			Deploy free cooling system
			Separation of hot and cool aisles
			Containment of hot and cool aisles
			Detailed monitoring of air temperatures
			Optimize air flows
			Eliminate hot spots and air circulation short cuts
			Increase data center temperature
			Consider energy flows in data center architecture
			Reuse data center heat
		Energy supply	Optimize energy supply
			Install modern and efficient UPS
			Increase UPS utilization rates
			Install UPS flywheel instead of batteries
			Reduce power conversion steps to decrease power losses

	Office environment		Use notebooks instead of desktop computers Utilize energy-efficient desktop PCs Install thin clients Deploy LED displays Activate power management functions of PCs Install power management software Inform and educate end users Install network multifunction printers Double sided black and white printing as default
IT disposal			Holistic end of IT life management Reuse computers Refurbish computers Extend life of IT equipment Manage e-waste Recycle hardware Track toxic materials E-waste policies and rules Engage in recycling initiatives Cooperate with suppliers and strive for takeback programs and recycling initiatives

These green IT initiatives are rather generic and that is why there is a need to envision processes, products, and services that are measured by using the initiatives (Loeser, 2013). That is where implementation examples and best practices have an important role bringing green IT to practice.

3.2 Sustainable software sourcing

Sourcing of sustainable software is the practice of purchasing environmentally preferable IT, which includes all the sourcing practices analyzed through sustainability perspective (Bokolo & Mazlina, 2016). In this chapter the two sustainable software sourcing practices that are in focus are evaluation of the software and its supplier. In order to find the best practices for sustainable software sourcing, green software characteristics and supplier evaluation criteria need to be studied.

3.2.1 Green software characteristics

There is no widely accepted method for evaluating environmental friendliness of software (Dastbaz et al., 2015, p. 112). The metrics already defined differ in many ways in terms of measures of resources, the kind of result generated, the analyzed environment and application domain, and their usage.

For analyzing the impact of software, its life cycle can be categorized roughly to three sources: production, use, and disposing (Dastbaz et al., 2015, p. 112-113, 122). Dastbaz et al. suggest that there are two main impacts that need to be considered, direct impact that results from the use of software during the use of the product that it is integrated into, and indirect impact when software needs to be exchange because of increased requirements. Previous generation hardware is often used as an excuse for not providing software upgrades after certain amount of time. The impacts that are resulting from these stages as well as environmental sustainability aspects should be considered already during the development phase of the software and it should be done by actors such as the software programmers (Dick, Naumann & Kuhn, 2010). That is why in this research it is important to focus on finding the characteristics of green software, but also keep in mind that the focus is on characteristics that can be evaluated during sourcing process, not only in software development phase.

New technologies such as cloud computing is seen as a possibility for harnessing computing power without affect to environment (Dastbaz et al., 2015, p. 95, 97, 106). Cloud computing can then be seen as one example of green IT, but it needs to be adjusted to support sustainability requirements. Mell and Grance (2010) have defined cloud computing as “a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service-provider interaction”. There are several categories of cloud computing, one of those being software as a service (SaaS). SaaS is a software or application, which is hosted as a service and provided to customers through Internet without

installing it to computer (Wang, Tao, Kunze, Castellanos, Kramer & Karl, 2008). By using cloud computing, organization can reduce their energy consumption that is used by on-site servers, as they are only using the server space they actually need (Dastbaz, et al., 2015, p. 97, 129-130). As hardware is becoming more powerful and at the same time less expensive, it gives a reason to adopt cloud infrastructure for sustainable IT. When there is less need for physical equipment, there is at the same time less demand for localized hardware cooling systems and other initiatives, which helps to save energy.

Thomond (2013) states that cloud computing is more a business model innovation than technological innovation and that in addition of changing the way of how cloud computing services are consumed it as well enables reducing of greenhouse gas emissions. Thomond found out that running services like email, CRM and groupware services in cloud, would on average reduce greenhouse gas emissions by 95%. This is because cloud computing service providers are able to utilize centralized data centers which are more energy efficient compared to individual or small groups of servers that are typically provided on-site by organizations IT teams.

Even though cloud computing can save energy, it is still important to remember that a cloud data center also consumes lot of energy because of the working of servers, processes, and networking equipment (Dastbaz et al., 2015, p. 130). Reducing data center energy consumption is ultimately their providers responsibility, but it needs to be acknowledged that cloud computing cannot be seen as only solution for achieving more sustainable ways of using software and therefore green IT needs to be investigated from other perspectives as well.

Madan et al. (2018) have identified nine environmental factors that can be used in ranking software environmental sustainability. These nine metrics are: energy, distribution or deployment of software, performance, power efficiency, dematerialization, percentage hazardous waste per total waste generated, process efficiency, work performance, and reuses of hardware equipment. In addition to environmental metrics, altogether 27

economic, technical, and social metrics have been identified in the research, which of only technical metrics are relevant regarding this research, as economic and social sustainability are both excluded from the scope. Technical metrics identified are CPU usage, tool suitability, tool efficiency, algorithmic/code efficiency, information flow complexity, storage usage, storage saving, modifiability, estimated system lifetime, support rate, relative response time, dependability, usability, experience, cloud computing, component-based software engineering, portability, number of available versions of software, processor efficiency, and processor overhead.

Bozzelli, Gu and Lago (2014) as for have made a comprehensive systematic literature review where they have analyzed several researches regarding green software metrics. There are some same elements than Madan et al. (2018) have identified but the list of metrics is more comprehensive and detailed. Bozzelli et al. (2014) have found total of 66 metrics that are designed for measuring energy consumption of software and those are listed by their name on table 2. Metrics are categorized by their measured resources and purpose. Measured resource represents the resource which is measured by the metric. Metric purpose as for tells if the metric is used for measurement and/or estimation. MEAS refers to metrics designed for perform a measurement whereas ESTI metrics perform an estimation of a certain value. MEAS/ESTI metrics are then designed to perform both, measurement, and estimation.

Table 2. Green software energy consumption metrics (Bozzelli et al., 2014).

	Purpose		
Measured Resource	**MEAS**	**ESTI**	**MEAS/ESTI**
Application	Application Energy Efficiency Application Performance Workload	First Order Software Energy ESTI Model Second Order Software Energy ESTI Model Specific Energy System's Overall Energy Consumption	Computational Energy Cost Infrastructure Energy Consumption
Architecture Elements		Client Connector Energy Cost Client Energy Cost Client-Server Facilitation Energy Cost Communication Energy Consumption Component Energy Cost Connector Conversion Energy Cost Conversion Pub-Sub Energy Cost Coordination Pub-Sub Energy Cost Distributed System Energy Consumption Facilitation Energy Cost Generic Component Energy Cost Generic Connector Energy Cost Local Pub-Sub Connector Energy Cost Pub-Sub Connector Energy Cost Remote Client Energy Cost Remote Pub-Sub Connector Energy Cost Services Energy Cost	
CPU	CPU Usage	CPU Energy Model	
Data Center	Data Center Energy Productivity (DCeP)		
DBMS	Aggregated Cost		

Financial Impact	Compliance Consumable Human Resources Lifecycle Cost		Average Revenue (Multi-tier Service Model) Average Revenue (Single-tier Service Model)
IT Resource	Asset Efficiency		
JVM			Infrastructure Energy Consumption
Memory	I/O Usage Memory Usage	Memory Energy Model	
Network			Communication Energy Cost
Percentage		Reduction in Power Imbalance	
Pollution	Supply Chain		
Power	Data Center Performance Efficiency System Power Usage		
Process	Process Engineering		
Server	Server Power Utilization		
Service	Availability Process Time/Job Duration Recoverability Reliability Response Time Throughput		
Service Center	Service Center Energy Consumption		
Service Execution Path	Energy Consumption Execution Plan Energy Efficiency		
Source Code	Executed Instruction Count Measure (EIC) Memory Access Count Measure (MAC) Software Energy (SEM)		
Storage	Storage Usage	Disk Energy Model	
System		System Energy Model	
Virtual Machines	Power Efficiency	Energy Savings	
Virtual Machines Energy Virtual Machine MEAS	Power Consumption		

In addition to green software energy consumption metrics, 29 metrics which are not measuring software energy consumption were found from the research that were looked through (Bozelli et al., 2014). These metrics are listed by their name on table 3.

Table 3. Green software metrics not measuring energy consumption (Bozzelli et al., 2014).

	Metric names		
Measured Resource	**MEAS**	**ESTI**	**MEAS/ESTI**
Application	Abstractness Defect Density Distance From Main Sequence Effectiveness Error Rate Instability Learnability Relative Response Time Testing Effectiveness Testing Efficiency		
Data Center	Corporate Average Data Centre Efficiency (CADE) Facility Efficiency		
Employees	Long-Haul Round-trips Work-From-Home Days		
Environment	Humidity Light Temperature		
Machines	Reduction of Power Consumption		
Policies	Compliance of Greenness Level Context Entropy Entropy Contribution GAMES Context Situation Threshold Green Level		
Server			Server Power
Service Execution Path	Expected Service Request Fulfilling Time		
Time	Return of Green Investments (RoGI)		
Virtual Machine	Benchmark Execution Elapsed Time Performance	Weighted Speedups	

Kern, Dick, Naumann, Guldner and Johann (2013) have also identified some useful metrics for measuring green software engineering. They have introduced more limited number of metrics of which some are same than presented in above table, but there are also

two new metrics that have not been acknowledged in previous lists of metrics. These metrics are all shown in table 4.

Table 4. Green software engineering metrics (Kern et al., 2013).

Aspect	**Metric**
Energy Efficiency	Energy / Unit of Work
CPU-Intensity	CPU Cycle Count
Memory Usage	Memory Consumption
Peripheral Intensity	Peripheral Usage Time
Idleness	Idle Time

CPU usage is also mentioned by Capra, Francalanci and Slaughter (2011) as factor which small reduction can have significant energy savings as even though software itself does not directly consume energy, it affects significantly to the consumption of its hardware equipment. This is because “if fewer elementary operations are required to satisfy a user functional requirement all the above layers (bus, storage, cooling etc.) are likely to work less and thus require less energy”. In some conditions a reduction of CPU can involve at the same time corresponding reduction of the TCO of the data center. Capra and others then state that investing to green design can be economically efficient to even for a single organization.

Some metrics are more complicated than others, but the idea is of this study is to find the ones that are most suitable for software sourcing process where the evaluation is done based on rather basic information about the software which is easily receivable from the supplier. Metrics selected should be easy to understand in order to be able to evaluate different software options without deep understanding about the technical details of several kind of software packages required in the organization’s different operations.

3.2.2 Sustainable supplier evaluation

Because of ongoing green movement across the world, organizations must take environmental impact into account nowadays when they are making supplier decisions (Kumar, Jain & Kumar, 2014). There are several methods that can be used in the evaluation process and for example, Sollish and Semanik (2011, p. 167-168) have presented a list of elements that can be added to solicitation as part of evaluating sustainability of the supplier:

- Do you have a full-time sustainability manager?
- Detail the key elements of your EMS.
- Please provide a copy of your company's Corporate Social Responsibility policy.
- What is your organization's current carbon footprint, and how are you planning to comply with global warming initiatives?
- Identify any toxic materials used in your processes and how you are controlling them.
- Do you currently generate nonrecyclable waste? Please list.
- Describe your program for reducing waste.
- List your accomplishments and goals for converting to sustainable energy sources.
- What significant amounts of recycled materials do you use in your operations?
- Is your organization currently certified to an environmental standard (Such as ISO 14001)? Please list.

In addition to this list, Sollish and Semanik (2011, p. 168) propose that if possible, hard measurements should be considered in the evaluation of supplier as well. List of the proposed measurements and their units of measure is in table 5. Sollish and Semanik have assessed the criteria which could be used for the measurements and those are current emission, initial baseline, and objective.

Table 5. Measurements for supplier evaluation (Sollish & Semanik, 2011, p. 168).

Element	**Unit of Measure**
Direct greenhouse gas emissions	Metric tons CO_2 or equivalent
Indirect greenhouse gas emissions	Metric tons CO_2 or equivalent
Hazardous waste disposal	Metric tons
Nonhazardous waste disposal	Metric tons
Electric energy usage	Giga-joules
Fuel energy usage	Giga-joules
Renewable energy usage	Giga-joules
Waste material recycled or reused	Metric tons

Luthra et al. (2017) have proposed a framework for evaluating sustainable supplier selection by using Analytical Hierarchy Process (AHP) to prioritize evaluation criteria and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method to select the most sustainable supplier from the alternatives. This framework considers environmental, ecological, and social aspects in the sustainable supplier selection but in table 6 only the environmental dimension for sustainable supplier selection evaluation criteria and the descriptions are presented. In this connection there is no need to take deeper look to evaluation criteria's comparison and prioritization so that is why that part from the research is not presented here.

Table 6. Sustainable supplier evaluation criteria environmental dimension (Luthra et al., 2017).

Sustainable supplier selection evaluation criteria	**Description**
Environment management systems	The structure, planning and implementing of supplier's policies for environmental protection
Green design and purchasing	Incorporating eco-friendly practices at the design and purchasing stages
Green manufacturing	The consumption of raw material and energy should be minimum while producing the product
Green management	The capability of product to maximize the environmental performance and management
Green packing and labeling	The capability of suppliers to take environmental considerations for packaging and labeling
Waste management and pollution prevention	The raw material is such that wastage and pollution should be minimum while producing the product
Environmental costs	The raw material and product should add minimum costs and damage to the environment
Environmental competencies	Supplier's capability of using environmentally friendly materials, implementing clean technologies, and reducing pollution effects
Green R&D and innovation	The capability of suppliers to provide efforts on research and development activities to innovate new cleaner technologies, processes, practices, and methods

Ahi and Searcy (2015) analyzed green supply chain metrics used and published in previous literature and they gathered comprehensive list from their findings (table 7). In the table there are only presented metrics that have frequency rate of ten or more among 445 analyzed articles. In the table metrics are shown as being either quantitative or qualitative by their nature and other metrics than metrics that have environmental focus have been excluded from this table.

Table 7. Green supply chain metrics with environmental focus (Ahi & Searcy, 2015).

Metric	**Quantitative / Qualitative**
Quality	Quantitative
Air emissions	Quantitative
Greenhouse gas emissions	Quantitative
Energy consumption	Quantitative
Recycling	Quantitative
Solid waste(s)	Quantitative
Environmental management system	Qualitative
Carbon footprint	Quantitative
Life cycle assessment (LCA)	Quantitative
Water consumption	Quantitative
Product characteristics	Quantitative
Energy efficiency	Quantitative
Environmental costs	Quantitative
Reduction of air emission(s)	Quantitative
Reduction of solid wastes	Quantitative
ISO 14001 certification	Qualitative
Level of process management	Quantitative
CO_2 emissions	Quantitative
Water waste	Quantitative

The International Organization for Standardization (ISO) has a 14001 standard (mentioned as one metric in above table as well) for environmental management system, which is a framework for organizations to follow (Dastbaz et al., 2015, p. 35-36). However, it is pointed out that the ISO 14001 standardization does not measure organization's environmental performance, so it does not accurately tell whether the organization pollutes. It could be still assumed that organization that have standardized by ISO 14001 are interested of their environmental performance.

Dastbaz et al. (2015, p. 36) suggests that organization's impact to environment should be evaluated by using a list of KPIs, which are metric measures used to evaluate organization's performance regarding the set targets. ITU-T report (2012) has listed KPIs proposed by global organization or initiatives, such as Carbon Disclosure Project (CDP), Dow Jones Sustainability Index (DJSI), GHP Protocol corporate standard, Global Reporting Initiative (GRI), ISO 14031, and ISO 14064-1 as well as KPIs proposed by ICT organizations or initiatives, such as European Telecommunications Network Operators' Association (ETNO), European Telecommunications Standards Institute (ETSI), The Green Grid, GSMA,

International Electrotechnical Commission (IEC), and International Telecommunication Union – Study Group 5 (ITU-T SG 5). These KPIs are mainly proposed to evaluate ICT organization's own performance, not supplier's performance, but Veit et al. (2018) notes that for example sustainability rankings have become popular also for benchmarking purposes.

Problem with rankings is that not every software provider is ranked in worldwide rankings so it might not always be the best possible way to compare suppliers especially if all of those are not operating globally. If big global suppliers are compared with each other, ranking might of course be something that is worth considering.

4 Methodology

In this chapter the methodologies used in the research and in data collection will be explored. First chapter will cover design science research method, whereas second chapter covers interviews, which will be used to collect data to support design science research process and findings from previous research.

4.1 Design science research

In design science, the fundamental purpose is to create things that serve human purposes by bringing value or utility (March & Smith, 1995). Hevner et al. (2004) have defined design science as a problem-solving process, that offers guidelines based on principles of acquiring knowledge and understanding about the design problem and its solution in order to create a new artifact, which can include constructs, models, methods, and instantiations. Van Aken (2004) has added new artifact to include social innovations whereas Järvinen (2007) has enlarged it with new properties of technical, social, and informational resources or their combination. Peffers, Tuunanen, Rothenberger and Chatterjee (2007) sums up the artifact as any designed object with embedded solution to research problem. Artifact created through the process is evaluated with respect of its utility in solving the problem (Hevner et al., 2004).

March and Smith (1995) have stated that design science consists of two basic activities, which are build and evaluate. Building is about constructing the artifact for certain purpose whereas evaluation is about determining how it performs. It is seen critical to anticipate the side-effects that might come from using artifact, and after that to make sure that those side-effects are avoided. Hevner et al. (2004) have defined design science guidelines for information systems research (table 8). The purpose of the guidelines is to help understand the requirements for effective design science research. When guidelines are applied to a specific research project, consideration is needed to determine when, where, and how it should be done.

Table 8. Design science research guidelines (Hevner et al., 2004).

Guideline	Description
Guideline 1: Design as an artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research contributions	Effective design-science research must provide clear and verifiable contribution in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Peffers et al. (2007) have presented a design science research methodology process model, which includes six steps: 1) problem identification and motivation, 2) definition of the objectives for a solution, 3) design and development, 4) demonstration, 5) evaluation, and 6) communication. The process is presented in sequential order, even though in reality there is no expectation that the proceeding would always happen in this particular order. The process can actually be started at almost any step depending on the approach for the process. This can be seen graphically presented in figure 4. A problem-centered approach starts from step one, where the idea for the research is a result of observation of the problem or suggestion for future research from a prior project. An objective-centered solution starts from step two as industry or research need which can be filled by developing an artifact. A design and development-centered approach starts from step three, where artifact is already developed but it does not quite fill the needs as a solution to certain problem. Finally, a client-/context-initiated solution starts from

step four, where the observation is done for already existing solution that works, but where the rigor will be applied to process retrospectively.

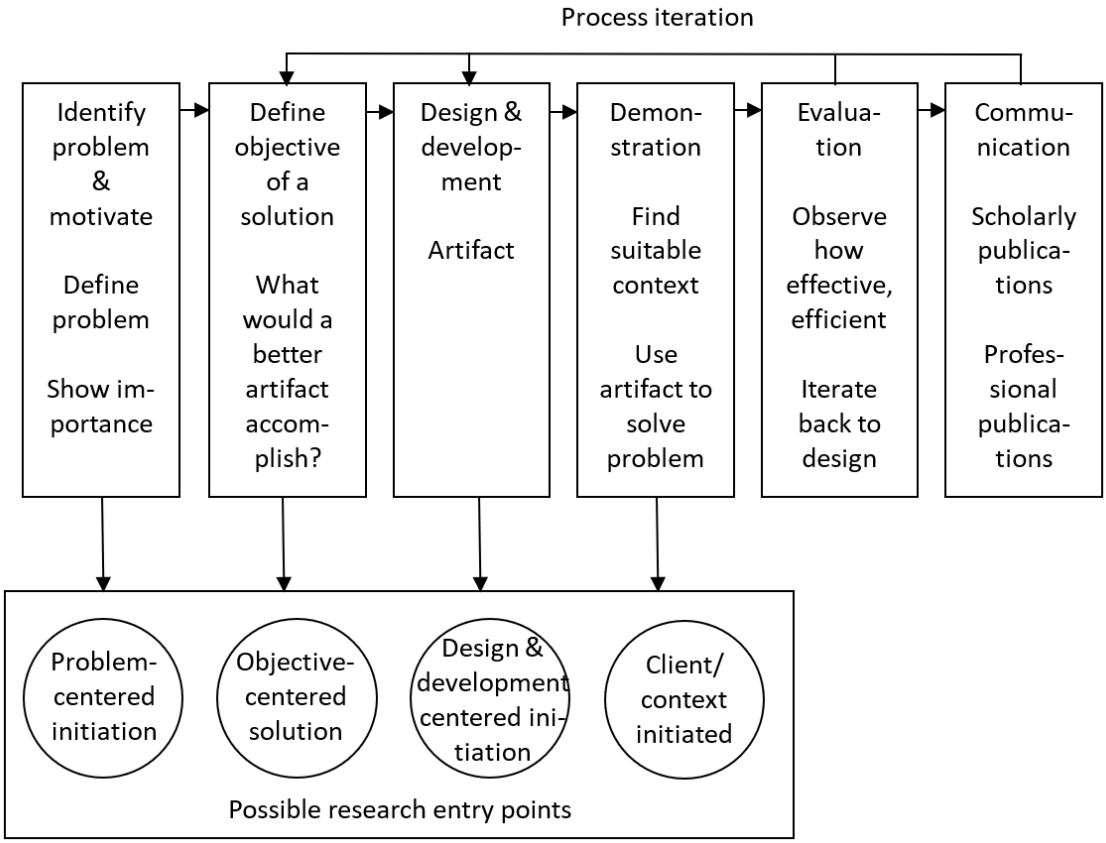

Figure 4. Design science research methodology process model (Peffers et al., 2007).

In the first step of design science research process model by Peffers et al. (2007), problem identification and motivation, the aim is to define the problem and validate the value that the solution will bring. Problem can be defined as the difference between current state and a goal state (Hevner et al., 2004). Because the artifact should provide a solution to defined problem, it may be useful to split the problem conceptually (Peffers et al., 2007). Validating the value of the solution should motivate and help to accept the results of the research. To success in the first step requires knowledge about the problem and the importance about finding a solution to it. This is supported by the design science guidelines, where it is stated that information systems research should enable the

development and implementation of solutions to unsolved and important business problems (Hevner et al., 2004).

After defining the problem, the next step is to define the objectives for a solution (Peffers et al., 2007). Objectives should be created through the problem definition and knowledge about what is possible. Objectives can be quantitative as well as qualitative. This step also requires knowledge about the state of the problem but in addition about possible current solutions and their efficiency. Hevner et al. (2004) has highlighted as well in the first of seven design science guidelines that the artifact must be effectively described in order to enable its implementation and application.

Third step, design and development, is about creating the artifact for the defined problem (Peffers et al., 2007). Designing and developing an artifact includes defining desired functionalities and architecture and creating the actual artifact. This step requires knowledge about theory that can be brough to the solution.

In the fourth step, it should be demonstrated that the artifact solves one or more instances of the defined problem (Peffers et al, 2007). This step can involve different kind of appropriate demonstration activities, such as experimentation, simulation, case study, or proof. For the demonstration, the requirement is effective knowledge about how the artifact should be used to solve the problem.

Fifth step of the process involves the evaluation of the created artifact, and the aim of this step is to measure how well the artifact supports the solution for defined problem (Peffers et al., 2007). During this step, the objectives of a solution should be compared to the results of using artifact in previous step of demonstration. Evaluation requires relevant metrics and analysis techniques. Evaluation can be done in many ways depending of the case, but it could for example include comparison of the artifact's functionality to defined objectives, measuring objective's quantitative performance, carrying out satisfaction surveys, client feedback, or simulations. Hevner et al. (2004) as well highlights

the fact that evaluation is crucial step in the process and artifacts can be evaluated by their functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes as well as evaluating artifacts mathematically. At the end of this step, it can be decided if there is a need to iterate back to step three and improve the artifact or if it will be continued to next step, communication and improvements are left to further projects (Peffers et al., 2007).

Last step of the design science research process is communication (Peffers et al., 2007). In this step, the problem and the value of the solution, the artifact and its utility, the rigor of artifact's design, and its effectiveness to solve the problem should be communicated to relevant audiences. This step requires knowledge about the disciplinary culture. The process model can be used also as a structure for scholarly research publication. In the seven guidelines of design science research Hevner et al. (2004) separates the communication of research to technology-oriented and management-oriented audiences. This allows practitioners to take the advantage of the artifact itself whereas researchers to build a knowledgebase for further research and evaluation.

4.2 Interviews

Research interviews are one of the most important qualitative data collection methods (Qu & Dumay, 2011). Carefully planned interview can provide a rich set of data and it can be a useful way to learn about the world of others. There are different types of interview methods in qualitative research including structured, semi-structured, and unstructured. In this research interview method utilized for carrying out the interviews is semi-structured method. It meets the needs of data collection for this research in the best way as it is efficient way to gather wider range of viewpoints from experts.

"The semi-structured interview involves prepared questioning guided by identified themes in a consistent and systematic manner interposed with probes designed to elicit more elaborate responses" (Qu & Dumay, 2011). Interview guide includes broad themes

about topics that should be covered during the interview, and it directs the conversation towards the issues that the interviewer desires to learn about. Interview guides can vary from scripted to relatively loose, but the purpose is always that it ensures the same thematic approach during the interview. Semi-structured interview is flexible, accessible, and easily understandable as well as most importantly capable to bring out wider viewpoints about human and organizational behavior. It is often the most effective way to gather information. Adams (2015) points out that semi-structured interview is time-consuming and labor-intensive way for gathering information as well as without possibility to large amount of time and personnel for interviewing, sample probably is not large enough to make precise percentual analyzes.

4.2.1 Interviewee selection

Intention of the research defines who should be interviewed and in qualitative investigation, sampling is usually purposeful (Bolderston, 2012). Participants are selected thinking that they may have insight and understanding about the research topic. For qualitative research, an appropriate sample size is the one that answers to research questions adequately.

In this research, interviews are targeted to organizations, that have interest to sustainability matters. Interviews are made from two different point of views of which this study also consists of: software design and supplier selection. Interviews are then conducted to representatives that in addition to their own profession also have knowledge and interest to the sustainability matter in order to get deeper understanding what is already done or alternatively what is seen possible to do in the future to improve sustainability in the field of information technology and in the process of software sourcing. Interviewees demographic information are presented in table 9.

Table 9. Interviewee demographic information.

Interviewee	Gender	Title
1	Male	Chief Technical Officer
2	Female	Founder

Interviews were held to representative from two different organizations. Interview perspectives were selected based on software design and supplier selection viewpoints. Table 10 shows that first interview is conducted from the perspective of information technology development, which supports software design viewpoint, whereas second interview is conducted from the perspective of organizations green actions, which supports the viewpoint of supplier selection.

Table 10. Interview perspectives.

Interview	Interview perspective
1	Information technology development
2	Organizations green actions

First interview was held to a representative from IT organization, and interview focused on information technology development and how green IT is currently seen in the field as well as what kind of activities for improving environmental sustainability would be most relevant for IT organization in practice. Second interview as for was held to representative of organization that is consulting green actions of other organizations. Second interview was then focused on organization green actions and their communication about these actions.

4.2.2 Conducting the interviews and analyzing results

Interviewees were contacted by email and suitable time was scheduled for both interviews. Interviews were held by using Zoom video communication service. Interviews were recorder in order to be able to use those as source material in this study. Interviews were semi-structured, being close to a form of a conversation. Interview structure and questions were defined to guide the conversation in a way that all necessary subjects

will be handled during the interview but at the same time structure was rather loose and it left space for open conversation about the defined topics. Interview structures can be found from appendix one and two.

Results of the interviews are analyzed by familiarizing carefully to interview material which is the recording taken from the interview situation. Content and results of the interviews are presented throughout, and perception is formed through these results. This perception is reflected to findings from literature review which directs to forming the guidelines through design science process, that combines findings from both.

5 Interview results

Two interviews and their content as well as most important results will be presented next, first interview one and then interview two. Interviews took about an hour each and covered questions that were determined in the research structure but not necessarily in that particular order, as interview was flowing more like a conversation, where there was room also to topics that were not determined beforehand.

5.1 Interview 1

First interview was started by finding out if green IT is something that is familiar in the field of information technology development or if it is something that has even generally been under discussion what comes to topics in the field today. It was found out that in the organization that interviewee represents, green IT and environmental aspect in the field was somehow met for the first time about two years ago “and it is only time which I know that this would have been as a concrete demand in the request for a quotation”, says interviewee. This demand of course kind of forced to create guideline for environmental management but before that bidding process, there was no signs about green IT coming to a relevant topic and still today, green IT has not really risen that topical in the field of information technology. Interviewee also mentioned that “it has been somewhat part of combination of quality and environmental management”, but in these cases, it is just a small part of wider picture. Large, global organizations are more or less an exception as they have stricter rules and demand about taking care of sustainability aspects, and many of those have announced their own sustainability and environmental strategies.

During the interview it was also found out that except the one bidding process mentioned earlier, green IT and environmental matters have not been part of customer demands “and there actually is no mechanisms for that yet” says interviewee. In the field where interviewed organization is operating, it is typical that customer defines strictly

the needs and this way the demands of customers affect highly to the whole operation of the organization. If customer is not demanding environmental matters to be considered in the process, many organizations do not have interest to invest sustainability aspects without a pressure coming outside. Interviewee also thought that demands for operating sustainably and environmentally friendly might be more familiar in traditional manufacturing, but when organization is selling a service, this point of view is still very unfamiliar.

Interviewee thought that it is possible that at some point there could be situation coming ahead where environmental aspect in information technology field might need to be taken care of in order to succeed in the competition. Interviewee states that “if these things are not taken into consideration, competitors will do it”. In addition to customer demands, it is possible that this kind of situation would come ahead also through legislation. However, interviewee thinks that “if these things are forced through legislation, it is easily only theoretical” and he also points out that “to make data visible is important so that is something where legislation could help but what happens after that is that it should be transformed to competition”. It was also pointed out that if demands and legislation would force to take environmental aspects to consideration, it would certainly be better to be in front than coming behind and lose a position in the competition.

Even though environmental aspects are currently not part of bidding process and their pointing system, the possible changes in legislation would make it as part of the process. When competition in the field is tough, this kind of changes would force organizations to take care of their environmental management. Interviewee thinks that these kind of changes in legislation would definitely make operating more transparent, but it is obviously uncertain what would happen after that and how it would affect to competition. One good example about how legislation can change the operation of great number of organizations is GDPR that forced to changes in the management of personal information collected in registers.

Interviewee discussed that one possible and considerable way to take first step towards taking environmental aspects as part of operating for information technology organization would be enabling compensation of carbon footprint for customers. “For us it would be quite easy to arrange that we would offer our customers a possibility to compensate the carbon footprint”. This would require organization to find out its carbon footprint but after that the estimation of carbon footprint of a certain project could be done through working hours. Compensation itself could be done through organization that is specialized to take care of the compensations. Interviewee pointed out that it would be a good way to take actions when organizations own resources and knowledge for these kinds of things are limited and this way the compensation would be channeled to the direction where there are enough resources to work for solving environmental issues. In this case compensation would be offered more as a service to a customer rather than customer being forced to investigate the whole process behind the product or service that is purchased.

5.2 Interview 2

Right in the beginning of the interview, it was found out that there is high variation in which kind of green actions organizations are willing to bring in public. Actions brought to public can be everything from rather small daily actions to informing about new certificates. Second interviewee represents organization that offers a platform for other organizations to communicate about their green actions and in addition consults green actions of other organization. Interviewee tells that the “idea behind it is that also small actions would be visible, as it is common that those actions are not communicated, and the message disappears despite otherwise active communication when it is more common to communicate about the core business”. It was also added that “needs for communication are of course different between big and small organizations” and this also affects to what is brought in public.

In the interview it was stated that organizations are quite cautious what they tell about their green actions in public, especially if they do not have environmental management system, which is considered to be reliable. There might be fear of being labelled for so called greenwashing if there is not enough accurate information available and some kind of proof of the greenness of the actions. If organization desires to operate in a green way, it is crucial to also find partners that are sharing the same values but at the same time finding partners with same values might be difficult if organizations does not communicate about their values openly. Interviewee mentioned that in some fields right partners are prerequisite for operating: “for circular economy it is crucial to network and find the right partners and it is like a main point in it, not only bringing out own message but finding new ideas and finding the partners that you want to work with”. Especially new innovations are something that are generally seen as intriguing for other organizations when observing organizations that would be potential partners.

It was also seen that interest for operating in a green way is often spreading inside an industry, and if one organization is doing something that is seen interesting, it might encourage other organizations to take actions as well. This way interest for operating more sustainably can start spreading, but it needs open communication from organizations. Green actions in the field of technology are still rather divided between organizations that have branded themselves as well as their green technology as part of their core business, but at the same time there are also organizations that think that environmental issues are not part of technology field and “not to mention that organizations in IT sector would be proactive even though the field is in key position and has lot of opportunities to go towards that position”. Environmental sustainability sector would benefit significantly about having IT organizations interest.

In the interview it was also pointed out that customer demands are in the center of organizations interests and some organizations pay attention to the need of taking care of environmental issues only after there is demand from outside. “As customers start to demand and ask, only after that organizations go forward with these things”. That is why

interviewee also said that “I always point out that it is everyone’s responsibility to demand these actions from their partners as it is better that the demand comes from customers”. These demands would then force even more organizations to take environmental issues into consideration in their operation. At the same time, it can be significant advantage to take environmental issues as part of the daily operation before the demands are coming from outside, as in some cases meeting the demands is not possible if nothing has been done in advance.

Environmental management systems and certificates are a common way to communicate to the outside about environmental awareness as they give a clear signal that the organizations operations are audited and trustworthy what comes to environmental aspect. There are still lot of varying in the environmental management systems and certificates also between different industries as some might be recognized only in certain fields. Nowadays there are countless of options available, and it depends on organizations needs which one is seen as a best option. Interviewee also pointed out that “in some fields there are also certain standards that are obligatory to even operate in the field so that forces organization to invest in it”. On the other hand, it is not still always all about familiar and known certificates as organization can create their own environmental management system which can also be considered reliable enough. That is always better than nothing, even though it would have not been audited by third party.

5.3 Interview findings

One of the most important findings that came up in both interviews was that demands coming outside the organization (typically from customers) are most efficient driver for taking environmental sustainability into consideration in organizations own operation. Customer demands are strongly directing organizations interests when succeeding in the competition is in the center of the operation. This supports the view that taking environmental issues as part of sourcing process is critical in setting pressure to suppliers.

In the second interview it was highlighted how important communication is. It is common for organizations to be cautious about communicating environmental sustainability, but without that, it is hard to find partners that are sharing same values which might be crucial if green values are highlighted in the operation of the organization. One of the key points was also that environmental actions are typically spreading especially inside an industry, as if competitor is doing something that interests, others will probably do that right after, but this also requires open communication. In the first interview it was also pointed out that making things visible is very important in reaching towards more sustainable way of doing business.

In the second interview it was also noteworthy that environmental management systems and certificates can be crucial in showing that environmental issues are taken into consideration. Different needs can affect to systems or certifications being used, but it is still way of gaining trustworthiness. First interview as for brought up a new point of view about compensation of carbon footprint. In addition of compensating own footprint, it could open up opportunities also for offering compensation as a service to customers.

6 Designing recommendations for green software sourcing

In this chapter the recommendations for green software sourcing will be formed by using design science process model introduced by Peffers et al. (2007). Process model includes six steps: identifying problem, defining objective of a solution, design and development, demonstration, evaluation, and communication, and each of these steps will be applied to this study and presented one by one.

6.1 Identifying problem

As the use of information technology is constantly growing, its share from global emissions is also increasing at the same time. Sustainability of information technology is part of whole concept of sustainable development just like any other field so there is a need to take sustainability into consideration also in the field of information technology. Fundamentally sustainability is about finding a balance for Earth to be to support its population and economic growth without threatening the health of humans, animals, and plants (Portney, 2015, p. 4). Premise of sustainability is that resources of Earth cannot be used, depleted, and damaged without limitations. Using resources indefinitely would lead to running out of the resources at some point, but also their exploitation would debilitate possibilities of life to persist. This addresses that sustainable way of living is prerequisite of life and it should be considered in every aspect of human environment.

Like interviews that were held as part of this study showed, it is common that it requires pressure and demands from customers and other stakeholders, for organization to take environmental aspects as part of their operations. Therefore it is important that environmental aspects would be part of sourcing process as evaluation criteria, for more organizations to be forced to consider the environmental impact that they are leaving behind.

Already existing research about sustainable IT is mainly focusing to all aspects of sustainable development, environmental, social, and economic aspects. In this research the

focus will be in environmental aspect, why the focus is on green IT, not in the wider concept of sustainable IT. What comes to already existing research papers about green IT, they mainly focus on very detailed software metrics that in order to apply in practice, require deeper knowledge about software design and development. Many research have their focus on measuring energy consumption, which might be hard for people participating on sourcing process to evaluate if supplier does not provide this detailed information. Evaluation should be able to be done without too much struggle for more organizations to take this kind of actions as part of their sourcing process. In addition to that, previous research has mainly focus in either green IT or supplier evaluation. There was no research found where these two aspects would have been combined in same research for evaluating software and its supplier in IT sourcing process. That is why this study strives to combine software and supplier evaluation to one guideline which can be used for sustainable software sourcing.

6.2 Defining objective of a solution

Recommendations designed through this study should give easily applicable way to evaluate both software and its supplier from environmentally sustainable perspective during software sourcing process. Evaluation should be able to be done without having considerable knowledge about information technology development in general as well as technical details from software itself, which under evaluation and considered to be purchased. Recommendations will focus on environmental sustainability which means that economic and social sustainability will not be included when recommendations are designed. Recommendations formulated through this study are primarily made from the perspective of large organizations as it is a belief that in large organizations sourcing process is in most cases more controlled than in smaller organizations. Despite that, recommendations are applicable for smaller organizations as well as there is no need for strict sourcing process models for taking recommendations as part of the process.

Objective of designed recommendation is to make it easier to follow green IT principles during software sourcing process. Recommendations should gather best practice guidelines for evaluating software and its supplier from environmentally sustainable aspect. Recommendations should be applicable for evaluation despite of the size of organization that is evaluated and software that it is offering. Recommendations should also motivate to take environmental aspects as part of software sourcing process.

6.3 Design and development

Recommendations for green software sourcing, are designed based on what was found out from previous research on literature review as well as on interviews that were held to specialists of information technology development and organizations sustainability actions. For evaluation of software and evaluation of supplier there are selected four guidelines for each.

Guidelines for evaluation of software are following:

1. Software efficiency
2. Upgradeability
3. Estimated lifetime
4. Cloud computing.

Guidelines for evaluation of supplier are:

1. Environmental program
2. Carbon footprint
3. Following certification
4. Compensation of emissions.

Software efficiency is the first guideline for evaluation of software as it was brought up in many previous studies. There are many ways to measure software efficiency and previous research presented many key figures and calculations for their determination. As in this study the aim is to keep recommendations easy to apply the recommendation of software efficiency focuses mainly to make sure that software fills the requirements that is set for it. It is important that software fits for its needs, has the possibility to have as many users as the organizations needs to have for it and of course that it is efficient enough for the work that it is supposed to enable. It is important that the software is efficient enough so that there is no need to change it and have other software to cover its shortages. Efficient software works efficiently as well as fills the needs due to which it has been supplied in the first place. For software to fill its needs, it is crucial to investigate what are these needs and make sure that different kind of users needs are taken into consideration when different options are evaluated. Inefficient software is just waste of resources in many ways, and it does not bring any advantage for organization. If some key figures are necessary for evaluating software efficiency, these figures can be combined to this first step of evaluation guidelines.

Second guideline for the evaluation of software is upgradeability. Software sourcing is expensive, time-consuming as well as consumptive for the environment. When software is upgradeable, it is most probably possible that it will be used longer than one that is not upgradeable. Software needs to be able to be upgraded when the needs are changing, especially if it is about slight changes. It is common that there is need to do changes for the number of users as well as have security updates, just to have couple of examples. Slight changes might be common if organization and its needs are constantly evolving, and software needs to be able to respond to this kind of changes in order to be able to serve organization in the long run.

When software is sourced it is important to estimate its lifetime, which is third guideline for evaluation of software. If software is sourced for filling the needs for long term it is important to estimate how long the lifetime of the software should be so it could fill its desired lifetime. Software should be able to reach this lifetime estimation for it to be

worth investing. Lifetime is closely in touch with software efficiency and upgradeability which are two software evaluation guidelines presented earlier. Efficient and upgradeable software is more likely to have also longer lifetime than software that is inefficient or not upgradeable.

Cloud computing and it being part of green IT has raised different viewpoints regarding different researchers, but it is added as fourth guideline for software evaluation as it supports other three guidelines. Cloud based software usually is upgradeable at least to a certain point and because of that usually also estimated lifetime can be rather long. In addition to that support and maintain is centralized to service provider, which reduces local responsibilities as well as does not tie as much resources inside the organization.

First guideline for evaluation of supplier is environmental program. This means that supplier's encumbrance to follow some kind of environmental program should be evaluated. Environmental programs can be very different dependent on several aspects. For example, size of the supplier, field where it is operating and whether supplier is operating globally or not, might affect to environmental program that is followed. Environmental programs can be bought from outside organization or build by organization itself, but what is preferred in the sourcing process, is dependent on the organization doing the sourcing process. Organization that is sourcing software and evaluating its supplier has to determine if some aspects in the environmental program are requirements.

Carbon footprint of supplier is second guideline for the evaluation of suppliers. Carbon footprint tells how environmentally responsible supplier operates and is able to provide its products or services. Finding out and calculating carbon footprint might not be easy for an organization but if it is done, it tells that organization is highly interested about the subject and maybe also willing to take actions for reducing its carbon footprint. Communicating about the carbon footprint can increase the trustworthiness and openness what comes to environmental actions also in general.

Third guideline for evaluating supplier is finding out if supplier is following environmental certification. Organization that is supplying software can define if supplier needs to be certified with certain (or some) environmental certification or if it is enough that supplier follows the guidelines of certain (or some) environmental certification. Certifications used can be different dependent of the field, size, and globality of supplier as there might be entirely different needs for the certification. That is why it is not told here which certification should be looked through when evaluating suppliers. Very often supplier communicates openly (for example in their web site) if they are certified with a certain certification and if they are not certified but follow a certain certification, most probably they are also then willing to tell about it at least when asked. Especially if supplier follows environmental certification and environmental aspects are important value for the organization, it is common that this is communicated onwards.

Fourth and last guideline of supplier evaluation is compensation of emissions. More and more organizations communicate openly about their compensation of emissions as it is seen something that adds the value. Compensation of emissions tells that supplier is taking their environmental responsibility seriously and wants to lead as an example. Some organizations do already compensation in some form, but like it was suggested in the first interview, one option would be also giving possibility for the organization supplying the product or service to compensate the emissions that are provided during production as well as when providing and maintaining the software. This could be more easy way to take the first step and at the same time give an option for the purchaser to share the responsibility of cooperation.

6.4 Demonstration

There are many ways how recommendations presented can be applied to a sourcing process. There is no one and only place where recommendations should be applied in the sourcing process as it depends on the needs that organization has and how important aspect green IT is in their sourcing process. But in order to demonstrate

recommendations designed earlier, it is worthwhile to use example description in what kind of situation recommendations could be used.

Let us take a medium-sized organization, that is sourcing ERP system, as an example. Environmental aspects are important for this organization so as it has a need to a new ERP system, it wants to take environmental aspects and principles of green IT in to account in the sourcing process. It is important for the organization that software as well as its supplier are as green as possible without sacrificing the demands set for system that should be sourced.

First step for organization is to define its needs. What kind of system is suitable for them and which features are necessary. After that organization can start sourcing possible software by taking four guidelines, software efficiency, upgradeability, estimated lifetime, and cloud computing, as its criteria for selecting possible systems. If system does not fill these criteria, it will be left out. Organization then decides that software needs to be efficient enough for its needs, it needs to be upgradeable, it needs to be evaluated to last at least desired lifetime, and it needs to be cloud based as cloud-based software seems to fill the previous criteria for this case and this particular organization's needs. Following these criteria, organization makes sure that software is right for its needs in the long run and there is no need to change system after only short time of use as it would be unprofitable financially but also when looking environmental aspects. Organization sees that environmentally favorable option is also the most beneficial option financially.

After organization has found the group of possible software that fill its requirements, it is time to take a look to suppliers of these software. Organization takes four guidelines, environmental program, carbon footprint, following certification, and compensation of emissions, to help evaluate most suitable supplier. Some suppliers might communicate about these aspects for example on their websites but with some there might be need to ask and discuss about their environmental actions and interest. Goal is to find out if

supplier has some kind of environmental program that they are following, if they have found out their carbon footprint and what it is, if they are certified with environmental certification or following a certain one, and if they are compensating their emissions or offering a possibility for their partners to do it.

When these four steps of supplier evaluation are looked through and suppliers' performance in these aspects found out, organization should evaluate which is the best possible combination of software and its supplier that fills the technical requirements as well as takes into account the environmental perspective in their operation. Eventually selection will be done by underlining the factors that are most critical to buying organization.

6.5 Evaluation

Hevner et al. (2004) have defined seven guidelines for helping to understand the requirements for effective design science research. These guidelines and their principles are appropriate also for evaluating the recommendation formed previously as they give an overview how recommendations are filling the criteria of design science research. These seven guidelines by Hevner et al. (2004) and their fulfillment in the process are presented in table 11.

Table 11. Evaluating the designed recommendations by utilizing design science research guidelines (Hevner et al., 2004).

Guideline description	**Evaluation of design process**
1. Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	Design science process model was utilized when carrying out this study. The result of the study is recommendations for software sourcing process that consider evaluation of software and its supplier from environmentally sustainable perspective. Recommendations created through this process can be seen as a method, which guides evaluation of sustainable software in sourcing process.
2. The objective of design-science research is to develop technology-based solutions to important and relevant business problems.	Solution, recommendations, are developed having the focus in environmental issues so it can be seen as a solution for important and relevant problem. Recommendations suggest taking green IT as part of software sourcing process and evaluate software and its supplier from environmentally sustainable perspective. As the recommendations focus on software souring, solution is also technology-based.
3. The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	Utility, quality, and efficiency of recommendations were demonstrated by using case example to what kind of situation they could be utilized. Recommendations can be adapted to different needs, so they leave room more precise requirements and metrics depending on the case where it is applied and organization that is utilizing them.
4. Effective design-science research must provide clear and verifiable contribution in the areas of the design artifact, design foundations, and/or design methodologies.	Recommendations combine the evaluation of software and its supplier to one set of guidelines from environmental aspects. This kind of combining from only environmentally sustainable perspective was not found from previous research.
5. Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	Recommendations were designed based on previous findings from the evaluation of software and the evaluation supplier as well as interviews. Recommendations were formed by utilizing design science research process model.
6. The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	In addition to previous research, in the process it was utilized interviews with two specialists from two different organizations that have insight to the subject that was in the center when recommendations were designed.

7. Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.	Recommendations designed during this process were represented in in the master's thesis seminar in University of Vaasa. In addition, this report will be available in the university's database.

The process of designing the recommendations as well as the recommendations themselves were able to answer to all seven design science guidelines defined by Hevner et al. (2004). It can be then stated that the study fills up the most essential requirements that have set for it from the design science research perspective.

6.6 Communication

This report acts as communication about guidelines designed in this study. This report and the recommendations presented in it are available in the database of University of Vaasa. Results of this study will be also presented in the university's master's thesis seminar.

7 Discussion

Objective of this study was to form guidelines for software sourcing process that are designed through green IT principles and take into consideration the evaluation of software as well as its supplier. Objective was that guidelines formed through the study should be easily applicable in different circumstances and environments, and the evaluation of software and its supplier should be able to be done without having considerable knowledge about information technology development or technical details from the software itself. Guidelines should make it easier to follow green IT principles during software sourcing process as well as they should motivate to take environmental aspects as part of software souring process.

Study was carried out by utilizing the method of design science process and its six steps including model introduced by Peffers et al. (2007). Designed guidelines were formed by utilizing the findings from previous research about green IT as well as two interviews that were held to two specialists from two different organizations. Guidelines that were designed through this study combined best practices found from these sources and final guidelines have four recommendations for each, evaluating greenness of software and evaluating green actions of software supplier.

7.1 Evaluation of designed guidelines

Recommendations formed in this study are mostly based on previous research made about the subject as well as two interviews that were held during this study. Based on the information about these sources, recommendations are formed by considering the findings that are most suitable to fill the objectives of the recommendations.

Guidelines for evaluating software and its supplier are designed being applicable to almost any organization that wants to utilize those. That is why guidelines are not all-embracing and detailed for certain kind of situation or environment. They work as high-level

guideline to help consider which kind of aspects could be taken into account when sourcing software from environmentally sustainable point of view. Guidelines are easy to understand, which motivates to use the presented recommendations and think about green values also in sourcing process. Different kind of organizations have different needs, and they have a possibility to emphasize different parts of guidelines by deciding which parts are more important than others. It might be also worthwhile to provide more detailed criteria inside these guidelines if more precise information from possible suppliers is needed. For example, software efficiency is something that can be measured in many ways numerically if there is a need to do that kind of comparison as well as when looking for suppliers' certificates, a certain one can be set as a demand for supplier to be able to be selected.

Guidelines formed in the study are well aligned with previous research and the findings made from previous research were highly utilized in the recommendations that were formed in this study. For example, Kern et al. (2013) as well as Bozzelli et al. (2014) both have presented energy efficiency as one metric for measuring software greenness level. Software efficiency and its monitoring is also considered as one recommendation in the guidelines designed in this study. What comes to Luthra et al. (2017) they defined environmental management system as evaluation criteria for sustainable supplier whereas Kumar et al. (2014) listed finding out supplier's carbon footprint and environmental certification as elements for evaluating a supplier. There elements are all somehow highlighted also in the guidelines of this study. It is still noteworthy that Kern et al. (2013) and Bozelli et al. (2014) researched only green software metrics whereas Luthra et al. (2017) and Kumar et al. (2014) researched only supplier evaluation methods. In this study, these two different aspects of software sourcing, evaluation of software and evaluation of supplier are both combined and taken into consideration when designing the guidelines.

Guidelines designed in this study are easier to apply than the numeric measures found from previous research. For example, Kern et al. (2013) suggest that energy efficiency

metric would be calculated by dividing used energy by unit of work which would require detailed and numeric information about these factors. In this study recommendations do not directly focus on energy efficiency but on software efficiency where the evaluation is based on how efficiently software fills the requirements set for it. Recommendations can be adapted to the needs of user by adding for example numeric measurements to evaluation criteria if that is required. That is why recommendations are rather user-friendly and do not require deep set of skills and understanding about software development. In addition to that, guidelines are also acting as a motivation to consider how environmental sustainability can be taken as part of all different parts of daily operations of organizations.

7.2 Limitations and further research

Designed recommendations were demonstrated by using a case example about the situation where organization could utilize the guidelines. In the demonstration it could be seen that recommendations are formed in general level. Recommendations can be utilized as they are but, in some situations, it might be worthwhile to have more detailed evaluation criteria. Using more detailed measurements, key figures and stricter requirements is left entirely to the responsibility of the organization that is utilizing these recommendations. Guidelines do not take into consideration how these four recommendations for evaluating software as well as four recommendations for evaluating supplier are rated between each other when comparing different findings from different suppliers. This is also something that is left to an organization utilizing recommendation in their sourcing process to decide.

Comprehensiveness of interviews is very narrow due to only two interviews held during this research process. As the purpose was to interview organizations that have high interest to environmental sustainability the possible contacts were searched among organizations that openly communicate about their green values. It was surprising how difficult it was to find this kind of potential organizations, especially from the field of

information technology. In addition to that, response rate to interview requests was also low. Difficulties in finding right person for making the first contact, might have also some kind of effect to this response rate. Because of these difficulties, the amount of interviews was lower than what was intended.

It is important to remember that recommendations designed in this study are only an objective outlook of researcher. Even though recommendations are based on findings from previous research and interviews, other researcher could design completely different set of recommendations. It is also important to note that researcher did not have previous insight to the concept of green IT, which might also have an effect to the outcome.

In further research, designed recommendations could be applied to real sourcing processes. This way recommendations could get more detailed and precise insight from practice and recommendations could gain more reliability and new ideas. Also, for further research it could be worthwhile to study which methods could be used for rating the evaluation criteria presented in the recommendations.

7.3 Conclusions

This study researched how software and its supplier can be evaluated during software sourcing process from environmentally sustainable perspective that supports green IT principles. Through the findings, a set of recommendations were formed to be utilized in environmentally sustainable sourcing process. Guidelines designed in this study consist of four recommendations for evaluating the software and four recommendations for evaluating the supplier of the software. It is suggested that this set of recommendations are utilized in sourcing process for evaluating software and its suppliers' performance from environmentally sustainable point of view.

In this study it is stated that taking environmental aspects into consideration in sourcing process is crucial in driving suppliers towards making more environmentally friendly actions. It is important to remember that recommendations are generalized and do not take all different possibilities and use environments into account but at the same time this study gives still an interesting insight to the topic and recommendations are worthwhile to consider as a first step to take environmental sustainability as part of sourcing process.

References

Adams, W. (2015). Conducting Semi-Structured Interviews. *Handbook of Practical Program Evaluation*, 4, 492-505. https://doi.org//10.1002/9781119171386.ch19

Ahi, P. & Searcy, C. (2015). An analysis of metrics used to measure performance in green and sustainable supply chains. *Journal of cleaner production*, 86, 360-377. https://doi.org//10.1016/j.jclepro.2014.08.005

Bokolo, A. & Mazlina, A. (2016). Green IS for Sustainable Decision Making in Software Management. *Journal of Soft Computing and Decision Support Systems*, 3(3), 20-34.

Bolderston, A. (2012). Conducting a Research Interview. *Journal of Medical Imaging and Radiation Sciences*, 43(1), 66-76. https://doi.org//10.1016/j.jmir.2011.12.002

Bozzelli, P., Gu, Q. & Lago, P. (2014). A systematic literature review of green software metrics. *VU Technical Report*.

Capra, E., Francalanci, C. & Slaughter, S. (2012). Is software "green"? Application development environments and energy efficiency in open source application. *Information and software technology*, 54(1), 60-71. https://doi.org//10.1016/j.infsof.2011.07.005

Carmel, E. & Sawyer, S. (1998). Packed software development teams: what makes them different?. *Information Technology & People*, 11(1), 7-19. https://doi.org//10.1108/09593849810204503

Gangadharan, G. R., Uden, L. & Luttighuis, P. O. (2016). Sourcing Requirements and Designs for Software as a Service. *International Journal of Systems and Service-Oriented Engineering*, 16(1). https://doi.org//10.4018/IJSSOE.2016010101

Dastbaz, M., Pattinson, C. & Akhgar, B. (2015). *Green Information Technology : A Sustainable Approach*. Elsevier Science & Technology.

Dick, M., Naumann, S. & Kuhn, N. (2010). A Model and Selected Instances of Green and Sustainable Software. *IFIP Advances in Information and Communication Technology*, 328, 248-259. https://doi.org//10.1007/978-3-642-15479-9_24

Harmon, R. R., & Auseklis, N. (2009). Sustainable IT Services: Assessing the Impact of Green Computing Practices. *Proceedings of the PICMET '09 – 2009 Portland International Conference on Management of Engineering & Technology*, 1707-1717. https://doi.org//10.1109/PICMET.2009.5261969

Hevner, A. R., March, S. T., Park, J. & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, 28(1), 75-105. https://doi.org//10.2307/25148625

Hiekkanen, K., Seppälä, T. & Ylhäinen, I. (2021). Energy and Electricity Consumption of the Information Economy Sector in Finland. *ETLA Report No 107*. https://pub.etla.fi/ETLA-Raportit-Reports-107.pdf

ITU-T report. (2012). Toolkit on Environmental Sustainability for the ICT Sector. https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-ICT-2012-09-PDF-E.pdf

Jenkin, T. A., Webster, J. & McShane, L. (2011). An agenda for 'Green' information technology and systems research. *Information and Organization*, 21(1), 17-40. https://doi.org//10.1016/j.infoandorg.2010.09.003

Järvinen, P. (2007). Action Research is Similar to Design Science. *Quality and Quantity*, 41(1), 37-54. https://doi.org//10.1007/s11135-005-5427-1

Kern, E., Dick, M., Naumann, S., Guldner, A. & Johann, T. (2013). Green Software and Green Software Engineering - Definitions, Measurements, and Quality Aspects. *ICT4S 2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability*, 87-94. https://doi.org//10.3929/ethz-a-007337628

Kumar, A., Jain, V. & Kumar, S. (2014). A comprehensive environment friendly approach for supplier selection. *Omega (Oxford)*, 42(1), 109-123. https://doi.org//10.1016/j.omega.2013.04.003

Loeser, F. (2013). Green IT and Green IS: Definition of Constructs and Overview of Current Practices. *Proceedings of the Nineteenth Americas Conference on Information Systems*. https://doi.org//10.13140/2.1.3065.6962

Luthra, S., Govindan, K., Kannan D., Mangla, S. K. & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production*, 140, 1686-1698. https://doi.org//10.1016/j.jclepro.2016.09.078

Madan, S., Sangwan, S. S. & Bhatia, R. (2019). Identification, selection and prioritization of sustainable and green software factors using fuzzy set theory. *International Journal of Comutational Intelligence & IoT*, 2(1), 394-401. https://ssrn.com/abstract=3355396

March, S. T. & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, 15(4), 251-266. https://doi.org/10.1016/0167-9236(94)00041-2

Marshall, M. N. (1996). Sampling for qualitative research. *Family Practice*, 13(6), 522-525. https://doi.org/10.1093/fampra/13.6.522

Mell, P. & Grance, T. (2010). The NIST Definition of Cloud Computing. *Communications of the ACM*, 53(6).

Nöhren, M., Heinzl, A. & Kude, T. (2014). Structural and Behavioral Fit in Software Sourcing Alignment. 2014 *47th Hawaii International Conference on System Science*, 3949-3958. https://doi.org/10.1109/HICSS.2014.489

Peffers, K., Tuunanen, T., Rothenberger, M. A. & Chatterjee, S. (2007). A Design Scinece Research Methodology for Information Systems Research. *Journal of Management Information Systems*, 24(3), 45-77. https://doi.org/10.2753/MIS0742-1222240302

Portney K. (2015). *Sustainability*. MIT Press.

Qu, S. Q. & Dumay, J. (2011). The qualitative research interview. *Qualitative Research in Accounting & Management*, 8(3), 238-264. https://doi.org/10.1108/11766091111162070

Santosh, R. B. & Shivangi V. T. (2019). Green procurement process model based on blockchain-IoT integrated architecture for a sustainable business. *Management of Environmental Quality: Ab International Jornal*, 31(3), 741-763. https://doi.org/10.1108/MEQ-06-2019-0136

Santy, K. & Sikkel, K. (2014). Sourcing Lifecycle for Software as a Service (SAAS). *EPJ Web of Conferences*, 68. https://doi.org/10.1051/epjconf/20146800010

Sollish, F. & Semanik, J. (2011). *Strategic Global Sourcing Best Practices*. John Wiley & Sons, Inc.

Thomond, P. (2013). The Enabling Technologies of a Low-Carbon Economy: A Focus on Cloud Computing. https://www.computerworld.com.pt/media/2013/07/Cloud-Study-FINAL-report_2.pdf

Van Aken, J. E. (2004). Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules. *Journal of Management Studies*, 41(2), 219-246. https://doi.org//10.1111/j.1467-6486.2004.00430.x

Van Heddeghem, W., Lambert, S., Lannoo, B., Colle, D., Pickavet, M. & Demeester, P. (2014). Trends in worldwide ICT electricity consumption from 2007 to 2012. *Computer Communications*, 50, 64-76. https://doi.org//10.1016/j.comcom.2014.02.008

Van Weele, A. J. (2010). *Purchasing and Supply Chain Management*. Cengage Learning EMEA.

Veit, C., Lambrechts, W., Quintens, L. & Semeijn, J. (2018). The Impact of Sustainable Sourcing on Customer Perceptions: Association by Guilt from Scandals in Local vs. Offshore Sourcing Countries. *Sustainability*, 10(7), 2519. https://doi.org//10.3390/su10072519

Wang, D. (2008). Meeting Green Computing Challenges. *2008 10th Electronics Packaging Technology Conference*, 121-126. https://doi.org//10.1109/EPTC.2008.4763421

Wang, L., Tao, J., Kunze, M., Castellanos, A. C., Kramer, D. & Karl, W. (2008). Scientific Cloud Computing: Early Definition and Experience. *2008 10th IEEE International*

Conference on High Performance Computing and Communications, 825-830. https://doi.org//10.1109/HPCC.2008.38

Wilbanks, L. (2008). Green: My Favorite Color. *IT Professional*, 10(6) 63-64. https://doi.org//10.1109/MITP.2008.122

World Commission on Environment and Development. (1987). Our Common Future. http://www.ask-force.org/web/Sustainability/Brundtland-Our-Common-Future-1987-2008.pdf

Appendices

Appendix 1. Interview themes: software development

1. Green IT in the field of software development today
2. Outside demands towards green IT
3. Green IT as value adding aspect to customers
4. How green IT could be part of IT organizations operations

Appendix 2. Interview themes: supplier selection

1. Bringing green actions in public and communicating about them
2. Green actions and their importance when selecting suppliers or partners
3. Actions that raise interest in other organizations when selecting suppliers or partners
4. Measuring and evaluating green actions