DEVELOPING GUIDELINES FOR GREEN INFORMATION AND COMMUNICATION TECHNOLOGY

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This dissertation is submitted in part fulfilment of the requirements for the degree of MSc of the University of Strathclyde.

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Abstract

Being 'green' has become increasingly more important during the last few years, due to the stringent environmental targets set by the United Nations, the European Union, and other international agencies. With Information and Communication Technology (ICT) playing a big part in most organisations, it is time to look at how it can become greener, and put less stress on the environment.

The aim of this dissertation is to define Green ICT, and explain the strategies one can use to lessen the environmental impact of ICT. Guidelines are produced, allowing organisations to see the green strategies and technologies available for different aspects of Green ICT.

It was found that there are two main ways in which the environmental impact of ICT can be lessened: the actual ICT equipment can be produced, used and recycled in a way that is more environmentally friendly, or ICT can act as a facilitator to make other parts of life greener, like in the commonly mentioned example of teleconferencing. Looking not only at the use phase, but the entire lifecycle of equipment, and having a person or group be in charge of Green ICT in the organisation were found to be important for Green ICT.

The guidelines produced are based on the literature review, where green strategies where uncovered, and refined with the help of interviews. The guidelines present suggestions for becoming greener, step-by-step, across five dimension; business, data, application, technology and policy. Both green technologies and green practices and behaviours are included in the guidelines.

Acknowledgements

This dissertation examines Green Information and Communication Technology. Unavoidably, there have been some setbacks, but writing the dissertation has been a worthwhile experience. Along the way, I have received help and guidance from a number of people, and for that I am very grateful.

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Thank you!

Glasgow, August 2014

Rebecka Jarbur

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1 Introduction

In this section, the reader will be introduced to the topic of Green Information and Communication Technology (ICT). Later, the aim of the dissertation will be explained, and the research question will be presented.

1.1 ICT's Role in the Environmental Debate

Searches on Google for 'sustainability' and 'the environment' return more than 40 million results each. 'Climate change' gives almost 35 million results. Being 'green', and aware of the natural environment is obviously a hot topic at the moment. Almost all aspects of our lives need to become more environmentally friendly if we are to reach the climate goals set by the European Union, the United Nations and other international agencies. EU's 2020 package is a set of binding legislation that deals exclusively with the environment. It includes targets for a 20% improvement in energy efficiency, and a 20% reduction in greenhouse gases from 1990 levels (EU, 2014). The United Nations created the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, as a forum for discussing environmental issues (UN, 2014).

A well cited report by Gartner and WWF claims that 2% of global greenhouse gas (GHG) emissions come from the Information and Communication Technology (ICT) sector, as much as from airline traffic (Mingay & Pamlin, 2008). Forge et al. (2009) estimate that ICT consumes 7.8% of EU electricity, and that this could grow to 10.5% by 2020. Based on these numbers, the impact of ICT on the environment is not negligible. The fact that ICTs share of total energy usage is set to grow makes it even more important to focus on how ICT can become greener.

1.1.1 ICT is a Problem and a Solution

ICT is in a unique position, as it is simultaneously part of the problem, and part of the solution. ICT has the potential to streamline processes, and thus saving natural resources, as well as providing better tools for analysing the current environment. At the same time, ICT uses large amounts of energy to run, and many rare, and sometimes hazardous materials go into the production of the actual equipment. Coupled with the short average lifecycle of ICT equipment, the impact on the environment is not an issue to be overlooked. As Andrew (2010) says "*The direct impact of ICT on the environment is much greater than is generally realised*" (p. 1392).

Williams (2011) discusses both the negative and positive impacts of ICT. Apart from the obvious fact that ICT consumes large amounts of energy, hazardous metals such as arsenic and cadmium go into the manufacturing of equipment. However, ICT can mitigate negative environmental impacts in a number of ways. Williams (2011) suggests these include teleworking, where employees work from home, avoiding daily commutes, and optimised manufacturing, where less material and energy go to waste. Often referred to as ICT for Green, or greening by IT, these new ideas have the potential to have a far greater positive impact on the environment, than what would be possible with more efficient equipment alone.

However, predictions for green effects from ICT have been wrong before (Plepys, 2002). ICT was predicted to create a paperless office, where everything was done online and on-screen. In reality, paper consumption increased with the introduction of affordable and available printers (Plepys, 2002). In addition to uncertainty about the possibilities of making other sectors greener with the help of ICT, there is fear that rebound effects will cancel out the effects of greener ICT. Hilty (2008) explains that more energy efficient ICT equipment, which would lower the cost of running it, or faster and cheaper equipment due to Moore's law, will make people buy more ICT equipment, thus cancelling out the effect. This has already been observed in the energy sector (Hilty, 2008).

Looking specifically at the energy efficiency of ICT, Jenkin, Webster and McShane (2011) claim that more than half of the energy consumed by ICT is wasted, due to inefficient technologies or the behaviours of employees. Commenting on the increasing share of energy consumed by ICT, some reasons given by Jenkin, Webster and McShane to explain the development are that efforts to green ICT frequently lack defined ownership, and that ICT is often overlooked when organisations assess their environmental footprint. Highlighting the environmental impact of ICT, and bringing it out in the open could be a solution to these problems.

The amount of data stored has increased exponentially in the last couple of years. The International Data Corporation (2014) estimates that data is growing 40% a year, from 4.4 zettabytes in 2013 to a projected 44 zettabytes in 2020. Harmond and Auseklis (2009) offer a number of explanations for the data growth. The simplest explanation is the growth of computer and Internet usage, but regulations like the Sarbanes-Oxley Act which governs data, retention and disaster recovery strategies that rely on duplicate records are further reasons why the amount of data stored is growing. With an ever-increasing storage capacity needed, concerns over the greenness of data storage are emerging (Osseyran, 2013). Recent figures show that some data centres now consume as much energy as the cities in which they are located (Andrew, 2010).

1.1.2 Implementing Green ICT

Although Green ICT can offer environmental benefits, like more energy efficient equipment, and less e-waste, as well as greening of other sectors, there are issues when it comes to implementation.

According to Suryawanshi and Narkhede (2013), a big issue is the lack of knowledge of Green ICT in organisations. Due in part to the fact that many impacts of ICT are hidden, it is not seen as a priority. Coupled with a lack of support from top management, the Green ICT strategy will suffer. Increasing awareness and knowledge of Green ICT has been presented by Molla, Abareshi and Cooper (2013) as a way of creating a more positive attitude towards Green ICT, and thus greener behaviour.

1.2 Purpose of the Dissertation

The objective of this dissertation is to examine the strategies currently available for achieving greener ICT, and to produce guidelines for organisations wanting to approach Green ICT. Having structured guidelines makes implementation of Green ICT easier as it reduces the time needed for research on Green ICT by the organisation. Green ICT consists of a number of choices that organisations can make to mitigate the environmental impacts of their actions. These include using technology in an optimal way, in order to avoid wasting energy and resources, as well as using new technology to make other parts of everyday life more environmentally friendly. The strategies will be identified and described, with a set of guidelines developed based on the findings.

1.2.1 The Research Question

The main research question will be "*What aspects need to be considered when moving towards Green ICT?*". In order to be able to answer that question, a number of smaller questions will need answers. The first one is how one should define Green ICT. This question will be answered largely through applying theories and concepts found during the literature review. It is also important to find which factors are most important in deciding an organisation's 'ICT greenness'. A direct answer to this question is unlikely to be found in the existing pool of knowledge, as there is no universal definition of Green ICT and what is included in the term, so the important factors will have to emerge as a combination of a search of the current literature, and interviews with appropriate people. The last step is to develop guidelines to help organisations wanting to work with Green ICT. They should be simple to understand, but the most important Green ICT areas must be covered. Some current Green ICT efforts look exclusively at the data centre; although a significant part of green ICT concerns the data centre, and a large amount of equipment can be found there, it would be misleading to only include the data centre. Doing so would give an over-simplified picture of the situation. Behaviours and attitudes of employees can be equally important in the assessment. Human behaviour has been discussed, and found to be an important part of green information management and Green ICT in various articles (see for example Jenkin, Webster and McShane, 2011 and Molla, Abareshi and Cooper, 2014).

Whereas inefficient technology is comparably simple to switch out, inefficient behaviours are more difficult to manage. However, green behaviour can lead to much larger emissions savings and other positive effects than efficient equipment itself. Still, behaviours are more difficult to measure than things such as energy usage, where absolute numbers are available.

When designing the guidelines, the issue of scope emerges. The guidelines must cover Green ICT in all parts of the organisation, whilst still maintaining a clear focus. Holistic scoping models already exist in the field of enterprise architecture, where organisations can be represented by a number of domains. This view was adopted in this dissertation, with the domains used here being business, data, application, technology and policy (see section 4.3).

1.2.2 Organisation of the Dissertation

To put the dissertation into perspective, an overview of Green ICT will be given in the literature review. Available Green ICT strategies, technologies and techniques will be discussed, and current issues in the sector will be brought up. Existing Green ICT frameworks will be presented and compared, in order to see where there is room for improvement, and where best practices seem to exist. The discussion of current literature and frameworks will lead to the development of a set of Green ICT guidelines.

The dissertation is organised as follows: chapter 2 outlines the research methods used, as well as the research strategy. The next chapter, the Literature Review, aims to define Green ICT, and to explain the strategies and technologies available to achieve greener ICT. In addition, a selection of existing green frameworks are presented and compared to each other. Next, the Green ICT guidelines arrived at in this dissertation is presented. The concluding chapter highlights the findings, and presents opportunities for future research.

2 Methodology

In this chapter, the research methods used in the dissertation will be explained. The chapter starts with outlining the two major types of research, and which one was chosen. It goes on to explain the strategy that was used, before going into greater detail of how the research was done in practice. Finally, there is a section on research ethics.

2.1 Quantitative versus Qualitative Research

When deciding on a research strategy, the nature of the study must be considered. This will allow a decision to be made between using quantitative and qualitative research methods. Both have their merits, and which one to choose depends on the aim of the research. Below, both strategies will be explained, and the chosen method will be presented.

2.1.1 Quantitative Research

Quantitative research methods were developed in the natural sciences, to study natural phenomena (Myers and Avison, 2002). Creswell (1994) explains that quantitative research is "*based on testing a theory composed of variables, measured with numbers, and analysed with statistical procedures*" (p. 2). Experiments are frequently used to test these theories, and within quantitative research they are the 'gold standard', due to the strong focus of hypothesis testing (Vogt, 2011). Quantitative research methods are thus a good choice when testing a theory, especially one that can be measured in absolute numbers.

2.1.2 Qualitative Research

Qualitative research on the other hand is "*based on building a complex, holistic picture, formed with words, reporting detailed views of informants, and conducted in a natural setting*" (Creswell, 1994, pp. 1-2). Flick (2009) explains that qualitative research has become increasingly more popular due to the understanding that in many fields, phenomena cannot be explained in isolation. In qualitative research, a number of methods can be used. Some examples are interviews, questionnaires, action research and case studies, but traditionally quantitative methods such as experiments and surveys may be used as well (Myers and Avison, 2002). Qualitative research methods are appropriate when the goal is to "*discover and develop the new*" (Flick, 2009, p. 15), rather than to test theories formulated in advance.

2.1.3 Selected Research Method for the Dissertation

The aim of this dissertation is to develop a set of guidelines helping organisations to implement Green ICT. Due to it being a fairly new field, not much theory exists that could be tested in a quantitative fashion. Instead, the dissertation will examine what the current literature suggests, as well as applying theories from other fields, and talking to people who have practical experience of some part of Green ICT. In this case, qualitative research methods are more appropriate. The dissertation will be inductive in nature, building concepts from existing literature, and new findings. In the next section, the research strategy will be presented, detailing how the research question "*What aspects need to be considered when moving towards Green ICT?*" will be answered.

2.2 Research Strategy

In order to gain a deeper understanding of the subject of Green ICT, a literature review will be undertaken. This will be the foundation of the dissertation. Based on the literature review, a set of Green ICT guidelines will be developed. To get a deeper understanding of Green ICT, interviews with people who work with ICT and/or environmental management will take place. The aim of the literature review is to uncover the existing material on Green ICT, and other material that can be applicable to the subject. The interviews, in addition to providing a possibility for preliminary testing of the guidelines, will help with general feedback.

The material to be examined in the literature review includes books and articles, but also reports from organisations and governments. As Green ICT is a fairly new subject, without an existing, clear foundation, finding good and reliable sources could prove difficult. One possible strategy is to use material from related fields, and to find the ways in which it can be useful in the field of Green ICT. As an example, the area of cost saving in the data storage sector often coincides with energy savings and optimal use of hardware. Thus, material related to cost saving can be relevant for the dissertation.

2.3 Literature Review

2.3.1 Purpose of the Literature Review

The purpose of the literature review is to, in a systematic way, examine the work already produced in the field of study (Booth et al., 2012). Blaxter et al. (2006) explain that a literature review helps to place the work in the context of what already exists in the field, and thus allows comparisons to be made between the new and existing works. In addition, it is possible to learn from others' mistakes, and avoid replicating what has already been done. It is important to realise that the work one does is "*not in a vacuum, but builds on the ideas of other people who have studied the field before*" (Jankowitz, 2005, p. 161).

The literature review is important as it allows the researcher to see "*how other people in your area work, what has been studied, what has been focused on, and what has been left out*" (Flick, 2009, p.

51). A good literature review will provide insight into what has already been produced in the field, and what has proven to be the best methods of research and presentation. The literature review will be vital in grounding the argumentation in the text, and supporting any statements made (Flick, 2009).

2.3.2 Types of Literature Examined

Ideally, only peer reviewed and scientific material is reviewed. However, as Jesson et al. (2011) point out, sometimes grey literature may be needed, especially if it is a new field, with current issues. Grey literature is not formally published, and can include commissioned research reports, working papers and government policy reports. Booth et al. (2012) are positive towards grey literature, as they mean it can minimise publication bias. In this dissertation, government publications and organisational research will be examined, in addition to scientific publications.

2.3.3 Search Strategy

Jesson et al. (2011) outline a search strategy for doing literature reviews which builds on the usage of keywords. The initial keywords used are natural language words based on educated guesses; using words in the dissertation title, and similar and related terms. Many databases use controlled vocabulary to identify topics. By doing initial searches with natural language keywords, these controlled terms will emerge. They can be used for more specific searching, and searching in other databases and online.

To keep track of the search activity, Jesson et al. (2011) suggest that a record should be kept of which information sources have been searched, and the keywords used. This allows the searcher to go back to successful searches, and possibly try to use the same strategy in a different database. Keeping a record is also useful to avoid repeating searches.

Booth et al. (2012) suggest that a bibliography search is a useful addition to the search strategy outlined above. By looking at the bibliography of all papers used, new and relevant material could emerge. Booth et al. also provide an outline of a search process in stages, beginning with a scoping search. The scoping search can help to focus the literature review, and provide a solid ground on which to build the subsequent search strategy.

After a scoping search with the dissertation title, some useful keywords appeared. The keywords, used in the initial literature searches, were 'Green ICT', 'Green IT', 'Green Computing', 'Sustainable ICT/IT/Computing' and versions of these. These keywords were inspired by Chai-Arayalert & Nakata (2011). Six databases were selected; ScienceDirect, IEEE Xplore, Emerald Journals, ProQuest, LISA and Business Source Complete. These represent a mixture of natural science and social science based sources. Due to the fact that ICT and its role in society is developing and changing at a rapid rate, recent material is required to make sure that any results are valid. Therefore, the goal of the selection process was to include material that was at most five years old at the time this dissertation was written. Approximately 60 articles that matched the criteria were found in the initial search.

All material found in the initial search was read, and notes were taken on the main themes and points. Any irrelevant material was discarded. Like Booth et al. (2012) recommend, reference lists from useful articles were examined to find further material of interest. New areas of interest emerged as the literature was reviewed. To find more information on these, often specific, techniques and concepts, new searches were carried out using keywords uncovered from the literature, in the databases mentioned above. In addition, general concepts were searched for on ordinary search engines to uncover grey literature.

The material was coded according to the five domains, business, data, application, technology and policy, of the scoping model borrowed from enterprise architecture (see section 4.3) and the specific strategy or technology discussed, to help in the design of the guidelines, and to organise the material before writing the literature review chapter.

2.4 Interviews

2.4.1 Purpose of the Interviews

Interviews are often used in an exploratory way, and work best for topics that can be talked about openly between people (Macnaghten & Myers, 2007). They allow a group of people to be chosen, based on their suitability, to take part in the study (Macnaghten & Myers, 2007). Interviews should be used when one wants to get material which provides an in-depth insight into the topic, rather than a wide overview (Denscombe, 2003). Denscombe further states that interviews can be used alongside other methods, as a way of adding depth. This is how the interviews will be used in the dissertation: as a help in designing the framework, once most background information has been collected through the literature review.

2.4.2 Design of the Interviews

Whenever interviews are used, there are design choices to be made. The main choice is between structured and unstructured interviews. Bryman (2008) explains that structured interviews follow the same pattern, to produce answers that can be coded. Unstructured interviews are used more frequently in qualitative research, and can produce new and unexpected insight into the topic (Bryman, 2008). As the goal of the interviews is to discuss new ideas, rather than testing a theory, qualitative, semi-structured, interview strategies were chosen. The strategies used in unstructured and semi-structured interviews include adapting the interview if a new question comes up, and interviewing people more than once (Bryman, 2008). By interviewing some of the participants more than once, changes to the framework can be made and later discussed and evaluated.

Semi-structured, or semi-standardised, interviews are often used in qualitative research, and should be used when the researcher knows about the topic of investigation, but cannot anticipate all possible responses, and therefore may need to adapt the interviews (Morse, 2012). Gillham (2001) explains that interviews can be everything from very unstructured conversations, mainly based on listening to other people's conversations, to highly structured, questionnaire like interviews. In between the two extremes, different types of semi-structured interviews can be found, where both open and closed questions may be asked. As semi-structured interviews allow a greater flexibility than structured interviews, but make it easier to maintain the right focus, they were chosen for this dissertation.

2.4.3 The Interviewees

Six interviews were conducted with individuals who through their work position are expected to have knowledge about practical ICT and/or environmental management. This is the number of interviewees suggested by Guest et al. (2006) to be needed to cover the majority of themes when doing purposive sampling. The individuals were selected from three different organisations large enough to deal with a considerable amount of data. Two organisations were from the public sector, and one from the private sector. As suggested by Creswell (2014), participants were purposefully selected to help understand the research question, rather than randomly selected. Purposive sampling is different from random sampling, where the aim is to have a representative image of the population as a whole (Flick, 2009).

When using purposive sampling, the aim is to find interviewees who will give the most interesting and helpful answers. A good interviewee is someone who "*has the necessary knowledge and experience of the issue or object at their disposal for answering the questions in the interview*" (Flick, 2009 p. 123). In this dissertation, good interviewees are those who have practical experience of working with Green ICT, or any neighbouring fields. In order to find good interviewees, organisations that are large enough to work with ICT and information management on a larger scale were selected. Initial contact was established with employees at the organisations, who could then suggest possible interviewees. Flick (2009) explains that it is often hard to find willing participants, who have the necessary knowledge of the field, and have the time to participate. A suggested way of dealing with the difficulties of finding participants is to use snowballing techniques, where possible participants are suggested by the people who have already been contacted. Snowballing was used here, by letting participants suggest additional persons of interest.

2.5 Data analysis

With all research, large quantities of data are gathered (Hardy and Bryman, 2004). Data analysis is the process of making sense of the data through reduction and coding (Flick, 2009). The data collected from qualitative research often differs from the data collected through quantitative research (Hardy and Bryman, 2004). Qualitative data often needs extensive coding to be useful and understandable (Creswell, 1994). The data produced in this project consisted of interview notes and transcripts. Flick (2009) states that there are two basic strategies of data analysis of such material; coding, where the aim is categorisation or theory development, and sequential analysis, where the aim is to reconstruct the structure of the text and case.

2.5.1 Coding

Creswell (1994) recommends the use of coding, in order to reduce the data to useful themes or categories. According to Creswell, the suggested way of coding unstructured data, like that from interviews, is to start with getting an overview, by going through all material, and writing down any ideas that come to mind. Next, a list of topics found in the interviews should be drawn up. After going through all topics, and making changes where needed, the data can be coded according to the list of topics. The topics may then need to change again after going through all the data (Creswell 1994, Hardy and Bryman 2004).

St. Pierre and Jackson (2014) warn about the dangers of focusing too much on coding, categorising text mindlessly, or reducing words to numbers, without knowing what to do with the finished product. They stress the importance of thinking beyond coding, where theory should be incorporated into the analysis and the results should be presented.

2.5.2 Analysing the Results

The post-coding analysis does not have to follow a set pattern in qualitative research; instead there are several different strategies of analysis one can use depending on the type of study (Bryman, 2008). In addition, data analysis in qualitative research is not as linear as that in quantitative research, but can be an on-going process (Dawson, 2002). Strategies for qualitative data analysis include grounded theory, analytic induction, thematic analysis and comparative analysis (Bryman 2008, Dawson 2002). The strategies are useful for different types of projects. Grounded theory is an iterative process where theory and concepts develop out of the collected data (Bryman, 2008). Analytic induction instead starts with theory, where a hypothetical explanation is given for the research problem and is then tested with the collection on data (Bryman, 2008). Thematic analysis and comparative analysis are often used together (Dawson, 2002). Thematic analysis is inductive, with themes emerging form the data.

Comparative analysis is based around comparing and contrasting data from different people, until no new issues arise (Dawson, 2002).

With the nature of this dissertation in mind, thematic analysis was selected as a suitable analysis strategy. Thematic analysis does not rely on predetermined codes or themes, but lets them emerge as the data is analysed (Creswell, 2014). Although material on green information management and ICT has been published previously, not enough material exists to develop a codebook before the interviews were carried out. New ideas and themes may still be discovered. Analysing the data based on themes can help in developing a theoretical model (Creswell, 2014). In thematic analysis, background reading can be a part of the analysis as well, and help to explain emerging themes (Dawson, 2002). With the help of thematic analysis, the interview notes could be analysed together, and the important themes, which kept coming back in a number of interviews, could be given greater attention.

2.5.3 Presenting the Results

When it comes to presenting results from a qualitative study, Creswell (2014) says that a narrative passage is the most common approach. The narrative can include a discussion on the main themes, as is done in chapter 4 in this dissertation. The final step in data analysis is concerned with interpreting the data, to see what has been learnt. Interpreting the results will show how the study compares to other published works, whether it confirms past research, or differs from it (Creswell, 2014). In addition, interpretation of the results can result in new research topics being suggested, where gaps in the existing base of knowledge are uncovered (Creswell, 2014).

2.6 Research Ethics

Although some academics argue that qualitative research poses no risks to participants, research ethics are always a consideration when working with people (Wiles, 2013). First of all, is important to have informed consent from everyone who will take part. ‘Informed’ refers to the fact that participants should have information about what the research is about, how it will be used, and what will be expected of them as participants, when the research objectives allow this information to be shared (Wiles, 2013).

Comstock (2013) highlights the fact that the benefit of the study must always outweigh any risks involved for the participants. The risks of “*psychological, professional, or physical harm*” (Comstock, 2013, p. 176) must be identified, and communicated to the participants so that they can make an informed decision. This is of particular concern when participants are vulnerable, or the nature of the study is such that it may pose particular risks to the participants (Comstock, 2013). This study does not pose any direct risk of physical harm. The risk of psychological harm is seen to be minor, with participants having the right to withdraw at any time. To avoid any professional harm, the identities of the participants are concealed in this dissertation.

Dawson (2002) argues that "*researchers should be open and honest about who they are and what they're doing*" (p. 148), and that this allows participants to make an informed choice whether or not to take part. Comstock (2013) acknowledges that in some research, the true purpose cannot be shared with participants, as it could influence the results. However, he says that any use of deception must be justified, and participants must be allowed to withdraw at any time. There is no reason for using covert research in this project, so to achieve informed consent in this dissertation, potential participants were informed of all details of the research before they made the decision to participate.

Oliver (2010), agreeing with Comstock (2013) argues that since participants cannot know how they will react to the experience, they must always have the right to withdraw from the research. Oliver further highlights the issue of storing data, especially with new technology that makes it easy to copy and transfer data all over the world. To maintain anonymity and confidentiality, no names or identifying details were stored together with the data collected from the interviews. Any data collected and stored will be deleted at the end of this project.

3 Literature Review

In this chapter, the current literature on Green ICT will be presented in an organised way. The chapter starts by defining Green ICT, and moves on to present the different strategies an organisation can use to reduce their environmental impact. The challenges that can be faced when working with Green ICT are introduced, before a selection of existing Green ICT frameworks are presented and compared. At the end of the chapter a summary can be found.

3.1 Defining 'Green'

Before delving deeper into the subject of Green ICT, 'Green' must be defined. Agarwal and Nath (2013) say that "*green is used in everyday language to refer to environmentally sustainable activities*" (p. 46). Being green is often used synonymously with being sustainable. Although these two concepts are closely linked, they are not identical. Being green is only a part of being sustainable. The United Nations often talk about the three dimensions of sustainable development, which are the social, economic and environmental dimensions (UN, 2013). Being green would correspond to the environmental dimension. However, it is clear that these dimensions are often interlinked, and that what is desirable from an environmental standpoint can benefit the other dimensions as well, like Zhang and Liang (2012) point out when they link green ICT with economic growth. Osseyran (2013) claims that sustainability is part of the reason why the ICT sector has grown so rapidly; it helps economic growth, gives broader access to new technologies, and improves the efficiency of other sectors.

Whenever sustainability or environmental issues are mentioned, Brundtlands definition of sustainability from the UN report "Our Common Future" is given; things are sustainable if they "*meet the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987, p. 34). Being green in the ICT sector is partly about taking conscious and informed decisions about how natural resources are used. Both rare and hazardous materials are used to produce ICT equipment (Williams, 2011). Hazardous materials affect not only the environment, but also the people working with production, as well as recycling of ICT equipment. It is a prime example of how the way we live today will impact the lives of future generations, both in terms of shortages of certain natural resources, and health problems for those working with production and recycling, and their children.

There are many ways of being green when dealing with ICT. A division can be made between green technologies and green behaviour. Green technologies include things like virtual servers, that allow a much higher rate of utilization, and thin clients, where energy savings of up to 85% are possible, compared to standard PCs (Joumaa & Kadry, 2012). However, technology that is used inefficiently or incorrectly will not be green. Thus, the behaviours of employees can have a large impact on an organisations environmental footprint. Turning off equipment when leaving the office, and using technology to green other parts of life, such as hosting video conferences instead of having to travel, or sharing environmentally unfriendly equipment like printers between departments, are examples of green behaviours in the workplace.

'Green' in terms of ICT and information management will not be exactly the same as being green in other sectors. Each sector has its own environmental issues, and mitigation strategies. The ICT sector is special, as greening other sectors is arguably where the biggest contribution can be made in order to reduce emissions, and achieve a better environment. However, this does not mean that the environmental impact of the ICT sector itself can be overlooked. Being green in the ICT sector is also about realising that the way we produce, use and recycle ICT equipment is not necessarily sustainable, and may need to change if we are to reach climate goals set by governments and organisations all over the world.

The most important aspects of being green discussed in this dissertation will be those concerned with conserving energy, and other resources, such as paper and rare elements. These are the categories where ICT and information storage have the biggest impact on the environment (Williams, 2011). By using all equipment in an optimal way, it is possible to reduce the impact on the environment as well as potentially saving money (Forge et al., 2009).

3.1.1 The Importance of Being Green

In recent years, being green has become increasingly more important as a business strategy, due in part to consumer environmentalism. Chang & Chen (2013) suggest that regarding environmental management as part of the strategic planning process has provided benefits for a number of successful companies, and that the new concept of green management has emerged as a result of it. In addition, they refer to a study by Chen et al. (2006) which shows that investing in green innovations and environmental protection is beneficial to companies from a profitability view too. Chen et al. found that being green could increase a company's competitive advantage, as well as bringing new market opportunities, and thus make green companies more profitable. However, Porter & Kramer (2006) warn about the dangers of 'green washing' when they say that "*the focus must move away from an emphasis on image to an emphasis on substance*" (p. 91). Green washing is the term used for companies that try to get the image of being green, but do so by cosmetic changes, rather than actual changes in the way the organisation operates. Nevertheless, if organisations pursue real green change, it can have a positive effect on society as a whole. Zhang & Liang (2012) found that greening of organisations can lead to new investments, in order to improve environmental performance, creating jobs and wealth for a country. Forge et al. (2009) agree, and say that investments in green ICT can provide a short-term economic boost.

3.1.2 Benefits of Going Green

A big potential benefit of going green is cost savings. Looking at green information technology, data centres and servers consume large amount of energy, both to keep running and to cool down. Despite being expensive to run, servers and other resources are often not used to their full potential. Gartner (2010) estimated that servers were running at 12% utilization. Vasan et al. (2010) found a utilization rate of 12.5%. These numbers highlight a problem of inefficiency in the ICT sector. Energy and money is wasted by not utilising the available resources in an optimal way. Vasan et al. (2010) found that 86% of the utilization needs can be met with 26% of the current energy consumption. There is still big room for improvement when it comes to utilization. Other pieces of technology can provide big savings when used in an environmentally friendly way too. Even when idle, many pieces of equipment consume considerable amounts energy. By turning off printers, and other energy consuming equipment, during the night or ideally whenever they are not used, money can be saved and the environmental impact can be reduced (Kamilaris et al., 2014).

Together with the obvious benefit of putting less strain on the environment, it is clear that green ICT can have positive effects on the image of an organisation, as well as the financial success. In addition, it can provide cost savings, with less energy and resources going to waste. However, the most important selling point for getting support from governments over the world is likely to be the positive effect green ICT can have on society as a whole. Åsa Torstensson, Minister for Communications, in Forge et al. (2009) acknowledges that moving towards a green knowledge society will require structural changes; she suggests that governments should help to enable this change. Doing so could provide benefits for the country as a whole.

3.2 Green ICT

Green ICT is a wide concept, and one that lacks a universal definition. It almost always encompasses the energy efficiency of equipment such as computers, servers and monitors. Sometimes the production of ICT equipment is included, and the recycling. Others include ways in which ICT can be used to mitigate the environmental impact of other sectors, but in this dissertation that will be referred to as ICT for Green and treated as a separate area, see section 3.4. Below, Green ICT will be defined for the purpose of this dissertation.

3.2.1 Defining Green ICT

Green ICT has been defined in the literature as "*the using of IT resources in an energy-efficient and cost-effective manner*" (Bose & Luo, 2011, p. 39) or "*an initiative to encourage individuals, groups, and organisations engaged in the use of ICT to consider environmental problems and find solutions to them*" (Chai-Arayalert & Nakata, 2011, p. 220). Green ICT is concerned with the environmental impact of the ICT sector itself, whereas ICT for Green, which will be explained below, details how ICT can be used to green other sectors. 2% of the world's GHG emissions come from the ICT sector, famously likened to the emissions from the aviation sector (Mingay & Pamlin, 2008). This may not seem much, but according to Despins et al. (2010) the ICT sector is the fastest growing sector when it comes to emissions, increasing its emissions at a rate of 6% annually. In addition, the environmental impact of ICT is largely overlooked (Kalsheim & Beulen, 2013). Whereas the aviation sector started to take an interest in the environment decades ago, the ICT sector has only started to worry about its effects on the environment recently (Paruchuri, 2011).

When talking about Green ICT, the main information and communication technologies are computers, monitors and peripherals, telecommunication and network equipment, storage devices, smart-phones and other devices, printers and data centres (Paruchuri 2011, Murugesan 2008, Kalsheim & Beulen 2013). For all of these categories of equipment, there are choices one can make to lessen the environmental impact. These green strategies will be presented below, in section 3.3 on Ways of greening ICT.

What should be included when talking about the environmental impact of ICT is a much debated topic; is it only energy efficiency, or should materials used in production be included, and how will this be measured? Energy efficiency is the easiest metric to use when talking about green ICT, as it is relatively easy to measure energy consumption. However, more energy can sometimes be used when producing the equipment, than during its entire lifespan. Ardito & Morisio (2014) found this to be the case for PCs. Additionally, only using energy efficiency as a metric does not take into account the materials used to produce the ICT equipment. A number of metals are used when producing computers, including aluminium, arsenic, copper and lead (Williams, 2011). Some of these are hazardous, which creates issues for those handling the equipment, especially when it comes to recycling. Informal recycling, where electronic waste, or e-waste, is shipped to third world countries, where health and safety regulations are not as stringent, is a major issue for the ICT sector (Williams, 2011). Ruth (2009) claims that 70% of all hazardous waste is e-waste. There are laws regarding the recycling of e-waste in a number of countries, but informal recycling offers a cheap way of dealing with the waste (Ruth, 2009). Difficulties in enforcing the laws means that informal recycling can carry on, despite the laws (Williams, 2011).

3.3 Ways of Greening ICT

There are ways of using ICT in a way that puts less stress on the environment than the traditional ways. New technologies, techniques and strategies allow organisations to achieve the same results, but with less energy and resources consumed. An important part of ICTs job is to store information. Our need for storage has been growing rapidly, due to factors like growing internet usage, new laws and regulations governing how information should be kept, and scientific computing (Harmon & Auseklis, 2009). Much of the stored information ends up in data centres. Berl et al. (2010) claim that data centres use enough energy to partially offset the positive effects ICT can have on society (see section 4.3 on ICT for Green). They further claim that "*a fraction of energy savings in ICT and networks could lead to significant financial and carbon savings*" (p. 1046). Andrew (2010) states that "*it is not uncommon for new data centres to consume more power than the rest of the cities in which they are located*" (p.1392). To achieve energy efficiency in information storage, one can either opt for more energy efficient hardware, or more energy efficient methods of using the equipment. Both ways will be presented below, with examples of different strategies for greening information management and ICT. An exhaustive list of green strategies is almost impossible to achieve as it is an ever-changing field, but the main strategies mentioned in the literature on Green ICT will be explained below.

3.3.1 Certified Green Hardware

If hardware is where an organisation wishes to go green, there are a number of tools which will help to identify greener options. Three of the most used tools are Energy Star, EPEAT and TCO Development. Energy Star is an initiative by the American Environmental Protection Agency (EPA). According to the website, the goal of Energy Star is to help "*businesses and individuals save money and protect our climate through superior energy efficiency*" (Energy Star, 2014a, About Energy Star). A range of ICT products can be Energy Star certified, including personal computers, monitors and servers. To receive the certification, products are tested in a pre-approved laboratory, and may later be subjected to off-the-shelf testing to make sure that any possible changes in the manufacturing process do not impact the energy efficiency (Energy Star, 2014a). Energy Star claim that if all computers sold each year in the US met the Energy Star requirements, the reduction in greenhouse gas emissions would be equal to that of 2 million vehicles (Energy Star, 2014b). To keep up with new technology, the Energy Star requirements are updated regularly. The current version for computers is 6.0, where a computer will use 30% to 65% less energy (Energy Star, 2014b). In addition to providing certifications, Energy Star offers advice on how to save on the ICT equipment already in use in organisations.

Unlike Energy Star, which provides certifications for everything from homes to pool pumps, EPEAT is focused solely on electronics. On their website, they claim that "*EPEAT® is the definitive global rating system for greener electronics*" (EPEAT, 2014a, Our Mission). EPEAT is managed by the Green Electronics Council, and like Energy Star it is based in the US. To qualify for an EPEAT certification, there are a number of criteria that must be met. Some of the criteria are required, whilst some are optional. EPEAT has three categories; bronze, silver and gold. To qualify for a bronze rating, all required criteria must be met. A silver rating requires at least 50% of the optional criteria to be met, and a gold rating requires at least 75% of the optional criteria to be met (EPEAT, 2014b). The criteria can be related to material selection, energy conservation and the corporate environmental policy (EPEAT, 2014b). EPEAT keeps an online registry of green electronics, where organisations and consumers can search for equipment, to see which products are certified in their country.

TCO Development, or TCO Certified as it is better known as internationally, is a sustainability certification for ICT products. TCO, or Tjänstemännens Centralorganisation (The Confederation of Professional Employees) is a Swedish trade union confederation, which set up the subsidiary TCO Certified in 1992 (TCO, 2014a). In the 1980s, TCO started to work with ICT, as it was introduced into the workplace, but at this time health and safety were the main issues (TCO, 2014a). Soon, energy consumption and efficiency were considered as well, and this led to the foundation of TCO Development (TCO, 2014a). TCO claim that their certification was the first environmental label for ICT products, and emphasise the fact that they have been an international program from the start (TCO, 2014a). Today, TCO Development have offices in Europe, North America and Asia (TCO, 2014b).

The difference between TCO Development, and Energy Star and EPEAT, is that TCO Development aims for sustainability, and not just environmentally friendly solutions. To be TCO Certified, products need to be environmentally, socially and economically sustainable, during the entire lifecycle (TCO, 2014b). The criteria used to decide whether a product will be TCO Certified include workers' condition in production, use of metals and chemicals, health and safety concerns and company policy on spare parts and take back at the end of the product lifecycle, as well as specific criteria for the different product groups (TCO, 2014c). The criteria are updated every three years to ensure that new developments are included. Just like Energy Star and EPEAT, TCO Development provides an online database where it is possible to find TCO Certified products.

Green ICT certifications can help an organisation to see what type of equipment they are buying and using. Looking at whether the hardware is certified by the different organisations can be a simpler alternative to lifecycle assessment, when done in combination with recycling metrics. Both EPEAT and

TCO Development ensure that manufacturing is done in a green way. Chou and Chou (2012) recommend using readily available tools like these to evaluate Green ICT. The benefits include the simplicity of use, and the very low cost compared to performing lifecycle assessment calculations for every piece of equipment.

3.3.2 Longevity of Equipment

Another option for those who want to concentrate their green ICT efforts to the hardware is to use the equipment for longer, rather than constantly buying new equipment. For some type of equipment, the period of use may be as little as 12 months (Forge et al., 2009). Murugesan (2008) says that when it comes to unwanted or unused ICT equipment, the three R's should be considered; reuse, refurbish and recycle, preferably in that order. Many of the components that go into ICT equipment contain rare and hazardous chemicals and metals. In addition, a significant amount of energy is required in production. Williams (2011) presents figures on lifecycle energy use of laptop computers, which show that 64% of the lifetime energy is used in production. He further states that to produce a 2 gram dynamic random access memory, 1200 grams of fossil fuel is used. Paruchuri (2011) says that manufacturing a PC may produce as much as 4 times the carbon footprint of its lifetime use, and therefore states that "*it is always better to tweak the existing equipment rather than opting for new equipment*" (p. 1400).

Agreeing with Parachuri, Fairweather (2011) strongly questions the practice of replacing equipment with new 'green' technology, claiming that "*its instinctive appeal is considerably reduced when the environmental costs of production are significant compared to the differentials in energy consumption, and the environmental costs associated*" (p. 71). A further issue Fairweather introduces is the concept of the 'upgrade treadmill', sometimes referred to as planned obsolescence, where new software requires higher performing hardware, forcing organisations to replace equipment that is still working. Planned obsolescence is also a problem for mobile telephones, where some are used for only a year, or less (Forge et al., 2009). Ardito and Morisio (2014) claim that it may be possible to limit planned obsolescence by upgrading older equipment instead of replacing it. Uddin and Rahman (2012) suggest that reusing old equipment is an effective way of going green, and recommend that the potential for reuse of the equipment should be considered at the time of purchase.

Philipson (2010) agrees that many organisations unnecessarily replace equipment due to a fear of falling behind, but acknowledges that sometimes system upgrades really are needed. However, they may not be needed for the entire organisation, so the old equipment could be passed down to other divisions, where ICT is not as important for everyday functions. If there is no place in the organisations for the old equipment, James and Hopkinson (2009) suggest that it can still be given a 'second life' by being donated to charity, and highlight the example of City & Islington College donating old equipment to developing countries.

Longevity of equipment is often seen as the single most important strategy in Green ICT. When all stages of production are considered, it becomes clear that a short equipment lifecycle, where equipment is replaced due to fears of lagging behind rather than an actual need of new equipment, will have a substantial impact on the environment (Uddin and Rahman, 2012). It is therefore important for organisations to keep equipment longevity in mind when designing their Green ICT strategy.

3.3.3 Standardisation/Modularisation

If one wants to use equipment for longer, and in a more environmentally friendly way, standardisation or modularisation is suggested as a way of making sure that equipment can be upgraded and refurbished, saving natural resources and energy (Egyedi and Muto, 2012). Egyedi and Muto highlight the example of standardised mobile telephone chargers, which would lead to chargers having a longer lifecycle, as they would not have to be replaced even if the telephone was exchanged for a new one. For ICT equipment such as computers and servers, which contain a number of components, standards could extend the lifecycle by making upgrades possible. Replacing only a component is much better for the environment than buying completely new equipment. With standards for all components, upgrades could be made that would counteract planned obsolescence. Another potential benefit of standardisation is increased lifecycles for peripheral devices, such as keyboards, screens and memory cards. The peripheral devices do not necessarily need replacing when the computers do, and with standardisation they can be used with the new computers. Egyedi and Muto further state that standards would reduce the risk of supplier lock-ins, and the environmental burden that follows.

3.3.4 Virtualization

In addition to the efficiency of the physical equipment, how the equipment is used can affect how green an organisations information management and ICT is. It is not uncommon for equipment to be underutilised, with the classic example being servers. Server utilisation rates have been found to be in the range from 5%-10% (Harmon and Auseklis, 2009) to approximately 12% (Gartner 2010, Vasan et al. 2010). The problem with underutilisation is that idle servers still consume large amounts of energy. Bodenstein, Schryen and Neumann (2012) found that idle machines consume 25%-75% of the energy consumed by fully utilised systems. In addition, it is known that servers follow a non-linear trend when it comes to energy consumption, meaning that energy consumption does not follow utilisation in a linear fashion (Bodenstein, Shryen and Neumann 2012, Uddin and Rahman 2010). With underutilised servers, not only energy is wasted, but also the resources that went into the production of the equipment. Uddin and Rahman (2010) claim that servers are "*being added continuously into data centers without considering the proper utilization of already installed servers*" (p. 1). If servers are chronically underutilised, it would be possible to use fewer servers, without compromising the performance of functions. Server virtualization has been suggested as a strategy that could help increase the utilisation rate. Osseyran (2013) goes as far as to claim that virtualization is "*recognized as the innovation with the greatest impact on the shape of modern datacenters*" (p. 34). Berl et al. (2010) agree that virtualization is "*the key current technology for energy-efficient operation of servers*" (p. 1048), pointing out that currently unused servers can be turned off or hibernated to save energy, and money.

Virtualization was developed in the 1960's by IBM, to increase the utilisation rates of mainframes, but it has gained more attention recently, when it has been applied to x86 servers in data centres (Harmon and Auseklis, 2009). Virtualization allows one physical server to host many virtual servers, allowing data centres to consolidate the physical servers (Murugesan, 2008). Virtualization also allows multiple operating systems to run on one server (Harmon and Auseklis, 2009). With one virtualized server being able to do the work of multiple physical servers, fewer physical servers are needed, saving both natural resources and energy, not to mention money. With virtualized servers, utilisation rates can be increased to 50-85% (Harmon and Auseklis, 2009) or 25%-+50% (Uddin and Rahman, 2010) depending on who you ask. Moreover, Liu, Masfary and Li (2011) found that "*virtualization technologies appear to save more than half of the power required by physical servers*" (p.84). Harmon and Auseklis (2009) point out that virtualized servers have additional, hidden potential to be environmentally friendly, as virtualization allows old data centres with no space for expansion to continue to be used with space saving virtualized servers, instead of new data centres being built.

3.3.5 Thin Clients

Ruth (2009) claims that "*thin-client approaches, which rely on "dumb" data terminals that do minimal computing and use very little electricity, can also save energy, especially in large systems*" (p. 76). Thin clients are simple computers, with little or no processing power and storage, instead relying on central servers (Joumaa and Kadry 2012, James and Hopkinson 2009). Thin clients offer much the same experience to users, with the same desktop interface and peripheral devices (Joumaa and Kadry, 2012). However, thin clients can offer significant green savings, compared to standard desktop computers. Due to the fact that thin clients are more compact than desktop computers, less material is required in production (Maga, Hiebel and Knermann (2013). Maga et al. found that the production of a thin client results in CO_2 emissions of 38 kg, whilst the production of a desktop computer produces 128 kg CO_2. Still, the most talked about way of achieving green results with thin clients is the power savings.

Joumaa and Kadry (2012) found the power requirements for thin clients and personal computers with monitors to be 90 Watts and 170 Watts respectively, but go on to say that some models of thin clients can use up to 85% less energy than desktop computers in real world settings. They further state that "*it is possible to lower the power consumption costs of computing environments through the use of desktop monitors that consume less power; however the cost savings are minimal in comparison to changing from a PC to a thin-client environment*" (p. 1055). In addition to being more resource and energy efficient, thin clients can offer the benefit of greater longevity, "*due to the avoidance of software obsolescence, limited points of failure, immunity from malware, and low intrinsic value which discourages theft*" (James and Hopkinson, 2009, p. 37).

Thin clients are more efficient in both production and use. One reason for the improved efficiency compared to desktop computers is how the processing is done. Ricciardi et al. (2013) explain that thin clients "*do not directly run complex and expensive applications but rely on virtual machines and remote storage resources*" (p. 282). In the previous section on virtualization, the benefits of being able to share a physical server were explained. A desktop computer, that relies on its own processing power, will rarely be fully utilised. Thin clients are essentially dumb terminals, so no processing power will be wasted. Even if one uses server based desktop computers, thin clients will be the greener choice (Joumaa and Kadry, 2012).

3.3.6 Cooling of Data Centres

Much of the literature on green ICT concerns data centres. In addition to the energy use and efficiency of servers and similar equipment, cooling of data centres is given a lot of attention. There is good reason for concern about the cooling of data centres, as a study has put the power needed for cooling at 60%-70% of the total power used by data centres (Berl et al., 2010). Harmon and Auseklis (2009) say that for each watt of power used in a data centre, 1.5 watts of cooling is needed. Mouftah and Kanterci (2013) and Harmon, Demirkan and Raffo (2012) agree that cooling power can exceed the power used by IT equipment. Data centres produce masses of heat due to the large amount of electronic equipment in a confined space. However, there are ways of increasing the efficiency of data centres. The placement of equipment inside the data centre can impact the energy use, so hot-cold aisles are suggested by Bodenstein, Shryen and Neumann (2012) as a method for saving energy.

Ideally, any equipment that is not in use should be switched off, to save energy and heat. Berl et al. (2010) suggest that virtualization can help reduce cooling costs, by allowing inactive servers to be turned off, or be put in hibernation mode. A further attempt to reduce the energy use is to locate data centres in naturally cold environments. Bodenstein, Shryen and Neumann (2012) provide the example of locating data centres in Alaska, but point out that due to the sometimes extreme temperatures, heating of data centres may become the next problem. In addition, they bring up the issue of connectability, acknowledging that many organisations have decided against placements of data centres in cold environments due to the above-mentioned problems.

With such a large amount of energy being used to cool data centres, research into waste heat recovery in data centres has been undertaken lately. Little and Garimella (2012) provide examples of how waste heat recovery can be used in practice: Intel has used waste heat to provide space and water heating in offices, and Brunschwiler has used waste heat to provide heating for residential houses. Little and Garimella further explain that although waste heat recovery is not a new concept, it has only recently been introduced into data centres. With the potential of increasing total system efficiency at least from 35% to 41%, waste heat recovery can be an effective way to green the data centre (Little and Garimella, 2012).

Due to the fact that data centres are responsible for such a big part of overall ICT energy use and emissions, this is where green metrics have been developed furthest. The most used green data centre metric is Power Usage Effectiveness (PUE) which is given by Total Facility Power / IT Equipment Power (see for example Erek 2011, Daim et al. 2009, Ricciardi et al. 2013, Uddin and Rahman 2012, Kipp et al. 2012). PUE can help an organisation see "*how much energy is being usefully deployed versus how much is wasted on overheads*" (Uddin and Rahman, 2012, p. 4089). The lowest possible PUE score is 1, where all power is used for the IT equipment. However, it is practically impossible to reach that number, due to the need for cooling, lighting etc. in data centres. Currently, many data centres have a PUE of over 3, but a PUE of 2 is achievable with current technology (Daim et al., 2009). The EPA predicts that PUE can be reduced to 1.2-1.7 (Uddin and Rahman, 2012). Tracking PUE can be a good starting point for going green.

3.3.7 Information Lifecycle Management

Storing information is energy demanding, especially if the information is stored on high performance storage media. Information Lifecycle Management (ILM) aims to place data in different tiers, based on how much it is used and modified, and how important it is that the data is available quickly. In a study at Cardiff University, 93% of files were not modified more than 60 days after their date of creation, but the more modest figure that has been agreed upon in the industry is 80% (JISC, 2010). Chowdhury (2012) claims that "*a division between most and least frequently used files and storage of those files on servers of different performance capacities can significantly reduce GHG emissions*" (p. 643). High performance servers have very fast response and availability rates, but require much more energy to run and cool down, and more physical space than lower performing servers (JISC, 2010). With the high environmental costs of storing all information on the high-performing servers, ILM has been suggested as a way of reducing the environmental impact, without impacting the experience of users too much.

ILM is based around the idea of Hierarchical Storage Management, or HSM (Moore, 2004). HSM introduces the concept of storing information at different levels, or tiers. Mookerjee (2002) explains that new and frequently used data is stored in the first level of storage, which is the fastest type of storage, but also the most expensive and energy inefficient. When a file becomes less frequently used, it is migrated to the next level of storage, without the user even noticing. This is much like how a personal computer works; the RAM drive is the fastest medium of storage, and keeps files that will be used soon and where minimal waiting time is required. Most files are kept in secondary storage, usually on disk drives. This type of storage is much cheaper, but not as fast. Cardiff University, in the Planet Filestore project, used two different tiers, but it is possible to have more (JISC, 2010). On the first tier, information was highly available, and frequently backed up, resulting in even more stored data. Second tier data was only backed up shortly after being transferred.

Without ILM, masses of data may be duplicated, and redundant data may be kept on expensive storage medium (O'Neill, 2005). In the Planet Filestore report, it was found that "*moving 80% of files to non-mirrored tier 2 storage results in a 72% energy saving*" (JISC, 2010, p. 12). In addition to moving data, decisions should be made about what actually needs to be kept. Information management is already seen as an enabler for reducing the environmental impact of information when it comes to paper (see for example IBM, 2008). However, storing information digitally uses resources as well. Just like there are strategies for saving paper in organisations, strategies for saving storage space on hard drives and servers could be a future development. With roughly 80% of files not modified 60 days after the date of creation (JISC, 2010) it would be reasonable to assume that some of those files are not used at all. Having information management policies that deal with the end-of-life strategies for information is an important aspect of green information management.

3.3.8 Green Printing

With the advent of modern computers many thought that we would reach a paperless office, but in fact paper consumption has increased (Plepys, 2002). Furthermore, printing one page with a PC printer gives the same environmental impact as printing five pages professionally, largely due to the different types of paper used (Hilty, 2008). The average office worker prints 10,000 pages per year (Kyocera, 2010, Minnesota Office of Environmental Assistance, 2014), of which as little as 50 percent is recycled according to some studies (Environmental Paper Network, 2012). The paper industry is both energy and water demanding, and releases 100 million kg of toxic pollutants every year, so it is important to consider these factors when evaluating the greenness (Rizvi, Shafi and Khan, 2012).

In addition to paper use, the energy use of printers should be considered. Chowdhury (2012) says that "*the cost of printing 100,000 pages in a month would be US$107.88 per year but the cost of electricity use in idle and sleep mode would be US$382.50*" (p. 940). James and Hopkinson (2009) present figures suggesting that digital printing accounts for 10-16% of ICT-related costs, and that due to the mechanical and thermal processes in a printer, they have higher energy consumption than computers and other equipment.

Because printers consume large amounts of energy, even when idle, ideally the overall number of printers in an organisation should be reduced when possible (James and Hopkinson, 2009). In a case study by the US Environmental Protection Agency (EPA), there was a 25% reduction in paper use and a 12% reduction in energy use when printers were consolidated (EPA, 2011). A further step to be taken is to implement print management, or secure print, schemes where a personal code is needed to print. The EPA highlight the fact that it can be used to protect confidential print jobs, but in another case study it was found that paper consumption decreased by 20% when a print management scheme was implemented (SIS, 2013).

3.3.9 Deduplication

Data storage is responsible for a fair share of ICT emissions. Therefore, storing duplicated data is not only unnecessary, but bad for the environment. Manual deduplication, often called pruning or weeding, can be done both to eliminate duplicate copies, and files that no longer have value to an organisation (McDonald et al., 2009). McDonald et al. suggest that manual pruning should be done with the help of a records retention schedule. The benefit of manual deduplication is that it is easy to carry out, as employee time is all that is needed (McDonald et al., 2009).

Automated deduplication, also known as single-instance storage, relies on an application that "*identifies common sequences of bytes both within and between files ("chunks"), and only stores a single instance of each chunk regardless of the number of times it occurs*" (Storer et al., 2008). The University of Sheffield managed to achieve 20-90% savings when using deduplication, depending on the type of data (James and Hopkinson, 2009). However, automated deduplication requires specific applications which can be both costly and complicated.

3.3.10 Green Behaviours

Employee behaviour is an important part of Green ICT (Jenkin, Webster and McShane, 2010). Green technology on its own is not enough to mitigate environmental issues, so green behaviours and practices must be encouraged. Involving employees and encouraging them to go green can be up to 30% more effective than automated power management programmes (Kamilaris et al., 2014).

According to Philipson (2010) good examples of green behaviours are *"turning off PCs when not in use, recycling printer paper and printing less, and using ICT equipment for longer rather than replacing it when it is still useful*" (p. 15).

Visualisation of energy use has been suggested as a way of encouraging green behaviours (Lehrer and Vasudev, 2011). Lehrer and Vasudev explain that it has been shown in studies that feedback on energy use can lead to energy saving behaviours, although many of the studies were of residential buildings rather than office buildings. In their own study, Lehrer and Vasudev found that 80% of respondents would make a greater effort to save energy if they knew how much energy they were consuming. There are a number of applications available, which make live energy use visible to users (Kamilaris et al., 2014).

3.3.11 Power Management

When green behaviours are not enough, automated tools have emerged as a way of greening ICT. Noble, Curtis and Tang (2009) claim that asking people to turn off computers at the end of the work day is the best way to reduce ICT-related energy consumption. However, they acknowledge that there are a number of reasons why relying on people to turn off computers does not always work; people may be unhappy to wait for their computer to boot up in the morning, they may require remote access or updates and backups may need to be run during the night. Noble, Curtis and Tang (2009) and Kamilaris et al. (2014) recommend Wake-on-LAN (WOL) technology, which allows computers to be switched on remotely. Using WOL solves many of the problems associated with switching off computers (Noble, Curtis and Tang, 2009).

In addition to WOL, there are applications controlling when a computer goes into sleep or hibernation mode (Kamilaris et al. 2009). Lazaros and Hua (2012) claim that "*the electricity costs for a personal computer can be cut in half by activating power management features*" (p. 17). Energy Star explain that power management can easily be enabled across networks, allowing computers to go into sleep mode after a set period of inactivity (Energy Star, n.d.). Kamilaris et al. (2009) refer to a study that estimates the potential power savings to be 56% for monitors and 96% for printers when using power management.

3.3.12 Environmental Management System

Environmental Management Systems (EMS) are tools providing a "*consistent, yet customized approach to the design of environmental monitoring, regulatory compliance, pollution prevention, and design of clean production programs across the whole supply chain*" (Khalili and Duecker, 2013, p. 189). Environmental Management Systems are addressed in ISO 14001, which has given organisations an extra incentive to adopt such a system (Iraldo, Testa and Frey, 2009). Environmental Management Systems are applied across the entire organisation, but can still be useful for individual parts, such as ICT, due to the fact that they provide both a good overview both of the use phase, and the life cycle perspective (Khalili and Duecker, 2013).

3.3.13 Green Energy

ICT equipment is energy demanding, but not all energy has the same environmental impact. While coal and other fossil fuels lead to large emissions, green energy, i.e. energy from renewable sources, will have a much reduced impact. Bodenstein, Schryen and Neumann (2012) present the example of Google, and the data centre they built near a hydroelectric facility, ensuring both cheaper and greener energy. With data centres' high energy use, green energy use there can have a real impact. Nguyen et al. (2012) explain that not all data centres can be located near green energy sources, and introduce the concept of green energy distribution networks. No matter how green energy is used, it offers environmental benefits for the organisation.

3.3.14 Conclusion

Green ICT is a fast-moving field, where new technology and techniques are emerging, and improvements in efficiency are done continuously. There are many different strategies for achieving greener ICT in an organisation, and it is not just about conserving energy in the use phase, which is a common view: it is important that the energy and materials used in production are included. Many of the green strategies presented above are aimed at using equipment for longer, making sure that it is fully utilised, and that it is shared between employees and departments when possible, which means that less equipment is needed. In addition, organisational policy and employee behaviours can have a large impact, in terms of using ICT equipment in a green way.

With everything from purchasing decisions to employee behaviours being a part of Green ICT, it is an issue that stretches beyond just the IT department in an organisation. However, lack of a holistic view is seen as one of the major challenges with Green ICT implementation (see section 3.6 on Green ICT Challenges). In addition to a holistic view of Green ICT in the organisation, a lifecycle view was brought up as an important aspect, with both production and recycling seen as parts of the lifecycle. Doing so makes the option of repairing and refurbishing equipment look more attractive.

3.4 ICT for Green

The concept of ICT for Green, also called greening by IT or greening by ICT, is based around ICTs ability to make other parts of everyday life more environmentally friendly. Faucheux & Nicolaï (2011) claim that ICT is to the knowledge economy what electricity was to the industrial revolution, and that ICT is the key to the decoupling between economic growth and climate change. Suggestions for how this can be done include dematerialisation, smart buildings and smart logistics (Faucheux & Nicolaï, 2011). Forge et al. (2009), in the report “A Green Knowledge Society”, state that ICTs largest environmental potential is in enabling energy efficiency in other sectors. Figures from the Climate Group (2008) are presented, where ICT is claimed to be so efficient in greening other sectors, that the CO_2 emissions savings can be five times that of the total emissions from the entire ICT sector. Forge et al. (2009) see ICT as a key component in the reduction of emissions, highlighting the goal of reducing emissions to below 1990 levels by 2020. They claim that a 15% reduction in emissions by 2020 is possible, just by using ICT (Forge et al., 2009). Below, ways in which ICT can green other parts of life are presented.

3.4.1 Teleworking/Teleconferencing

Ruth (2009), although not specifically mentioning ICT for Green, suggests that ICT can promote telecommuting, also known as teleworking, which would save large amounts of oil. He points to the numbers from an ITIF report stating that if 14% of American office jobs were converted to teleworking jobs, 136 billion vehicle travel miles would be saved annually. However, Ruth recognises that, so far, teleworking has not gained any real success. The main reason for the inability of teleworking to take off is claimed to be management resistance (Ruth, 2009). Osseyran (2013) sees smart work centres as an option to teleworking. Smart work centres would be shared by a number of employers, located in residential areas, and offer employees a better work environment, that does not have the classical problem of social isolation associated with teleworking (Osseyran, 2013).

3.4.2 Green Transports and Supply Chain Management

In addition to providing energy and emissions savings on transport to and from work, ICT has the ability to green the transport of goods (Murugesan, 2010). Osseyran (2013) provides a number of ways in which ICT can help the transport sector to go green; with the help of optimisation techniques, filling rates for vehicles can be improved, and the optimal route can be chosen. With the help of smart technology, traffic congestion can be avoided, smart parking solutions can be implemented, and dynamic road pricing schemes can lead to less traffic on the roads, resulting in less emissions (Osseyran, 2013).

3.4.3 Dematerialisation

Another talked about topic in ICT for Green is dematerialisation. Dematerialisation means using less resources and energy to achieve the same result, or replacing high emission products and services with more environmentally friendly options. Examples of dematerialisation include videoconferencing instead of physical meetings, and e-billing instead of using paper (The Climate Group, 2008). The Climate Group suggest that dematerialisation could lead to a reduction in emissions of CO_2 by 500 megaton, or approximately Australia's total emissions in 2005. However, many companies are unwilling to adopt dematerialisation technology, due to the fact that it requires new ways of working, and a shift away from the familiar. In addition, the infrastructure to allow dematerialisation is not always available (The Climate Group, 2008). As a way of overcoming these issues, The Climate Group recommends that analyses should be undertaken to see where dematerialisation could have the biggest impact, and letting governments develop policies to promote dematerialisation in those areas.

3.4.4 Environmental Monitoring

Murugesan (2010) is one of the supporters for using ICT to green other sectors. He points out that ICT can be used to monitor environmental effects, and handle environmental data. In addition, ICT offers the possibility of modelling and simulating environmental impacts under different scenarios (Murugesan, 2010). Using the computational power of ICT to combat climate change, with monitoring and simulations, is a possibility that seems to be overlooked by many supporters of ICT for Green. An additional example given by Murugesan (2010) is ICTs role in providing platforms for emissions trading, a system that is already in use in parts of the world, and whose implementation was largely dependent on the availability of ICT. In both of the examples, ICT acts as an enabler for green efforts.

3.4.5 Conclusion

ICT for Green will not necessarily give the same measureable results for an organisation as Green ICT. ICT for Green can lead to cost savings, especially in the areas of dematerialisation and optimisation as demonstrated above. The importance of green behaviours and green attitudes has been touched upon previously in the text. In many publications (see for example Chai-Arayalert and Nakata 2011 and The Climate Group 2008), ICT for Green is seen as an important part of Green ICT.

3.5 Rebound effect

Despite all the positive influences Green ICT and ICT for Green can have on the environment, there is still reason to be cautious when talking about the positive environmental effects of ICT. The rebound effect could result in green initiatives not helping the environment at all, or at least not as much as expected. Goswani (2014) explains the rebound effect by stating that with more efficient technology, the price of goods and services will go down, allowing a higher level of consumption. Forge et al. (2009) give the example of cars to illustrate the rebound effect; more efficient cars use less fuel, but this has not had the expected impact on emissions, as it allows some people to use their cars more than they would have been able to otherwise. There is evidence to suggest that ICT has increased productivity and efficiency, but this has led to an increasing output rather than a reducing input, just like with cars (Goswani, 2014).

More evidence of rebound effects with ICT can be found in teleworking. Teleworking has been presented as an ICT for Green solution. However, Fairweather (2011) points out that teleworking has led some employees to move further away from the office, so when they do have to be there, they have to travel further, thus increasing emissions per journey. In addition to longer journeys, the issue of heating or cooling of the work environment will impact the environmental effects of teleworking; it is often more energy efficient to heat or cool a large office building with multiple employees, rather than a large number of home offices (Fairweather, 2011).

Further proof of the rebound effect can be found when looking at 'the paperless office', which was thought to become a reality with the introduction of ICT. The idea was that everything would be done on-screen and online. In reality, personal computers and the availability of printers led to an increase in paper consumption (Egyedi & Muto, 2012).

The actual ICT equipment can also be cause for concern when it comes to rebound effects. Hilty (2008) points to the fact that ICT is constantly evolving, and creating more efficient solutions. Despite that, the total energy and materials used for ICT is not decreasing; instead, ICTs share of total energy consumption continues to rise, and there is no shortage of electronic waste (Hilty, 2008).

Rebound effects can be the result of different situations. Williams (2011) talks about two different rebound effects: economic and time saving. Economic rebound effects are those that Goswami (2014) explained, where cheaper products and services allow consumption to increase. Time saving rebound effects occur when time saved due to more efficient ways of doing things allow people to change behaviours, in a way that negatively impacts the environment, such as non-work driving by teleworkers (Williams, 2011).

Fairweather (2011) argues that reducing airline travel would be a good outcome of ICT for green, due to the fact that emissions from aircrafts are more damaging than the same amount of emissions on ground level. However, he sees a correlation between ICT and travel. ICT allows organisations to work across borders, with increased travel as a result (Fairweather, 2011). Forge et al. (2009) claim the opposite, that the use of ICTs can lead to substitution effects, where physical travel can be avoided. However, they do not point to any studies that can verify this.

According to Egyedi & Muto (2012), the problem with negative externalities in the ICT sector is that they are often overlooked, and ICT is seen as a clean sector even though ICT can be the reason, or at least the facilitator, of environmentally unfriendly activities. Forge et al. (2009) acknowledge this by saying that "*a more complete model of savings and consumption is required, especially where ICT substitutes for other practices, e.g. teleshopping*" (p. 29). Goswami (2014) suggests that measures restricting input and output are needed to avoid the rebound effects.

3.6 Green ICT Challenges

Green ICT can bring many benefits for an organisation, but there are a number of challenges in the implementation stage, as with all changes in an organisation. The main challenges will be explained below.

3.6.1 Insufficient Knowledge of Green ICT

Suryawanshi and Narkhede (2013) found a number of challenges for organisation implementing Green ICT in their study of education institutions. An obvious issue is that of insufficient knowledge of the problem; Suryawanshi and Narkhede found that there was often a lack of knowledge regarding Green ICT. The employees did not see their part, as many of the impacts are hidden. Suryawanshi and Narkhede bring up the example of energy costs; oftentimes employees do not know how much energy is consumed by their equipment. Paruchuri (2011) agrees that things like energy consumption are not often communicated to employees, and that the result is that people neither know how much energy their equipment is consuming, nor how to improve the efficiency.

3.6.2 No Holistic View

A major challenge for Green ICT is the fact that a holistic view is often missing in organisations. Paruchuri (2011) illustrates this by the example of purchasing of new equipment. The person who is in charge of purchases is seldom the person who will use the equipment, so he or she will be concerned mostly about the price, and not with operational costs or energy efficiency. Kamilaris et al. (2014) and James and Hopkinson (2009) point out that the energy bill for ICT equipment very rarely ends up with the IT department, and that it means that "*IT managers do not know how much energy they are consuming hence they cannot know the scale of emissions they are responsible for*" (Kamilaris et al., 2014, p. 538).

3.6.3 Lack of Support and Guidance from Management

Chou (2012) claims that "*in order to craft Green IT strategy, a strong support from top management is crucial*" (p. 235). Suryawanshi and Narkede (2013) see lack of adequate funding and support from top management as the main challenge for Green ICT implementation. Both Chou (2012) and Suryawanshi and Narkhede (2013) point out the importance of funding, but James and Hopkinson (2009) add that guidance and information are important factors of Green ICT implementation. With Green ICT being a new subject for many employees, they need someone who can lead them in the right direction, and help them understand the choices they can make to become greener (James and Hopkinson, 2009).

3.6.4 Costs

In their study of Green IT Challenges for Macedonian Companies, Gavrilovksa, Zdraveski and Trajanov (2013) found that the cost of Green ICT solutions was perceived to be one of the biggest challenges. Gavrilovksa, Zdraveski and Trajanov (2013) and James and Hopkinson (2009) point out that investments in greener equipment and technologies will often pay off quite fast due to improved efficiency, but that organisations are either unaware of this fact, or that they cannot find room in their budget to finance even short-term investments. The cost issue is related to the lack of a holistic view, in that departments will try to save money in their area, not aware of the fact that it leads to higher costs in another area (James and Hopkinson, 2009). James and Hopkinson (2009) again gives the example of ICT energy costs, which are not usually paid from the ICT budget.

3.6.5 Lack of Motivation

Suryawanshi and Narkhede (2013), Chou and Chou (2012) and James and Hopkinson (2009) all mention factors related to lack of motivation as a big issue. James and Hopkinson (2009) look at it as a question of priorities; with a high workload on employees, some tasks need to be given lower priority. Green ICT "*can appear to be complex and time consuming*" (James and Hopkinson, 2009, p. 70) and is therefore not attempted. Chou and Chou (2012) suggest that "*creating measures for reporting Green IT performance results to employees*" (p. 450) is important in order to motivate people.

3.6.6 Conclusion and Mitigation Strategies

There are a number of challenges for Green ICT implementation. Many of the challenges explained above are related to one another; many of the problems go back to a lack of knowledge of Green ICT and how it can be implemented, and a lack of someone in charge, who can monitor and coordinate Green ICT efforts. Appointing a person or a group to be responsible for Green ICT could help with many of the challenges. O'Flynn (2010) claims that "*in organizations lacking an individual with responsibility for Green IT, it is simply not possible to achieve the necessary level of cooperation*" (p. 11). The benefits of having a person responsible for Green ICT include a better overview of Green ICT in all parts of the organisation.

An additional strategy is to make sure that there is greater accountability for everyone who works with ICT. The most commonly suggested approach is to hand over the responsibility for energy bills for data centres and general ICT equipment to the IT department (see for example Kamilaris et al. 2014, James and Hopkinson 2009). By making the IT department responsible for the costs they have incurred, the idea is that they will be more motivated to opt for efficient hardware and processes.

Increasing awareness and increasing knowledge of Green ICT is a further strategy to overcome some of the Green ICT challenges presented above. Molla, Abareshi and Cooper (2013) found that Green ICT attitudes correlated positively with Green ICT practice. Concerns "*such as the role of IT in causing and resolving environmental problems*" (Molla, Abareshi and Cooper, 2013, p. 145) were found to contribute towards green behaviours. Communicating the environmental impact of ICT, and the ways in which the impact can be reduced may lead to a more positive attitude towards Green ICT, and thus greener behaviour.

Molla, Abareshi and Cooper (2013) further found that institutional support and organisational structure and culture influence employees' beliefs, and state that "*when companies put Green IT on their radar, IT professionals appear to align their values and form strong Green IT belief*" (p. 146). Thus, support from top management may lead to increased motivation amongst employees.

3.7 Green ICT Frameworks

Green ICT Frameworks can be useful to measure and evaluate an organisations green efforts. There are a number of frameworks that have been developed to do just this. A selection of commonly mentioned frameworks will be presented below, and later compared to each other based on what is included in the framework, how measuring is done and how results can be used, to see where there are agreements and disagreements. Finally, the lessons to be learned for future frameworks are presented.

The selected frameworks are Chai-Arayalert and Nakata's (2011) Green ICT Analysis Framework, Kalsheim and Beulen's (2013) Green Hardware IT Infrastructure Framework, the Connection Research-RMIT Green ICT Framework (Philipson, 2010) and the UK HMG Green ICT Maturity Model (HMG, 2013). They were the frameworks uncovered in the literature search, which did not focus on only one aspect of Green ICT (usually the data centre). The selection of frameworks represents developed by academic efforts, research organisations, and the government.

3.7.1 Green ICT Analysis Framework

Chai-Arayalert and Nakata (2011) have developed a Green ICT Analysis Framework especially for the Higher Education sector, but one that should be applicable for other sectors as well due to its general nature. The three main categories in the framework are Green ICT Strategy, Green ICT Practice and Green ICT Measurement. An overview of the framework can be seen in figure 3.1. According to Chai-

Arayalert and Nakata, Green ICT Strategy is the first step towards Green ICT. The Green ICT Strategy details what the organisation aims to achieve when working with Green ICT, and includes things such as minimising the carbon footprint, reducing energy costs and complying with regulations. Green ICT Strategies lead to Green ICT Practices. In the framework, practices are divided into wider groups. An example of a green practice given by Chai-Arayalert and Nakata, under the "Working and study activities" heading is changing from on-site teaching to online teaching, reducing emissions from travelling. The last category in the framework is Green ICT Measurement. Chai-Arayalert and Nakata state that "*to manage the efforts leading to the achievement of Green ICT goals, Green strategy and practice should be measured*" (p. 223). They further say that measuring Green ICT could prove difficult, but it is still an important part of the process of becoming green. However, they do not offer any guidance on how to measure Green ICT. There are no metrics presented in the article, and no clear methodology on how to conduct the measuring and monitoring.

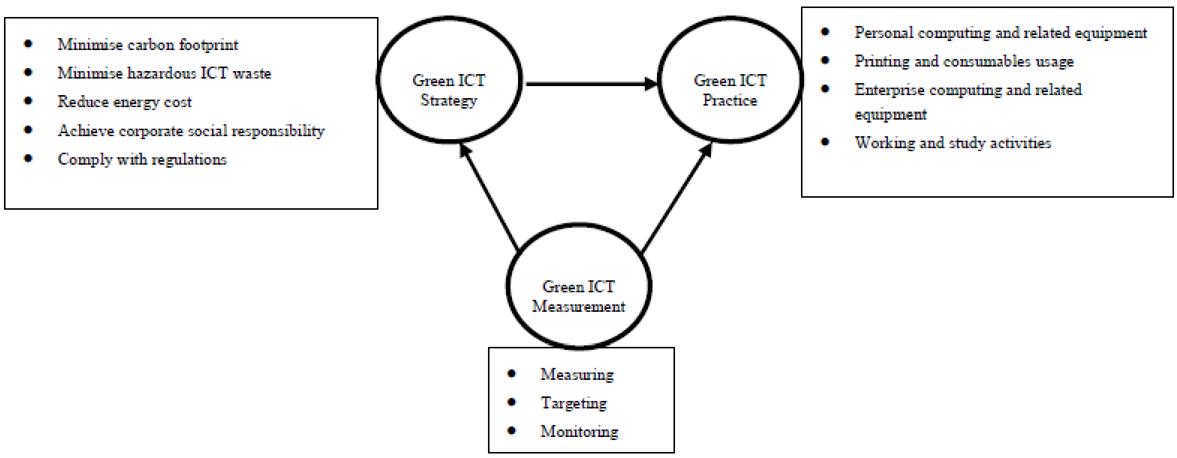

Figure 3. 1 Green ICT Analysis Framework from Chai-Arayalert & Nakata (2011)

3.7.2 Green Hardware IT Infrastructure Framework (GHITI)

Unlike Chai-Arayalert and Nakata (2011) Kalsheim and Beulen (2013) developed their framework, the Green Hardware IT Infrastructure Framework (GHITI), with metrics and performance indicators in mind. The GHITI is lifecycle focused, and consists of five assessment categories; water use, energy use, raw material waste generation, greenhouse gas emissions and costs. These are all measured over the lifecycle of the hardware. For each category or criteria, there are procure performance indicators, user performance indicators and dispose performance indicators, based on the procure, use, dispose lifecycle model. In addition to the framework, Kalsheim and Beulen offer a management process, or method, detailing how the measurement process can be done in an effective way. The management process is based on the Plan Do Check Act method. In the Plan phase, middle management and employees should be involved, and indicators, data sources and data collection procedures should be decided on. In the Do phase, data is collected, analysed and evaluated. Kalsheim and Beulen recommend data verification in this stage, to enhance the quality. The Check phase is where the results are communicated, both internally and externally. In addition, the GHITI evaluation is reviewed and improved. The last phase, Act, is where the performance indicators and the evaluation system used should be evaluated, and improved where possible, for the next iteration. Kalsheim and Beulen explain that the framework can measure the progression in greenness, where the results from a number of iterations are analysed and compared.

Although Kalsheim and Beulen (2013) suggest a number of metrics and performance indicators to be used, they do not specify exactly how one should measure these factors in a systematic way. Allowing organisations to calculate things such as 'amount of greenhouse gas emission related to the extraction and production process of hardware IT' without any guidance could lead to very different results, based on how the calculations are made. This makes it harder to compare results between organisations. Kalsheim and Beulen suggest that a social dimension should be added, to make the framework more complete. However, it is suggested here that a behavioural dimension could be considered as well, due to the fact that nothing in the framework measures how the equipment is used, and whether it is done in a green way.

3.7.3 The Connection Research-RMIT Green ICT Framework

The Connection Research-RMIT Green ICT Framework was developed by Connection Research, in conjunction with RMIT University in Melbourne, and includes four pillars; Equipment Lifecycle, End User Computing, Enterprise & Data Center, and ICT as a Low-Carbon Enabler (Philipson, 2010). Each of the pillars are broken down further, as can be seen in figure 3.2. Across the four pillars are five actions; Attitude, Policy, Practice, Technology and Metrics. The pillars show the different categories looked at in Green ICT, and further specify subcategories that one can examine to gain a deeper understanding of Green ICT. All of the subcategories are identified and explained in Philipson (2010).

The five actions can be applied across the pillars. Attitude describes how people feel about Green ICT. Philipson (2010) explains that a positive attitude towards Green ICT comes before everything else. Policy should make sure that Green ICT becomes internalised, instead of just a one-off project. Practice talks about what we do, and how we do it. Practices can be green, with examples such as recycling paper given. Technology refers to the physical equipment. Philipson is fast to point out that technology is just a part of Green ICT, as he feels that technology is often singled out as the biggest, or only, part of Green ICT. Metrics, the fifth action, is slightly different compared to the other four: just like the other frameworks, the importance of measuring is brought up in the Connection Research-RMIT Green

ICT Framework, but Philipson presents four phases of the metrics process; measure, monitor, manage, mitigate.

For the measuring, a modified capability maturity model is used. Questions are asked across all four pillars, and responses are rated from 0-5, where 0 means that the organisation has no knowledge of the specific area and 5 means that all processes are optimised. The questions are based on the actions (attitude, policy, practice and technology). The questions from each pillar are aggregated, to give a score of 0-100 for that pillar. In the evaluation, Metrics is treated as a separate pillar. When looking at all pillars together, the result is a Green ICT Readiness Index, which can be expressed visually. Due to the standardised nature of the Connection Research-RMIT Green ICT Framework, organisations can be compared to each other, and so can sectors. However, the drawback of the Connection Research-RMIT Green ICT Framework is that organisations cannot assess themselves. Instead, they must work with an external surveyor, with higher costs and greater complexity as possible consequences. This, in turn, could lead to less frequent measurements, and smaller organisations not being able to participate.

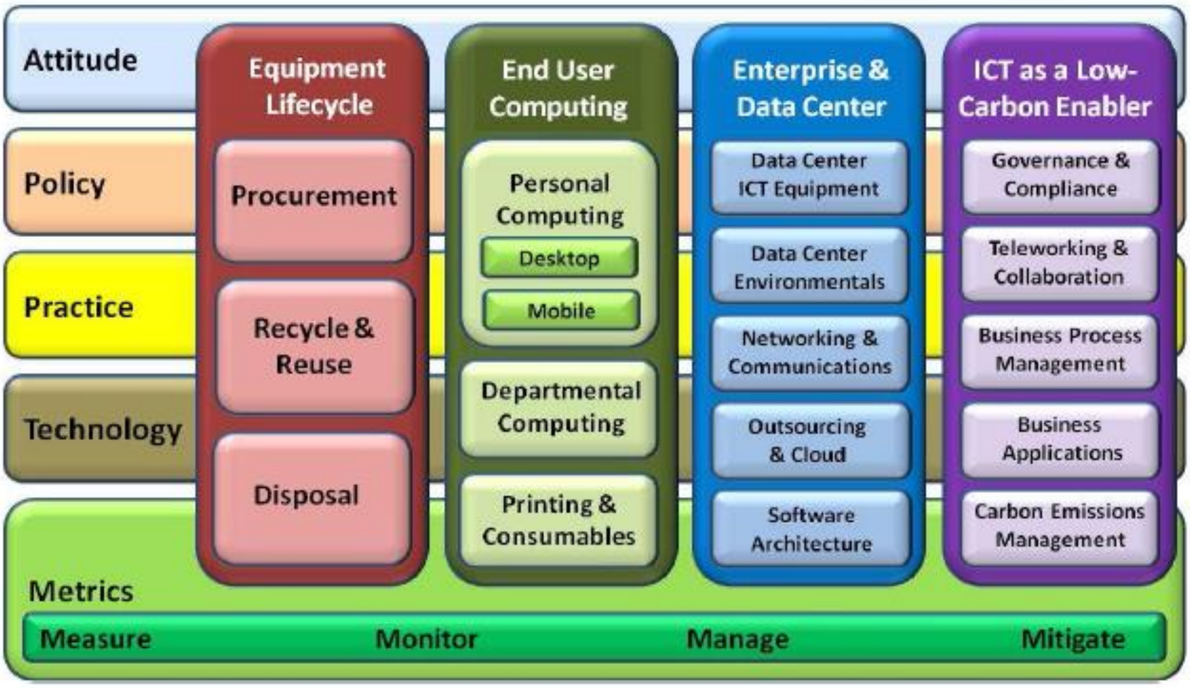

Figure 3. 2 The Connection Research-RMIT Green ICT Framework from Philipson (2010)

3.7.4 UK HM Government Green ICT Maturity Model

The UK HM Government Green ICT Maturity Model was launched by Her Majesty's Government (HMG) Green ICT Delivery Unit in 2013, after being developed and tested since 2011 (HMG, 2013). The Green ICT Maturity Model was created for public sector bodies in the United Kingdom, to support the Greening Government Commitments (GGC) programme. The Green ICT Maturity Model is available as an Excel workbook, where organisations can assess their Green ICT efforts, and keep track of progress made (HMG, 2013). A maturity model is used to assess greenness, just as in The Connection Research-RMIT Green ICT Framework. However, the UK HM Government Green ICT Maturity Model is based around self-assessment. There are five maturity levels; foundation, Embedded, Practiced, Enhanced and Leadership. A further two categories, Not appropriate and Ad hoc, were added for when the assessment cannot be done and when no direction has been set (HMG, 2013).

Maturity is measured over four categories of ICT activity; Managing ICT Services, Managing ICT Technology, Changing ICT Services and Exploiting ICT (HMG, 2013). Managing ICT Services deals with what goes on around the actual equipment, and includes recycling/re-use initiatives, Information Lifecycle Management and capacity planning. Managing ICT Technology focuses on the hardware and applications, with utilisation rates, virtualization and peripherals sharing found at different levels of the maturity model. Changing ICT Services includes green procurement, investment decisions and project design. Many of the criteria in the Changing ICT Services sector could be defined as ICT for Green, with things like greening the supply chain mentioned. The final category, Exploiting ICT, is concerned mainly with dematerialisation and optimisation of processes.

For each of the categories, there are criteria that need to be met to move up through the maturity levels. For example, to reach 'Leadership' in the Exploiting ICT category the criteria include "*ICT adopted as a key enabler for the business to reduce its environmental impact - quantifiable footprint savings achieved*" (HMG, 2013, Exploiting ICT).

The scores for each of the four categories, plus the overall score, are presented in a spider chart. The model was formulated to include a peer-review assessment, where different departments and organisations were paired up with another department or organisation "*judged to be of similar size, complexity and business*" (HMG, 2013, Peer review).

3.7.5 Comparing the Frameworks

The four frameworks discussed above, Chai-Arayalert and Nakata's (2011) Green ICT Analysis Framework, Kalsheim and Beulen's (2013) Green Hardware IT Infrastructure Framework, the Connection Research-RMIT Green ICT Framework (Philipson, 2010) and the UK HMG Green ICT Maturity Model (HMG, 2013) have chosen different perspectives on Green ICT. Chai-Arayalert and Nakata (2011), Philipson (2010) and HMG (2013) all include the behavioural dimension in their frameworks. They acknowledge that the attitudes and behaviours of employees can affect the greenness of an organisations ICT. In addition, they all highlight the fact that ICT can be used to green other parts of our society, with ICT for Green being a factor in both frameworks. Kalsheim and Beulen's (2013) framework is more technology focused, and does not include human factors.

All of the frameworks agree that measuring Green ICT is important, and the famous quote "*You can't manage what you can't measure*" is mentioned. However, the suggested way of measuring differs between the three frameworks. Kalsheim and Beulen (2013), Philipson (2010) and HMG (2013) define what should be measured in order to judge the Green ICT performance, whereas Chai-Arayalert and Nakata (2011) only state that measuring is important, without explaining what needs to be measured. However, even for the frameworks that specify metrics and measurements, there are big differences. Kalsheim and Beulen have a few assessment criteria, and apply these to the ICT lifecycle. Philipson instead judges the greenness of an organisations ICT through a survey with a number (unspecified in the text) of questions, for each of the pillars. HMG is based around self-assessment, and allows organisations to see where they place on a pre-defined scale. Philipson (2010) and HMG (2013) both allow comparisons to be made between different organisations, and between a single organisation at different points in time, due to the standardised nature of the frameworks. However, only Kalsheim and Beulen offer a method to be used together with the framework, to ensure that the right people are involved, and the right decisions are made.

Kalsheim and Beulen's (2013) framework relies, to a great extent, on the organisation measuring factors such as raw material waste themselves. For an organisation buying equipment from third parties, such a task would be almost impossible, as there is no stated source from which one should gather data. In practice, this could mean that organisations base their evaluations on different data, where some use reference numbers from the manufacturers, others use actual energy consumption, allocated to each piece of equipment by one of many costing methods, and yet others use different estimations by those working in IT departments. With so many alternative ways of calculating the different performance indicators, no standardised and comparable value can be attained. Being able to compare results of different organisations, and the same organisation at different points in time is important, as it will allow organisations to evaluate their own performance.

ICT for Green is an interesting issue, as it is not technically Green ICT, but still has a large impact on the environment, and is mentioned in many of the academic articles about Green ICT. Chai-Arayalert and Nakata (2011), Philipson (2010) and HMG (2013) include ICT for Green in their frameworks, but Kalsheim and Beulen (2013) have chosen to focus on the more traditional definition of Green ICT. Philipsons justification for including ICT for Green in the framework is that ICT is responsible for a comparably small part of worldwide emissions, and that "*the real potential benefits of Green ICT are in using ICT as an enabling technology to help the organisation, and the wider community, reduce its carbon emissions*" (p. 12). HMG (2013) seem to agree with Philipson that there are great potential benefits in ICT for Green, and their framework includes such strategies under the sections Changing Services and Exploiting ICT. Chai-Arayalert and Nakata do not differentiate between Green ICT and ICT for Green, but put all environmentally friendly strategies under the ‘Green ICT Practice’ heading. However, as there is no exhaustive list in Chai-Arayalert and Nakata (2011) of what should be considered Green ICT practices, it is difficult to know whether the suggested practice of teleworking is thought to be representative of other ICT for Green practices, or if the authors did not in fact intend to include ICT for Green in the framework, as it is not given any more attention in the paper.

3.7.6 Lessons for Future Frameworks

The importance of being able to measure results has been brought up in all of the frameworks discussed above. However, some of the frameworks have made it easier to measure and interpret Green ICT than others. Chai-Arayalert and Nakata (2011) offer no guidance on which metrics to use. Kalsheim and Beulen (2013) are clear about what should be measured, but it would be hard to measure it in a standardised way. The two frameworks that stand out are the Connection Research-RMIT Green ICT Framework and the UK HM Government ICT Maturity Model. Both have defined Green ICT levels, which makes it possible to both measure results, and compare them. In addition, the results can be presented visually, which means that it is easy to understand for everyone in the organisation (Global Metrics Harmonization Taskforce, 2012).

When it comes to what to include in the framework, there is no absolute agreement. However, it has been pointed out that the assessment should stretch further than just the data centre (Philipson, 2010). None of the frameworks presented above include just the data centre, but Kalsheim and Beulen’s (2013) framework is focused solely on lifecycle assessment of the actual hardware.

Behavioural factors are included in three out of the four frameworks examined, and can have such a large impact on the greenness that any framework opting for a holistic view of Green ICT should think about including them. Both individual behaviours, and overall company climate and attitude are factors to consider.

ICT for Green is another topic that is covered by some frameworks, but not all. In addition, it can be seen as part of Green ICT, or as a separate topic. The reason given for inclusion of ICT for Green is the big potential in greening other sectors: due to the large potential emissions savings that can be achieved, it should be considered when designing Green ICT frameworks. Considering ICT for Green does not automatically mean including it, but justifications for why or why not are a good addition.

Only Kalsheim and Beulen’s (2013) framework includes a method for doing the assessment. Philipson (2010) is not included here, as although it undoubtedly includes a method, it is not available to examine due to the assessment being done by a third party. Kalsheim and Beulen use the Plan-Do-Check-Act method that has also been recommended in Antunes, Carreira and Mira da Silva (2014) to be used with maturity models. Although it does not necessarily have to be the Plan-Do-Check-Act method, some sort of guidance for the assessment process would be beneficial.

3.8 Summary of Literature Review

In this section, Green ICT has been defined as using ICT equipment in a way that saves both resources and energy. 'Green' refers to the environmental dimension of sustainability, but going green can benefit the other dimensions of sustainability as well (Zhang and Liang, 2012). The difference between Green ICT and ICT for Green has been explained; Green ICT is concerned with the actual ICT equipment, whilst ICT for Green focuses on how ICT can be used to make other parts of life greener (Faucheux and Nicolaï, 2011).

A number of ways of greening ICT have been presented; the two main categories are more efficient equipment and greener policies and practices, although a fair bit of overlap exists. More efficient equipment includes replacing desktop computers with thin clients, opting for certified green hardware and using new cooling strategies for data centres. Greener policies and practices include everything from how long equipment is used for, to whether or not there are any green management programmes in place. In addition, green behaviours are highlighted as a major factor in Green ICT.

Working with Green ICT is not always straightforward; both the rebound effect and challenges for implementing Green ICT are discussed. The rebound effect can be explained in a simplified way by saying that with more efficient technology, the price of goods and services will go down, allowing a higher level of consumption. This means that green efforts do not always lead to the expected outcomes. The Green ICT challenges are often based on a lack of knowledge about what Green ICT actually is, and how it can be implemented. With insufficient knowledge, there is no overall view in the organisations, and not enough management support, which leads to a lack of motivation amongst employees. The single most important mitigation strategy is to appoint someone in the organisation to be responsible for Green ICT (O'Flynn, 2010).

Four existing Green ICT frameworks were examined; Chai-Arayalert and Nakata's (2011) Green ICT Analysis Framework, Kalsheim and Beulen's (2013) Green Hardware IT Infrastructure Framework, The Connection Research-RMIT Green ICT Framework (Philipson, 2010) and UK HM Government Green ICT Maturity Model (HMG, 2013). All four are different in terms of what they measure and how they do it. It was determined that behavioural factors are important when looking at Green ICT. For the measuring, a clear method and predefined green levels was found to be beneficial.

4 The Guidelines

This chapter presents the Green ICT guidelines that have been developed. After a brief introduction, the concept of maturity models is explained. That is followed by an outline of the five domains spanned by the guidelines. After that, the actual guidelines are presented, with definitions for each of the maturity models. Finally, findings from the interviews will be presented.

4.1 Introduction to the Guidelines

A lack of knowledge is quoted by many as a challenge to the implementation of Green ICT (see for example Suryawanshi and Narkhede 2013, Paruchuri 2011). Therefore, guidelines have been developed for how Green ICT can be implemented step-by-step in an organisation. The Green ICT guidelines developed in this dissertation look at five different domains; business, data, application, technology and policy. The domains will be explained further in section 4.3. For each of the domains, there are five levels of greenness for the organisation to strive for. These levels are based around a maturity model, which will be explained further in sections 4.2 on Maturity Models and section 4.4 on The Maturity Levels. The aim is for the organisation to move up through the maturity levels, as the use of Green ICT becomes more common in the organisation.

Each of the levels in the maturity model includes suggestions on what the organisation can do to improve the Green ICT situation in that particular domain. These suggestions are based on the Green ICT and ICT for Green strategies found in the literature review. The hope is that the guidelines can be used as a roadmap for organisations wanting to move towards Green ICT, with clearly defined suggestions of what the organisation can do to move upwards in the maturity model, and thus become greener.

4.1.1 Limitations of the Guidelines

The guidelines are not claimed to present an exhaustive list of all green technologies and problems. Instead, they are meant as guide for organisations wishing to work with Green ICT. Due to the large amount of suggested Green ICT strategies, and the fact that new technologies and techniques are constantly being presented, it is difficult to include everything.

The guidelines look especially at the environmental dimension of ICT. They are not sustainability guidelines, but environmental guidelines. Although some elements of sustainability are included, with green certified hardware and responsible recycling, it is not the main focus, and it will therefore not provide a good picture of the sustainability of an organisations ICT.

Some of the suggestion in the guidelines may be unsuitable for some organisations, if they operate on a very small scale, or some other factor makes it impossible to achieve. They are meant to be general guidelines, so each organisation should analyse which Green strategies are possible to realise for them.

4.2 Maturity Models

Since the launch of the Capability Maturity Model in 1993 (Paulk et al., 1993), maturity models have been gaining popularity and have been given quite a bit of academic attention (Antunes, Carreira and Mira da Silva, 2014). The original Capability Maturity Model was designed to assess software engineering processes (Paulk et al., 1993), but maturity models can be used in other fields as well. Paulk et al. define maturity as "*the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective*" (p. 4). Antunes, Carreira and Mira da Silva (2014) explain that maturity models define maturity levels and "*represent a theory of stage-based evolution, aiming at describing stages and maturation paths*" (p. 4). The five maturity levels used in Paulk et al. (1993) are Initial, Repeatable, Defined, Managed and Optimized, but there are a number of alternative levels in later maturity models, see for example Antunes, Carreira and Mira da Silva (2014) and Philipson (2010).

The maturity model used in this dissertation will be a modified version, which uses the idea of moving through maturity levels, but does not include the processes found in the original capability maturity model, and with maturity levels more appropriate for environmental management than the original. The levels used will be discussed in more detail in section 4.4 on The Maturity Levels.

4.3 The Five Domains

The guidelines are designed to promote greenness over five domains: business, data, application, technology and policy. These domains are frequently used in enterprise architecture, after data, application and technology domains were suggested as a useful way of viewing an organisation in Spewak and Hill (1993). Enterprise architecture aims to give a holistic view of the organisation, looking at business needs, requirements, and available resources. Information, and the flow of it, are important parts of enterprise architecture. With the purpose of the guidelines being to look at an organisation and in a holistic way determine the steps that can be taken to achieve greener ICT, the domains from enterprise architecture are a good starting point for analysis. Below, the five domains will be introduced.

4.3.1 Business

The business domain deals with the "*interaction between the business strategy, organization, functions, business processes, and information needs*" (The Open Group, n.d.). All organisations have a goal, and something they want to accomplish. Reaching that goal requires resources in terms of knowledge and information, but also supporting technology. Business functions such as printing and computer use demand resources, but there are ways of reducing the environmental impact. In addition, there is big potential in working with ICT for Green, for example with teleworking and dematerialisation (Ruth 2009, Osseyran 2014, The Climate Group 2008).

4.3.2 Data

The data domain "*identifies and defines the major kinds of data that support the business functions defined in the business model*" (Spewak and Hill, 1993, p.169). Data is an important asset for almost all organisations nowadays, but the storage of data is a big issue in green information management. Large quantities of data are often stored in the wrong type of storage, with infrequently used data stored in tier 1 storage, leading to a bigger impact on the environment (JISC, 2010).

4.3.3 Application

The application domain concerns "*the structure and interaction of the applications as groups of capabilities that provide key business functions and manage the data assets*" (The Open Group, n.d.). Applications manage data, and make it available to the people who need it (Spewak and Hill, 1993). The right applications can have a positive impact on the environment, making both data management and access to data greener. Applications make possible the use of green techniques like server based computing, virtualization and server consolidation, and deduplication (Joumaa and Kadry 2012, Berl et al. 2010, Storer et al. 2008).

4.3.4 Technology

The aim of the technology domain is "*to define the major kinds of technologies needed to provide an environment for the applications that are managing data*" (Spewak and Hill, 1993, p. 223). The technology used is undoubtedly a big part of how green an organisation is. Much of the present work on green ICT and information management is on green technology. Numerous technology standards and certifications exist, like Energy Star and EPEAT, where hardware is evaluated and rated. The technology domain has received an unfair amount of attention, possibly due to the relative ease with which one can measure things like energy efficiency of equipment, and recycling rates. Still, it is an important part of green information management, especially when considering how large an impact things like data centres can have.

4.3.5 Policy

The policy domain is not traditionally seen as a stand-alone part of enterprise architecture frameworks, but it is looked at in isolation here due to the large role played by policy and attitude in green information management. Company policy can affect a wide range of questions, like how long computers are used for and what happens at the disposal stage, whether equipment and devices are shared between people and departments, and whether or not green information management is encouraged from the top management.

4.4 The Maturity Levels

The guidelines are based around a modified maturity model. The idea is that organisations move through the levels, and in section 4.5 below there are suggestions on the steps to take to become greener at each level. The original levels used in maturity models, Initial, Repeatable, Defined, Managed and Optimized, were designed for use with software-development maturity assessments. The levels used here were adapted to better suit environmental management, with inspiration from other green maturity models, like those found in Philipson (2010), Antunes, Carreira and Mira da Silva (2014) and HMG (2013). The five maturity levels that will be used in the framework are Ad hoc, Initial, Managed, Internalised and Leader.

The five levels in the maturity model used here go from unstructured or no Green ICT effort, to Green ICT leadership. Due to the laws and regulation regarding environmental management, many organisations may have some Green ICT in place, even if it is only for regulatory compliance. Ad hoc is therefore the first level, where there is little or no conscious effort to become greener. Ad hoc, although not used in the original maturity model, can be found in many of the environmental management and Green ICT maturity models. Sometimes there is a zero or not applicable level below, but as is explained above, there are often some forms of Green ICT present even if they may not be thought of as Green ICT.

The next level, initial, is present in most of the maturity models looked at, but is not consistently defined. Antunes, Carreira and Mira da Silva (2014) describe it as no defined activities, whilst Philipson (2010) describe it as the organisation having some knowledge of Green ICT, but nothing being implemented yet. Here, Philipson’s definition is closer to the one given below.

The third level, managed, gains its name from the fact that the organisation has started to work actively with Green ICT. In both the original capability maturity model and Philipson (2010), managed is the fourth level, the one called internalised here. Internalised was added above managed, as the internalised level requires the organisation to work with Green ICT as part of its business culture. At this level, it is not only about implementing certain green strategies, but to communicate it to employees and create support for it in the organisation.

The fifth level, leader, is quite often called optimised in other maturity models. This comes from the original capability maturity model, which assesses processes. Since Green ICT is about more than processes, keeping the name optimised would not give a true picture. Leader is more appropriate, as the organisation would be a Green ICT leader in the sector, working with innovative technologies to become greener. Below, all five maturity levels are defined.

4.4.1 Ad hoc

At the first level, any green initiatives are uncoordinated and limited to parts of the organisation. There is either no Green ICT effort, or Green ICT is only implemented for regulatory compliance.

4.4.2 Initial

At the second level, the organisation begins to look at the possible benefits of Green ICT. Possibilities for greening the organisation’s ICT are examined.

4.4.3 Managed

At the third level, steps are taken towards greener ICT and information management. Conscious decisions are made to opt for green technologies.

4.4.4 Internalised

At the fourth level, Green ICT has become part of the business culture. The potential of ICT to green other parts of the organisation is examined.

4.4.5 Leader

At the fifth level, the organisation works with state of the art technologies to become greener. Holistic assessments are made, for all parts of Green ICT.

4.5 The Guidelines

Below, the guidelines will be presented. The maturity levels for each of the five domains will be defined.

4.5.1 Business

Ad hoc

Normal business activities are carried out without any regard to environmental issues with the ICT used. No connection is made between how the organisation operates, and the effects it will have on the environment.

Initial

Small steps are taken towards greener ICT, in the form of evaluating different strategies that can be used. Both Green ICT, like duplex printing and printer consolidation, and ICT for green, like teleconferencing and greening of the supply chain, are examined. There is an active wish to become greener, although it may partly be based on cost savings at this stage.

Managed

Some green processes have been implemented; teleconferencing is seen as an option to physical meetings, and printing is recognised as having a large potential impact on the environment, and is discussed with employees. A person or team responsible for Green ICT is appointed. The possibilities of greening business processes with the help of optimisation and dematerialisation aided by ICT are evaluated. The infrastructure needed for things like teleconferencing and teleworking is being developed.

Internalised

Green ICT is seen as a business goal, and communicated both to employees and customers. Printers are consolidated, and shared between employees and departments. Teleworking is accepted. ICT is used to make business processes greener, for example with route optimisation in transports. Dematerialisation can be seen in the organisation, with examples like electronic billing being used to save paper, as well as emissions caused by transports.

Leader

Demands are made for business partners to work with Green ICT. Print management schemes are introduced, to limit copying and printing. Reports on Green ICT are available both for employees and the public. ICT tools are used to analyse processes and practices in terms of their impact on the environment, and to find greener ways of doing business.

4.5.2 Data

Ad hoc

Data is saved where it is most convenient at the moment, and is not seen as something that can have a negative effect on the environment. Data is seen as something intangible, that can neither have a negative environmental impact, nor a positive one.

Initial

The organisation acknowledges that data, and the storage of it, can impact the environment. A connection is made in the minds of the employees, between data and the physical equipment used to store it. Green technologies, like tiered storage, are examined. There is a realisation that not all stored data is needed; obsolete and duplicated data do not add any value.

Managed

The organisation realises that not all data needs to be in energy demanding tier 1 storage. New, greener, types of storage are used for less frequently accessed data. Some manual pruning is done to decrease the amount of data stored. Data retention schedules are starting to be developed, allowing the stored data to be managed in a better way, with obsolete data removed.

Internalised

Data is not mindlessly saved and kept, but retention schedules are in place to allow old, unused data to be discarded. An effort is made not to store duplicated files, for example by not attaching files to emails but having intranets where the file will be stored only once. Data storage is centralised in the organisation, allowing a higher rate of utilisation for storage media, and thus less physical equipment needed.

Leader

Data is in tiered storage, with automated Information Lifecycle Management/Hierarchical Storage Management programmes implemented. Retention schedules allow deduplication and migration of data to be done automatically. Awareness of green data handling has spread across the entire organisation.

4.5.3 Application

Ad hoc

No connection is seen between applications and the environment. The potential of using green applications is not recognised.

Initial

With a goal of becoming greener, the organisation starts to examine opportunities for green applications, like server virtualization and deduplication applications. The opportunities for greening with the help of applications, both by saving energy and by increased hardware utilisation, are looked at.

Managed

Server virtualization is implemented for specific functions in the organisation, leading to higher utilisation rates and a decreased need of buying new equipment. A client-server model is in place, offering thin clients and/or mobile devices as an option to standard desktop computers. Less devices are needed, and less powerful devices are needed, with centralised processing. Applications such as

Auto Shutdown and Wake-on-LAN, which will allow equipment to be switched off/on automatically are starting to be introduced to the organisation, allowing the organisation to turn off idle machines, but still not impact productivity.

Internalised

Virtualization has been implemented for a wider range of functions, and servers have been consolidated where possible, leading to a reduced need of new equipment, and energy savings for data centre cooling. Auto Shutdown and Wake-on-LAN are implemented across the organisation, saving energy and increasing the longevity of equipment.

Leader

Automatic data deduplication tools are used, to decrease the amount of storage that is needed. Applications making energy use visible for each individual employee are used, allowing the employees to take greater responsibility. When developing or purchasing applications, attention is paid to the green dimension

4.5.4 Technology

Ad hoc

Some green technology may be used, due to regulations and laws, but it is not a priority for the organisation. New equipment is purchased without any regard to environmental factors.

Initial

The potential impact of green technology is starting to be recognised. Green equipment is seen as a good starting point for going green. Different green certifications, like Energy Star and EPEAT are examined for inclusion in procurement strategies. Metrics for energy efficiency are researched, in order to evaluate both new and existing equipment.

Managed

The purchase of new technology is controlled, with mostly green certified hardware purchased. Servers are consolidated, to save energy and avoid buying new equipment unless absolutely necessary. The period of use for equipment is tracked. Power Usage Efficiency for data centres is tracked, and improved. Sharing certain equipment, like printers and cameras and other peripherals used for teleconferencing, is seen as an environmentally friendly option.

Internalised

Inefficient desktops are replaced with laptops, thin clients and mobile devices where possible. Energy use and cooling of data centres are focus areas, with green options like natural air cooling and greener UPS used where possible. The data centre bill is included in the IT budget, to promote a greater understanding of how decisions impact energy use. The period of use for equipment is increased by re-use and upgrade strategies.

Leader

All equipment is purchased with re-use in mind. Standardisation or modularisation allows upgrades of components, instead of buying new equipment. Old equipment is examined to see if it can be re-used for other purposes, if it cannot be re-used within the organisation. New technologies and strategies are used to mitigate environmental issues, like excess heat from data centres being used for heating of offices or homes and equipment being bought with extended service contracts, to promote longevity.

4.5.5 Policy

Ad hoc

No holistic, organisation-wide Green ICT policy exists. No green strategies are communicated to employees or stakeholders.

Initial

A Green ICT policy is starting to be developed centrally in the organisation. Employees are encouraged to take steps towards reducing the environmental impact of ICT, like powering down devices, recycling office paper and sharing equipment where possible. Policies and practices are acknowledged to be of importance in greening the organisation.

Managed

Steps towards Green ICT are taken, with enforced policies on simple methods of going green, like powering down devices at night and recycling paper. Employees are educated about Green ICT, where the main environmental issues are, and what they can do to lessen the impacts. Local policies are examined to find best practice, and to harmonise policies.

Internalised

An effort is made to upgrade components in equipment instead of buying new equipment altogether. Equipment is regularly re-used in other parts of the organisation when it can no longer fill its original purpose. Any equipment that can neither be upgraded, nor re-used is recycled in a responsible manner. All local policies have been harmonised, and an organisation-wide policy is in place. Green ICT efforts are communicated to employees, along with ways for employees to get involved.

Leader

An environmental management system is in place, and green reports are available both to employees and stakeholders. Green energy, i.e. from renewable sources, is used where possible. Environmental concerns are present in all parts of decision making in the organisation. Employees are aware of the Green ICT policy, and are motivated to act in an environmentally friendly way.

4.6 Reflections on the Interviews

To improve the guidelines, and to get an idea of awareness and application of Green ICT in real-life organisations, six interviews were carried out. The interviewees were from three different organisations, two in the public sector and one in the private sector. The interviewees worked with and had experience of ICT, environmental management, or both. Three interviewees worked predominantly with ICT, two with environmental management, and one had experience of both. Due to the relatively small amount of interviews carried out, the results are not claimed to be generalizable, but to offer an insight into some of the Green ICT issues faced by organisations today. A discussion on the topics brought up in the interviews can be found below.

Some themes stand out in the interviews; although all interviewees saw benefits of working with Green ICT, none of them claimed that their organisation works with Green ICT in an optimal way. The issue of responsibility of Green ICT in the organisation was brought up. It is still unclear who in the organisation should be ultimately responsible for such efforts. Another issue, that of costs, was brought up in all interviews: it is seen both as a hindrance to the implementation of Green ICT strategies, and as an important motivational factor. Some Green ICT strategies, like virtualization, make it easy to see how money could be saved without impacting performance. Such strategies are readily used in the organisations today. Problems arise when the organisation cannot see the potential for cost savings. Without cost savings as a justification, it is harder to gain support from top management, as well as employees, for new ways of working.

To increase the motivation to work with Green ICT, increasing the knowledge and understanding of ICT's impact on the environment and Green ICT in the organisation was brought up as the main strategy, both amongst those working with ICT and those working with environmental management. Suggestions of how it can be done included presenting Green ICT success stories, to show that working with Green ICT makes a difference, and can provide benefits such as cost savings and a competitive advantage for the organisation. It was also mentioned that the IT department should take greater responsibility in spreading awareness of Green ICT.

Energy efficiency was brought up in a couple of the interviews as a good focus area for Green ICT. It is an attractive option, as it is measurable in absolute numbers, and saves money straight away. However, a lifecycle perspective was requested by others, especially those working with ICT, as the energy and materials used in production was seen as an issue. Responsible recycling was also brought up as an important part of Green ICT.

To achieve Greener ICT, the interviewees who work specifically with ICT pointed out the importance of making informed purchasing decisions to increase the longevity of products, and decrease the overall amount of equipment needed. One of the interviewees said that their organisation has started to buy equipment with extended service contracts, to prepare for a longer period of use already in the purchasing stage.

Looking at how equipment will be used is another example given of how ICT can become greener by one of the interviewees working with ICT: if someone will spend large amounts of time travelling, or meeting clients, a light and portable computer is needed. If that employee is provided with a bulky laptop, he or she will most likely also require a tablet or some other more portable device. It is therefore better to purchase a more portable laptop for that employee, even though it may cost more initially.

When it comes to implementation of Green ICT, many of the interviewees, both those working with ICT and environmental management, agreed that the easiest way to do it is to make sure that all new equipment purchased is environmentally friendly. It is easier to make green changes when old equipment is updated, as the common view is that people do not like changes, especially when they cannot see the benefits.

In addition to the cost issue, which all of the interviewees mentioned, the ease of use was brought up as a factor when implementing Green ICT, by those working with ICT. Strategies such as replacing business trips with videoconferencing have become much more common lately, as the supporting technology has become more user friendly. With simpler and more user friendly technology, it is easier to convince people to change their ways.

In conclusion, the main challenges seen by the interviewees to the implementation of Green ICT are the costs involved, and people’s unwillingness to change. The suggestions for how these challenges can be overcome are based mainly around communicating the potential benefits of Green ICT, and how successful changes have been made in other organisations, or departments. Many of the interviewees agreed that green policies could be developed further in the organisation, to make it easier to choose greener options.

5 Conclusions and Recommendations

This last chapter will highlight what has been found in this dissertation, how it can be used, and how it can be developed further. First, conclusions from the literature review and the interviews are presented. Based on that, recommendations are given, and suggestions are given for future research topics related to Green ICT. Finally, there is a section on reflections from writing.

5.1 Conclusions

The aim of this dissertation has been to examine the available strategies for greening ICT, and to develop guidelines that can be used by an organisation wanting to move towards Green ICT. It was found that there are quite a few strategies for greening ICT, but much of the literature was focused either just on data centres, on one particular strategy, or just energy efficiency. Challenges for implementing Green ICT were frequently left out. This dissertation has therefore collected the strategies, to give a wider picture of Green ICT, and includes common challenges faced by organisations implementing Green ICT.

Many of the government and organisational reports examined in this dissertation seemed to paint a very positive image of ICTs ability to help green other sectors. However, they did not often mention the environmental footprint of ICT itself, or the fact that green strategies, like teleworking, are still not broadly accepted in organisations. Looking only at the positives gives a distorted image of reality, and is not a good basis for decisions.

After analysing the material for the literature review, a distinction was made between Green ICT and ICT for Green. Green ICT consists of the technologies and strategies directly linked with ICT, for example cooling of servers, efficient printing schemes and longevity of products. ICT for Green is concerned with the many ways ICT can act as an enabler to help to make other parts of life more environmentally friendly, with route optimisation in the transport sector, teleworking/teleconferencing and dematerialisation. The reason for this distinction is the fact that Green ICT and ICT for Green belong to very different parts of organisations; Green ICT should largely be the responsibility of the IT-department, but ICT for Green efforts are more likely to be found all over the organisation. ICT for Green is included in this dissertation, as it is claimed by some to have the largest potential for a positive environmental change (see for example Forge et al., 2009).

Looking at Green ICT, the single most important factor for organisations wishing to go green was claimed to be the longevity of equipment (Uddin and Rahman, 2012). This is due to the fact that a large amount of overall lifecycle energy and material is used in the production stage. However, it is an issue that is often overlooked when energy efficiency is seen as being synonymous with greenness. Nonetheless, energy efficiency can have a large impact on overall greenness, and it has the benefit of being something that is clearly visible and measurable for the organisation.

The main issue with implementing Green ICT, that was discussed both in the literature and the interviews, was the cost issue. Insufficient knowledge, lack of motivation and lack of support from top management were also brought up as issues with Green ICT implementation. To overcome these issues, having someone in charge of Green ICT, who can spread awareness and knowledge, and provide a holistic view, has been suggested. A lack of knowledge of Green ICT, both amongst management, and employees, means that it is harder to gain support for green efforts, and that the right motivation is likely to be lacking as well. Without the right motivation, green washing rather than actual green efforts could be the result.

This dissertation has produced Green ICT guidelines, which allow an organisation to see how Green ICT can be implemented, step-by-step, over the five domains business, data, application, technology and policy. The guidelines were developed as lack of information was quoted as one of the main challenges for organisations wishing to work with Green ICT. It is hoped that the guidelines can act as an aid to Green ICT implementation.

5.2 Recommendations

Green ICT is still not a priority in many organisations, as the positive effects, where ICT enables sustainability in other sectors, hides the impact of the actual ICT equipment (Egyedi and Muto, 2012). A number of challenges for implementing Green ICT have been uncovered, both in the literature review and the interviews. One such challenge that was frequently brought up in the interviews was the cost issue. Green ICT is seen as something that is potentially costly, and therefore hard to get support for. Pointing to the cost savings available, in terms of less equipment needed, and lower energy bills, as well as the potential for improving the organisations image in the eyes of its customers, would therefore appear to be a good strategy for getting support from top management (Chang and Chen, 2013).

When it comes to working with Green ICT, most people agree that it is important to measure progress in some way, in order to improve (see for example Global Metrics Harmonization Taskforce 2012, Chai-Arayalert and Nakata 2011 and Daim et al. 2009). The main point is that it should "*enable benchmarking and comparisons*" (Philipson, 2011, p. 12), in order for the assessment to be useful in comparing organisations to each other, and to track the performance of a single organisation over a period of time. Four frameworks for measuring Green ICT were examined in this dissertation. Any one of these could be used, or the organisation could develop its own set of metrics for measuring Green ICT. The main point is that organisations should keep track of Green ICT in some way, in order to be able to improve.

There are a number of ways of going green when working with ICT. However, it is important to keep the entire lifecycle in mind, and not just think about the use phase. Exchanging older but still functioning equipment for newer, more energy efficient equipment, is a good example of a small energy saving leading to a large negative impact due to the large amounts of energy and material used to produce the new piece of equipment. All decisions should therefore be looked at holistically, to not miss any negative or positive impacts in other parts of the lifecycle.

The main success factor for Green ICT efforts is to have a person or a group be responsible for Green ICT. Without someone in charge, it is hard to get a holistic view of Green ICT in the organisation, and to educate and motivate employees. Having someone who is responsible for Green ICT means that they can coordinate the efforts across the organisation, to promote things like re-use across departments.

Another important aspect to think about when implementing Green ICT in an organisation is to ensure that employees are motivated. Without motivated employees, green guidelines may not be followed, and it will be hard to achieve good results. To increase motivation, knowledge of Green ICT, the impact it can have on the environment, and the strategies available to reduce that impact, could be communicated to employees.

5.3 Future Research

Currently, the guidelines developed in this dissertation are focused solely on the environment, but social factors could be included as well, and it could be adapted to work as sustainability guidelines rather than just green guidelines. The social and economic aspects in the production stage would probably be quite a big part of sustainability guidelines.

During the information gathering stage, it was discovered that sustainable ICT is an underdeveloped field of research. Although 'Sustainable IT' is a common key word, it seems to be much more concerned with the environmental dimension than the social or economic dimensions. The social and economic dimensions could be examined in further detail, both in the use-phase and production and disposal.

Lifecycle assessment of ICT equipment is another area where there is much talk, but there seems to be no clear agreement on how to measure and present results. Although it is recognised in literature as being a crucially important part of Green ICT (see for example Mingay and Pamlin 2008 and Ardito and Morisio 2014), it is hard to measure the lifecycle impact of equipment due to production and recycling often being outside of the organisations control. The importance of lifecycle assessment is partly overlooked with green certifications like Energy Star, which mostly focus on energy use, being synonymous with Green ICT. Developing a standard for lifecycle assessment could make it a more frequently used mode of assessment.

5.4 Reflections

This dissertation was initially meant to produce a framework for measuring Green ICT in an organisation. However, it became evident that measuring, in terms of producing a hard number, is difficult when it comes to Green ICT, for a number of reasons. The main issue with measuring Green ICT is that there is no commonly accepted definition of what Green ICT consists of. As can be seen by the existing frameworks examined in the literature review, some include just the hardware, whilst others include ICT for Green, green behaviours and numerous other factors. To produce a Green ICT framework, the question of scope must be given a great deal of attention. There needs to be clear limitations of what is included in the term Green ICT.

After deciding upon the scope of the framework, Green ICT metrics must be selected. These must be able to measure the different factors of Green ICT included in the framework. Some such metrics already exist, with PUE being the most talked about, but the current issue when it comes to metrics is that a great deal of them deal predominantly with the data centre. Lifecycle assessment is claimed to be of great importance when it comes to judging the greenness of ICT (see for example Paruchuri, 2011), but overall lifecycle impact of equipment is very difficult to measure for individual organisations.

A further issue, after the scope of the framework has been agreed upon and metrics have been selected, is that one must determine the relative importance of different metrics. If the aim of the framework is to produce a comparable result, the results for the different measurements need to be weighed to create such a result. The question is whether all metrics should be given equal attention, or if some metrics should decide a proportionally larger part of the result. There is reason to expect that some metrics may be more important than others in a holistic assessment.

The difficulty in producing a framework to assess Green ICT is based on two main factors: the fact that technology is always evolving and improving and the fact that ICT is used differently in every organisation. With changing technology, a target for what is ‘good’ or ‘acceptable’ in terms of energy efficiency, raw material use etc. will need to change continuously to account for the improvements made every year. The different ways ICT can be used in an organisation makes it harder to achieve a standardised result. Depending on the type of organisation, the main environmental impacts may come from the data centre, portable devices, printers, or any other category of ICT. Developing a framework which can assess organisations in different sectors fairly is thus a big challenge.

Instead of producing a framework, this dissertation has produced a set of guidelines for organisations wishing to move towards Green ICT. The guidelines are largely based on the literature review, where different green strategies were discussed. The interviews were initially designed to test the framework before the focus changed towards producing guidelines for Green ICT instead, but the interviewees were able to provide insight into how Green ICT is approached in their organisations, and feedback on the guidelines.

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