Defining an auditing protocol to measure the maturity level of sustainable ICT in Utrecht University

Master thesis

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Abstract

Sustainability is becoming an important subject for organizations these days aiming to perform well in a competitive environment. It is no longer only about making money; people now expect organizations to contribute to a sustainable environment in different ways. At the same time, IT is becoming crucial for organizations in supporting business processes. However, IT also has a huge impact on the environment through its entire lifecycle. Another problem is that sustainable IT is not yet a well-researched topic. Therefore, it is not widely known which capabilities organizations should focus on successfully making their IT sustainable and at the same time apply IT to lower the impact of their business processes on the environment. For Utrecht University (UU) and more specifically the Information and Technology Services department (ITS), this topic is also an important issue. Sustainability is one of the main strategic themes of Utrecht University and therefore the ITS department needs to pay attention to how sustainable their IT is. Therefore, the main goal of this thesis is to define an auditing protocol for measuring the maturity level of sustainable ICT in the ITS department.

A common tool these days for organizations assessing capabilities in a certain domain are maturity models. Originating from software development, maturity models are now used in a wide range of domains. To be effective, maturity models need to contain the right capabilities in a certain domain to provide valuable information for the users. When a domain is not yet mature, like in the case of sustainable ICT, it can be hard to specify a complete conceptual framework for a maturity model. For this issue, we have developed a comparison method that allows users to systematically compare the concepts of frameworks to the concepts of one reference framework to determine what concepts are not present in the reference framework. Based on these missing concepts, the reference framework can be improved and extended to include those concepts if these are deemed to be a valuable addition.

Using this comparison method, we compared one central framework, the Surf Green ICT Maturity Model (SGIMM), with several other frameworks in the field of sustainable ICT. This comparison helped us determine which subjects were not in the SGIMM. These topics were analyzed through interviews, literature and discussion to determine possible improvements. Using the resulting information, we extended the SGIMM with several concepts related to 'People' and laid the foundation for other future improvements that were out of scope for this project. We tested the improved SGIMM in an audit at ITS, with ITS scoring quite low overall. ITS mentioned that this was caused by sustainability currently not being a priority for ITS. However, reactions were positive towards the model and clear actions were defined for improving the maturity level of ITS. It was decided that the focus should be on improving the people and strategy domain.

Furthermore, we recommend setting up several projects to investigate further elaboration on the suggested improvements in the SGIMM and generalization of the proposed comparison method.

Preface

This master thesis contains the results of the research project I performed for my graduation. It has been a long, intense process, but I also enjoyed it a lot. Performing this project has taught me a lot about several subjects. First, my knowledge about sustainability and ICT has improved substantially. Furthermore, it was an educational experience to learn more about auditing, a skill that will come in handy later in my career. Additionally, performing a project of this size in collaboration with other people was a treasured experience overall.

A few people have delivered a considerable contribution to this project and will now be acknowledged for their work. First, I would like to thank my first supervisor Sergio España. He has done an excellent job supervising me and also actively participated in the project itself, which was a major contribution to the quality of the work.
Secondly, I would like to thank my second supervisor Sietse Overbeek for his time to review my work and provide me with extensive feedback on the paper and thesis.
Another person who has delivered a major contribution to this project is Albert Hankel. He was willing to participate in defining the new SGIMM and also contributed to the paper that was written in parallel with this thesis.
Furthermore, I would also like to thank my mother for her extensive reviewing of several versions of my thesis for grammar mistakes and formulation of sentences. Finally, I would like to thank the employees of the ITS department of UU for helping me through interviews and advice. Especially Jeroen Schipper and Aloysia Kluck have been very helpful in finding interviewees for my research and have also been very active in providing me with information about the ITS department, which was crucial for defining the auditing protocol.

David Lautenschutz, October 31, 2016

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1 Introduction

Sustainability is becoming more and more important for both public and private companies these days. A recent example comes from Google, who have signed a contract for 842 Megawatts of power to supply their data centers, made by green energy producers (Doorenbosch, 2015). At the same time, information technology (IT) is becoming crucial for sustainability, for example with the development of apps which helps employees of energy companies monitor energy networks in a more efficient way (AG Partnerblog, 2015).

IT plays an integral role in almost all components of business and each stage of the IT lifecycle, from production to usage and disposal (Elliot & Binney, 2008). Each of these stages has a substantial impact on the environment and therefore the environmental problems caused by business activities supported by IT have worsened over the past years. For example, in 2010 in the United States of America, IT consumes 20 million gigajoules of energy, which in turn produces 4 million tons of carbon dioxide annually (Ranganathan, 2010). On the other side, however, IT can be used to improve sustainability for a company. An example which uses the concept of flow networks: a parcel delivery company uses an information system (IS) that employs an algorithm to calculate the most efficient route for their delivery vehicles. Another example is used in a totally different sector: agriculture. Here an information flow model is proposed for farmers in Sri Lanka to provide them with information which will help them with their farming activities (De Silva, Goonetillake, Wikramanayake, & Ginige, 2012).

In the past decade more and more businesses have realized the long-term effects of pollution and are taking responsibility for their actions through several social and environmental initiatives that reduce the impact on the environment (Molla, Cooper, & Pittayachawan, 2009). A hot topic today and for the coming years as well is 'Green IT' (Murugesan, 2008). Green IT, combined from several definitions, is defined as follows by Molla et al. (2009) : '*Green IT is an organization's ability to systematically apply environmental sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure'*. From this definition, we can see here that green IT involves practices to lower resources needed and lower effects on the environments.

According to Molla, green IT benefits the environment by improving energy efficiency, lowering greenhouse gas emissions, using less harmful materials and encouraging reuse and recycling. To successfully develop Green IT, several questions must be answered, like:

- Which are the key environmental impacts arising from IT?
- Which are the major environmental IT issues that we must address?
- How can IT assist businesses and society as a whole in their efforts to improve our environmental sustainability?

Another possible use of ICT to lower impact on the environment are "Green Information Systems" (Green IS). Boudreau, Chen and Huber define Green IS as *'the design and implementation of information systems that contribute to sustainable business processes'* (2008).

We can see here that IT has two opposing sides. The one hand shows that IT is a big energy consumer but also producing it costs a significant amount of energy. The other hand demonstrates that IT can help organizations and people improve their sustainability (Molla, 2009). Supporting sustainable behavior with IT can be done in three ways, by greening IT usage, using IT to support sustainability and using IT to create green awareness (Murugesan, 2008). There are discussions about how this should be classified, but for this paper, the distinction will be made between "Green IT" and "Green Information Systems (IS)." Green IT will be aimed at the physical, hardware aspect of IT, while Green IS will be a different domain which includes the use of IT to enhance sustainability (Dedrick, 2010). When both terms are used simultaneously as one concept, the name 'Green ICT' will be used to avoid misunderstandings.

There are many examples of companies that have implemented instances of Green IT (Computerworld staff, 2010), but there hasn't been much research in what capabilities organizations need for greening their IT and how to measure those levels of maturity (Molla et al., 2009). Furthermore, there hasn't been much research on how and if Green ICT is related to organizational goals. Around twenty years ago, Porter and van der Linde (1995) stated that implementing Green ICT can provide a competitive advantage in the long-term and provide more innovative solutions than remaining at a basic compliance level.

Also for Utrecht University (UU) this statement is an interesting opportunity since sustainability is also one of its strategic themes. However, if UU wants to improve on Green ICT practices, it should first be measured how sustainable UU already is. The Information and Technology Services (ITS) department is responsible for providing UU with IT services, and there is a desire to improve on sustainability in the IT infrastructure. The first step they would like to take it to specify a baseline for the IT infrastructure to see how sustainable the current IT infrastructure already is. With that baseline, it can be decided where ITS wants to go in the future. However, since there aren't protocols available yet that fit directly into the specific situation of UU, an environmental auditing protocol tuned to the requirements of UU should first be specified, containing up to date knowledge about the necessary capabilities for measuring sustainability in ICT. Therefore, defining and testing this auditing protocol is the goal of this thesis, and will be further explained in the next section. Environmental auditing here is defined as: '*an independent evaluation of policy and principles, systems, procedures, practices and performance, and other elements of business relating to the environment. It aims at verification and validation to ensure that various environmental laws are complied with and adequate care has been taken towards environmental protection and preservation* '(Pahuja, 2013).

2 Research set-up

2.1 Problem statement & research objective

Sustainability is one of the strategic themes for the University of Utrecht (UU). UU aims to execute this strategy in two ways:

1. Sharing scientific knowledge.
2. Being an inspiring example for other organizations.

At the start of this project, ITS stated that they would like to examine how the usage and implementation of IT can be made more sustainable and also how ICT can support a more sustainable organization. To do this, however, a baseline first needs to be set. With the information provided by the baseline, it could be measured how sustainable the current ICT organization of UU is. This baseline should take into account all of the current actions that were already performed to be more durable. The interest in a baseline comes from the need to perform strategic management (i.e. govern the sustainability improvement actions and govern the ICT in a more sustainable way). The baseline allows stakeholders to analyze the current situation and thus enables them to spot possible improvements and define proper improvements for them. A baseline also allows for measuring the improvements by comparing the baseline to the new situation after the improvement actions. It will also define how the results of the auditing will be used to determine concrete actions that will make UU ICT even more sustainable and will specify a timeline of future measurements (e.g. after one year another audit can be done to see if any progress has been made).

ITS specified the following principal requirements that were necessary for the auditing protocol:

1. Quick wins should be able to be identified with the protocol. ITS specified quick wins as improvements that made ITS more sustainable and were easy and rapid to implement with no significant investment of resources.
2. The protocol should be easy to understand, meaning that employees must be able to use it without consulting other information sources like the Internet, consultants, or books.
3. The protocol should be quick in usage. The ITS department is going through a series of changes and therefore employees are often occupied or not concerned with sustainability. Therefore, conducting the audit should not take more than one full working day, shorter would be even better.
4. Using the protocol should produce a visual, preferably quantitative result in the same template on several different capabilities that are necessary for Green ICT. This result should be able to be compared to other instances of the protocol to analyze whether ITS has improved in sustainable ICT due to the actions that were taken.

Based on the results of the audit, UU can take action in the near future to improve the implementation of Green ICT, if desired. Therefore, based on the requirements of ITS, the main goal of this thesis is to**: define an ICT sustainability auditing protocol for UU and prepare the necessary instrumentation.**

A full PDD containing the steps that were taken during the entire project can be found in Appendix A. It describes the complete project. A more specific PDD of certain steps, which are the analysis & comparison of frameworks (the comparison method) and the audit, can be found in respectively Appendix B and C.

A conceptual model of the audit can be seen in Figure 2-1.

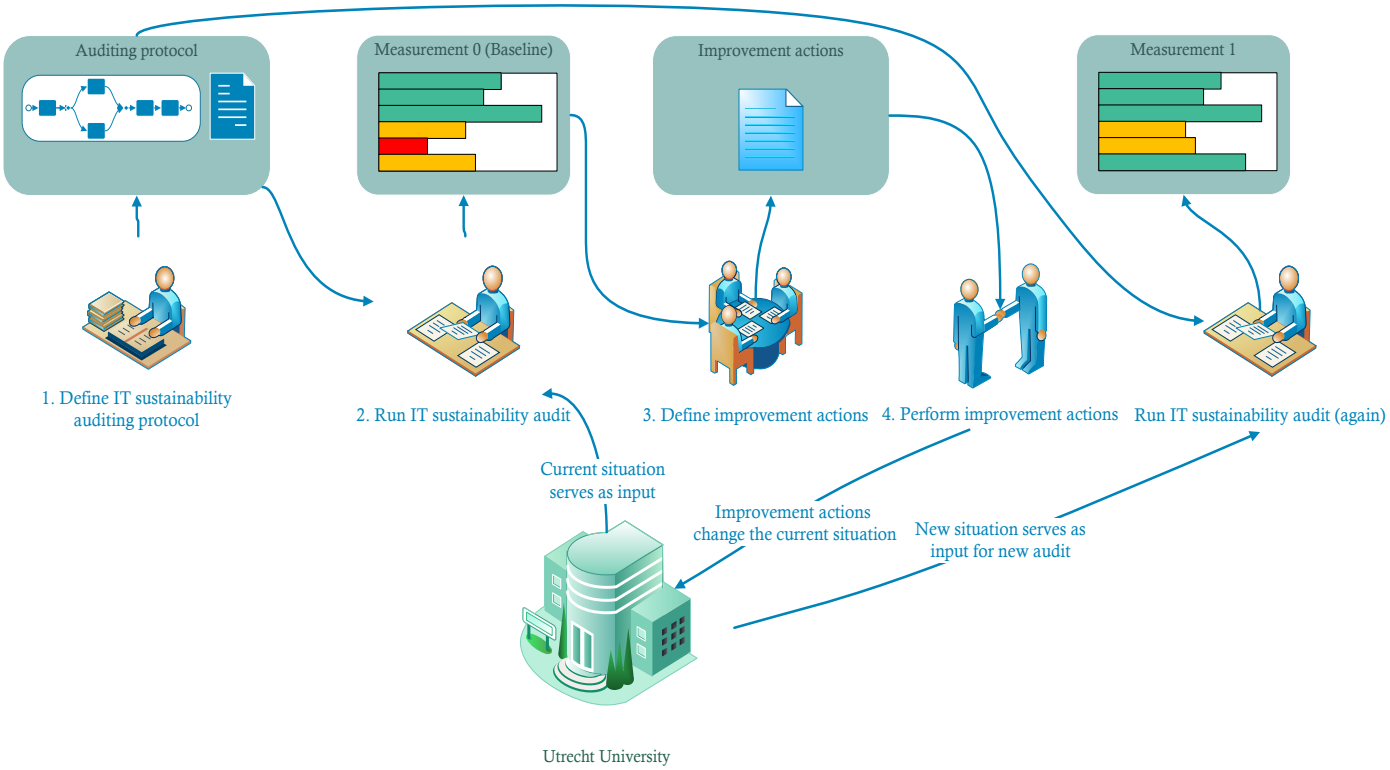


FIGURE 2-1: CONCEPTUAL MODEL OF ICT SUSTAINABILITY AUDIT

The model should be interpreted as follows:

1. The first step is to define the auditing protocol along with documentation on how to use it and its theoretical foundations.
2. The second step is to run the first IT sustainability audit. Running the audit will result in measurement 0, which will serve as the baseline for UU.
3. Based on the results, improvement actions are defined which are to be implemented.
4. The improvement actions are implemented.
5. The next step is to start the cycle over again and keep measuring and monitoring the IT maturity.

2.2 Research questions

The following research questions (RQ) are defined, based on the earlier mentioned main goal:

1. What are the requirements of UU for defining an auditing protocol for measuring sustainability in the ICT infrastructure?
2. Which kinds of protocols/frameworks are available for ICT sustainability auditing, what are the differences and to what extent they can be used within UU?
3. Defining the auditing protocol applicable to the current structure of UU.
4. Does the designed protocol satisfy the requirements?
5. Which are the expected benefits from the protocol?

2.3 Relevancy

This project is relevant for both UU as an organization and as a scientific community. About UU, sustainability is one of its strategic themes. To decide which domains should be improved, it is in the first place necessary to determine what the current maturity is regarding sustainability in ICT. Based on the result from an auditing protocol, proper changes can be proposed. When these changes have been implemented, it is important to see if the IT sustainability has increased overall. In that case, the maturity should be measured again to see if there has been an improvement.

For the scientific community, this thesis will help in defining a comparison method to aid in comparing frameworks to see what capabilities are present in existing frameworks and which are not. This comparison method can, in turn, help further improving frameworks based on other frameworks.

Energy is an essential resource for organizations to keep running and execute their daily business practices. These days IT is a significant energy consumer for organizations. Research has shown that IT is a significant contributor to worldwide energy consumption (Gelenbe & Caseau, 2015). This heavy usage of energy is a concern for both CO^2 emissions itself and the economic costs that come with it. The resulting environmental & economic impact shows the necessity for both Green IT and IT solutions that help organizations reduce energy costs.

About the scientific community, even though Green ICT is now becoming much more popular in society, there hasn't been much research on which capabilities companies need to green their IT and how to measure these capabilities (Molla et al., 2009).

This project contributes to this knowledge in two ways:

1. Determining an auditing protocol for educational organizations in general, but also applicable to UU's specific situation.
2. Defining a comparison method for comparing maturity models and frameworks that can contribute to the discussion of determining which capabilities are necessary for developing a maturity model in a certain domain.

2.4 Design science approach

In the information systems domain, there are two main ways to characterize research, which is behavioral science and design science.

Behavioral science is defined as follows: "*Behavioral science seeks to develop and justify theories that explain or predict organizational and human phenomena surrounding the analysis, design, implementation, management and use of information systems.*" (von Alan, March, Park, & Ram, 2004).

These theories are used to determine if an information system will achieve its stated purpose, which is to improve effectiveness and efficiency in an organization.

Design science has the following definition: *Design science is fundamentally a problem-solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities and products through which the analysis, design, implementation, management and use of information systems can be effectively and efficiently accomplished* (von Alan et al., 2004). It creates and evaluates artifacts to solve organizational problems.

Since this project aimed to create an artifact to solve a problem (measuring the sustainability of the current IT structure), it can be considered a design science research. Von Alan et al. defines the following seven guidelines for design science research, which were used for the creation of the auditing protocol.

1. **Design as an artifact**: *The research must produce a viable artifact in the form of a construct, a model, a method or an instantiation.*
   This research produced an auditing protocol for UU, which can be seen as the artifact. The basis for the auditing protocol was an existing auditing protocol for measuring sustainability in ICT, the Surf Green ICT Capability Maturity Model (SGIMM) (Hankel, Oud, Saan, & Lago, 2014a).
2. **Problem relevance***: The objective of design-science research is to develop technology-based solutions to important and relevant business problems.*
   This project extended an existing tool in the form of an excel sheet which can be used for filling in maturity levels to several constructs. The sheet was extended with new constructs and other additions which will be elaborated later on.
3. **Design evaluation:** *The utility, quality and efficacy of design must be rigorously demonstrated via well-executed assessment methods.*
   The SGIMM was evaluated by comparing the method to other existing frameworks of Green ICT. For this comparison, a comparison method was developed. Based on the findings from using the developed comparison method, version 2 of the SGIMM was improved. The evaluation of the renewed SGIMM was done by interviewing stakeholders and experts.
4. **Research contributions**: *Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations and design methodologies.*
   This project will aid UU and possibly other organizations when performing sustainability audits. Whether other organizations can use this new SGIMM depends on if they satisfy the requirements needed to use the SGIMM. Furthermore, the

comparison method aims to help researchers and organizations with comparing frameworks with each other to determine their differences regarding what theoretical concepts they implement.

5. **Research rigor**: *Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.*
   Based on several existing comparison methods for maturity models from literature, the comparison method was constructed. This comparison approach was then used for comparing existing maturity models and framework with the SGIMM.
6. **Design as a search process**: *The search for a powerful artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment*.
   Based on the found literature, the comparison method was constructed with method engineering and pseudo-coding. The comparison method was applied using existing conceptual frameworks and maturity models on Green ICT.
7. **Communication of research**: *Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences.* This project is interesting for both UU, researchers and other organizations. It will give stakeholders an insight into the sustainability of the IT organization without going deep into the technical details. Furthermore, the comparison method can be used in this field and other areas for comparing and improving maturity models and frameworks.

This research will be performed using the design science cycle as defined by Wieringa (2014). The full cycle contains five steps.

1. **Problem investigation**: Defines which phenomena must be improved and why. Based on this, goals are specified for the artifact to accomplish.
2. **Treatment design**: In this phase, the requirements are specified and it is investigated if the requirements contribute to the goals specified earlier. Furthermore, it is investigated which available treatments there are already and based on the gathered data; the artifact is designed.
3. **Treatment validation**: Here the artifact is validated for satisfying the requirements. Furthermore, it is tested if any other effects if observed in the validation, apply in the specific context of the validation.
4. **Treatment implementation**: Implementation can be interpreted broadly in this methodology. It is defined here as the application of the treatment to the original problem context.
5. **Implementation evaluation:** the goal of this phase is to see how an artifact interacts with its real world context.

This project will not involve all five steps mentioned above. From these steps, the first three will be part of the master thesis project. The final two stages will be continued in new follow-up projects. The protocol, however, will be tested in an audit. Another methodology was proposed, the design science research methodology (DSRM) (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).

The DSRM involves the following steps:

1. **Problem identification and motivation***:* Define the specific research problem and provide justification for the added value of the proposed solution. The research problem has already been defined in the introduction.
2. **Define the objectives for a solution:** Based on the problem definition and knowledge of what is possible and feasible, the objectives for the solution will be specified. These objectives can be either quantitative and qualitative.
3. **Design and development:** This phase involves determining the artifacts desired functionality, its architecture and eventually, creating the artifact.
4. **Demonstration**: This step is about testing the artifact to solve the problem or one or several instances of it. In this case, the auditing protocol will be tested in an audit at ITS.
5. **Evaluation:** Here the artifact is evaluated by comparing the original objectives with the outcome of the test in the demonstration.
6. **Communication***:* Finally, the artifact should be presented to other people, like researchers, managers, etc. to share the gained knowledge from the artifact with the environment.

Here it can be seen that the final three steps involve testing the artifact and communicating the results. Based on this DSRM, we will integrate these stages in the treatment validation step of Wieringa.

Summarized, we will do the following in each step:

1. **Problem investigation:** to understand better the sustainability domain, the purpose of sustainability auditing and the important aspects of such practice (RQ1), we *conducted a literature review*. To learn about the current efforts of UU concerning sustainability and to proper scope the project, we *conducted semi-structured interviews* with the major stakeholders and *performed a perspective-based reading* of UU documents on the matter.

2. **Treatment design:**
   In this phase, we *compared existing protocols and frameworks* concerning the measurement of IT sustainability in organizations. For comparing these protocols, we *constructed a comparison method.* Based on this data, we *defined the protocol* according to found literature and the data acquired from the comparison. This protocol is an improved version of the SGIMM. Also, we *created a new version of the Excel sheet for the SGIMM.*

3. **Treatment validation:** This phase consisted of a small *validation* of the tool for the SGIMM with three people. With the stakeholders, this will be achieved by *semi-structured interviews* and *reviews.* Finally, we will *compare* the protocol with literature to see if it satisfies the requirements of an auditing protocol and more specifically UU.

3 Theoretical background

3.1 Sustainability

This chapter aims to build a solid theoretical foundation of the concept 'Sustainability' and its relation to business. First, the definition of sustainability as a whole will be discussed. Then the relation between sustainability and business will be explored and finally, the role of IT will be included.

Sustainability is a much-debated concept which gained popularity after the Brundtland Commission's report "Our Common Future" (World Commission on Environment and Development, 1987). Here the United Nations defined sustainable development as: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs*". This definition is not without its flaws, however. There has been much discussion about the concept of sustainability and it is hard to give it a proper definition because the concept can have different meanings in different contexts (Brown, Hanson, Liverman, & Merideth Jr, 1987; Gatto, 1995).

Sustainable development is an important subject for the United Nations. The current list of goals for sustainable development post-2015 is the following enumeration of items[1]:

- *Goal 1. End poverty in all its forms everywhere.*
- *Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.*
- *Goal 3. Ensure healthy lives and promote well-being for all at all ages.*
- *Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.*
- *Goal 5. Achieve gender equality and empower all women and girls.*
- *Goal 6. Ensure availability and sustainable management of water and sanitation for all.*
- *Goal 7. Secure access to affordable, reliable, lasting and modern energy for all.*
- *Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.*
- *Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.*
- *Goal 10. Reduce inequality within and among countries.*
- *Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable*
- *Goal 12. Ensure sustainable consumption and production patterns.*
- *Goal 13. Take urgent action to combat climate change and its impacts*.*
- *Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.*

[1] Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld in January, 2016

- *Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.*
- *Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.*
- *Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.*

It can be seen here, that the list is very broad. Therefore, it is difficult to give a central definition to 'sustainability.' Because this thesis focuses on Green ICT, we will look at sustainability from an environmental perspective, which means that we will focus on capabilities that lower the impact of ICT on the environment. A recent definition specifies environmental sustainability as *'meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them'* (Morelli, 2013).

Sustainability is commonly believed to have three dimensions: Economic, Environmental and Social (Dyllick & Hockerts, 2002; Giddings, Hopwood, & O'brien, 2002). A visualization of this concept can be seen in Figure 3-1.

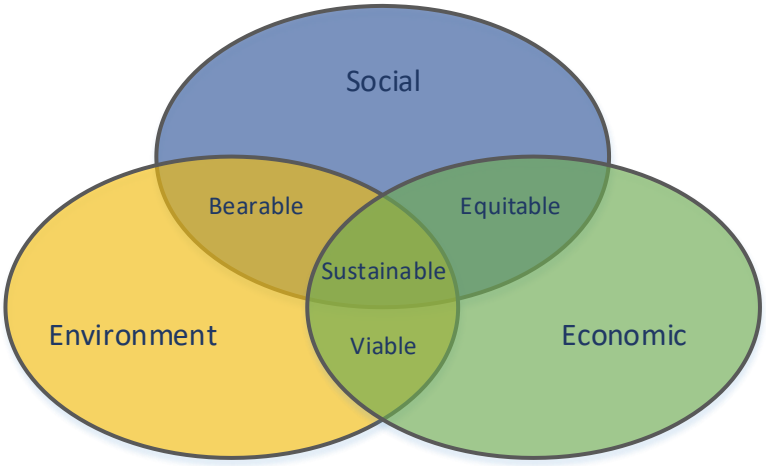


FIGURE 3-1: CONCEPTUAL MODEL OF THREE DIMENSIONS OF SUSTAINABILITY, RETRIEVED FROM WWW.THWINK.ORG (2014)

- **Economical**: These variables involve the flow of money, so for example profits, income, expenses, etc.
- **Environment**: Environmental variables describe the measurement of natural resources, like the use of water, air, paper, electricity and such.
- **Social**: Finally, these variables describe the social factors of a community, like education, employment, health and crime.

In the past few years, a term that has become more popular for organizations is Corporate Social Responsibility (CSR). Governments, activists and the media have become adept at forcing companies to take the social consequences of their activities into account. As a result, CSR has emerged as a top-priority issue for organizations around the world (Porter &

Kramer, 2006). According to Dahlsrud, it is hard to define CSR because it is mostly viewed as a social construction or phenomenon. Therefore, it is tough to formulate an unbiased definition (2008). Instead, he discusses several dimensions which describe it according to an analysis of existing definitions of CSR. Also for UU, CSR is a major factor because sustainability is one of the leading strategic themes.
Ebner & Baumgartner state in a study that the terms Sustainable Development, CSR and Corporate Sustainability are often used interchangeable. They all point in one direction: the objective is to consider an organization's output, impacts and not only satisfying the interests of the involved stakeholders (Ebner & Baumgartner, 2006). However, a clear distinction should be made, since it is very hard to create a common definition if the terms keep being used with a different meaning by different people. Ebner & Baumgartner proposed the following original model to describe the relationship between sustainable development, Corporate Sustainability and CSR. It can be seen in Figure 3-2.

In this model, sustainable development is shown to be at the macro-level. When the term is used in an organizational context, it is referred to as 'Corporate Sustainability'. CSR represents one of the pillars of Corporate Sustainability, namely the 'Social' aspect. Here it can be seen that the three dimensions of sustainability mentioned in Figure 2-1 can be noticed again here.

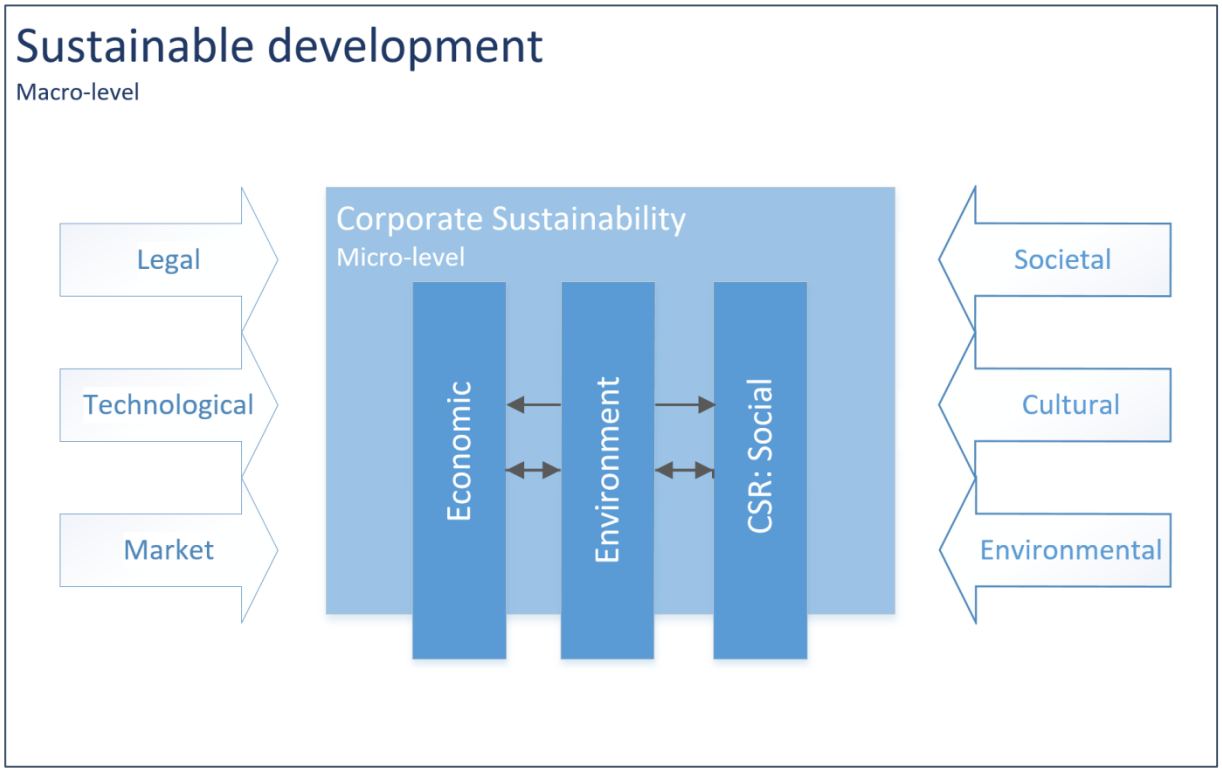


FIGURE 3-2: CORPORATE SUSTAINABILITY

This model can help making a clear distinction between the terms Sustainable Development and Corporate Sustainability.

However, it has been argued that CSR should not only encompass the social pillar but the environmental pillar as well (Carroll, 1999; Tilt, 2009). With the other literature found that companies should now take into account the environment as well, it is reasonable to assume that CSR should indeed incorporate both. Dahlsrud even argues that CSR, according to his research, should include all pillars of sustainability, among other dimensions as well (2008). This thesis will not draw any conclusions about which author is right, so it is assumed here that CSR could include all of the three pillars.

Porter & Kramer (2006) state in their study that because of the rising popularity of CSR over the past few years, society and organizations are now connected inseparably. However, most organizations struggle with aligning their CSR strategy with their main business strategy because the approaches to CSR are fragmented and disconnected from the business.

The debate for sustainability in organizations is being engaged in three ways (Benn, Dunphy, & Griffiths, 2014):

1. **Intellectual level**: we become aware of unsustainable practices and the challenges of changing these practices.
2. **Corporate level**: Employees of an organization execute multiple actions each day that has an impact on society and the environment.
3. **Consumption level**: the use of products that impact the world with waste and energy consumption.

On all these three levels, multiple reasons have been mentioned for organizations to become more sustainable. Esty & Winston name three: the potential for upside benefits, the management of downside risks & and a value-based concern for environmental stewardship (Esty & Winston, 2009). Hitchcock & Millard (2009) mention several more, for both big organizations and medium to small organizations.

For big organizations, some of the reasons mentioned are for example:

1. Society expects it from a big organization to invest also in sustainability to build a better society for all.
2. Investors have discovered that organizations paying attention to sustainability are better managed, thereby making it more attractive to invest in organizations with a high maturity level in sustainability.
3. Reporting on sustainability is the norm, by 2011, 95% of the 250 biggest companies in the world reported on sustainability.
4. Protecting the image of the organization in the form of brand management.

For small to midsized companies, some examples mentioned are:

1. Customers demand it.
2. Giving meaning to the work that you do.
3. Younger employees want to make a difference and expect from their employer that sustainability is a major factor in daily business practices.

Also, several benefits are mentioned, for example:

1. Better strategic management, because of a new perspective of the business, which can lead to new insights about the organization.
2. Attract and retain the best employees, because as mentioned before, employees these days want to give meaning to their work.
3. Improve image with shareholders and the public, for example by receiving recognition in journals.
4. Better use of raw materials and energy. By focusing on sustainable resources for the long term, an organization can prepare for when a resource is exhausted or becomes much more expensive to buy.

From these enumerations, it can be concluded that organizations have several well-founded reasons for investing in corporate sustainability. Several aspects in economic, social and environmental reasons provide benefits that can help organizations thrive and prosper. The next section will delve more deeply into the focus of this project, the relation of IT with sustainability

3.2 IT and sustainability

3.2.1 Negative effects of IT on the environment

The whole process of designing until disposing of IT has a significant impact on the environment and should not be underestimated (Elliot & Binney, 2008). Various studies have acknowledged the contribution of IT to the survival and success of organizations (Aral & Weill, 2007; Rai, Patnayakuni, & Seth, 2006; Ray, Muhanna, & Barney, 2005) and therefore simply abandoning the use of IT is not an option organizations will likely choose.

However, the use of IT in organizations accounts for a huge consumption of electricity. In 2008, server farms were accounted for the consumption of 180 billion of kWh, 1% of global electricity consumption. Furthermore, its consumption is set to double each 4-5 years. If the trend continues, in 15 years, server farms and telecommunications infrastructure's energy consumption will match the world's global power consumption in 2008(Fettweis & Zimmermann, 2008). Another research presented in the same paper estimated that IT was responsible for 2% of global emissions of Co_2 in 2007. A significant component of energy consumption by ICT is caused by running pc's (40%) and their servers (23%) (Uddin & Rahman, 2012a). The remaining part is caused by other factors like Printers and Fixed-line Telecoms. A pie chart of this can be seen in Figure 3-3 below.

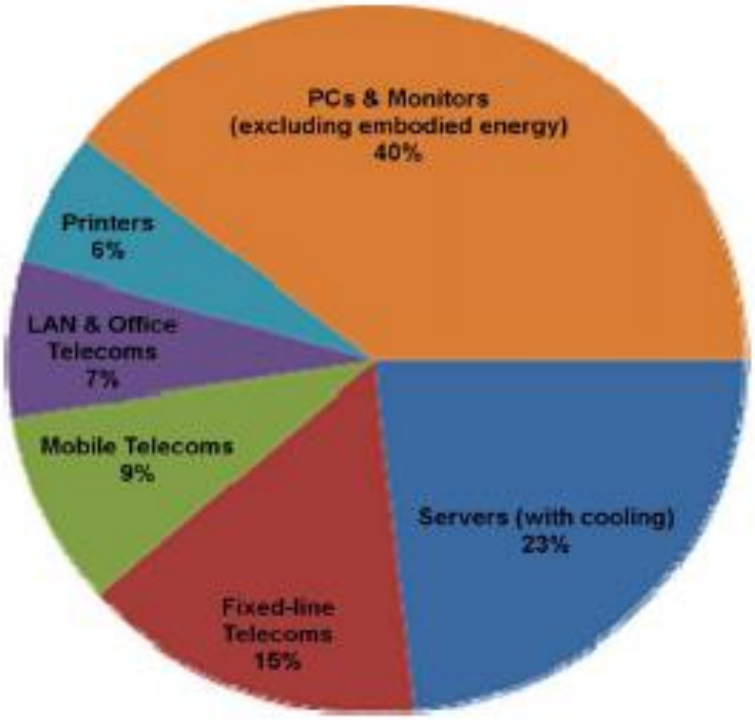


FIGURE 3-3: ESTIMATED ICT CO_2 EMISSIONS, ADOPTED FROM UDDIN & RAHMAN (2012)

A typical IT-Component that uses much energy, but is becoming more and more popular to use with the growth of cloud computing services, is employing a data center (Kliazovich, Bouvry, & Khan, 2012). Their consumption of energy accounted for 10% of total operational expenses in 2012 but was expected to grow to up to 50% in the coming few years. Adding to that, computing based energy consumption is also not the only factor that consumes energy in IT. High power consumption generates heat and for the equipment to work properly, it needs to be cooled down. So, adding to the IT components itself, are cooling systems which reduce the temperature to the optimal level. In a 30,000 ft^2 data center with 1000 standard computing racks, each consuming 10 kW of power, the cost of just purchasing and installing the computer room air conditioning units can already add up to a cost of 2 - 5 million dollars; with an average electricity cost of $100 MW/hr, the annual costs for cooling alone are 4 - 8 million dollars (Patel, Bash, Sharma, Beitelmal, & Friedrich, 2003). There are already initiatives to reduce these cooling costs. A recent example by Microsoft (de Vrede, 2016) involves a pilot in which the company tested a data center located in the sea itself, using the cold temperature of the cold seawater to cool their systems. In addition to this, they can be placed closer to cities located next to the sea, because currently, data centers have to be placed more landward.

3.2.2 Using IT for sustainability

Although ICT has an environmental impact through the energy consumption and the materials it requires, it also enables organizations to improve their processes in a more sustainable way. Computer-based systems for processing environmental information have been in use since the 1970s (L. Hilty, Lohmann, & Huang, 2011). These systems provide organizations with information to for example monitor and control their processes, analyze data, support with decision making etc. In the last two decades, the use of ICT for sustainability has increased. However, concerning research, it is still a relatively unexplored area. When looking at ICT to reach sustainability in a broad context, going further than simply stating cost-saving benefits of ICT, the "triangle of ICT for Sustainability" can be used to model the role of ICT in achieving sustainability. It can be seen below in Figure 3-4.

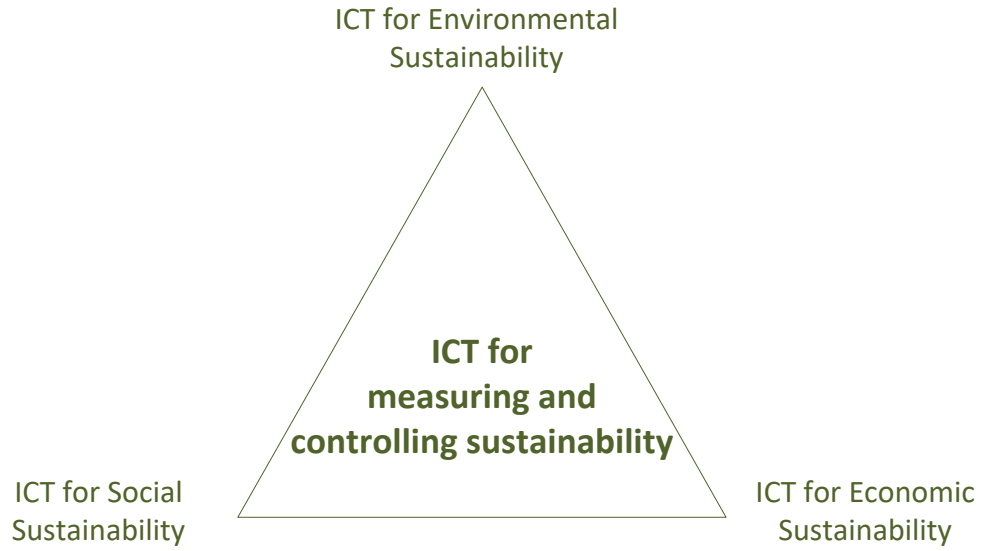


FIGURE 3-4: TRIANGLE OF ICT FOR SUSTAINABILITY, ADAPTED FROM GOSWAMI (2014)

In this triangle, it can be seen that the three dimensions of sustainability are part of the triangle. Each dimension here has its own description.

ICT for Environmental Sustainability: The impacts of this dimension can be classified into two orders (L. M. Hilty, Page, & Hřebíček, 2006). First, there are the negative environmental consequences related to production, use and disposal of ICT technology. It involves the energy and resources used for production and use and the toxicity and social impact of disposal of the components. The second order involves the environmental impact of dematerializing physical assets such as books, letters, CDs and other activities that require physical activities or resources.

ICT for Social Sustainability: This dimension describes the abilities of ICT to create a more social sustainable future, like improving the way societies and governments provide education, healthcare and services to citizens.

ICT for Economic Sustainability: The third dimension describes the possibilities ICT provide for organizations to support their business to generate revenue.

According to Murugesan (2007), there are three strategies an organization could take to green their IT:

1. *Tactical incremental approach*: Here the current IT infrastructure and policies are preserved and simple measures are incorporated to achieve modest green goals, like energy consumption.
2. *Strategic approach*: In this approach, an enterprise conducts an audit of its IT infrastructure and its use from an environmental perspective, develops a plan addressing broader aspects of greening its IT and implements new initiatives.
3. *Deep green approach*: This approach expands upon the measures highlighted in the strategic approach. Additional measures are taken such as energy consumption policies to lower energy costs. An organization can also choose to make its employees more aware of green IT.

Hart (1997), states that there are three follow-up goals for sustainability which apply to three levels. The three goals are *Pollution Prevention, Product Stewardship* and *Clean Technology*, in that order, while the three levels are *Individual, Organizational* and *Societal.*
The three goals will be shortly explained:

1. **Pollution prevention:** Minimizing emissions, effluents and wastes.
2. **Product stewardship:** Focus on both reducing pollution and minimizing the adverse environmental effects associated with the full lifecycle of a product.
3. **Clean technology:** use of technology that creates no harmful emissions or waste.

Table 3-1 shows some representative opportunities for Green IT and Green IS for all these levels and goals.

	Individual	**Organizational**	**Societal**
Pollution Prevention	No more printing Turning off computers while not using	Virtualization Telecommunication	Electronic exchange of information E-mailing instead of letters
Product Stewardship	Recycling	Reuse components Recycle computers	Governmental policies Societal norms
Clean Technology	Paperless interaction	Video conferencing Collaboration tools	e-commerce vs. traditional Internet of things Open source software

TABLE 3-1: GREEN IS AND IT OPPORTUNITIES, ADOPTED FROM BOUDREAU ET AL. (2008)

3.2.3 Green IT

This section will provide a more detailed overview of 'Green IT' as defined by Dedrick (2010), which involves the physical aspect of sustainable IT. As mentioned in the Introduction, Green IT has its view mostly on the IT itself which is a problem that needs to be mitigated. It focuses on improving energy efficiency and effective utilization of equipment such as using energy consumption of data centers and reducing electronic waste (Dedrick, 2010).
Murugesan (2008) takes a holistic approach to the physical aspect of green IT, which can be seen in Figure 3-5.

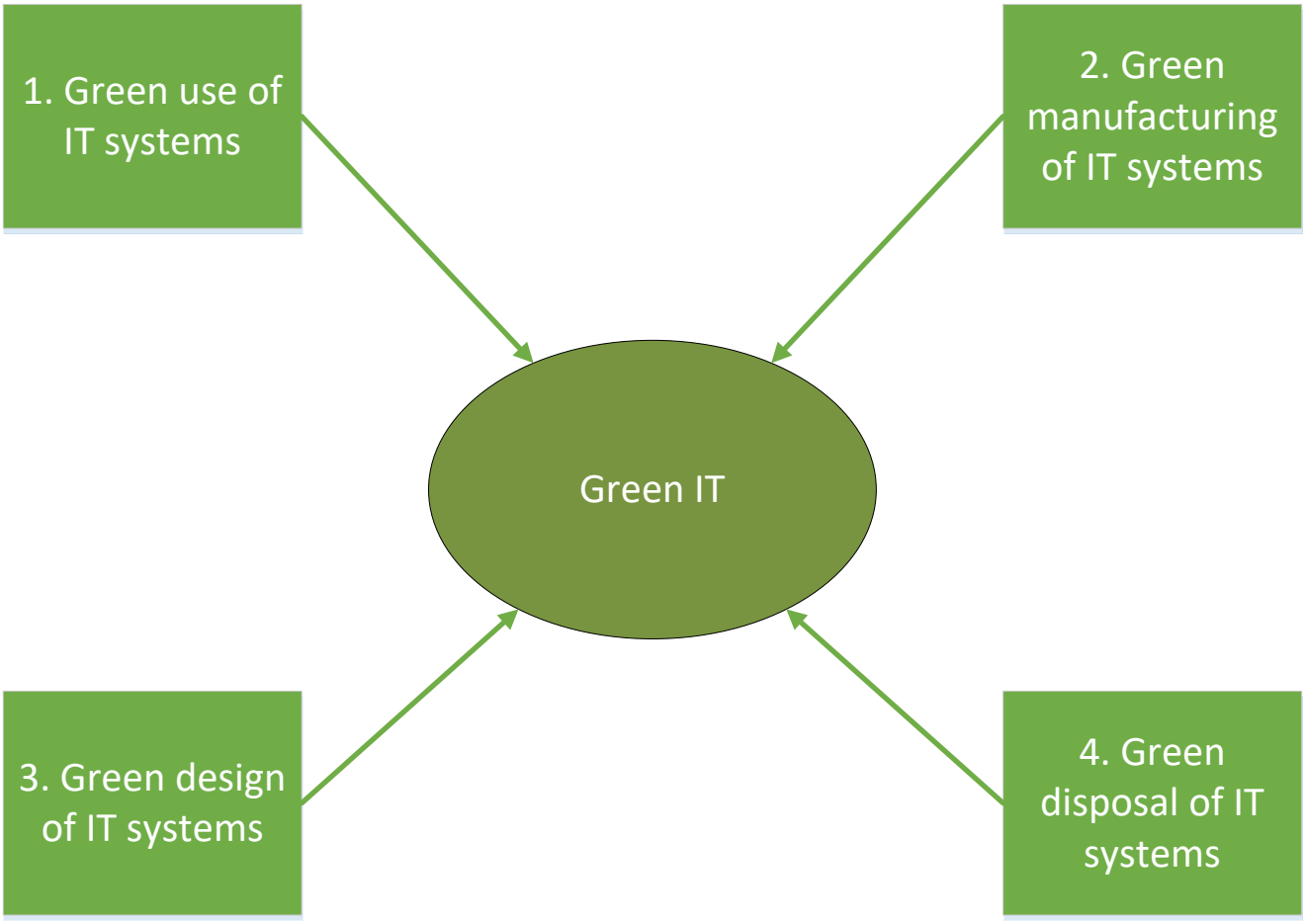


FIGURE 3-5: HOLISTIC APPROACH TO GREEN IT, ADAPTED FROM MURUGESAN (2008)

This model involves four components of Green IT as a whole:

1. **Green use of IT systems**: reducing the energy consumption of computers and other information systems and using them in an environmentally sound way.
2. **Green manufacturing of IT systems**: manufacture electronic components, computers and other associated subsystems with minimal or no impact on the environment.
3. **Green design of IT systems**: design energy efficient and environmentally sound components, computers, servers and cooling equipment.
4. **Green disposal of IT system:** refurbish and reuse old computers and recycle components.

Murugesan mentions several reasons and benefits for investing in green IT practices, which can be seen in Figure 3-6. It shows the results of a survey of 1500 companies that have implemented green IT solutions. The respondents were asked about their reasons to do so.

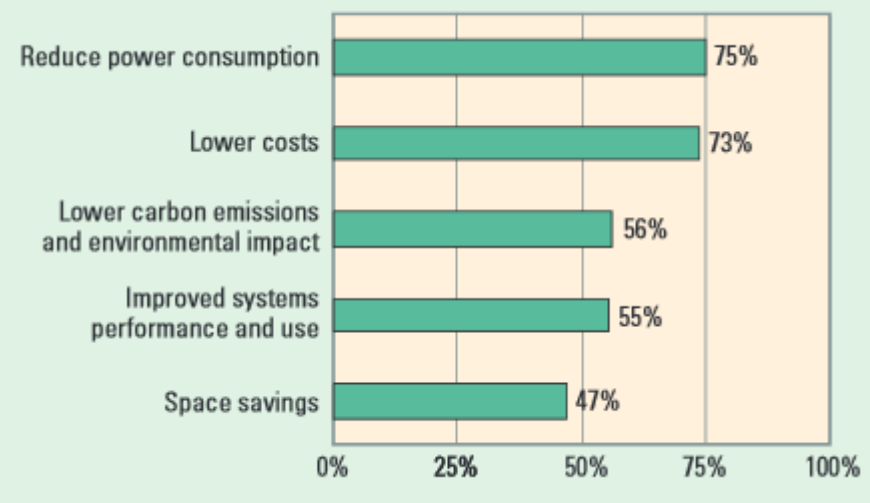


FIGURE 3-6: REASONS AND BENEFITS FOR USING GREEN IT, ADOPTED FROM MURUGESAN (2008)

Green IT is the study and practice of designing, manufacturing, using and disposing of IT efficiently and effectively with minimal or no impact on the environment. (Murugesan, 2008). Murugesan mentions some focus areas, with a few examples being:

- Power management.
- Design for environmental sustainability.
- Responsible disposal and recycling.
- Green metrics, assessment tools and methodology.

A growing number of IT vendors and users are now moving towards green IT to help build a green society and economy. Because of the benefits it offers to organizations, it is becoming more and more attractive to invest in green IT solutions. For organizations to implement a successful green IT strategy, it must be aligned with the overall enterprise-wide green strategy. A policy should be developed outlining aims, objectives, goals, plans of action and schedules.

3.2.4 Green IS

This section will delve more deeply into using IT to help organizations improve their business processes into becoming more sustainable. It should be noted that there is no common name for this particular use of IT. Boudreau et al. (2008), for example, refer to the concept as "Green IS," while Murugesan still relates to this use of IT as "Green IT" but highlights the three different uses of IT (2008).

For this thesis, the use of information systems for supporting sustainable practices will be referred to as "Green IS." It will follow the following definition as stated by Boudreau et al.

(2008): Green IS refers to *the design and implementation of information systems that contribute to sustainable business processes.*

Boudreau et al. (2008) state that Green IS have a greater potential than green IT because it treats a much larger overall problem. It helps entire systems becoming more sustainable instead of just looking at the energy consumption of information technologies and their supporting components. Organizations should not see it as a cost of doing business, but as an opportunity to improve productivity, reduce costs and increase profitability. For example, by not employing environmental practices, much waste is produced. All forms of waste decrease economic efficiency, so less waste means a more efficient enterprise.
A few possible examples of Green IS:

- An app which provides environmental information about products in a supermarket concerning their components and production.
- An IS which shuts down a computer when someone does not use it for a certain amount of time.
- A system that shuts down the radiators and air conditioning when people are not present in a room.
- A planning system that helps train operators to use the most efficient route to their destination.

For IS to work properly, four information drives should be satisfied and these are therefore also crucial for successfully employing Green IS for sustainable business practices (Junglas & Watson, 2006). The four information drives are also referred to as U-drives and are *Ubiquity, Uniqueness, Unison* and *Universality.* Table 3-2 shows why these constructs are relevant.

	Informational	**Physical**
U-Construct	**The drive to…**	**The drive to…**
Ubiquity	Have access to information unconstrained by time and space	Have ready availability of the desired resource
Uniqueness	Know precisely the characteristics and location of a person or entity	Have the capability to tailor precisely the use of a physical resource to one's unique needs
Unison	Have information consistency	Have procedural consistency
Universality	Overcome the friction of information systems' incompatibilities	Overcome the friction of physical differences

TABLE 3-2: THE INFORMATION DRIVES AND THEIR PHYSICAL COUNTERPARTS, ADOPTED FROM BOUDREAU ET AL. (2008)

Each of these drives will now shortly explained.

Ubiquity: this construct describes access to information unconstrained by time and space. For an IS, this means that the IS can always provide information that it is intended to provide, not just at certain times or only from certain locations.

Uniqueness: Uniqueness means *'knowing precisely the characteristics and location of a person or entity.'* This means that an IS can provide information tuned to the needs of the user.

Unison: this means that information provided by an IS should produce consistent information. An information system should provide simple and familiar procedures and integration of information across several systems.

Universality: This final construct is aimed to overcome *'the friction of information systems.'* This friction is described as the use of different standards for the same entity (like the metric system of measurement). IS can aid in here by transforming the data behind-the-scenes into a universally known form for all stakeholders.

4 Environmental auditing

4.1 Introduction to environmental auditing

The term "environmental auditing" originates from the Unites States in the 1970's (Pahuja, 2013). It has become a term that has different meanings to different people. Some organizations consider the term only to be applicable to environmental matters, while others use the term to describe an audit of health, safety and environmental issues. A reminder of the definition of an environmental audit by Pahuja (2013): '*An environmental audit is an independent evaluation of policy and principles, systems, procedures, practices, performance and other elements of an organization relating to the environment. It aims at verification and validation to ensure that various environmental laws are complied with and adequate care has been taken towards environmental protection and preservation.*'

Another definition, by the International Chambers of Commerce (ICC), state the following definition (International Chamber of Commerce, 1989): *An environmental audit is a management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing, with the aim of helping safeguard the environment by:*

1. *Facilitating management control of environmental practices.*
2. *Assessing compliance with company policies which would include meeting regulatory requirements.*

This definition is the most commonly accepted one. From both definitions the terms evaluation and validation against laws/requirements are central. The definition by ICC also states that it is an important management tool, which shows that management should comply with an environmental audit.

The specific objectives of an environmental audit can vary for different organizations, but at the national level, the aim is to see that the natural resources are properly used and proper steps have been undertaken to control or to prevent disadvantageous effects of production, development and other activities on the environment. The aim is to ensure that the natural resources are used for industrial development and national progress. At the same time, the proper steps should have been undertaken for maintaining the health and welfare of the community and also for dispersal of harmful waste and social risks.

At the corporate level, Pahuja describes a few responsibilities for an organization concerning the environment, which an environmental audit should check, like:

- Meeting regulatory requirements.
- Cleaning up pollution that already exists.
- Proper disposal of the hazardous material.

- Informing the investors the amount and nature of the preventive measures taken by the management.
- Operating in a way that environmental damage does not happen
- Promoting a company-wide environmental attitude.

4.2 Types of environmental audit

Pahuja describes three main areas of environmental auditing, which all have several subtypes:

1. Environmental Compliance Audits
2. Environmental Performance Audits
3. Environmental Financial Audits

Environmental Compliance Audit

An environmental compliance audit is the most common type of an environmental audit. It consists of environmental activities where compliance is checked with environmental legislation, standards, industry guidelines, and company policy. The need for this type of audit is of particular importance because laws and regulation concerning the environment have increased in size and complexity over the past few years. Violation of these statutes can result in heavy fines or other penalties. Several subtypes exist in this field, like an audit for compliance with a specific law, audits for verification for certification (concerning sustainability) and audits for verification if an organization deserves an eco-label, etc..

Environmental Performance Audit

This type of audit is based on the auditing of the performance of an organization, which in this case, is its performance concerning the environment. The main objective is to assess whether an organization meets its environmental objectives, is effective in its production of environmental results and operates in an efficient and economical way. In this field, several subtypes exist, like *surveys*, to scope the audit and take first steps in improving environmental practices, *issues,* which has its focus on a specific environmental issue like waste production, and process audits, which focus on a particular process or activity. An organization using these audits seeks an integrated environmental management strategy which leads organizations to consider as low environmental effects as possible.

Environmental Financial Audit

In this type of audit, as the name implies, all financial transactions relating to environmental activities are verified by the audit. Its main objective is to audit if all significant environmental costs, benefits, assets, liabilities and contingencies are accounted for.

4.3 Environmental audit process

Even though there are three types of environmental audits with even more subtypes, an environmental audit should at least consist of four basic stages. Pahuja shows the following model which describes the steps in each stage (2013):

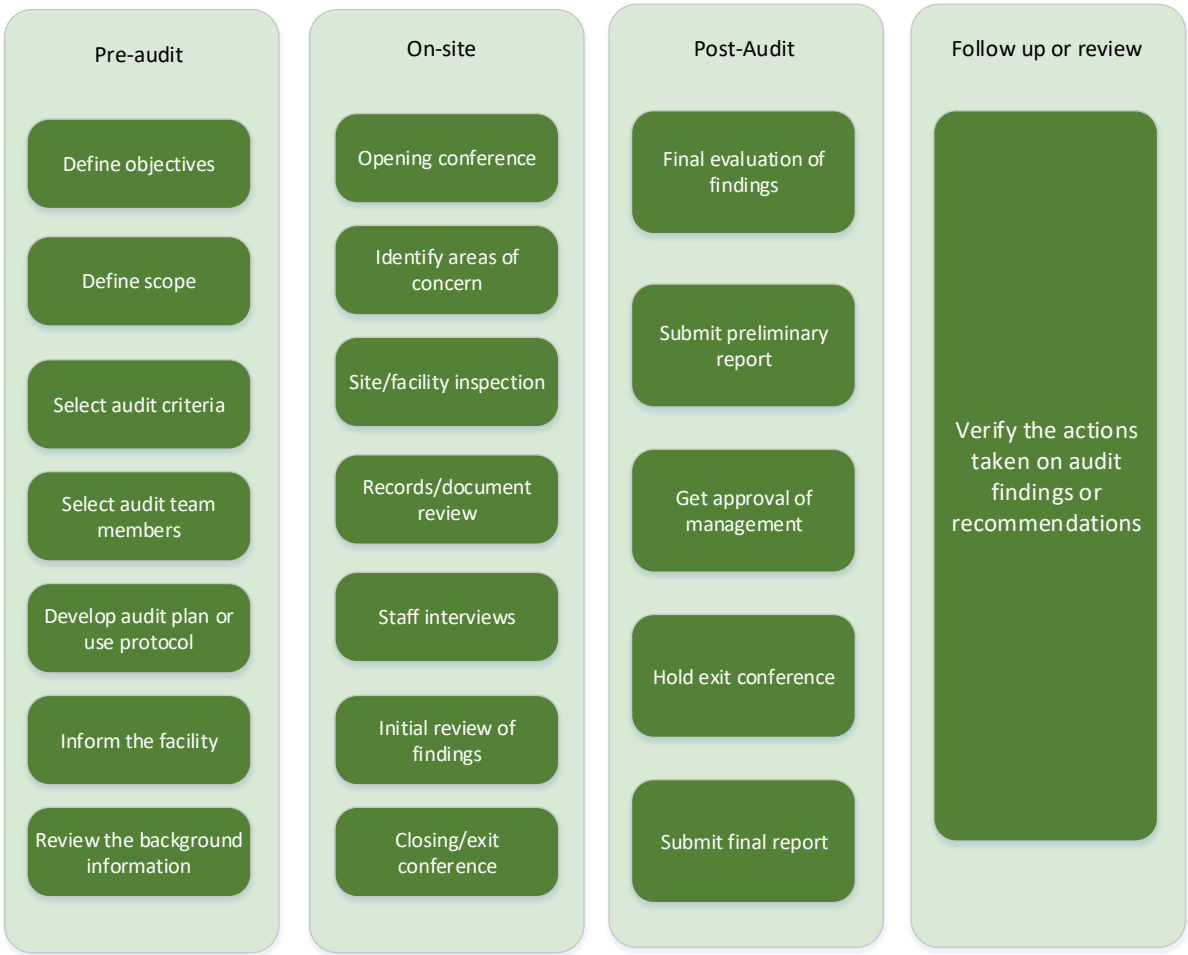


FIGURE 4-1 STAGES AND STEPS FROM AN ENVIRONMENTAL AUDIT, ADAPTED FROM PAHUJA (2013)

Each activity has the following description:

***Pre-audit*:** This phase describes the activities that need to be done before the actual audit takes place. Most of them are preparations for the audit. It has the following activities:

1. **Define objectives**: defining the goals of the audit.
2. **Define scope**: What parts of the organization & which programs will be audited and what timescale will be audited.
3. **Select audit criteria**: Against which criteria the facility will be audited.
4. **Select audit team members**: a team leader is selected, along with team members based on knowledge and experience. The team can consist of external consultants, internal staff, or both.
5. **Develop audit plan or use protocol**: An auditing protocol is developed, or an existing one is chosen, based on the audit criteria and activities that it contains.

6. **Inform the facility**: Arrangements for on-site activities are made.
7. **Review the background information**: any background information that might influence the auditing process is discussed and arrangements are made for this.

On-site: The second phase involves the gathering of input for the auditing protocol.

1. **Opening conference**: The objectives and methods of the audit are communicated to key facility personnel, important meetings and interviews are scheduled.
2. **Identify areas of concern**: areas of concern are identified for more detailed inspection to get a feel for the site. According to this inspection, the audit schedule is modified accordingly.
3. **Site/facility inspection**: The facility is inspected according to established protocols. Areas of concern are inspected in more detail.
4. **Records/document review**: Findings are recorded and documented according to instructions of the auditing protocol.
5. **Staff Interviews**: Interviews are conducted with the main stakeholders for identification of potential problems and in collecting information about facility operations.
6. **Initial review of findings**: It is examined where the facility does not meet the audit criteria.
7. **Closing/exit conference on audit**: Auditees are introduced to the findings of the audit team and misunderstandings are identified.

***Post-audit*:** The third phase involves the creation of the final report and discussing recommendations.

1. **Final evaluation of findings**: Evidence is held against the findings to validate them.
2. **Submit preliminary report:** The first version of the report is submitted for approval.
3. **Get approval of management**: The report is adapted to receive approval of management.
4. **Hold exit conference**: the audit process is closed.
5. **Submit final report**: the final report is delivered to management.

***Follow up or review*:** The final phase, while not technically part of the audit, is discussing the follow-up actions and defining an action plan

Pahuja names several tools and techniques which can be used during an environmental audit.

- **Checklists**: Used to ensure that no tasks or topics are missed during the audit and are included in specific cases.
- **Questionnaires:** More complex and detailed than checklists to acquire information.
- **Questioning:** One of the most crucial aspects. The information gathering should be in nature and therefore, the interviewer should be sensitive to the perspective of the auditee.

- **Observation**: a disciplined activity that should be executed at least twice to check if the observation is accurately noted, analyzed and recorded.
- **Pho**tographs: A treasured aid to gather information.
- **Research:** this technique is useful to become familiar with the organizational context the audit takes place in.

This model will form the basis of the auditing protocol for UU, for which the SGIMM will be used. There will be slight changes in this set-up to make it more suitable for this particular auditing protocol. The PDD of the adapted version can be found in Appendix C. It has a few small changes from the steps showed in figure 8 that reflect the specific situation of ITS.

The following changes have been made:

1. The defining of the auditing protocol happens right after determining the scope because the SGIMM is defined for not only the ITS department. Therefore, an extra step is added right after it to determine the specific constructs of ITS for SGIMM. After that, the audit criteria will be determined to specify which part of the SURF constructs will be used for ITS.
2. An extra step is added after informing the facility because the SGIMM is a self-assessment, the documents will need to be sent to the team and they need to be instructed on how to use it.

5 Maturity models and frameworks on Green ICT

This section will explore existing frameworks in the field of Green ICT. We will first discuss several definitions of 'framework' to determine what content of the frameworks will be analyzed.
Some definitions used by Johnson (1997) are:

- *"A framework is a reusable design of all or part of a system that is represented by a set of abstract classes and the way their instances interact."*
- *"A framework is the skeleton of an application that can be customized by an application developer."*

These definitions are mostly applied in software frameworks like OLE, OpenDoc and DSOM. Johnson describes in his paper how frameworks help software developers reuse designs, use a common language and solve problems with standard solutions.

Another definition is the definition of ISO 42010, which defines a framework (although focused on architecture) as follows: "*An architecture framework establishes a common practice for using, creating, interpreting, and analyzing architecture descriptions within a particular domain of application or stakeholder community."* An architecture description is defined as: *"An artifact describing the architecture for some system of interest."* Here a system can be defined as human-made and natural systems of interacting components.

Finally, a definition by businessdictionairy.com, which focuses on terms mostly used in a business context: *Broad overview, outline, or skeleton of interlinked items which supports a particular approach to a specific objective, and serves as a guide that can be modified as required by adding or deleting items.*

Although these definitions vary in their contents and focus. However, they also contain some similarities. The following similarities can be seen here:

1. A framework contains several items, classes or artifacts (basically, components containing information).
2. The items interact with each other.
3. A framework can be expanded/changed.

Through searching in sources like Google Scholar, we found that there are several available frameworks or maturity models to choose (Butler, 2011; Donnellan, Sheridan, & Curry, 2011; Molla et al., 2008; Philipson, 2010). It was already specified in the introduction that the problem here is that there is no universal definition of Green ICT, and therefore these frameworks can lack consistency and one uniform collection of capabilities that are important in Green ICT. To specify a proper auditing protocol, we will construct a comparison method to choose an auditing protocol best suited for the situation of ITS and also improve it in order to reflect up to date knowledge on Green ICT.

6 Comparison method

This section will contain an explanation of the procedure used to analyze the frameworks. To determine possible improvements in a structured way, we will construct a comparison method for comparing conceptual frameworks with each other. The idea for this approach originated from the statement of Molla et al. (2009). As stated earlier, there are many maturity models for measuring Green ICT, but these are not consistent since it is quite a new research domain. This problem also applies to other new research areas (De Bruin, Freeze, Kaulkarni, & Rosemann, 2005). The comparison method will, therefore, be constructed as a method that applies to maturity models and frameworks in one specific domain. The PDD of the comparison method, along with the corresponding tables, can be found in Appendix B. Furthermore, a paper will be written about the comparison method.

6.1 Maturity models

Nowadays maturity models are a common tool for organizations to assess their maturity in a specific domain. Organizations continually face pressures to gain and retain competitive advantage against competitors and maturity models can assist organizations in this matter. A lot of different maturity models have been developed in several fields, like software development, business process management, knowledge management and project management (De Bruin et al., 2005; Humphrey, 1988; Jiankang, Jiuling, Qianwen, & Kun, 2011; Khoshgoftar & Osman, 2009; Lee, Kang, Lee, Ahn, & Park, 2009; Wendler, 2012) since the introduction of the Capability Maturity Model (CMM) by the Software Engineering Institute (De Bruin et al., 2005).

De Bruin, Freeze, Kaulkarni and Rosemann (2005) describe certain steps in the development of maturity models. Steps include deciding what the maturity model should measure and which concepts are to be included in this model. Furthermore, they describe how one can specify these using an extensive literature search. However, if literature is not available or scarce, collecting these concepts may prove a problem when developing a complete and accurate maturity model. According to de Bruin et al.: *'In a relatively new domain, it may not be possible to gather sufficient evidence through existing literature to derive a comprehensive list of domain components. In this instance, a literature review is considered only sufficient in providing a theoretical starting point and other means of identification is necessary'.*

Some domains where this problem could arise are Knowledge Management (De Bruin et al., 2005) and Sustainable (Green) ICT (Molla et al., 2009) since these fields are relatively new. Take 'Green ICT' which covers the environmental impact of ICT as well as the use of ICT tools, services and technologies to stimulate green practices and green behavior (Hankel, 2014). Moreover Green or Sustainable ICT contributes not only to the protection and restoration of the environment but also to the enhancement of the quality of human life (Andreopoulou, 2012). If for example, a concept such as e-waste (the responsible disposal of used ICT resources) is missing in maturity model, this can lead to suboptimal or negative results.

A mapping study (Wendler, 2012) found that when validating maturity models much effort is put into developing new maturity models without looking for existing models to check their applicability and possibilities to improve existing models. A rigorous method that compares existing maturity models would be a great addition to the validation and improvement of existing maturity models.

This paper proposes a method (incorporating qualitative content analysis (Elo & Kyngäs, 2008)) to help organizations and researchers compare existing frameworks and maturity models with each other. By analyzing the differences between several frameworks and maturity models, existing frameworks and maturity models can be expanded and improved with components of other conceptual frameworks and maturity models, if these elements are deemed to be a valuable addition to the chosen framework or maturity model. The method both aims to provide organizations with a method to further expand their used frameworks and maturity models and to provide researchers with a method to systematically compare conceptual frameworks and maturity models.

The following section describes related work on comparing methods for maturity models and the gaps we identified. We then explain how we created our method for comparing and analyzing maturity models. Finally, we demonstrate our method by applying it to the field of Green ICT.

6.2 State of the art: comparisons of maturity models

This section will contain a review of several existing comparisons of maturity models. There are several papers available which main focus is to compare several maturity models. This section will shortly discuss the approach taken in these comparisons to identify the gaps in these comparisons.

A comparison by Jiankang et al. (2011) focuses on knowledge management maturity models. In their comparison, they map 26 maturity models for knowledge management to determine their basic characteristics. They map each models 'Key process area' (relevant domains to focus on to achieve a certain level of maturity) and the specified maturity levels. After this, a conclusion is drawn by qualitatively scanning the created tables.

Another paper that compares maturity models is focused on maturity models in project management (Khoshgoftar & Osman, 2009). This paper takes a different approach from the previous paper, although results of the analysis are still mapped in a table. The authors specify a vertical list of variables which are assumed to be important in project management (how these are chosen is not specified). In this case, all chosen frameworks in the analysis are listed horizontally. For each framework, it is shortly specified if the variables are implemented in the framework and how. Eventually, one framework is chosen that satisfies the variables the most and is deemed to be the best maturity model. The author specifies several arguments with qualitative motivations on why a specific framework is considered to be the best.

A third paper focusing on comparing maturity models concentrates on Service Oriented Architecture (SOA) (Pulparambil & Baghdadi, 2015). The primary objective of an SOA is to align the gap between business and IT by applying design principles originating from SOA. The authors first gather a large list of concepts that are deemed to be valuable for SOA architectures, like 'Value chain,' 'Business process' and 'Governance.' This approach is very similar to the paper of Khoshgoftar & Osman (2009). Furthermore, they list a collection of SOA maturity models horizontally and map the approach of how these concepts are implemented in the models in a large table. After the mapping, a conclusion is drawn by analyzing the data in the table qualitatively. Specifying this conclusion is done manually by the author.

The final paper that we analyzed is a paper that compares two process maturity models (Lee et al., 2009). These process maturity models (vPMM & BPMM) are used to improve an organization's business process performance capability.

The approach taken consists of four aspects that are analyzed:

1. **Inputs and philosophies** (based on fundamental principles, reference models and engineering principles.)
2. **Structural components:** how the model is structured.
3. **Normative components***:* the specifications of the maturity levels.
4. **Informative components**: used for clear analysis of the normative elements.

Like in the previous papers, the aspects on which the papers are analyzed (these are split into several tables) are listed vertically while the maturity models are listed horizontally. It is then shortly specified how the concepts are being analyzed and compared as well how these are implemented in the respective maturity models. Interesting to see here is that the key process areas are analyzed for each maturity level in this comparison. The analysis is therefore very detailed. Like in the other papers, a conclusion is drawn by performing a manual qualitative analysis on the table. In this case, this is done on each of the four aspects.

6.3 Conclusion of the comparison approaches

It can be seen here that there are similarities between the approaches taken to compare the maturity models.

1. A list of variables is defined and maturity models are mapped on these in a table.
2. The steps that were taken in the comparisons include:
    a. Identifying key process areas, success factors or important concepts of a domain.
    b. Specification of maturity levels.
3. The conclusion of the comparison was drawn by the author manually and qualitatively.

The papers each had their level of detail, based on what they were trying to compare. From the papers analyzed, it is clear that each paper uses their own comparison approach; there does not seem to be a consensus on how to approach such comparisons systematically. Furthermore, none of them address the improvement of a maturity model or the conceptual parts that are missing from one model.

We aim to solve this issue by constructing a comparison method that helps the users improve an existing framework or maturity model. Based on the findings from these papers, we will specify a foundation for this comparison method which can be used for extending and improving existing maturity models in a structured way.

The main focus of the method will be comparing concepts or key process areas with each other, to provide a user of the method with an overview of possible extra extensions of their own used model (from now on referred to as the 'reference framework').

6.4 Method description

De Bruin et al. (2005) describe several steps in the development of a maturity model:

1. **Scope:** Setting the outer boundaries for model application and use.
2. **Design:** determining a design or architecture for the maturity model, making decisions for the target audience: method of application (*how*), driver of application (*why*), respondents (*who*) and target of application (*what*).
3. **Populate:** Identify *what* needs to be measured and *how* this can be measured. The domain components and sub-components need to be mutually exclusive and collectively exhaustive.
4. **Test:** The model is tested for relevance and rigor. Both the construct of the model and the model instruments are tested for validity, reliability and generalizability.
5. **Deploy:** Making the model available for use and verifying the extent of the model's generalizability.
6. **Maintain:** Evolving the model as the domain knowledge and model understanding deepens.

The comparison method that we constructed focuses on aiding in the 'Populate' and 'Maintain' stage. We used design science (Wieringa, 2014) for specifying the comparison method since this approach specifies detailed steps for creating an artifact in information science; and specification through a Process Deliverable Diagram (PDD) (van de Weerd & Brinkkemper, 2008). A PDD can help in clarifying the deliverables of each activity in the method in a structured manner.

The main goal of the method is to compare concepts, or key process areas to provide the user with an overview of possible extra extensions of their own used model (from now on referred to as the 'reference framework').

Itorgas main target audience is intended to be researchers aiming to improve an existing framework or maturity model by creating an overview of components of a certain concept and view which are not present in the reference framework. Organizations can use the method as well if they seek a method that can aid them in improving their own used framework. It does not aim to provide the user with data on how to specify their maturity levels if the chosen framework is a maturity model, but it can still be decided to extend a maturity level based on the findings. This is also a possible extension of the method in a follow-up research.

Based on the goal of the model and the literature survey, the following phases are defined for the comparison method, shown in Figure 6-1:

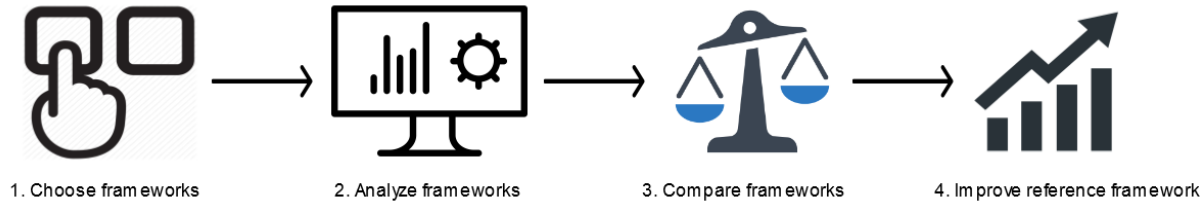


FIGURE 6-1: COMPARISON METHOD

Each of these phases is described in detail in the upcoming sections. Furthermore, a PDD of the method can be found in Appendix B, specifying the method in more individual activities.

6.4.1 Choose frameworks

The first step in our method is to consider selecting a reference framework which means that all constructs of the reference framework are listed vertically for comparison with the constructs of the other frameworks. A typical reference framework can be a framework created by the user or a framework used by an organization. The reference framework should be a framework that the user wants to improve or extent with items that are not present yet in the model. If the user has no reference framework yet, one can be chosen by considering the goal that the practitioner wants to achieve with the maturity model and choosing the frameworks that satisfy this goal best. Furthermore, the frameworks (the reference framework and the frameworks that will be compared with the reference framework) should all represent the same domain. There is no certain amount of frameworks needed for comparing with the reference framework.

6.4.2 Analyzing each framework

The second step analyzes the frameworks that are to be compared. For each framework, at least the following items should be described:

1. **The main goal**: what the model aims to achieve.
2. **Application**: how the framework is applied, for example, does it only present an overview of the domain, or does it specify maturity levels?
3. **Concept diagram:** a diagram showing the domain components of the domain of the respective framework.

4. **Theoretical foundation:** why the framework has the structure and content as it is.

The main goal of this phase is to determine all the domain components in the framework and how to use the framework. Visualizing the model in a concept diagram in the previous phase (if this has not been done by the creator of the framework) can help determining the domain components and the constructs it contains. This step usually involves reading the chapter or paper in which the model is presented. It is important that it be evident what concepts are found in each framework and how they are represented in constructs. To determine the concepts, accompanying descriptions of the framework can be read, along with other literature if desired to understand the concept that is present in the model. If the user of the method has no framework for improvement yet, the reference framework is chosen from the collection of frameworks right before the comparison starts. In that case, the reference framework should be the framework that satisfies the requirements of the users of the method best.

6.4.3 Compare frameworks

The comparison phase is the most crucial part of the method. A method that can help in determining the concepts for comparison is qualitative content analysis (Elo & Kyngäs, 2008), with two possible variations: deductive and inductive. Deductive content analysis is a method for deductive reasoning, going from general to detailed. Inductive content analysis (also called abstraction) is the opposite direction of deductive content analysis, instead of going from detailed to general. The level of detail in this matter is something that the users of the method should decide upon. Deductive content analysis will provide more items for comparison, but will also cost more time to execute. Inductive content analysis is suited for situations where a construct is too specifically specified to one maturity model and it cannot be used in the reference framework.

An example when deductive content analysis can be used: when the user has a reference framework about 'Healthy food' that contains very specific items about vegetables, like cabbage, broccoli, carrots, etc. A framework that is compared against this framework also has 'Vegetables' is then probably too general, since it already has a concept 'healthy vegetables.' In that case, the user can perform deductive content analysis on the concept 'healthy vegetables' based on the description of the framework, since it needs to be clear what the author meant with 'Healthy vegetables.' The resulting analysis can show that 'Spinach' is also part of the framework that was compared against the reference framework. If 'Spinach' is not in the reference framework, it can be added to the reference framework.

An example for inductive content analysis: a fictional framework about possible pets for humans that has a construct called 'labrador retriever' can be deemed too specific for one framework or maturity model if the reference framework only contains general umbrella terms about pets. So in this case, it would be better to use inductive content analysis to formulate 'dog' out of 'Labrador retriever.' This shows that 'dog' is an essential item for a framework about possible pets for humans.

The comparison step in a nutshell: for all frameworks, each of its constructs is compared with all constructs of the reference framework to determine whether they share a common interpretation. The constructs in two models do not need to have the exact same name or application; the theoretical concept behind the construct is more relevant. To help determine this theoretical concept, inductive content analysis is a helpful technique. On the other hand, it is possible that, while comparing, one framework uses a more broad, general term for a construct while the other framework uses a more detailed set of constructs. In this case, deductive content analysis can help in determining the similarities between constructs by splitting the general term into more (smaller) components. It should be decided by the users of the method if a construct in a model is deemed to be too general or should be split down into smaller components.

An example: during the case study concerning Green ICT, one framework had a construct called 'Operations & lifecycle' while the reference framework had a construct called 'E-waste policy.' 'Operations & Lifecycle' includes the processing of 'E-waste' as well, but the author also describes more terms in 'Operations & Lifecycle' like 'production' and 'operation.' In the mapping table, the construct 'Operations & Lifecycle' was then split into the components 'Operations & lifecycle (e-waste)', 'Operations & lifecycle (operations)' and 'Operations & lifecycle (production)'. These resulting constructs were then each used in the comparison.

After the comparison, all pairwise comparisons that did not match with each other are again are listed to provide a comprehensive list of concepts that do not appear in the reference framework. It is possible that several constructs are specified differently (since they originate from different frameworks) but point towards the same direction regarding the concept that it contains. For example, in the case study, some of the constructs that did not appear in the SGIMM were 'Measure CO^2 emissions' and 'Attitude' regarding carbon dioxide emissions. These constructs were each present in a different framework, but both are related to carbon emissions. In cases like this, the constructs should be abstracted through inductive content analysis (Elo & Kyngäs, 2008). In this example, these constructs were generalized to 'Carbon emission management,' to efficiently determine the added value of carbon emission management to the SGIMM. This allowed us, during improvement, to focus on the added value of adding a construct related to 'Carbon emission management,' and possibly specify *how* to implement this in the SGIMM later.

Finally, since this method is performed manually, the results of the pairwise comparisons need to be visualized. This should be decided upon what the users deem to be the most practical way of presenting the data. A common way of presenting the data in the comparisons we found was a comparison matrix. In the case study, we listed the constructs of the reference framework as the most left column, containing the items to be compared, and mapped all the constructs for the other frameworks that matched with those items in columns next to it. For the non-matching constructs, we performed abstraction and listed the abstractions along with their original constructs. This provided us with a comprehensive list of domain components that were not present in the SGIMM.

6.4.4 Improving the reference framework

The comparison results in a list of components not present in the reference framework. These findings are translated into proposals, to show possible improvements to the reference framework.

To help determine the value of the improvement proposals, extra information can be acquired through sources like literature and interviewing experts to improve understanding of a concept and the possible added value to the reference framework if it is to be included. After specifying the improvement proposals, each improvement proposal is discussed and information is gathered to provide arguments on why or why not include each improvement proposal. Possible information sources are: scientific literature, interviewing experts, discussions, looking at own past experiences and hiring consultants. It is important to not only look at the concepts themselves but also if they fit in the reference framework, regarding its goal, level of detail, structure etcetera.

The next step is to make decisions for each improvement proposal whether to implement the proposal in the reference framework and how. Based on the decisions made, a new version of the reference framework is created, including new constructs and other possible improvements that are defined during this step. This new version should be validated, which can, for example, be through discussion, consulting scientific literature, testing it in practice or hiring consultants. If the stakeholders are satisfied with the result, it is made available for use. If the new version does not satisfy the stakeholders, the improvement phase is executed in a new iteration.

The main focus of the improvement proposals should be theoretical components of a certain domain, but other improvement proposals are also possible (for example aimed at structure or specification of maturity levels). However, the method currently provides no structured approach for other improvements than theoretical improvements, so improvements proposals other than theoretical concepts are entirely dependent on the views of the stakeholders that are involved. This is done deliberately since we aimed to provide a method to aid users in improving a framework or maturity model in a field that does not yet have consistent standards of domain components. However, if a user has an idea for an improvement for the reference framework not related to the theoretical aspect by looking at other frameworks, and it is deemed to be a valuable addition, we do not think this improvement should be skipped. We also believe that this phase can be improved in the future, but this will not be part of this thesis because the focus is on the comparison phase of the method. An interesting domain with techniques for this phase, for example, could be situational maturity modeling (Mettler & Rohner, 2009).

7 State of the art: Frameworks on Green ICT

7.1 Approach to analyzing frameworks

This section will contain the results of the analysis of several existing frameworks concerning the use Green IS or Green IT (or both) in an organization using the comparison method constructed in the previous section. The most important framework here is the SURF Green ICT Maturity Model (SGIMM) (Hankel, Oud, Saan, & Lago, 2014b), which is a maturity model for measuring Green ICT in an educational organization. It will form the basis of the auditing protocol for UU. Based on the analysis of the frameworks, an improved version of the SGIMM will be proposed and eventually, it will be tuned to the specific needs of UU.

Furthermore, based on the information discussed in chapter 5, we can see that in the context of business, maturity models are used for achieving a certain objective in a structured way. Based on these findings, the following information will especially be valuable for the analysis:

1. The items (named constructs in the analysis).
2. The processes on how to use these items.

There will also be some background research to clarify the context of the framework.

If a framework uses the terms of Green IS and Green IT combined (focusing on the use of hardware or software), the umbrella term 'Green ICT' will be utilized. Note that not all frameworks analyzed are necessarily (part of) an auditing protocol or used for measuring a level of maturity, because the goal of this analysis is to see how these frameworks are structured and which domain components each of those frameworks contain. Based on their goal, their contents and the theory used to develop them, possible domains can be identified relevant for defining the auditing protocol for UU. The frameworks will be analyzed and compared with each other, with the results being presented in the following structure:

1. Background information.
2. The Construct view.
3. The Process view.
4. The presence of sustainability pillars.
5. A metamodel of the framework.
6. Validation.

After the analysis, the following issues will be discussed:

1. First impression of the analysis.
2. Relation to Green IT and Green IS.
3. Similarities of Frameworks to SGIMM.
4. Differences of Frameworks to SGIMM.

For analyzing the similarities and differences, the different constructs will be compared with each other and mapped into a table showing which constructs are similar to each other and which ones are not.

The frameworks analyzed are (note that not all are specifically named):

1. G-Readiness, by Molla, A. & Cooper, V. (2010)
2. Green IS Framework, by Butler, T. (2011)
3. Holistic approach to Green IT, by Murugesan, S. & Gangadharan, G. (2012)
4. Green IT Framework for Data Centers, by Uddin, M. & Rahman, A. (2012)
5. Sustainable ICT Capability Maturity Framework, by Donnellan et al. (2011)
6. Envirability maturity framework, by Philipson (2010).
7. SGIMM for Green ICT, by Hankel, A (2014). This framework will serve as the **reference framework.**

The frameworks were found in 'Google Scholar' using a variety of terms like 'sustainable ICT,' 'green ICT,' 'green IT frameworks' etc.. They were chosen based on whether they were structured as a collection of constructs and components of what Green ICT should contain. The framework about greening data centers was chosen despite being structured as a phased process in order to investigate what the results would be when a process-based framework would be compared against SGIMM.

7.2 Results of the analysis

7.2.1 G-readiness model by Molla (2008)

Background

The G-readiness model is a framework developed in 2008 by Molla, A. It has been designed to aid companies in determining their "G-readiness" which can be described as an organization's capability to implement holistic Green IT practices. Molla states that without G-readiness, companies would react ad hoc and reactive, which is not the right approach for successful Green IT implementation. Molla defines Green IT as a more broad term than is used in this thesis because his definition involves the term Green IS as employed in this paper as well. Molla defines Green IT as follows:

- *Green IT can be considered as a holistic and systematic approach to addressing the challenges surrounding the IT **infrastructure** such as data center energy efficiency; IT's **contribution** to reducing the environmental impacts of business IT activities (such as through adopting green technologies), IT's **support** for environmentally sustainable business practices (such as in enabling green supply chain management through carbon footprint monitoring and building tools for energy management options) and IT's **role** (such as supplanting high CO2 emitting business practices) in the low-carbon economy.*

Conceptualized, this means that Green IT covers four interrelated perspectives:

- **Sourcing perspective**: The practice of environmentally preferable IT purchasing. This involves the adoption of sourcing practices such as analyzing the environmental impact of IT hardware, incorporating green issues when evaluating vendors and inclusion of social concerns such as the presence of harmful materials in the IT supply chain.
- **Operations perspective**: This point of view deals with improving energy efficiency with the powering and cooling of used IT equipment and reducing emissions. This can be done with temporary consumption avoidance (like shutting down computers when they are not used) and structural consumption avoidance (using a more expensive cooling system that uses water instead of air to cool a data center, which uses less energy).
- **Systems perspective**: supporting a business overall sustainability initiatives. Molla also refers to this perspective as Green IS, which is the same definition as used in this thesis.
- **End of IT life management perspective**: this refers to practices in reusing, recycling and disposing of IT hardware.

Artifact view

Molla transforms these perspectives into the following model: the G-Readiness Framework, which can be seen in Figure 7-1.

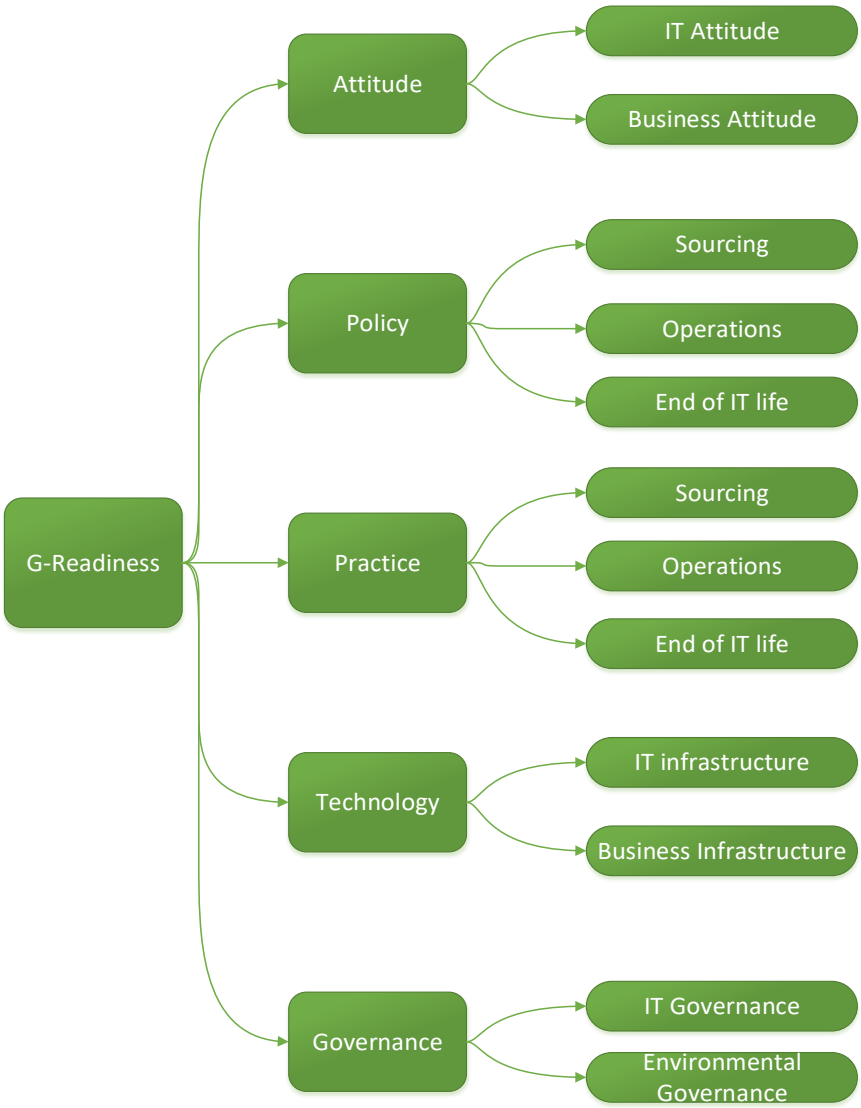


FIGURE 7-1: G-READINESS FRAMEWORK, ADAPTED FROM MOLLA (2010)

The framework has five main properties: *Attitude, Policy, Practice, Technology* and *Governance.* It can be seen that each of these main properties have a few subcategories. These will be explained for each of the subcategories.

Attitude: This category measures the interest and attitude of both IT professionals and business professionals towards the environmental impact of IT and the use of IT in achieving sustainability. This does not only include attitude based on logical facts, but emotional appeal is just as important, if not more (Chan & Yam, 1995).

Policy: this category refers to the extent of developed green and sustainable policies in the organization. This refers to the earlier mentioned perspectives of sourcing, operations and end of IT life management.

Practice: This category is closely related to 'Policy,' where the previous is focused on an intellectual perspective, this category refers to the actual daily practice of actually implementing those policies.

***Technology*:** This refers to companies (green) technological infrastructure. Server virtualization, sustainable cooling equipment and acquiring energy through sunlight are examples of green technologies.

Governance: the final category refers to the management infrastructure to implement Green IT initiatives and defines the administration of Green IT initiatives. Roles, responsibilities, accountability and control for Green IT initiatives are common factors that all need to be established clearly to be successful in implementing Green IT.

Process view

This framework is not structured as such that a certain defined maturity level can be measured. For example, with the 'Technology' aspect, indicators can be used such as:

- The extent to which server virtualization is used
- The use of green power sources
- The use of software to support sustainable development in an enterprise

The other categories have similar indicators related to the specific category but are also dependent on contextual factors and are therefore possible to change. Molla presents in total 32 pre-defined basic items that can be used to measure the G-readiness (Molla, Cooper, & Pittayachawan, 2011), which is done ona Likert scale from 1 (Strongly disagree) to 7 (Strongly agree). The scores for each domain can be averaged which can then be added to add a total score (with a maximum of 35). This score can be used to indicate the total G-Readiness.
To measure the G-Readiness successfully, it is needed for the stakeholders to create a common understanding of the artifacts that G-Readiness envisions.

The framework does not present specific pre-defined steps to take because it is more fit to show a company in what aspects it is ready for Green IT and in which it is not. The stakeholders who execute the assessment should define their own process to measure the constructs. Stakeholders like managers or consultants should propose specific improvements to improve the G-readiness of an organization if desired. Molla et al. have presented several initial item measures to measure the constructs presented in a new paper (2011). They are structured as statements to which participants of the assessment can agree or disagree (on a one to seven-point scale). The item measures presented in this paper are also used to compare the SGIMM with the G-readiness Model.

The resulting G-readiness can be presented in a report giving a detailed overview of the company while also showing the scores for each construct. Finally, actions for improvement could be part of the output. It is up to the managers to decide which of these components are necessary and relevant for the organization.

Metamodel

The metamodel of the G-readiness framework can be seen here in Figure 7-2.

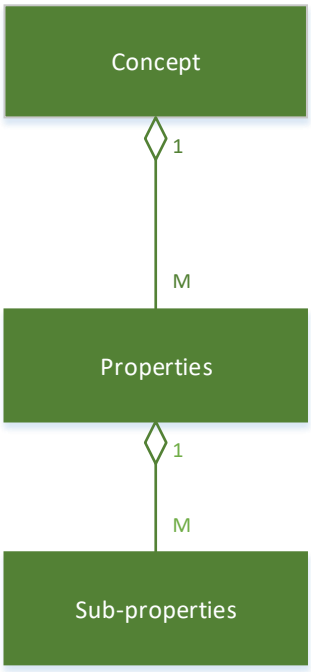


FIGURE 7-2: METAMODEL OF G-READINESS FRAMEWORK

It can be seen that there is one central concept in the model (which is G-readiness), which has multiple properties, which in turn has multiple sub-properties. It has a structure that shows what G-readiness should contain and breaks down into multiple components.

Sustainability pillars

For each pillar, their presence in this framework will now be discussed.

Economic

- This pillar is present in all five components of the framework. Since economic concerns (which in the end is about making money) are important for organizations, these can influence all five elements for an organization trying to improve their G-readiness.

Environmental

- In this framework, all components are in some way concerned with the use of resources from the environment

Social

- The social pillar has no prominent role in this framework since this framework is mostly focused on environmental issues. The only presence could be seen in the 'Attitude' component since social issues (for example training and background of employees) could influence the attitude of employees towards sustainability.

It can be seen that in this framework, two out of three pillars are prominently present in this framework. Since this framework mostly focuses on organizational issues concerned with environmental impact, the Social pillar is not clearly featured here.

Validation

This framework has been validated in a study in 2011(Molla et al., 2011). First, a list of around 100 measurement items was gathered (based on sources like Infotech and surveys used by Accenture) and evaluated by experts. Several techniques were used to analyze the results like unidimensionality, convergent validity, discriminant validity, factorial validity, nomological validity and predictive validity. The conclusions from the study were that these current items fit in the construct of G-readiness, but no research was done in additional elements, which could be relevant since IT is evolving.

7.2.2 Green IS framework by Butler (2011)

Background

Butler has created this framework because of a need for a comprehensive, practice-oriented Green IS-framework (Butler, 2011). Its goal is to aid organizations in implementing green initiatives in several domains, which can, in turn, lower overall the emissions of Greenhouse Gas (GHG). Green ICT is described to be a part of Organizational Governance of an organization and is named the 'Green Business and IS strategy.' Butler concluded from a field study that more and more organizations adopt green strategies as part of their management of the company and his framework is aimed to aid an organization becoming greener in several different domains.

Artifact view

The total Green IS framework can be seen in Figure 7-3 below.

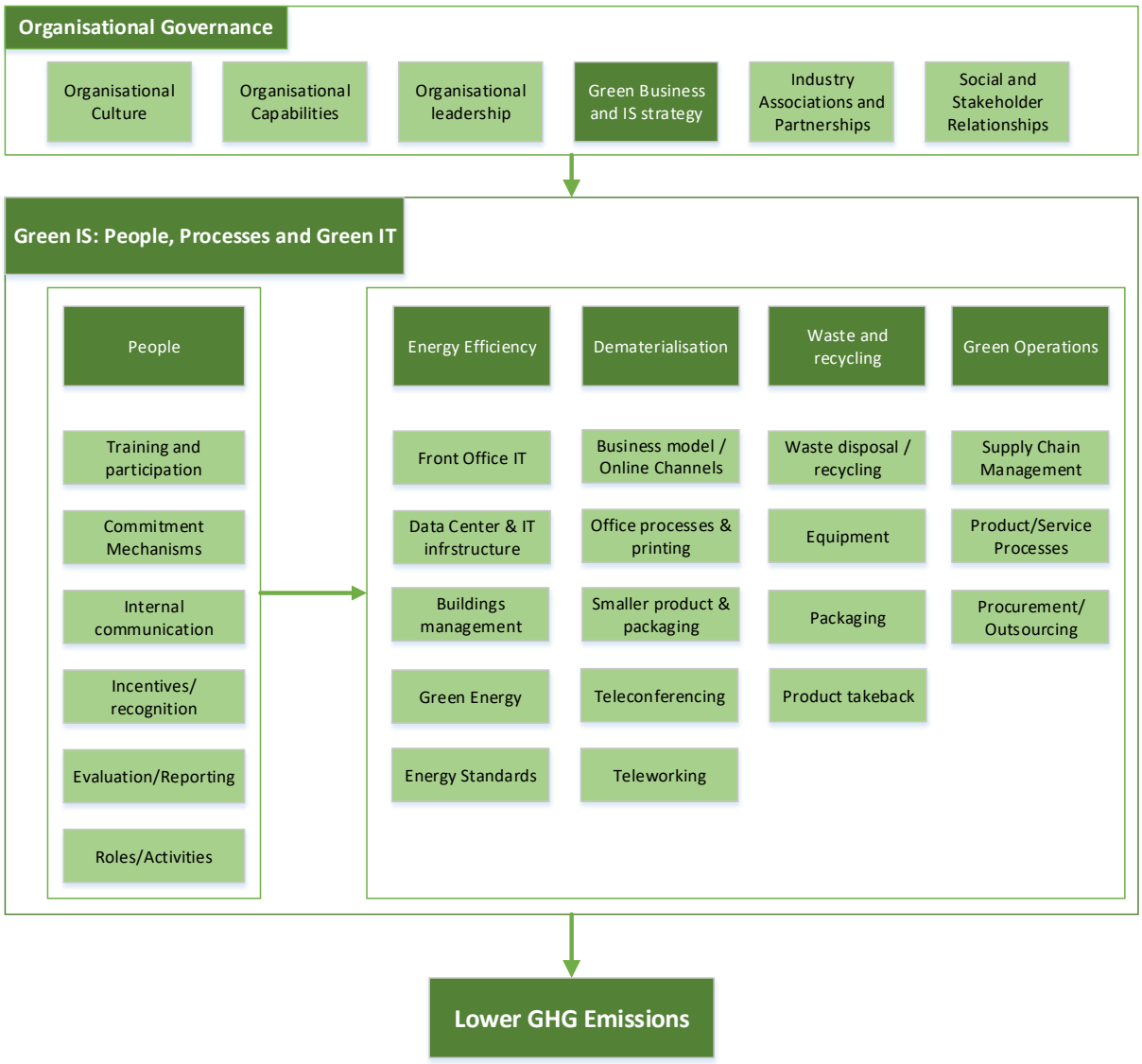


FIGURE 7-3: GREEN IS FRAMEWORK, ADAPTED FROM BUTLER, T. (2011)

Each of the aspects presented in the 'Green IS: People, Processes and Green IT' rectangle will now be discussed in short.

- **People:** This aspect is presented as the most important part of an organization trying to become greener. For example, if people do not commit themselves to making an organization greener or do not receive proper training in how to do so, all technical and management decisions and actions will be wasted. Butler presents the following elements to be an important part of the people dimension: training and user participation, an instituting mechanism for employee buy-in or commitment; internal communication; incentives and employee recognition; staff evaluation and reporting; and the institution of new roles and activities.

The 'People' domain influences all other domains presented in this model, which are Energy Efficiency, dematerialization, waste & recycling and Green Operations.

Energy efficiency

This domain describes how companies could improve energy efficiency through the use of several practices like implementing instances of Green IT and Green IS.

- Greening the Front Office: At Front Office level, typical energy savings can, for example, be achieved by personnel shutting down desktops when not in use. Furthermore, Green IS can be used to aid in saving energy and other frameworks can be utilized for purchasing energy efficient computers for office use.
- Data center & IT infrastructure: Data centers are and will continue to be, a major source of GHG emissions, Butler concludes from several sources. Several practices, like consolidation and virtualization, have been developed in research to help reduce the amount of servers and costs for powering data centers. Other techniques could be improving airflow, better cooling systems and even code optimization.
- Buildings management: Butler found in his paper that buildings also consume much electricity in an organization's total consumption. Through the use of Smart Buildings, organizations can implement IT in the architecture of the building to manage several aspects like heating, lighting and ventilation.
- Green energy and standards: This concept involves using energy from 'green' sources like wind, water and solar energy. Furthermore, standards can be adopted like ISO 14000 which provides practical tools for companies to aid them in environmental management.

Dematerialization

The second domain describes the minimization of the use of and production of material objects.

- Business model / online channels: this concept describes the shift of business-to-business and business-to-consumer activities from face to face to online.
- Office Processes & printing: This involves the switch from hard documents (printed) to soft and e-documents. Furthermore, practices like double-sided printing and using a centralized printer instead of personal printers also belong to this category.
- Smaller product & packaging: Minimizing packaging costs of products, like using pallets or containers instead of individual boxes for each product.
- Teleconferencing & Teleworking: This involves minimizing employee travel to reduce GHG emissions. With the use of technological solutions, employees can communicate with each other during meetings while not being at the same place and work outside of the office.

Waste & recycling

This domain describes the end of the lifecycle of electronic products and how companies regulate this. Companies are being measured on issues such as *waste disposal/recycling, equipment* (used for waste & recycling), *packaging* and *product take-back.*

Green Operations

This final domain involves lowering GHG emissions of business and manufacturing operations through the enabling effect of Green IS.

- Supply Chain Management (SCM): Greening this domain means that IS are used to improve the supply chain as a whole, for example by providing the most optimal route for trucks to deliver products from A to B.
- Product/Service Processes: this involves the use of Environmental Management Systems (EMS) to make production and service processes sustainable. EMS can aid for example in waste reduction and measure compliance with ISO standards.
- Procurement/Outsourcing: This final section describes procurement (in a manufacturing context) and outsourcing issues of Green IS and Green IT.

Process view

Since this framework is very conceptual, Butler does not elaborate on how to use this framework in real cases. The description stays very high level with words like 'evaluating progress across the key areas.' Companies can, therefore, decide themselves how they wish to evaluate these key areas, depending on the requirements of their organizational structure. Resulting from the evaluation could be a report describing progress in each key area and based on these findings, improvements actions can be defined. How the report is structured and the key areas are defined, is up to the organization using the framework, since Butler does not provide a template for this.

Metamodel

The metamodel of Butler's framework can be seen in Figure 7-4.

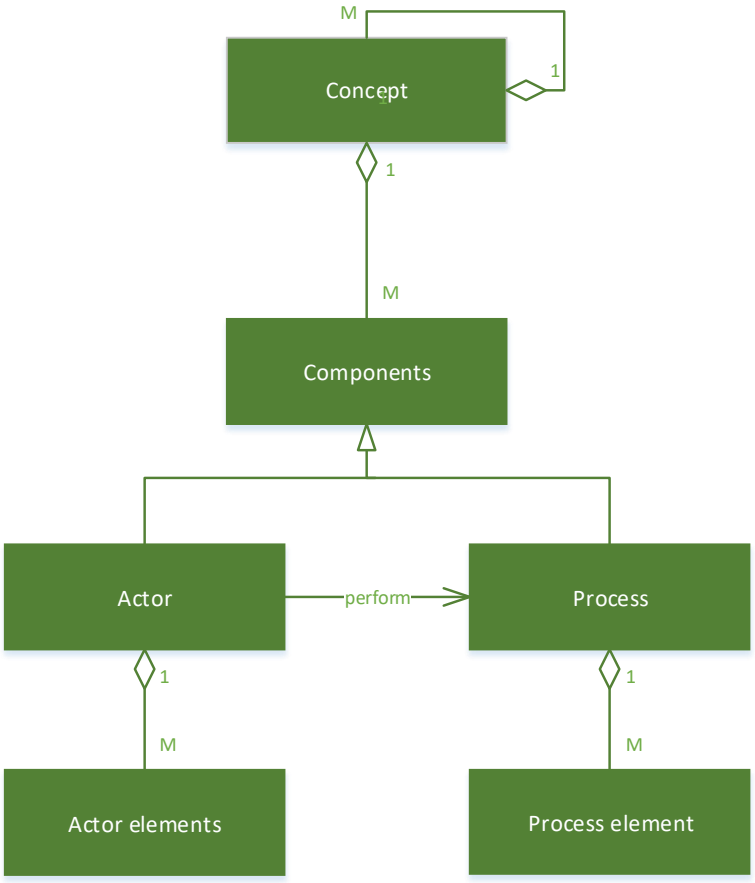


FIGURE 7-4: METAMODEL OF THE GREEN ICT FRAMEWORK BY BUTLER

Like the G-readiness framework, it all starts with a central concept. In this case, the author states that a 'Green Business and IS strategy' is part of Organizational Governance. The author then states further that the strategy contains several processes and areas of activity, in which 'People' are considered the most significant. Therefore, the metamodel splits 'Components' into two parts, which are actors and processes. The actors, in this case, are the people who perform the processes. Furthermore, both the 'Processes' and 'Actors' have several elements that describe them.

Sustainability pillars

Economic

- Energy Efficiency: some typical examples here are the processes of Front office IT, which incorporates the expenses on desktops and Buildings Management, which includes expenses on IT to make a building 'smart'.

- Dematerialization: This category is entirely focused on spending fewer resources on physical assets like paper and packaging, but also traveling expenses like gas and cars.
- Waste and recycling: the focus of this category is how waste and recycling is handled. Depending on the practices of an organization, the expenses on this matter can vary.
- Green Operations: This issue focusses on business processes, to execute these processes, expenses have to be made. These costs are part of the Economic pillar.

Environmental

- *Energy Efficiency*: The environmental issue is featured here because it focuses on practices that involve a more sustainable use and procurement of energy to perform business operations. For example, policies that involve using solar energy are described here.
- *Dematerialization:* materials used in daily business practices have an environmental impact. This category describes what an organization does to reduce the use of environmentally harmful materials.
- *Waste and recycling*: The environmental pillar is featured here because this category involves practices like recycling and reducing packaging waste.
- *Green Operations:* this final category features the environmental issue because a few of its concerns are reducing resources needed to perform production and service processes and supply chain management.

Social

- The 'People' category features the Social pillar. Here issues are described such as involving people in sustainability issues, educating them in sustainable development and assigning roles to them in helping the organization becoming greener.

Validation

No information could be found about the validation of this framework.

7.2.3 Holistic approach to green IT, by Murugesan, S. & Gangadharan, G. (2012)

Background

Murugesan & Gangadharan have created this framework to address the environmental impacts of IT comprehensively and efficiently. The framework was developed in 2008, and slightly expanded in 2012. It has been developed to achieve total sustainability from the IT side and making IT greener through its entire lifecycle. Note that Murugesan's definition of Green IS as used in this thesis is incorporated in his use of Green IT and therefore the difference between the two terms are not easy to see in the model. Murugesan & Gangadharan presents the following model to illustrate the dimensions of Green IT, which can be seen in Figure 7-5 (2012).

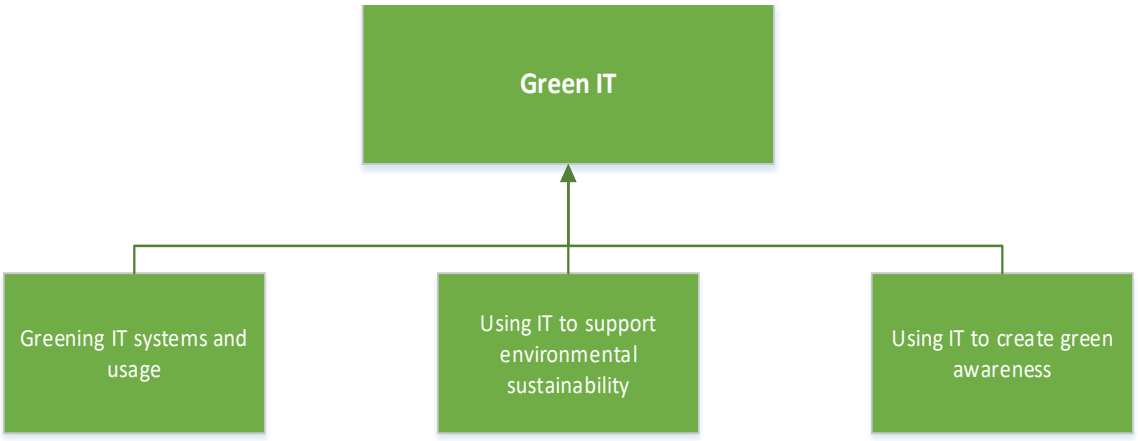


FIGURE 7-5: DIMENSIONS OF GREEN ICT, BY MURUGESAN & GANGADHARAN

It shows that Green IT has three dimensions:

1. Greening the hardware and usage of IT
2. Using IT to improve sustainability in different domains
3. Using IT to make people more aware of sustainability

Sustainability pillars

Economic

- Green standards and metrics, because of focuses on benchmarking and metrics.
- Green IT strategies and policies, since this component focuses on the short and long term benefits, which also includes costs.

Environmental

- Green Use of IT systems
- Green disposal of IT systems
- Green Design of IT systems
- Green Manufacturing: of IT systems
    - In all these four constructs, the environmental impact is considered.

Social

- It can be argued that all six components could also be applied to the social aspect of sustainability, mostly since Murugesan and Gangadharan do not really have an extensive explanation of their constructs.

Artifact view

The framework encompasses six domains to achieve sustainability in Green IT (and not Green IS), it can be seen in Figure 7-6 below.

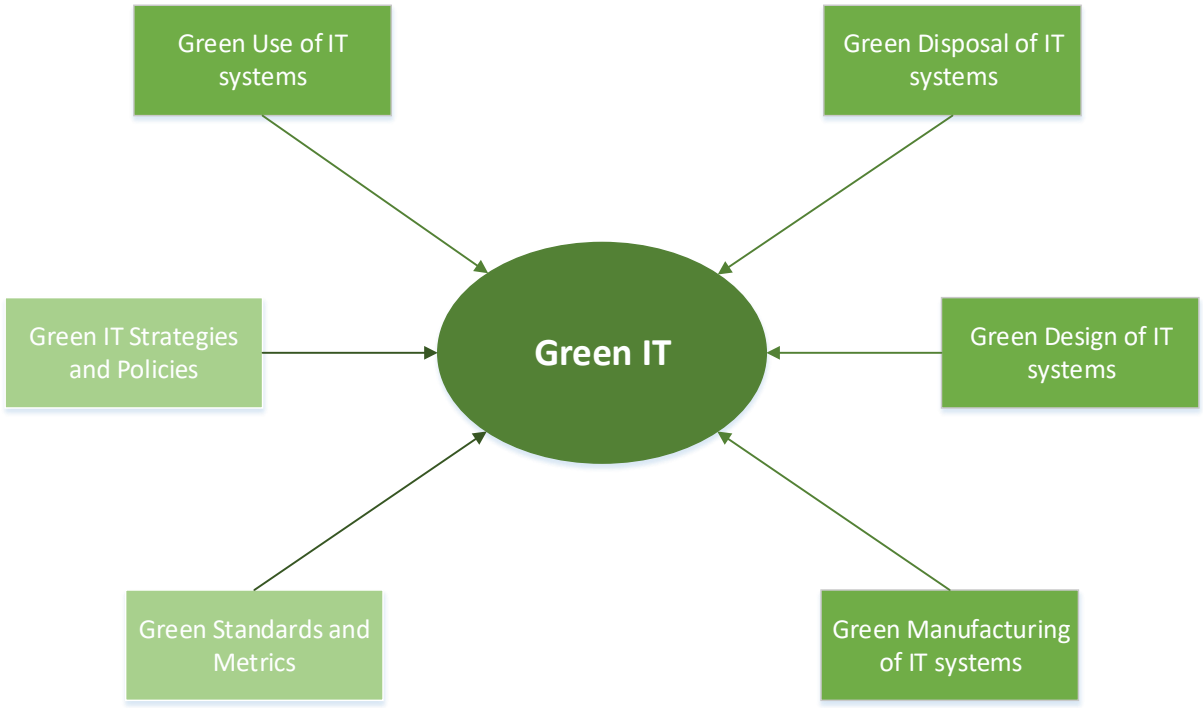


FIGURE 7-6: HOLISTIC APPROACH TO GREEN IT, BY MURUGESAN (2012)

"Green IT Strategies and Policies" and "Green Standards and Metrics" are colored differently to show that these were added later to the model.

Green Use: Reducing the energy consumption of computers and using them in an environmentally sound manner. This includes using practices like reducing power consumption, using power management and turning off the computers when not in use.
Green disposal: Refurbishing and reusing old computers and properly recycling unwanted IT components.
Green Design: The designing off energy efficient and environmentally sound components, computers, servers and cooling equipment.
Green Manufacturing: Manufacturing of electronic components, computers and other associated subsystems with as little impact as possible on the environment.

Green Strategies and Policies: Effective and actionable strategies and policies that add value and focus on both long and short-term benefits. These are aligned with business strategies, practices and are key components of greening IT in an organization.
Green Standards and metrics: These are required for promotion, comparison and benchmarking of sustainability initiatives, products, services and practices.

Process view

This framework does not provide any means of measurement or a maturity level since it is more aimed to give an overview in what aspects should be taken into account when greening the entire lifecycle of IT. It does, however, provide a framework that shows how these components are interrelated with each other. Murugesan specifies the three Rs of greening unwanted hardware to illustrate these relationships.

- **Reuse**: reusing old computers (if they still satisfy the requirements) instead of buying new computers every few years or donating them to other people.
- **Refurbish**: Upgrading old computers and servers with new components (instead of completely replacing the old IT component) to match new requirements.
- **Recycle**: if computers cannot be refurbished or reused, they can be disposed of in environmentally friendly ways.

Murugesan's framework for greening the IT lifecycle can be seen below in Figure 7-7.

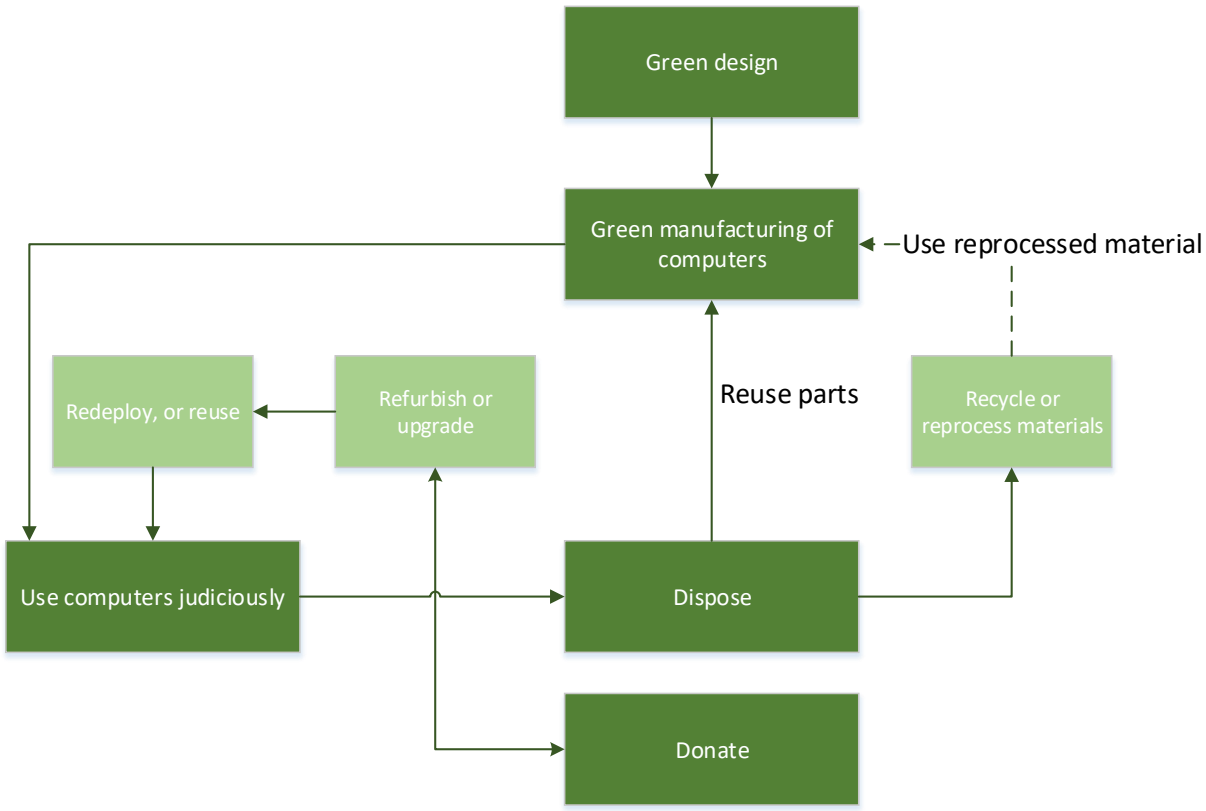


FIGURE 7-7: GREENING THE IT-LIFECYCLE, BY MURUGESAN (2012)

The model shows the following relations:

- Green Design influences Green manufacturing.
- Green Manufacturing influences Green Use.
- Green Use Influences Green Disposing.
- Green Disposing influences Green manufacturing (through reusing materials for recycling).
- Donating (can be part of policy) influences Refurbishing, which influences Reuse, which influences Green Use.

During the gathering of the requirements, it will be researched to what extent it is possible to incorporate these components into the auditing protocol. For example, it could be measured to which extent UU recycles IT components. There was no information about how to use this framework in an analysis or what should be the result of applying it.

Metamodel

The metamodel of Murugesan's holistic approach on Green IT can be seen here in Figure 7-8.

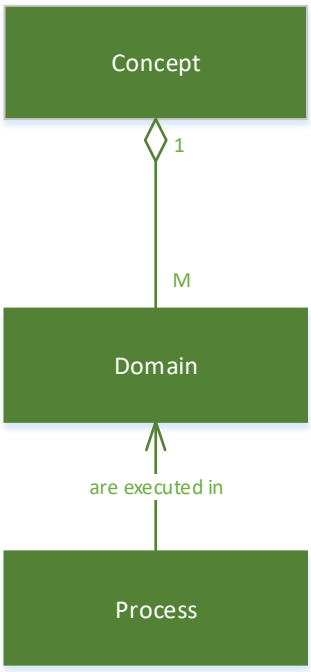


FIGURE 7-8: METAMODEL OF MURUGESAN'S HOLISTIC APPROACH TO GREEN IT

It can be seen that the framework is structured as a central concept, which involves several domains. In these domains, processes are executed that are necessary for that domain.

Validation

Murugesan has based this framework on research into green IT and has combined it into this framework, which is mostly described in his book: *"Harnessing Green IT: principles and practices."* There is no information available, however, to which extent it has been validated

7.2.4 Green IT framework for data centers considering green metrics, by Uddin, M. & Rahman, A (2012)

Background

The next framework has a more detailed focus, which is on data centers (Uddin & Rahman, 2012a). A data center comprises of thousands of servers that run many of today's Internet, financial, commercial and business applications and these continue to increase. Data centers are a major source of IT's GHG emissions and are therefore an important issue in reducing the energy consumption of IT. Also, due to energy prices rising the need for reducing the power consumption of data centers (which can, according to Uddin & Rahman, can be as high as that of a small city) becomes even greater. Another problem is that 90% of the time the servers are idle performing no tasks but are still running and consuming huge amounts of energy. Therefore, this framework has been developed with more detail on data centers.

Process view

The framework is structured as a process with different phases, which each containing different artifacts. Because the framework is process based, the application of it will be discussed first. The frame consists of five steps, which have the eventual goal of greening a data center. It can be seen in Figure 7-9.

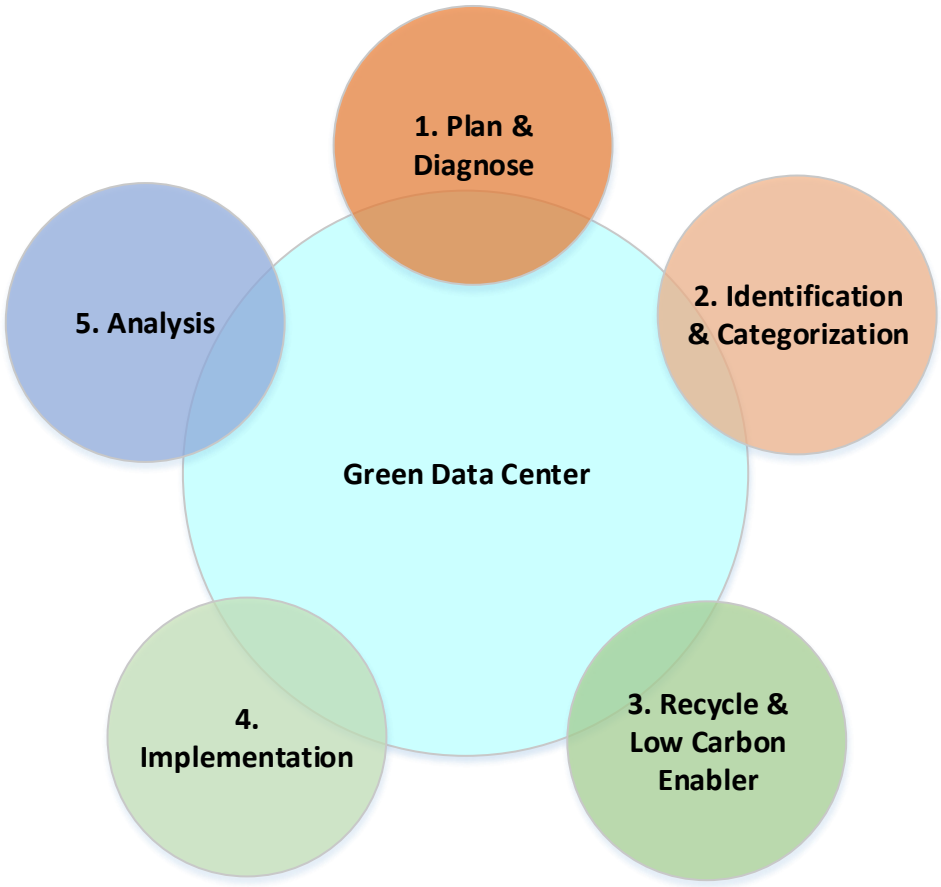


FIGURE 7-9: FRAMEWORK OF UDDIN & RAHMAN (2012) ON GREENING DATA CENTERS

1. **Plan and diagnose**: This phase is mostly concerned with preparation for the greening of the data center. It involves some research into existing techniques concerning Green data centers and analyzing important aspects of the organization that could influence the success of implementing a more green data center.
    a. Identify current Green IT initiatives in data centers
    b. Identify best practices and potential advantages for implementing green data centers
    c. Establish efficiency teams and goals
2. **Identification and categorization**: Data centers are large entities consists of many different components and devices performing all kinds of tasks to meet the specified requirements. These components should be categorized into measurable categories depending on the workloads they execute so that green metrics can be applied to measure their performance and efficiency individually and furthermore to find out the overall efficiency of the data center because it's hard to manage and measure the efficiency of the complete data center. Some typical category examples that Uddin & Rahman present (but there are much more):
    a. Servers
    b. Storage devices
    c. Switchgear

d. Chillers
e. Cooling tower
f. Generators

Furthermore, this phase lays the foundation for the benchmarking process. The authors specify a benchmark as a combination of three components: a workload to run, which should represent some real-world task of interest, a metric or score to compare different systems and operational rules to ensure the benchmark runs under realistic conditions.

3. **Recycle and low carbon enabler:** This phase covers the biggest component of the process of greening a data center. It covers the acquisition and procurement of data center equipment and disposal or recycling at the end of its lifecycle with low environmental impact. It also implies that carbon emissions should be reduced by formulating a policy based on green metrics that measure the emission of GHG from data centers at regular intervals.
4. **Implementation**: This phase deals with the actual implementation of the acquired equipment in the earlier phases. It is important to highlight the importance of infrastructure and cost needed for implementing the necessary measures specified in previous phases.
5. **Analysis:** This Phase deals with measuring the performance of data center regularly from time to time using the metrics selected.

After using this framework, the output generated is not one single artifact, because of the nature of the analysis phase. After a successful implementation of the defined actions to green the data center, the framework suggests that the organization keeps analyzing data related to energy usage, carbon emissions, utilization ratio, etc. of all categories of the used data center equipment. For this analysis, several tools can be utilized which can perform a comparison of power versus performance. Based on the output, new improvements can be defined. The authors suggest that this analysis is done on a regular basis until maximum efficiency is achieved. The authors do not specify a specific template for structure the output of the analysis.

Artifact view

As mentioned before, each of the phases contains several components which are part of the framework and should be executed in each step. The model that shows those components can be seen below in Figure 7-10.

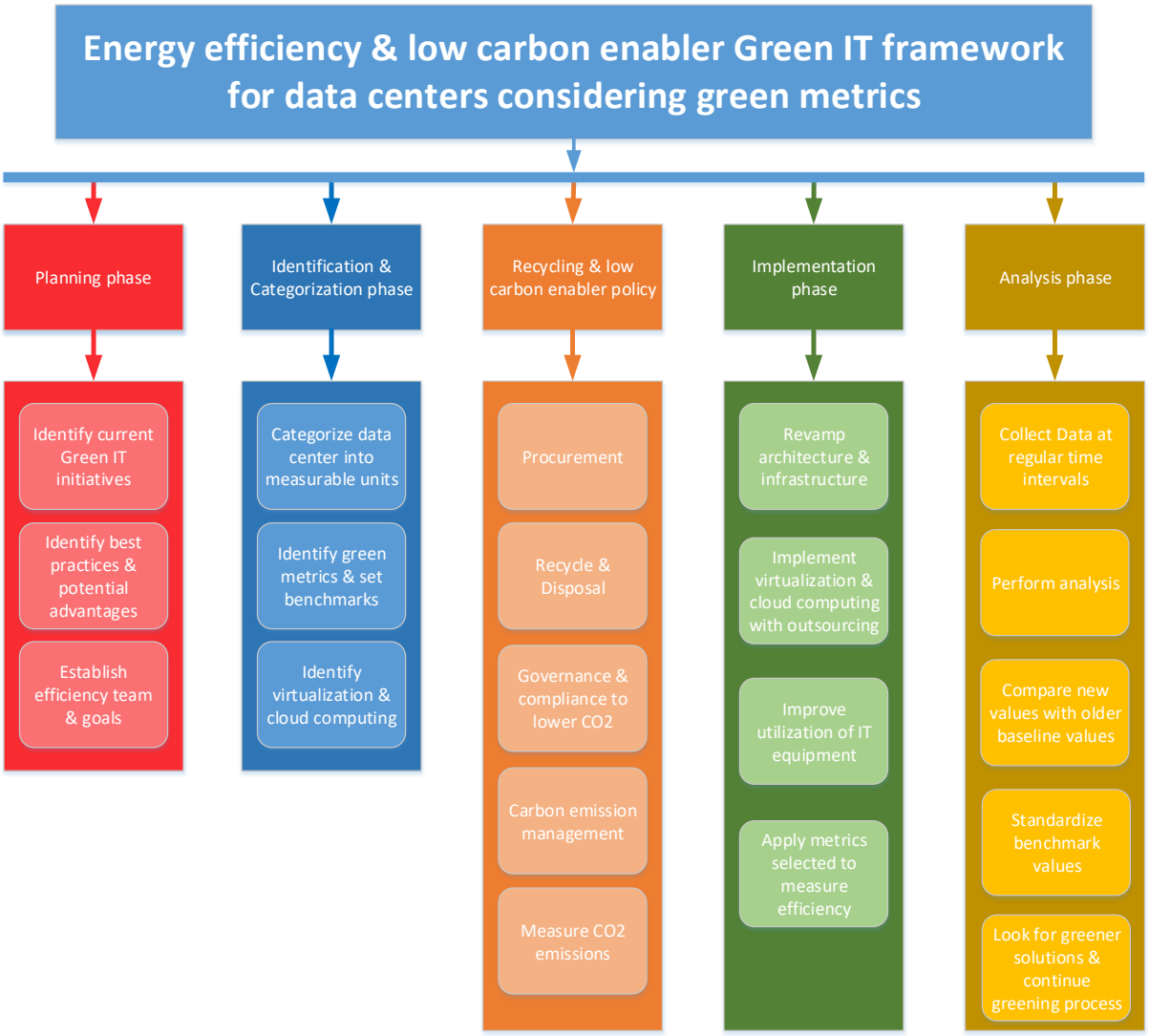


FIGURE 7-10: ARTIFACTS OF UDDIN'S & RAHMAN'S FRAMEWORK, ADAPTED FROM UDDIN & RAHMAN (2010)

Each component will now be explained in short:

Planning phase:

a. Identify current Green IT initiatives in data centers: Identification of all Green IT initiatives in all tiers of the data center industry.
b. Identify best practices and potential advantages for implementing green data centers: From the earlier identification, best practices are identified that can be applied in the data centers considering several issues like cost, energy efficiency.
c. Establish efficiency teams and goals: Teams will be formed to work on greening the data centers and each team will specify goals that are to be achieved

Identification & Categorization phase

This phase lays the foundation for the benchmarking process. The authors specify a benchmark as a combination of three components: a workload to run, which should represent some real-world task of interest, a metric or score to compare different systems and operational rules to ensure the benchmark runs under realistic conditions.

a. Categorize data center into measurable units: For the metrics to run properly, the data center needs to be categorized into measurable units so that energy efficiency metrics can be applied to measure their performance individually or as a whole separately.
b. Identify green metrics & set benchmarks: After categorizing, the next step is to determine the suitable metrics for the benchmarking process and lay the baseline for these metrics.
c. Identify virtualization & cloud computing: Here the stakeholders should identify which type of virtualization & cloud computing (two common technologies for data centers) are fit for the specific data centers used.

Recycling & low carbon enabler policy

a. Procurement: This is presented as the most important aspect of making an impact on sustainability with greening the data center. Two aspects are important here, which is the nature of both the equipment and the supplier.
b. Recycle & Dispose: Since ICT-equipment must be replaced periodically, a policy should be defined for this so that this process happens in an environmentally sustainable way. The three R's by Murugesan apply in this case.
c. "Governance & Compliance to lower CO^2", "Carbon emission management" & "measure carbon dioxide emissions": these three steps can be summarized into a few actions. Here tools are used to measure the power efficiency of data centers and applied for different causes, like checking for compliance and managing the GHG emissions.

The author does not elaborate on the implementation and analysis phase, so their description matches the explanation given in the model.

Implementation phase.

a. Revamp architecture & infrastructure
b. Implement virtualization & cloud computing with outsourcing
c. Improve utilization of IT equipment
d. Apply metrics selected to measure efficiency

Analysis phase

a. Collect data at regular time intervals
b. Perform analysis
c. Compare new values with older baseline values
d. Standardize benchmark values

e. Look for greener solutions & continue greening process

Sustainability pillars

Economic

- Procurement**:** This involves buying new components for the data center
- Several actions**:** Some actions in this model will indirectly involve money, like measuring energy consumption and cost, costs of revamping architecture, etc.

Environmental

- Several actions here are focused on issues like measuring GHG emissions, disposing of old IT components and improving the efficiency of the data centers.

Social

- The social element is not directly involved in here since it mostly focuses on improving the energy efficiency of the data center.

Metamodel

The metamodel of Uddin's & Rahman's framework can be seen below in Figure 7-11.

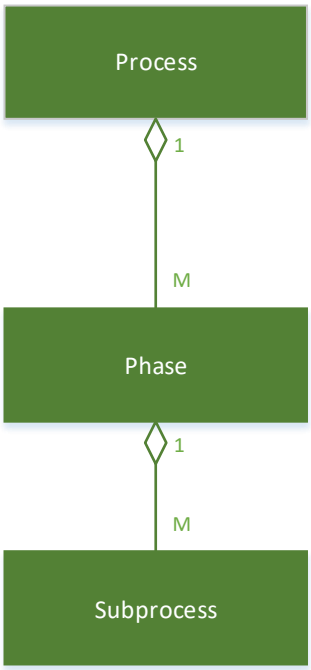


FIGURE 7-11: METAMODEL OF UDDIN'S & RAHMAN'S FRAMEWORK ON GREENING DATA CENTERS

This framework is structured as a whole process of improving the sustainability of a data center. It contains several phases, which each have smaller subprocesses.

Validation

The framework is not validated in the paper where it is presented for the first time, but Uddin and Rahman have validated it in a case study in 2012 (Uddin & Rahman, 2012b). They

performed this case study in different tier level data centers in Pakistan to test the validity, reliability, and credibility of the framework. The authors created a list of criteria with items such as:

- The overall structure is sensible and suitable to be implemented.
- It is feasible, easily understood and can be implemented with ease.
- It is a comprehensive approach and covers all the major aspects of the benchmarking implementation for data centers.

The authors filled in a checklist with items such as:

- It helps data center managers to implement green IT techniques to achieve energy efficient & environment-friendly data centers
- Its overall structure is simple, sensible and suitable for data center managers
- It is a practical, realistic and uncomplicated framework, which can easily be used in a real working environment.

Through group discussions, semi-structured interviews and a survey questionnaire from different data center managers responsible for performing technical and operational actions, the checklist was filled in. The authors concluded from the case study that the framework is valid, credible, reliable and authenticated and can indeed help data centers becoming greener.

7.2.5 Sustainable ICT Capability Maturity Framework, by Donnellan et al. (2011)

Background

The final model that will be discussed is a model from a paper by Donnellan et al. (2011). Development of this model has been initiated by the need for sustainable ICT (SICT). Donnellan et al. believe this can be accomplished by:

- Aligning all ICT processes and practices with the core principles of sustainability, which are to reduce, reuse, and recycle. These three processes were mentioned earlier when discussing Murugesan's holistic approach to Green IT.
- Finding innovative ways to use ICT in business processes to deliver benefits for sustainability across the enterprise and beyond.

The framework has been developed by the Innovation Value Institute in collaboration with organizations from industry, academia and the non-profit sector. It has been created using several frameworks, including the G-readiness framework from Molla. Its assessment methodology determines how SICT capabilities are contributing to the business organization's overall sustainability goals and objectives.

The framework focuses on four key actions for increasing the business value of SICT:

1. Define the scope and goal of SICT.
2. Understand the current SICT capability maturity level.

3. Systematically develop and manage the SICT capability building blocks.
4. Assess and manage SICT progress over time.

Artifact view

The model possesses several capability building blocks, which form the basis for sustainable ICT in an organization. These five levels are described as follows by Donnellan et al.

1. **Initial:** SICT is ad hoc; there is little understanding of the subject and there are no policies regarding this domain. Responsibilities are not defined and SICT is not considered in the life cycle of IT systems.
2. **Basic:** There's a limited ICT strategy with associated execution plans. It is largely reactive and lacks consistency. There's an increasing awareness of the subject, but accountability is not clearly established. Policies might exist but are executed inconsistently.
3. **Intermediate:** An SICT strategy exists along with associated plans and priorities. The organization has developed capabilities and skills and encourages individuals to contribute to sustainability programs. The organization includes SICT across the full systems life cycle and it tracks targets and metrics on an individual project basis.
4. **Advanced:** Sustainability is a core component of the IT and business planning life cycles. IT and business jointly drive programs and progress. The organization recognizes SICT as a significant contributor to its sustainability strategy. It aligns business and SICT metrics to achieve success across the enterprise. It also defines policies to enable best practices.
5. **Optimizing**: The organization employs SICT practices across the extended enterprise to include customers, suppliers and partners. The industry recognizes the organization as a sustainability leader and uses its SICT practices to drive industry standards. The organization recognizes SICT as a key factor in driving sustainability as a competitive differentiator.

These maturity levels can be assigned to each of the nine buildings blocks, which are spread across four categories:

- **Strategy and Planning**: This includes the specific objectives of implementing SICT and its alignment with the organization's overall strategy, targets and goals concerning sustainability.
- **Process management**: this category describes the sourcing, operation and disposal of ICT systems, as well as the provision of systems based on sustainability objectives and the reporting of performance.
- **People and culture**: this category defines a common language to improve communication throughout the enterprise and establishes activities to help embed sustainability principles across IT and business.
- **Governance**: this final category develops common and consistent policies and requires accountability and compliance with relevant regulation and legislation.

The accompanying building blocks along with their description can be seen below in Table 7-1.

Category	Building block	Description
Strategy and planning	**Alignment**	Define and execute the ICT sustainability strategy to influence and align to business sustainability objectives
	Objectives	Define and agree on sustainability targets for ICT
Process management	**Operations and life cycle**	Source (purchase), operate, and dispose of ICT systems to deliver sustainability objectives
	ICT-enabled business processes	Create provisions for ICT systems that enable improved sustainability outcomes across the extended enterprise.
	Performance and reporting	Report and demonstrate progress against ICT-specific and ICT-enabled sustainability objectives, within the ICT business and across the extended enterprise
People and culture	**Adoption**	Embed sustainability principles across ICT and the extended enterprise.
	Language	Define, communicate, and use common sustainability language and vocabulary across ICT and other business units, including the extended enterprise, to leverage a common understanding
Governance	**External Compliance**	Evangelize sustainability successes and contribute to industry best practices
	Corporate policies	Enable and demonstrate compliance with ICT and business sustainability legislation and regulation. Require accountability for sustainability roles and decision making across ICT and enterprise matters.

TABLE 7-1: CONSTRUCTS OF DONNELLAN ET ALL'S FRAMEWORK ON SUSTAINABLE ICT, ADAPTED FROM DONNELLAN ET ALL. (2011)

A conceptual diagram of the model, showing the main categories with the constructs can be seen below in Figure 7-12.

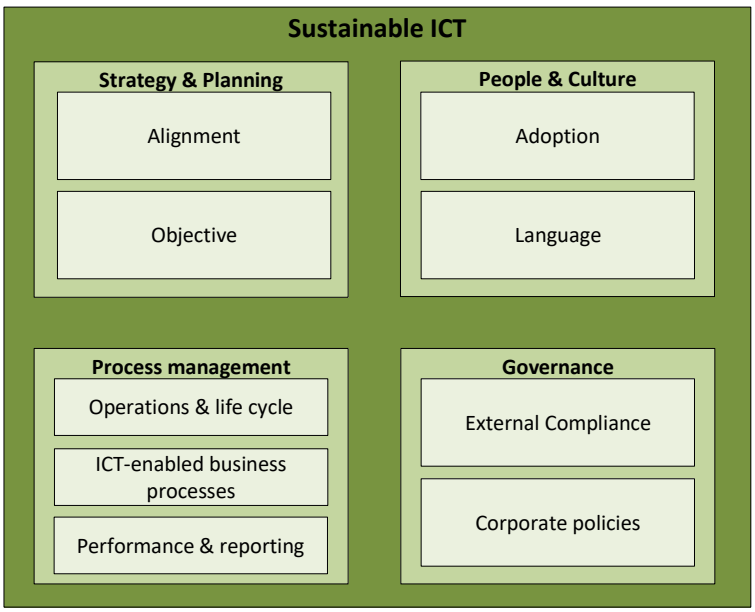


FIGURE 7-12: ARTIFACTS OF SICT FRAMEWORK BY DONNELLAN ET AL.

Process view

Donnellan et al. describe several phases that should be executed to successfully apply this model. However, not all of them are described to be an essential part of applying the model. The core steps are:

1. Conducting a survey among IT and business leaders to understand their individual assessments of the maturity and importance of these capabilities. A series of interviews are conducted with the main stakeholder in conjunction with the surveys to understand key business priorities and SICT drives, successes achieved and initiatives taken or planned.
2. The results are plotted based on importance for the company and maturity level, up to a total of five for both factors. A fictional example is shown on the next page in Figure 7-13 and Figure 7-14. It shows two graphs, each showing the maturity of the assessed organization in a different way.

FIGURE 7-13: FICTIONAL PLOTTING OF BUILDING BLOCKS IN SICT FRAMEWORK BASED ON IMPORTANCE AND MATURITY LEVEL

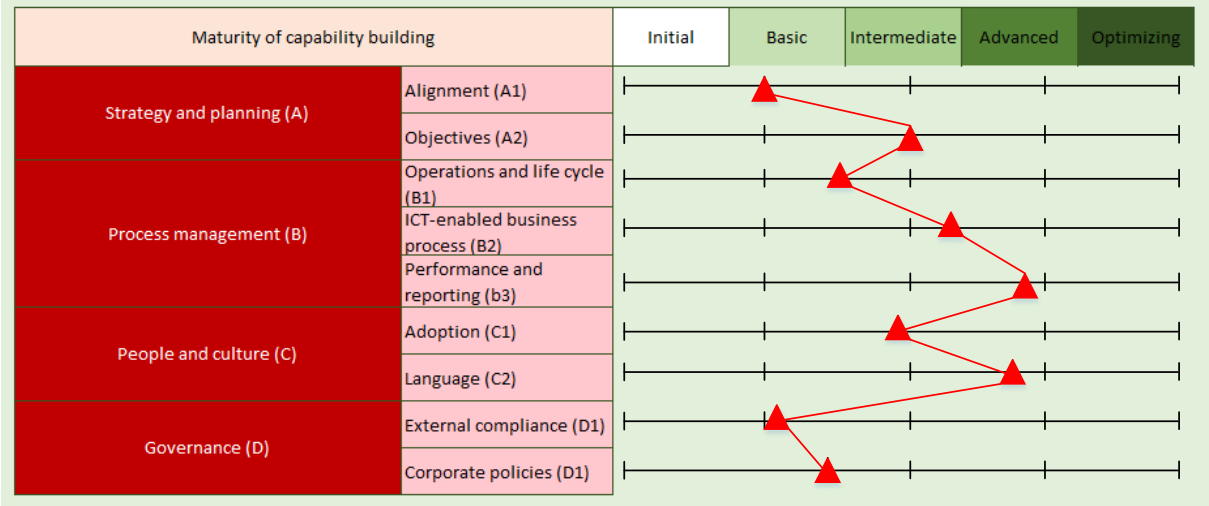


FIGURE 7-14: FICTIONAL MAPPING OF MATURITY LEVELS IN SICT FRAMEWORK

After assessing the organization, the company will have a clear view of current capabilities and key areas for improvement. The results should be used to:

1. Develop a roadmap and action plan.
2. Add a yearly follow-up assessment to the overall IT management process to measure over time both progress and the value delivered from adopting SICT.

Sustainability pillars

Economic

- This pillar can be seen directly in the building block 'Operations and life cycle' in the part of purchasing. Furthermore, it can be seen indirectly in several blocks that involve money, like sustainability objectives, operations and improves sustainability outcomes.

Environmental

- This pillar can be seen indirectly in the blocks that describe issues that involve sustainability initiatives and objectives, as these will contain matters that involve the environment.

Social

- The social pillar appears in 'People and Culture,' which is a category entirely focused on the human aspect in greening ICT. It involves creating a common language and letting people adopt sustainability in their daily business practices.

Metamodel

The metamodel of the Sustainable ICT capability maturity framework can be seen below in Figure 7-15.

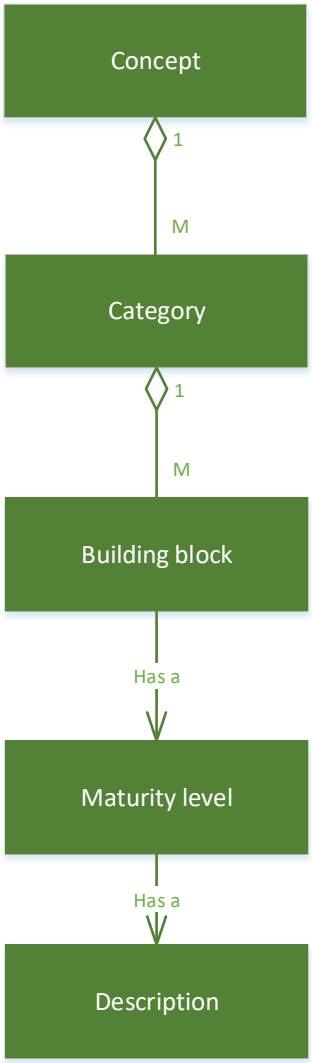


FIGURE 7-15: METAMODEL OF THE SICT CAPABILITY MATURITY FRAMEWORK BY DONNELLAN ET AL.

The metamodel shows that the concept is the subject of the model (in this case 'Sustainable ICT'), has several categories. Each category has several building blocks and each building block can be assigned a maturity level. Each maturity level has a description of what it means to have that specific maturity level.

Validation

Several pilots have been performed to test this model. From these initial assessments, some requirements have been specified to apply the framework successfully.

1. Obtain Senior Management vision: Senior level drive, visibility, accountability and communication are essential for developing the capabilities in the framework.
2. Engage IT and Business Organizations: For improving sustainability in IT, not only the IT department should take action, but other departments of the organization should also be actively involved.
3. Accept cultural change: The general workforce needs to be engaged to agree on the right metrics and other changes resulting from improving sustainability capabilities.
4. Understand the potential and expand expertise: Senior management needs to understand the potential benefits and not only see becoming more sustainability as a 'cost' to the organization. Not only some experts should possess experience and expertise of SICT, but the whole organization also needs to be educated in this field to improve the sustainability of IT. This is also the key to changing the culture and embedding SICT in the core organizational values.

7.2.6 Envirability Green ICT framework, by Philipson (2010)

Background

This framework has been developed by Philipson because of the need for a comprehensive framework to measure the use of Green ICT into different aspects (Philipson, 2010). The author states that, even though the issue is heavily debated, there is still little agreement on how Green ICT should be defined. The author takes a holistic view on Green ICT and sustainability, then breaks down into smaller components that can be measured. Its content is based on academic research but still provides a practical approach to determine a maturity for several different aspects concerning Green ICT. The maturity levels are based on the Capability Maturity Model by Humphrey (1988). This will be discussed later once the content of the model is explained.

Artifact view

The model breaks into several components or pillars, as they are named in the model. The model can be seen below in Figure 7-16.

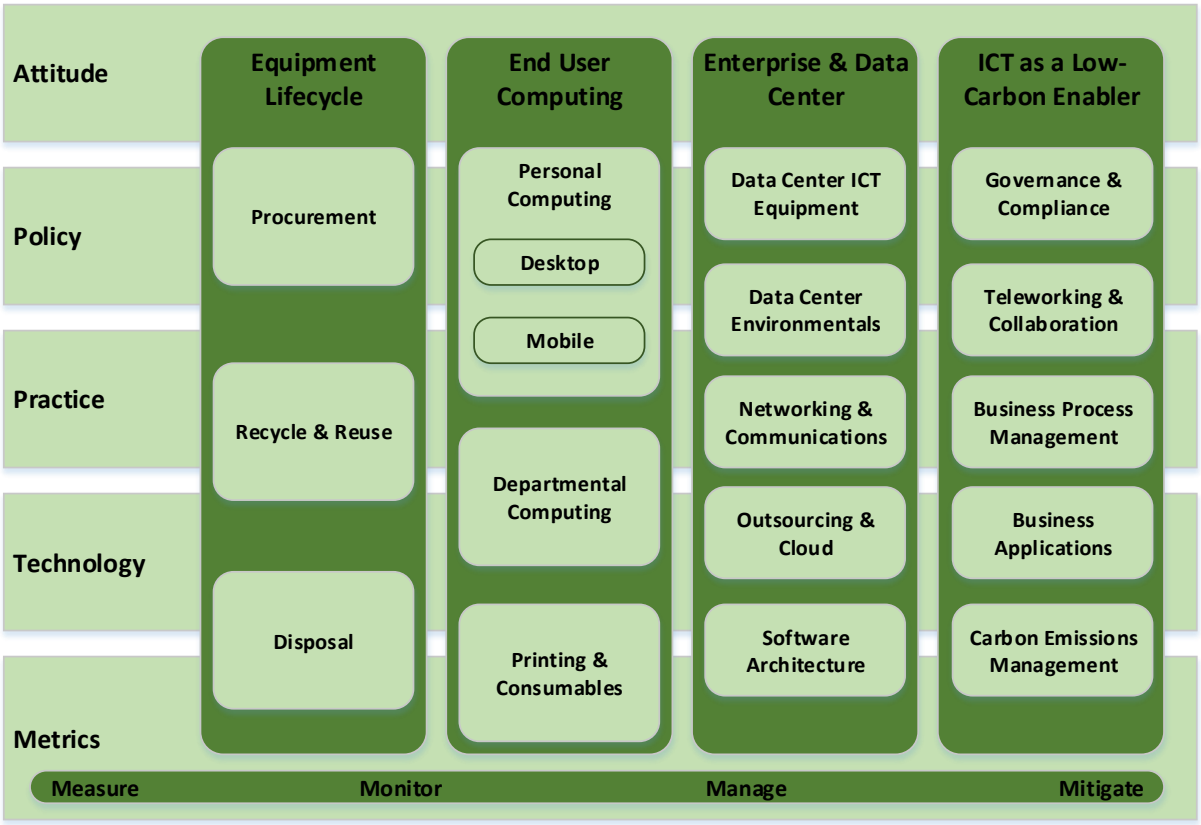


FIGURE 7-16: ENVIRABILITY GREEN ICT FRAMEWORK, ADAPTED FROM PHILIPSON (2010)

The artifacts will be explained in short. The four pillars each involve a separate area of Green ICT.

Equipment Lifecycle: This pillar covers the acquisition and procurement of ICT equipment and the disposal and recycling/reuse practices at the end of its lifecycle.

End User Computing: The part of the ICT processes which are controlled by the end users. Here the personal computing represents all personal computing devices, like desktops but also tablets and mobile phones. Departmental computing refers to computing not controlled by the ICT department. This usually consists of servers, storage devices and peripherals. According to Philipson, these devices are often very inefficient in energy usage and use of resources. They are therefore a prime target of energy reduction.
Enterprise & Data Center: This is the part of the ICT function controlled directly by the ICT department, which typically are the data center, networking, software development and outsourcing. Philipson states that management of data centers can be one of the most important aspects of Green ICT. It is also said that software architecture can have a major impact on energy consumption of software and therefore should be included in the attempt to reduce power consumption.
ICT as a Low-Carbon Enabler: It is stated that the real potential benefits of Green ICT are in using ICT as an enabling technology to reduce carbon emissions (which follows the definition of Green IS as utilized in this thesis).
'Governance & Compliance' here describes the practices and methodologies that ensure that ICT is managed properly.
'Teleworking & Collaboration" refers to tools that help people to collaborate more efficiently. Teleworking is here mostly focused on reducing travel required while Collaboration refers more specifically to tools used to share information, documents and processes.
'Business Process Management' refers to improving business processes as a whole, while business applications are the smaller applications used for smaller business actions in these business processes.

It is notable that the G-Readiness Framework by Molla, which has been discussed as well in this analysis, appears again in this model. All aspects, except for Governance, are part of the horizontal dimension here, which are referred to as 'Actions.' All aspects have a different focus on what kind of actions they envision. Actions can, for example, concentrate on changing the attitude of people or implementing new technologies. The horizontal dimension also includes another action called 'Metrics.' Metrics is applied across the four pillars like the other actions, but with a different approach. It contains four phases:

1. **Measure**: Defining what should be measured and with which units of measurement.
2. **Monitor:** Continuous measurement; the ability to measure over time.
3. **Manage:** Taking the results of measurements and control progress. Furthermore, from data, it is determined what should be done.
4. **Mitigate**: A change in the process that a permanent improvement occurs.

The horizontal dimension will be further discussed in the process view.

Process view

Like some of the other frameworks, there are no predefined phases to apply this framework. It is stated that a survey among employees should be conducted to determine the capability

maturity level of the several constructs described in the framework. Questions about each 'Action' as discussed earlier should be defined that are suitable for determining the maturity of each construct. The capability levels are described as follows in Figure 7-17.

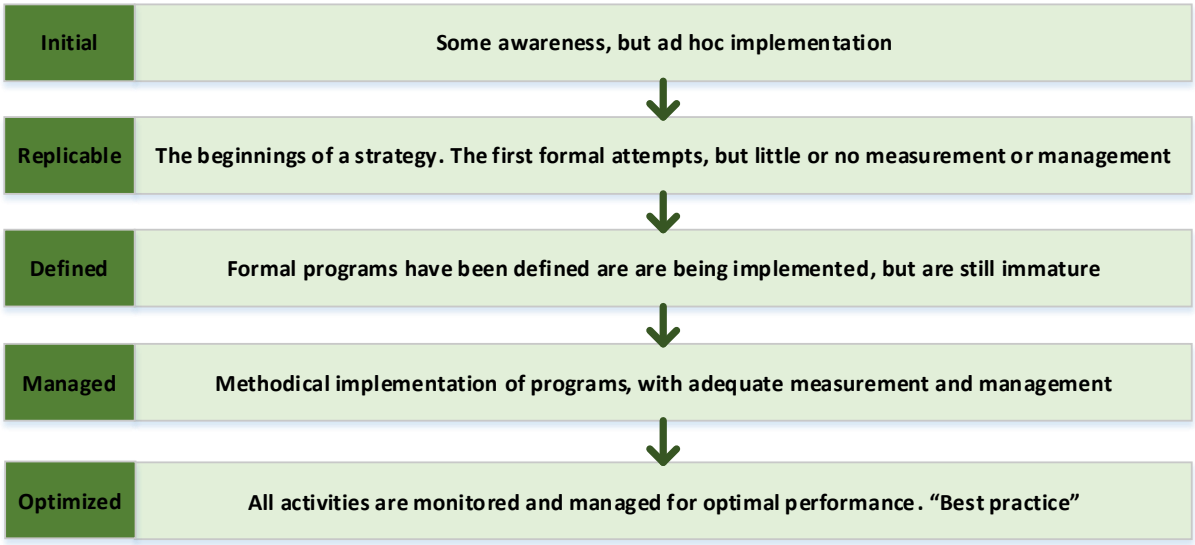


FIGURE 7-17: PROCESS VIEW OF ENVIRABILITY GREEN ICT FRAMEWORK, ADAPTED FROM PHILIPSON (2010)

The questions are rated from 0 to 5 and are then aggregated and weighted to deliver a score up to a maximum of 100. The action 'Metrics' is also assigned a score, it is specified to be a 'similar' process in the survey and can be treated as a fifth pillar. So in the end, five factors receive a score.

Sustainability pillars

Economic

- This pillar can be seen in several constructs of this model. Especially in constructs like 'procurement,' 'printing and consumables' (which also includes the purchase of those items) and 'Outsourcing and cloud,' money is also a component.

Environmental

- Like in the other models, this pillar is present most prominently. Most constructs in the model focus on environmental issues which are aimed at improving energy efficiency, lowering energy usage and improving recycling and disposal.

Social

- This dimension focuses on the social aspect of sustainability. Since it concentrates on the actions to take for each construct, it considers the social dimension in all constructs of the model. It does not include the social pillar completely though and focuses only on the attitude of the people regarded in using this model.

Metamodel

The metamodel for the Envirability framework can be seen in Figure 7-18.

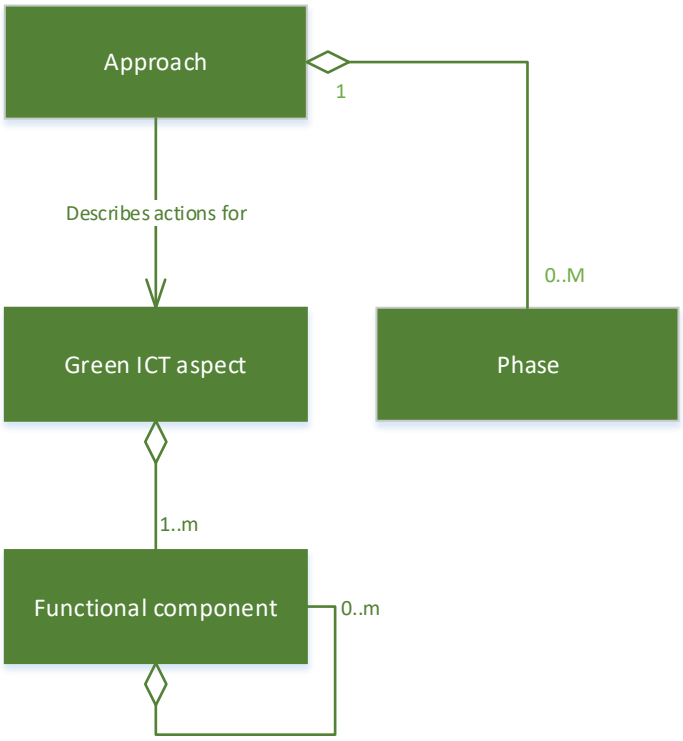


FIGURE 7-18: METAMODEL OF ENVIRABILITY GREEN ICT FRAMEWORK

This model is structured as follows:

1. There are several aspects of Green ICT, and each aspect has one or more functional components. It is possible for a functional component to contain another functional element.
2. Several approaches describe actions to take to improve on a Green ICT aspect. One approach, in this case, 'Metrics,' contains several phases.

Validation

The model has been applied across several industries to formulate a benchmark for these sectors, but no information is available about the actual validation of the framework. The author, however, states that the benchmarking tool is 'simple, yet highly effective.'

7.2.7 SURF Green ICT Maturity Model, by Hankel, A. (2014)

Background

The SURF Green ICT Maturity Model (SGIMM) has been developed by SURF; a Dutch organization focused on developing ICT for educational institutions. The author of the model's description is Albert Hankel. The manual states that the model has been developed when SURF found out that educational institutions needed more facts and examples about Green IT and Green IS and which the maturity level was the institution itself. It consists of 18 base attributes, but depending on the needs of the organization; more attributes can be added. The model has been developed as a 'lightweight scan,' which means it is limited by its level of detail. On the other hand, however, this means using the model is cheap, fast and independent from other organizations. Hankel also states that the model does ***not pretend to be complete,*** but should help an organization see the essential components of Green ICT and helping them to start identifying improvements.
The SGIMM is presented to have the following goals:

- Starting an internal dialogue.
- Gaining an agreement on the status quo.
- Defining actions for improvement.

The manual also states that the model is still open for improvement, which is an excellent opportunity for this thesis to propose an improvement version of the model.

Artifact view

The SGIMM measures a maturity level (on a scale of 1-5) on different attributes, which are divided into four domains:

1. **Green ICT in the organization:** these attributes are aimed towards more general issues surrounding Green ICT, like procurement and waste policy.
2. **Greening of ICT:** This refers to the Green IT definition used in this thesis and the surrounding issues, like how long computers are used, where they are stored, etc.
3. **Greening of operations with ICT:** This refers mostly to the Green IS definition used. It focuses on reducing the environmental impact of several general business operations through ICT.
4. **Greening of primary processes with ICT:** This is a section of the model that an organization using the model can utilize to tune it to specific primary business processes for the organization.

Those four domains are divided into several attributes. A model of those attributes can be seen on the next page in Figure 7-19.

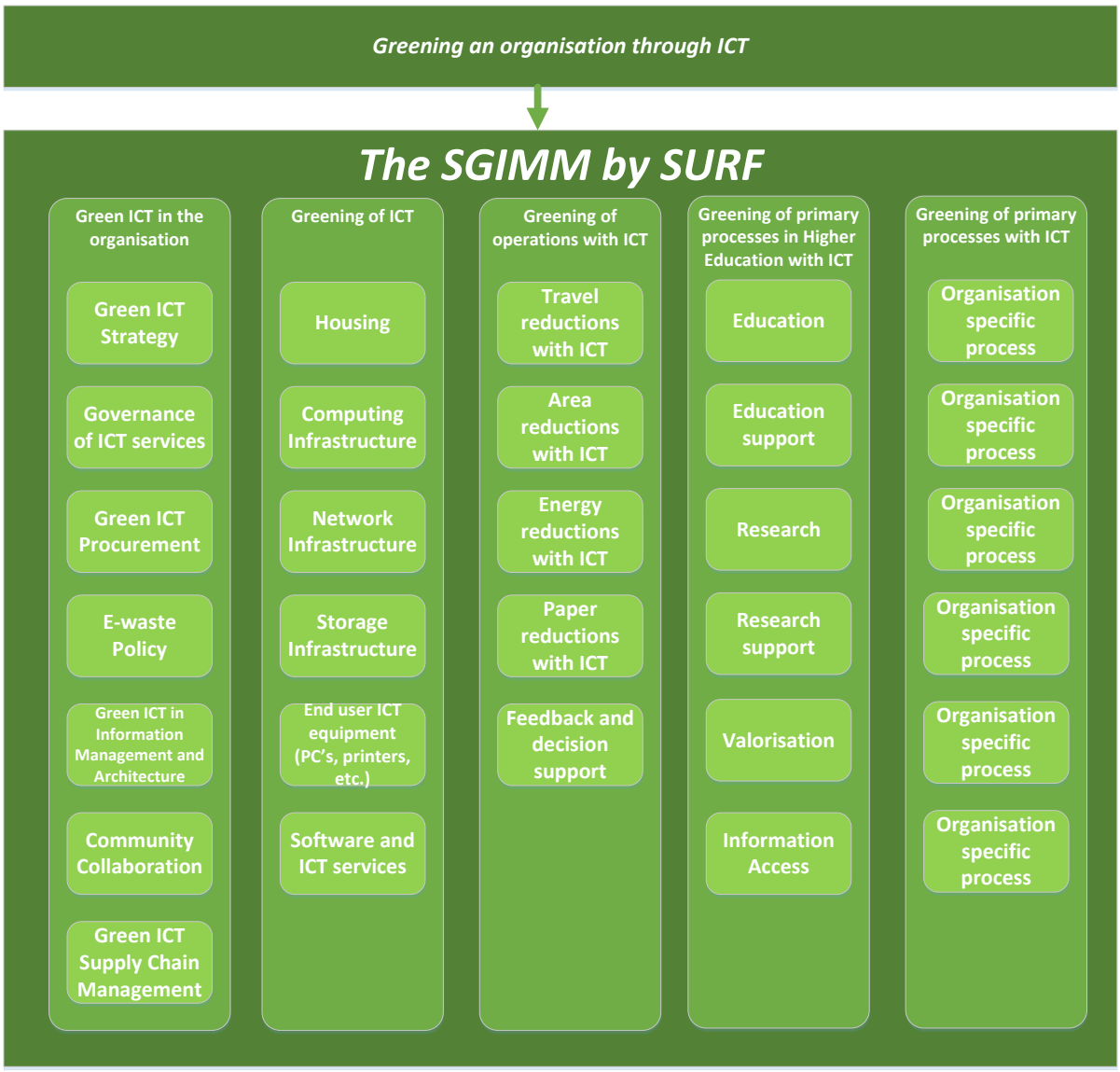


FIGURE 7-19: SURF GREEN ICT MATURITY MODEL, BY HANKEL

Each of the definitions of the constructs in the SGIMM will now be shown, as they are found in the SGIMM. Note that they are mostly specified as a sentence to which someone can assign a maturity level from 1 until 5.

Green ICT in the organization

- *Green ICT Strategy*: The ICT department works according to a Green ICT strategy.
- *Governance of ICT services:* The level of control on ICT services by the ICT department.
- *Green ICT Procurement*: Whenever ICT equipment or services are procured, the environmental impact is considered.
- *E-waste Policy*: An E-waste policy is in use to reuse or recycle ICT equipment.
- *Green ICT in Information Management and Architecture*: How sustainability is considered in information management and architecture.
- *Community Collaboration*: How the ICT department collaborates on sustainability issues with outside organizations.

- *Green ICT Supply Chain Management*: How the ICT department considers the environmental impact of the entire ICT supply chain in collaboration with suppliers and users.

Greening of ICT

- *Housing*: The resource and energy efficiency of the housing for infrastructural equipment.
- *Computing Infrastructure*: The resource and energy efficiency of the computing infrastructure.
- *Network Infrastructure*: The resource and energy efficiency of the network infrastructure.
- *Storage Infrastructure*: The resource and energy efficiency of the storage infrastructure.
- *End user ICT equipment (PC's, printers, etc.):* The resource and energy efficiency of end user equipment.
- *Software and ICT services*: The resource and energy efficiency of software applications and their development process.

Greening of operations with ICT

- *Travel reductions with ICT:* ICT is used to enable travel reduction of everyone within the organization.
- *Area reductions with ICT:* ICT is used to allow the reduction of area utilization in buildings.
- *Energy reductions with ICT*: ICT is used to allow the reduction of power consumption of the organization as a whole.
- *Paper reductions with ICT:* ICT is used to allow reduction of the use of paper by digitalizing business processes.
- *Feedback and decision support*: ICT is used to give the organization detailed comments and decision support on energy and resource consumption.

Greening of primary processes in Higher Education with ICT

- *Education*: ICT is used to enable reduction of energy and resource use in education processes.
- *Education support*: ICT is used to allow reduction of energy and resource use in education support processes
- *Research:* ICT is used to allow reduction of energy and resource use in research support processes
- *Valorization:* ICT is used to enable reduction of energy and resource use in valorization processes.
- *Information Access*: ICT is used to enable reduction of energy and resource use in information access processes.

These items, along with the descriptions in the maturity levels to further determine what was meant with these items, were compared with the definitions presented in the papers. The

comparison was executed based on whether the constructs that did appear in the frameworks also appeared in the SGIMM and matched the definitions to some extent.

Process view

SURF has presented a detailed overview of how to apply the process, how to create an assessment team, and how to build a plan for improvements.
All steps will be discussed now:

1. **Someone in the organization should take the initiative**

Someone has to start applying the protocol. This would in most cases be a CIO or an ICT manager with sustainability in his or her portfolio. This person will be assigned as the Assessment Manager (AM). Most important here is that the AM has the influence and the ability to make sure that the audit is properly executed and that the proposed improvements are also actually implemented.

2. **The AM composes an assessment team**

The assessment team should consist of people who represent the organization in filling out the maturity model. They all give scores for each attribute, which are averaged to obtain a final maturity level. Composing the right assessment team is crucial. Surf proposes the following criteria for employees to create the assessment team:

- Employees who can fill out the form for most attributes and motivate their choices.
- Employees who are necessary for following up on the defined actions, such as heads of departments responsible for carrying out any agreed actions for Green ICT improvement.
- Employees who are necessary for support, such as those that oppose any changes when they were not involved in the decision process.

Regarding the content of the attributes, the SGIMM is relevant for:

- ICT as well as Sustainability policies
- Strategic ICT issues
- Operational ICT issues
- General business operations of the organization
- The primary processes and the role of ICT in those in the case of the higher education, these primary processes are education and research.

Therefore it is important for the AM to choose people who have knowledge of these five domains.

3. **The AM organizes a kick-off meeting for the assessment team.**

Here, the audit starts with a meeting where the model is discussed, along with how to fill in the maturity levels. Furthermore, the whole assessment process is explained. Finally, the spreadsheet is sent to all participants.

4. **All participants individually fill out the spreadsheet and score all attributes.**

When this is done, the participants sent their spreadsheets to the AM. After this, the AM will analyze the results. SURF proposes four ways to do this:

a) Individual scores of all participants on all attributes visualized as a radar chart per domain.
b) Per participant per domain a median score, visualized as a radar chart with the domains on the axes.
c) A summarizing radar chart with the median scores of all attributes as well as the minimum and maximum scores.
d) As an illustration of similarities or big differences, a histogram per attribute showing the median, minimum and maximum scores.

5. **The scores are discussed**

The summary of maturity scores and the relation to the individual scores are reviewed in an evaluation session. Based on this session, improvements are defined and an action plan is created. How to create this action plan will be examined in this section.

6. **The action plan is performed**

First, the action plan should be implemented. After some time, the AM can evaluate the results. The SGIMM can be used again to obtain new maturity scores and perform new actions for improvements. This could be done over and over again in a cycle

Creation of an action plan

SURF specifies some guidelines on how to create the action plan mentioned in the process view, which will be discussed here. SURF recommends paying particular attention to:

a) Those attributes on which there is a large degree of consensus within the team. This creates a sense of belonging and sets the stage for further cooperation.
b) Those attributes where there is a great difference in individual scores amongst the team. If extreme score differences occur, it is good to discuss the different point of views. Possibly those differences can be resolved by checking whether they are caused by the various uses of definitions.

When creating an action plan, the team should start with choosing the right attributes to improve. SURF suggests the following to efficiently and effectively apply improvements:

- First of all, the organization should start with quick wins. If any attributes can be easily improved, these can be used to create a sense of achievement. Quick wins also provide an excellent base for follow ups.
- The organization should take a look at those attributes with very low (average) maturity scores. It is likely that taking steps in the relevant areas will benefit the organization in general, so it is relatively easy to create value.
- The organization should compare itself with others. There are probably examples of peer institutions that are known for powerful performances in certain attributes used

in the SGIMM. These 'best practices' could be a source of inspiration for the organization's actions of improvement. Also, the AM might collect some best practices before starting the evaluation of his/her organization to have some details on how to copy those achievements.

- The organization could create a graph that maps the complexity of actions for improvement against added value. This generates an overview of priorities: pick those actions that have high value and low complexity first. However, creating the graph itself could be challenging and time-consuming.
- Determining the risks of 'doing nothing.' The organization should take a look at those attributes, which pose the greatest risks.

Sustainability pillars

Economic

- The SGIMM, like some of the other models, has a construct 'procurement' that involves buying ICT equipment. There is also a construct that focuses on procuring ICT services. Furthermore, it appears indirectly in every construct that can involve money in some way.

Environmental

- Most constructs here involve reducing energy costs and other environmental impacts. Therefore, the environmental pillar has a great prominence here.

Social

- The only construct that directly involves the social pillar is 'community collaboration.' This construct focuses on the cooperation of the organization with other organizations like suppliers, partners and customers.

Metamodel

The metamodel for the SURF Green ICT Maturity Model can be seen below in Figure 7-20.

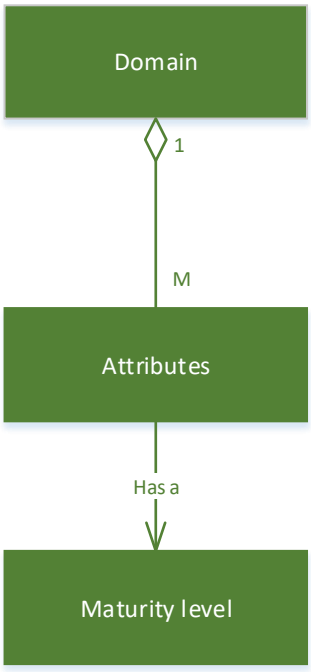


FIGURE 7-20: METAMODEL OF THE SGIMM

The SGIMM has several domains, which each has several attributes. Each attribute has a maturity level with a description of what it contains. This maturity level has the same structure as the Sustainable ICT capability maturity framework.

Validation

The model has been evaluated in a survey of green ICT experts (Hankel et al., 2014b). The focus of this study was to determine the relevancy of the attributes used in the model and whether their descriptions were correct. There were 20 participants in the survey.
First, they asked the participants to rate themselves and their organizations how mature they were on green ICT. The authors assumed here that the opinion of people with a mature organization in green ICT (and probably more experience) are more important in determining the relevancy of attributes.
The participants were asked to give a relevancy score on a scale of 1-5, with a score of 3 or higher being 'Relevant.' Two attributes ("information management" and "Other reductions with ICT") were considered not relevant. Six more attributes were suggested to add to the model, which were: *Maintenance management; People and Culture; Mindset and experience of staff; Sustainable offices; Savings in productions* and *logistics; Improving work inefficiencies with ICT.*
The second quality aspect was the definition of the attributes. Most participants of the survey suggested small modifications based on their experience or had suggestions based on the need for more examples (too abstract), ambiguousness, scoping and focus issues.

7.3 Results of analysis

This section will contain a discussion about results of the analysis that compared the SGIMM to the other frameworks. Each of the different sections of the SGIMM will be discussed in short. Tables for this can be found in Appendix D. In the discussion, if it is not clear where a construct belongs, the construct will receive a name in advance which corresponds with the name of the framework to easily differentiate between the constructs in the different models.

G-Readiness, by Molla, A. & Cooper, V. (2010)

General/business issues

Four out of five constructs (G-readiness framework) had the same subjects as the general problems in the SGIMM (only 'Technology' did not appear here). Notable was that there was no item measure concerning an overall Green ICT strategy, even though some item measures mentioned, were considered to be part of it. Both 'Green ICT procurement' and 'E-waste policy' were referred to in three constructs of the G-readiness framework, which were Attitude, Policy and Practice. Governance was also present in both frameworks (G-readiness: 'Governance'), as was Green ICT Supply Chain Management (Policy). Both 'Green ICT in Information Management and Architecture' and 'Community Collaboration' made no appearance.

Greening of ICT (Green IT)

All constructs of the SGIMM in this category could be found in the G-readiness framework. They were mostly centered around 'Technology' which is not surprising. Some components were also described in other components of the G-readiness framework which were 'Policy' and 'Practice.' Note that the item measures from the 'Technology' section were very specific technologies like 'liquid cooling' and 'data de-duplication', which can all be placed under the 'Computing infrastructure', 'Network infrastructure', 'Storage infrastructure', 'End user ICT equipment' and 'Software and ICT services' from the SGIMM.

Greening of operations with ICT (Green IS)

Three out of five components of this domain could be found in the G-readiness framework. Travel and area reductions could not be found in the G-readiness framework. The other three components could be located in the G-readiness framework and were concerned with the reduction of Energy consumption(Attitude, Policy, Technology) Paper reductions (Practice, Technology) and giving feedback to users to help with making decisions concerning energy consumption (Attitude, Policy & Practice).

Greening of primary processes in higher education with ICT

The issues described in the SGIMM were comparable with Policy and Practice from the G-readiness framework, but the constructs from the G-readiness framework were described in more general terms instead of focusing on education and research.

Not appearing

There were three subjects from the G-readiness framework which were not directly appearing in the SGIMM. These were:

- GHG emissions, from Attitude.
- Green sources of energy, from Policy.
- Extra waste (paper, batteries, etc.), from Practice.

However, it can be argued that reducing GHG emissions is a result of reducing energy consumption. Still, in the SGIMM, no mention is made at all about the actual *source* of energy, only about *reducing* energy use. Furthermore, the SGIMM has a component called 'Paper reduction,' but does not include other forms of waste like batteries, plastic, etc.

Green IS Framework, by Butler, T. (2011)

In this framework, one remarkable issue was that it was structured with different main domains in contrast with the SGIMM. Resulting from this was that constructs of various domains from Butler's framework could fit into one domain in the SGIMM.

General/business issues

All of the components in the SGIMM could be found in the Butler's framework, except for 'Green ICT in Information Management and Architecture' and 'Community Collaboration.' Furthermore, Butler's framework is structured as Green ICT being a part of 'Organizational Governance' as a whole. In the SGIMM, governance is a part of 'Governance of ICT services.'

Greening of ICT (Green IT)

All of the components in the SGIMM were present in Butler's framework. The three infrastructure components in SURF could be summarized in the 'Datacenter & IT infrastructure' component in Butler's framework, while the other three constructs in SGIMM each had a corresponding construct in Butler's model.

Greening of operations with ICT (Green IS)

Several constructs of SGIMM could be found in this model. 'Travel reductions with ICT' was present in a more applied construct in Butler's model, which were Teleconferencing & Teleworking. However, other applications of travel reductions are not present. The constructs for area reductions with ICT were not present at all. Butler's framework had a construct for energy reductions in the form of 'Product/Service Operations' which includes the possible use of an environmental management system, which is a system that helps business becoming more sustainable. An environmental management system can do more that aid with energy reductions, so in Butler's framework this construct is aimed more broad than in the model of SURF. 'Feedback and decision support' from the SGIMM could be found in 'Product/service operations' in Butler's framework and again in the concept of the Environmental Management System. It can also be found in the construct of 'Buildings management system.'

Greening of primary processes in higher education with ICT
This domain appeared again in 'Product/Service processes' of Butler's framework, but again, since Butler's framework is not aimed at higher education, the interpretation of this construct is more generic.

Not appearing
A big part (and according to Butler, the most important aspect as well) that did not appear in the SGIMM was the domain of 'People.' It did not consider the role of people in greening the IT of an organization, like their training, attitude, awareness, etc. Furthermore, the model of SURF did not incorporate the extra waste of packaging computers, which Butler's framework did in the form of the construct 'Smaller product & packaging'.

Holistic approach to Green IT, by Murugesan, S. & Gangadharan, G. (2012)

This framework was structured to include a very broad view of the IT lifecycle and therefore did not go into as much detail as the other frameworks did.

General/business issues
Since this framework focuses on the IT lifecycle, only two constructs of the SGIMM could be found in Murugesan's framework, which was 'Green IT strategies & policies' and 'Green disposal of IT systems.'

Greening of ICT (Green IT), Greening of operations with ICT (Green IS) & Greening of primary processes in higher education with ICT
One construct of Murugesan's framework covers these three domains since it considers the use of IT systems in an environmentally sound manner and reduces their energy consumption. However, since it is very broadly defined, it is hard to conclude what Murugesan exactly means with this construct.

Not appearing
There are three constructs of Murugesan's framework not appearing in the SGIMM, which are 'Green standards and metrics,' 'Green Manufacturing of IT systems' and 'Green Design of IT systems.' It is not surprising that the manufacturing and designing component here do not appear in the model of SURF since the model is not aimed towards a soft- or hardware producer. 'Green standards and metrics', however, could be in the SGIMM but it isn't.

Green IT Framework for Data Centers, by Uddin, M. & Rahman, A. (2012)

General/business issues
Only two constructs from the SGIMM matched with the Green Datacenter framework, which was Green ICT procurement and E-waste Policy.

Greening of ICT (Green IT)

In this section of the SGIMM, again only two constructs from the Green Data Center framework corresponded with the SGIMM, which were 'Revamp architecture & infrastructure' and 'Implement Virtualization & Cloud Computing with Outsourcing.' The three constructs of the SGIMM concerning Infrastructure corresponded with the revamping of the architecture, while 'Software and ICT services' corresponded with 'Implement Virtualization & Cloud Computing with Outsourcing' because of the outsourcing component in there.

Greening of operations with ICT (Green IS)

Only one construct, which was also an entire phase in the Green Data Center Framework, corresponded with this component of the SGIMM. It was similar to the Feedback and Decision support construct. The analysis phase has several steps concerning analyzing data and making decisions based on this data, so it is pretty similar to the SGIMM's construct of feedback and decision support.

Greening of primary processes in higher education with ICT

No construct of the Green Data Center Framework corresponded with this component of the SGIMM.

Not appearing

First, all actions specified in the Green Data Center framework which were concerned with GHG emissions did not appear in the SGIMM. Like in the Holistic approach of Murugesan, a construct concerning green metrics and benchmarks did appear in the framework, but not in the SGIMM. Furthermore, some specific actions concerning structuring data centers into units and identifying technologies for data centers did not appear in the SGIMM. Finally, the entire planning phase of the Green Data Center framework did not appear in the SGIMM.

Sustainable ICT Capability Maturity Framework, by Donnellan et al. (2011)

General/Business issues

Every construct of the SGIMM appeared in here with a specific component of the SICT framework. This was also the only framework to incorporate 'Green ICT in Information Management and Architecture' (although with general terms) and 'Community Collaboration.'

Greening of ICT (Green IT)

This entire domain of the SGIMM is covered by blocks of the category 'Process management' in the SICT model. The blocks each cover different aspects of the constructs in the SGIMM. 'Operations and life cycle cover all constructs except for 'Software and ICT-services,' which is covered by 'ICT-enabled business processes.

Greening of operations with ICT (Green IS)
The SICT framework had two constructs that covered this domain of the SGIMM. 'ICT enabled business processes' covered all the constructs that include 'reduction.' The construct 'Feedback and decision support ' of the SGIMM were covered by 'Performance and reporting' of the SICT model.

Greening of primary processes in higher education with ICT
Like with the other frameworks, the SICT framework had a construct that covered this but was not focused on education, though, but more in a general manner. In this case, this was the construct 'ICT enabled business processes'.

Not appearing
There was one construct that did not appear in the SGIMM and this construct was similar to Butler's framework. The construct was called: 'People and culture' and was aimed at the adoption of sustainability principles and the development of a 'common language' for sustainability across the enterprise.

Envirability maturity framework, by Philipson (2010).

General/Business issues
All of the constructs of the SGIMM matched with constructs of the Envirability model except for 'Green ICT in Information Management and Architecture' and 'Community Collaboration.' 'Green ICT Supply Chain Management' of the SGIMM can be incorporated in 'Business process management' in the Evirability framework since this construct is very broadly defined.

Greening of ICT (Green IT)
Three constructs of the Envirability framework were each very similar to one construct in the SGIMM, with a very similar name and definition. 'Storage infrastructure' and 'Computing infrastructure' of the SGIMM were very similar to the construct 'Data Center Environmentals' since this construct was very broadly defined as well.

Greening of operations with ICT (Green IS)
All but one of the constructs of the SGIMM had similar constructs with the Envirability model. 'Travel reductions with ICT' was covered with a construct that was very applied and was called 'Teleworking & Collaboration.' 'Energy reductions with ICT' and 'Paper reductions with ICT' both had similar constructs in the Envirability framework. 'Feedback and decision support' of the SGIMM had a very similar meaning with 'Metrics.' Both are aimed at measuring data and taking decisions based on this data. 'Area reductions with ICT' was the only construct in the SGIMM that had no corresponding construct in the Envirability framework.

Greening of primary processes in higher education with ICT

Two constructs covered this domain in the Envirability framework, which was 'Business process management' and 'Business applications.' Again, in the Envirability framework, the definition of these constructs was more general.

Not appearing

There was one aspect that did not appear in the SGIMM, which was 'Software Architecture.' This construct is aimed to measure the extent to which the architecture of the software is designed to consume less computing power (and therefore less energy).

Results of the metamodels

By looking at the metamodels, it can be seen that most of them have a very similar structure. Many of the metamodels are organized in a way that specifies what Green ICT should contain and what concepts consisting of several components are important for Green ICT. Some of the models include additional aspects like approaches to a concept or a form of measurement. The only model that was different regarding constructs was the framework about greening data centers since this model focuses purely on a process with different phases. A generic metamodel which was applicable for most frameworks can be seen in Figure 7-21.

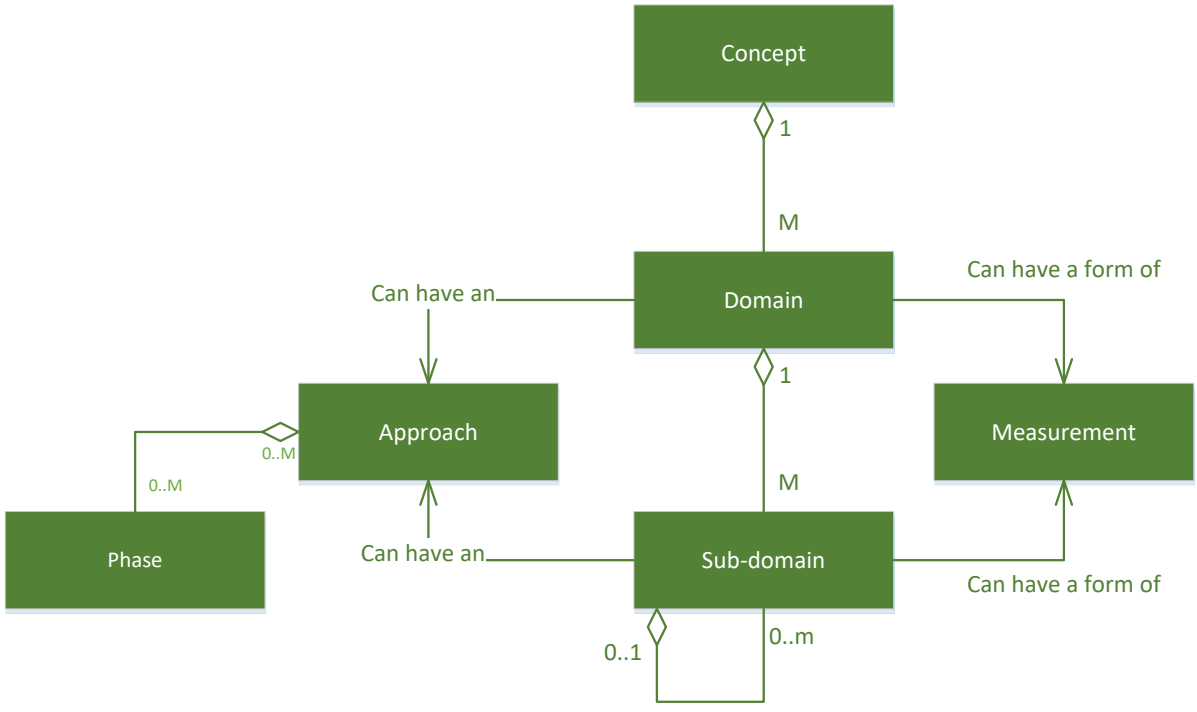


FIGURE 7-21: GENERIC METAMODEL OF ALL FRAMEWORKS ANALYZED

From this model, we can see that concepts were mostly specified as a domain within Green ICT, or as a smaller domain within one domain in a top-down approach. Depending on the model, there could be more sub domains within subdomains. Furthermore, all domains could have a form of measurement (usually a maturity level) or an approach (which

happened in one framework). Concepts that are deemed to be a valuable addition to the SGIMM will be tuned to fit in the SGIMM in the form of a new domain or sub-domain since the SGIMM also has this structure. We will also discuss the possibility of adding other components (like 'Approach' or 'Phase') to the SGIMM if this fits the SGIMM.

7.4 Discussion of the results

This section will contain a result of the analysis that was done previously. Although the analysis gave an enormous amount of chances for discussion the focus will mostly be on the constructs that were not present in the SGIMM but were in the frameworks for comparison. This approach is taken because the main objective of the analysis is to improve the existing SGIMM regarding theoretical domain components.

Overall, most analyzed frameworks did contain many constructs that also appeared in the SGIMM. There were two frameworks which did not have a lot of characteristics in common with the SGIMM:

1. The holistic approach of Murugesan did not have a lot of features in common with the SGIMM, which was not surprising since it was a very broad framework with very limited available data. Although 'Green use of IT systems' could theoretically fit in many constructs in the SGIMM theoretically, it is hard to apply it since the authors do not specify which their own interpretation is.
2. The Green Data Center framework did not match the SGIMM on many constructs due to the nature of the framework. It was the only framework analyzed that is proposed as a process to improve the sustainability of a data center and not as a framework with constructs of what the concept of greening a data center should contain. For example, a planning phase was also proposed (this was not present in the SGIMM) and very specific technologies were part of the model while the others were focused in more general terms.

Two constructs hardly appeared in any of the frameworks. These are the constructs 'Green ICT in Information Management and Architecture' & 'Community Collaboration.' 'Green ICT in Information Management' was also the construct which was identified in the evaluation by the creator of the model (Hankel et al., 2014b) as not being relevant.

There were several constructs in the analyzed frameworks that did not appear in the SGIMM. A list will now follow with these constructs summarized into several more general domains:

1. **People:** The matters concerning the employees of the organization regarding their personal characteristics. For example education, attitude, their roles as well as the culture and common language of the organization.
2. **GHG emissions**: the emissions of CO^2 and other gasses when using IT and performing other business processes.
3. **Energy Sources***:* This could have two interpretations. It could either be:

    a. The actual sources of energy that the company uses. For example solar or wind energy, or coal.
    b. The extent to which the company that provides the energy implements a sustainable process to produce the energy.
4. **Extra waste caused by IT***:* The extra waste which is produced by using, buying or disposing of IT. Waste can be for example batteries, paper, packaging etc.
5. **Green standards and metrics:** Standards and metrics used by the company to compare monitored values of those metrics to a certain baseline.
6. **Green production** *of IT systems:* The production of an IT system is done in a sustainable way.
7. **Green design of IT systems:** The design of an IT system is sustainable in a sense that the IT system itself will be sustainable when used.
8. **Green data centers***:* The data center itself is designed with sustainability in mind.
9. **Shorten refreshment time of IT:** To improve the energy efficiency of IT systems, refreshing time is reduced.
10. **Corporate Social Responsibility***:* The impact which the company has on society and environment.
11. **Data center specific technologies***:* Specifically applied technologies for making data centers greener. In this case, it was virtualization and cloud computing.
12. **Categorization of data centers***:* Categorizing data centers into measurable units.
13. **Software Architecture***:* The software architecture of used software and whether those are designed efficiently to reduce energy costs and execution time.

7.5 Determining improvements for the SGIMM

This section will contain a discussion of which items will be included in the improved version of the SGIMM. Although the list from the previous chapter contains thirteen items, it is unlikely that all will be included separately. Based on a combination of interviews, common sense and literature, this section will determine which items will be added to the SGIMM. Based on feedback, later on, it is possible that this will change.

Each item from the previous list will now be considered for possible addition to the SGIMM. This section will not yet actually implement the elements chosen in the model; this is done later on. Note that the addition of sustainable criteria in the contract will also be considered, based on the work of the company SOMO, who are trying to let organizations include sustainable criteria in their ICT procurement (already part of the SGIMM), considering the sustainability level of their suppliers.

7.5.1 Additions based on analysis of frameworks

People

The 'People' aspect appeared in two of the analyzed frameworks. In Butler's framework the 'people' aspect was quite elaborated, while in the SICT framework by Donnellan this

category was named 'People and culture' and only included 'Adoption' and 'Language.' Butler provided several arguments from several studies why the 'People' domain is necessary. One central statement from these studies is: *All technical and management decisions will come to nothing if the people in your organization are not on board.* This means, on all aspects of Green ICT, the people dimension is the most important, because people will determine how all other dimensions are being handled. This is also evident in the structure of Butler's framework since the 'People' dimension points to all other dimensions with an arrow. Donnellan's framework, while not elaborating as much as Butler's framework, also mentions a common requirement concerning people. This is 'Accepting cultural change,' which is accepting the use Green ICT in the everyday work routine.
Since people are not considered at all in the SGIMM, this dimension will become an addition to the SGIMM, in a newly added section. The basis will be the components of Butler's framework which will be tested in the audit. During the ITS audit, it will be determined whether all these items will be included separately in the final new version of the SGIMM since for example, it is possible that while discussing 'Internal communication', 'Evaluation and reporting' is discussed as well indirectly, which makes this second construct redundant as a separate construct.

GHG emissions

During interviews, it was found that this concept can be implemented very broadly. Because of the focus of the SGIMM on IT and being a protocol designed to easily get a quick view on the sustainability of used IT, this will not be included in the model. Another argument is that most GHG emissions from IT come from the energy consumption (Fettweis & Zimmermann, 2008), which is already targeted at other constructs in the SGIMM. Therefore, this concept will not be included in the model as a separate concept.

Energy sources

As specified earlier, IT is a huge consumer of energy. When looking at the power consumption of IT, it is, therefore, important to not only consider this matter but also the production of energy. This factor will, therefore, be included in the model. This will be done by looking at the energy sources of the energy supplier (solar, wind, oil, coal, etc.) and the production methods. Interviewees stated that this concept could be implemented very broadly since UU does not have control over all energy sources that its partners use or produce. Furthermore, it was stated that a factor in 'Housing' already dealt with energy sources. Therefore, it was decided not to implement this concept as a separate construct in the SGIMM.

Extra waste caused by IT

Two frameworks analyzed considered the extra waste produced when using or procuring IT, like the packaging, batteries, paper, etc. Although the SGIMM already does include a section

'Paper reductions with ICT', it does not contain paper in the form of waste. According to Butler, packaging is becoming more and more regulated due to its contribution to GHG emissions. During interviews, it was stated that there was a bit of doubt adding this concept as a construct to the SGIMM since it was unknown how people would think about this issue. Therefore, it was decided to test this concept in the form of a construct during the audit in ITS. If it is deemed to be valuable during discussion, it will be added to the final version of the SGIMM. Packaging and other forms of waste will, therefore, be included in the new version of the SGIMM.

Green standards and metrics

It was stated during interviews, that it is hard to cover this subject completely in the SGIMM, due to a significant amount of exceptions possible. However, according to the interviewees, it is an important topic, mostly in the form of reporting. It was also suggested that this concept is added in a separate tab on the Excel sheet with more explanation about this concept and suggesting that it should be used for measuring all kinds data that are relevant for greening ICT. This concept will be added in the future, but it will require a more expanded investigation to determine *how*.

Green production of IT systems & Green design of IT systems

Since UU does not produce their IT systems, these dimensions do not need to be added directly to the framework. However, it can be added *indirectly* through the clauses proposed by SOMO. This means that when procuring ICT, sustainable criteria in the procurement contract enforces a sustainable production method for the manufacturer and supplier. Furthermore, these issues are handled in 'Supply Chain Management' and were suggested to become part of an information tab to describe 'Supply Chain Management' in more detail.

Green Datacenters

Uddin & Rahman already stated that data centers are a huge consumer of energy (2012a). This was also found during interviews when interviewees said that the data center of UU is a huge consumer of electricity. They also expressed a desire for the protocol to be able to express the maturity level of the used data center. Based on these two arguments, the data center will, therefore, be included in its own section. During interviews, it was discussed that it could be an addition, but currently, the model is not fit for it due to its focus being more on the concept side. However, for the future, it was deemed to be a possible valuable addition to the model if a section were to be included that would be structured to focus more on the processes aimed to green ICT.

Shorten refreshment time of IT

During interviews, it was mentioned that this was mostly done in financial administration. Although this is a desirable issue to include to be up to date with sustainable technologies, it

is important also to include criteria about what is done with the *old* computers. However, it was also stated that this issue is too small to include as a separate concept since it is also contained in the factor 'asset management'. Therefore, this concept will not be included in the SGIMM.

CSR

Due the earlier found literature about CSR that it is a very hard concept to define, since it as different interpretations. It is, therefore, problematic to put it in the model. This concept could be interpreted differently across the various organizations or even different people in the same organization, which would lead to a misinterpreted maturity level. This adds no value to the model, the maturity levels and the resulting actions defined based on this data. The interviews resulted in the same argumentation that it is a concept which is very hard to give a common definition. Another possibility was introduced by interviewees, which was being transparent by reporting on its business practices. With this view, an organization reports on its business practices to be sustainable from a social perspective. It was stated, that 'transparency' could be included in 'Green ICT strategy' as a new factor since it is too small to be a separate factor.

Data center specific technologies

This construct will be processed in the separate section for data centers.

Categorization of data centers

This construct will be addressed in the separate section for data centers.

Planning

This construct will be processed in the separate section for data centers.

Equipment for processing waste

During interviews, it was stated that this addition would be too complex to include in the SGIMM. Since organizations often deliver their waste to other companies, having no equipment and being at maturity level 1 would give no insight into where a company wants to go with their maturity level. It was also mentioned to be something that will be discussed in E-waste Policy, and therefore it is not a valuable addition to the SGIMM.

Product take-back

During interviews, it was stated that it would be most optimal if this is fixed during the procurement process. This section will, therefore, be added in 'ICT procurement.' However, it will not be stated as something mandatory, since computers can be disposed of in other ways as well other than returning them to the supplier. For example, they could be delivered

to a company that has a business model focused on collecting and recycling old ICT equipment. This can be seen in the construct 'E-waste policy', which describes 'responsible disposal.' Since it is already included in 'E-waste policy', it will not be a separate concept.

Software architecture

This aspect appeared in the 'Envirability' framework. Although it is quite an interesting concept to look at, it is not fit for the SGIMM, since adapting algorithms and software architecture would require UU to maintain extensive contact with their software suppliers or their own programmers to adjust the software architecture. During the interviews, it was also found that this issue is very interesting but very hard to implement. It is, therefore, more suited for an independent project, which could focus on how to buy sustainable software. Since the SGIMM is designed to be easy to use and concentrate on quick wins mainly, this dimension will not be added to the SGIMM.

Addition of clauses

The addition of this concept is based on the work of SOMO and several interviews.
SOMO is an independent, not-for-profit organization focused on social, ecological and economic issues related to sustainable development. One of their current focuses as of April 2016 is 'sustainable procurement,' which is an extensive dossier on their website. In this file, several papers describe issues on sustainable procurement in a very broad sense. One paper focusses specifically on sustainable procurement in IT(Slob & Steinweg, 2009). One of the factors that are extensively discussed here is the addition of 'sustainable criteria' in a procurement contract. A 'sustainable criteria' describes criteria in a procurement contract that for example an IT supplier has to conform to for the acquisition to continue. These criteria can be specified in several domains considering sustainable development, like production, waste, working environment, etc.. Some examples that can be included in a contract:

- Packaging should be made of a material that can be recycled.
- The products must have an energy-saving function.
- No child labor is involved in the production of the products.
- GHG emissions during production should not exceed x tons of CO^2
- If the supplier does not stay below 1000 tons of carbon dioxide emissions, a fine of 1000 euros will be sent to the vendor.

It can be seen here that adding sustainable criteria in a clause can cover a broad range of issues. They can aid in helping an organization only procuring sustainable products and therefore, enforcing other organizations to satisfy the specified criteria. Because of this issue, the SGIMM will be expanded to include sustainable criteria in contracts as well. This will be added in the following sections:

- **ICT procurement**
- **Energy sources**
- **Software and ICT services**

- **E-waste policy**

The statements in the SGIMM will be structured like this:

- **Level 3**: Adding sustainable criteria in clauses are part of discussions and are considered when procuring. Sustainable behavior is a factor in choosing a supplier.
- **Level 4:** Adding sustainable criteria in clauses are part of discussions and are considered when procuring and preferably also are part of the procurement contract. The sustainable behavior of external parties is a relatively important factor during procurement.
- **Level 5:** Adding sustainable criteria in clauses are always discussed and are preferably part of the purchase contract. Sustainable behavior is a critical factor when choosing a supplier.

During interviews, opinions varied about this subject, but interviewees mostly agreed on the matter that it would not be possible to structure sustainable criteria so that sustainable behavior becomes 'mandatory' because it would lower potential suppliers considerably. However, it is possible, when starting tender, to say that sustainability is a vital factor in the process of choosing a provider for a certain product or service. Furthermore, it is up to a company, to define which factors in sustainability are important for them. To truly determine the best factors for optimal sustainable initiatives by the supplier, it is best to start a separate project for this with possibly an external consultancy firm.

8 Improving the SGIMM

8.1 Maturity levels for the constructs

This section will contain the defined improvements for the SGIMM, which were discussed in the previous chapter. This section will specify the newly added components and the changed components, based on literature and interviews. The maturity levels will be based on the SICT-maturity model (Curry & Donnellan, 2012). These maturity levels are based on the maturity levels of the general Capability Maturity Model (Team, 2002).

The maturity levels of the SICT-maturity model have the following descriptions, as defined by Curry & Donnellan:

- **Level 1 - Initial (Chaotic)**: Implementing sustainable ICT is ad-hoc. There's little understanding of the subject and few or no related policies. Accountabilities for SICT are not defined and SICT is not considered in the systems life cycle.
- **Level 2 – Basic:** There's a limited SICT strategy with associated execution plans. It is largely reactive and lacks consistency. There's an increasing awareness of the subject, but accountability is not clearly established. Some policies might exist but are adopted inconsistently.
- **Level 3 – Intermediate**: An SICT strategy exists with associated plans and priorities. The organization has developed capabilities and skills and encourages individuals to contribute to sustainability programs. The organization includes SICT across the full systems life cycle, and it tracks targets and metrics on an individual project basis.
- **Level 4 – Advanced:** Sustainability is a core component of the IT and business planning life cycles. IT and business jointly drive programs and progress. The organization recognizes SICT as a significant contributor to its sustainability strategy. It aligns business and SICT metrics to achieve success across the enterprise. It also designs policies to enable the achievement of best practices**.**
- **Level 5 – Optimizing:** The organization employs SICT practices across the extended enterprise to include customers, suppliers, and partners. The industry recognizes the organization as a sustainability leader and uses its SICT practices to drive industry standards. The organization recognizes SICT as a key factor in driving sustainability as a competitive differentiator.

These descriptions will be used to create new sections and add/change existing sections.

8.2 Additions to the SGIMM

People

The people aspect was considered to be a valuable addition to the SGIMM. The people aspect will be a new separate category in the SGIMM, since, in Butler's model, it is also structured in such a way and specified as a crucial aspect in greening ICT in an organization. Out of Butler's investigation, the following items were considered necessary, which will be added to the SGIMM: *Training & Participation, Commitment Mechanisms, Internal communication, Incentives/recognition* and *Evaluation/Reporting & Roles/activities.* The commitment mechanisms are based on another paper of Butler (2003).

Each construct will have the following definition, along with the following specified factors:

- **Training & Participation**: Employees are trained in using IT sustainable and are actively involved in greening IT in the organization.
    - ***Factors:*** *Training employees; participation activities; awareness*
- **Commitment Mechanisms**: Employees are committed to greening the IT infrastructure in the organization.
    - ***Factors:*** *Commitment by imperatives, Commitment by social character; Commitment by institutionalization; Commitment by social and cultural environment; Commitment by centers of interest*
- **Internal Communication**: Employees communicate with each other concerning the implementation and use of Green ICT in the organization.
    - ***Factors:*** *Meetings, E-mail, Discussions*
- **Incentives/Recognition:** Employees receive recognition and incentives for their contributions to using and implementing Green ICT in the organization.
    - ***Factors:*** *Salary bonus; awards; privileges*
- **Evaluation/Reporting**: People evaluate and report on utilization and implementation of Green ICT in the organization.
    - ***Factors****: Reports; discussions; meetings; sessions*
- **Roles/activities**: Employees have clear assigned roles/activities concerning the use and implementation of Green ICT initiatives.
    - ***Factors:*** *Roles; Activities*

Data centers

During interviews, it was found that the data center of Utrecht University is, like other data centers according to literature, a huge consumer of energy. Therefore, a separate section would be a possible inclusion in the SGIMM in which organizations can evaluate the improvement process that is in place for greening the IT infrastructure of the organization, for example for greening data centers. This is not in the scope of this project, however, since this will take more time than is available to specify this section.

Extra waste caused by IT

This construct is added in the section 'Greening of ICT'. It has the following description and factors:

- **Extra forms of waste by IT:** The processing of the extra waste caused by procuring, using and disposing of IT.
    - **Factors:** *Packaging; batteries; gas; waste destination; Sustainable criteria in clauses*

8.3 Changes to the SGIMM

Green ICT Procurement

A small addition is made in this section focusing on maturity level 3, 4 and 5. It involves the possible addition of sustainable criteria into clauses with the following additions:

- **Level 3** Adding sustainable criteria to clauses are considered and are mentioned during procurement
- **Level 4:** Adding sustainable criteria to clauses are part of negotiations. Sustainable behavior is a relatively important factor during procurement and for choosing a supplier
- **Level 5:** Sustainable behavior is a crucial factor in procurement. Sustainable criteria are very much preferred for being part of the acquisition contract.

Note that these statements will not contain information on how to these sustainable criteria are best constructed, because of the focus of the SGIMM, which is to provide an organization with quick insight into the Green ICT maturity level. For information on how these sustainable criteria are best constructed, the papers of SOMO on sustainable procurement can be read[2].

Product take-back

This issue is mentioned in maturity level 3, 4 and 5 of the construct 'E-waste policy'. During interviews, it was decided not to make the statement in the SGIMM mandatory for sustainable criteria to include product take-back, since there are also other sustainable options that can be used to dispose of ICT equipment, like selling or donating it to an organization that has a business model to recycle ICT equipment. Again, no information is provided on how to construct these sustainable criteria.

[2] A link to the web page: http://www.somo.nl/themes-en/sustainable-procurement

8.4 New version of the SGIMM

The new version of the SGIMM is presented in Figure 8-1. The adapted constructs are recolored with a slightly darker green than the original constructs, while the new constructs are colored dark green. The new section 'People' has a dark green column along with green constructs.

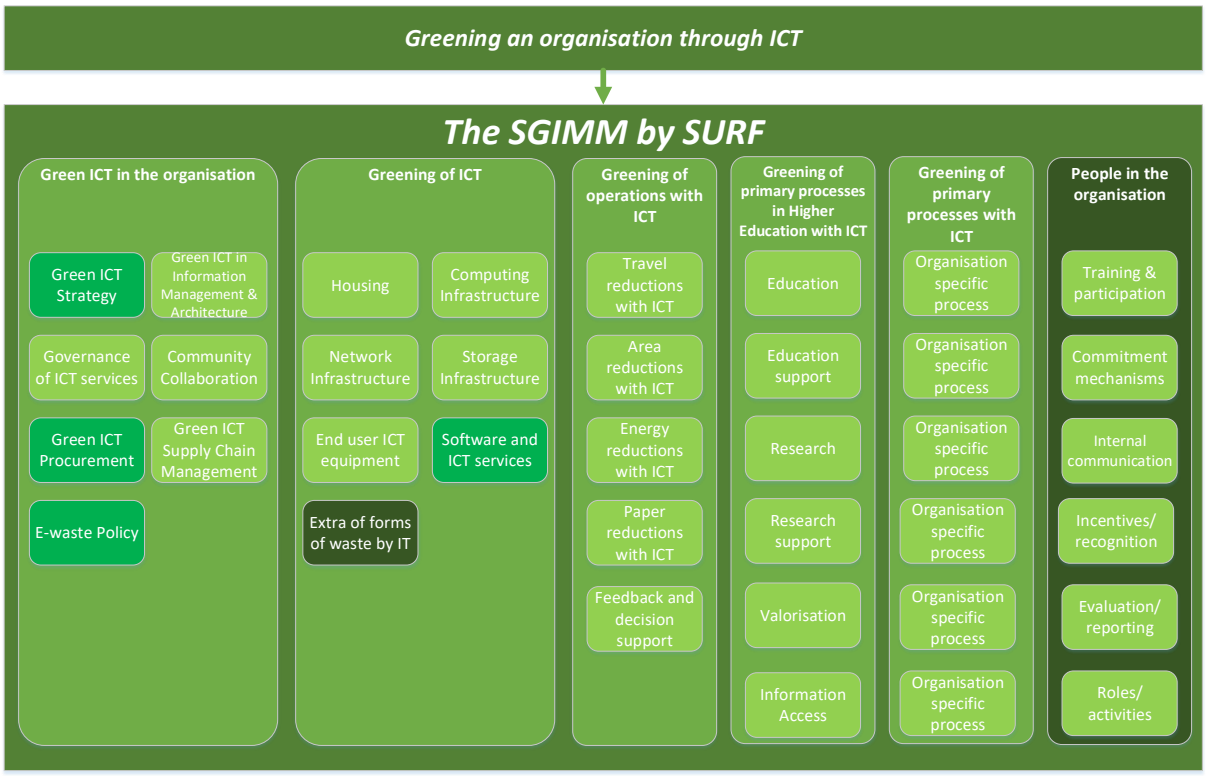


FIGURE 8-1: IMPROVED SGIMM

It can be seen that most changes have occurred in more general issues and the greening of ICT. No changes have taken place in 'Greening of operations with ICT' since no valuable additions were found for this section. It is not surprising that no additions were found for 'Greening of primary processes in higher education with ICT' since no frameworks were analyzed that had a primary focus on education.

9 Audit in the ITS department

This section will contain information about the organizational structure of UU to sketch the context of the problem and to determine what improvements and additions should be made to the current SGIMM to make it valuable for UU. After this, the results of the audit will be presented. The enterprise models will be made in Archimate 2.1 (Josey, 2013), due to earlier experience with this modeling language. Archimate is an enterprise modeling language that can be used to model different aspects of an organization in an unambiguous way, like business functions, actors and technical infrastructure.

First, a complete overview of UU will be given; then the focus will shift to the Information and Technology Services department, which is where the audit will be executed. All data presented here is based on documents from UU.

9.1 Profile of UU

Utrecht University is a large research based university in Utrecht in the Netherlands. It presents itself as a university that offers education and research of international quality. It has specified the following goals:

- To develop young people academically.
- To educate new generations of researchers.
- To educate academics who combine knowledge and professional skills.
- To conduct ground-breaking research.
- To contribute to solving issues in society.

UU focuses its research on four strategic themes:

1. **Dynamics of youth**: research into development of young people in a rapidly changing society
2. **Institutions for open societies**: How do institutions – the formal and informal rules of human action – contribute to long-term prosperity, equality and democracy.
3. **Life Sciences**: Research into infectious diseases (including those transmitted from animals to humans) and chronic diseases such as cancer and cardiovascular diseases that pose major social problems that demand new medicines and technologies.
4. **Sustainability**: UU makes an active contribution to sustainability by sharing academic knowledge and by providing an inspirational example for others.

This thesis will aid UU in becoming more sustainable in more ways by:

1. Delivering a contribution to academic knowledge.
2. Aiding UU in creating an action plan to improve sustainability.
3. By improving sustainability, UU can be an inspiring example for others.

9.2 Structure of UU

UU is organized with two layers of governance: one central management and management for each of the service departments and faculties. The overall structure can be seen in Figure 9-1.

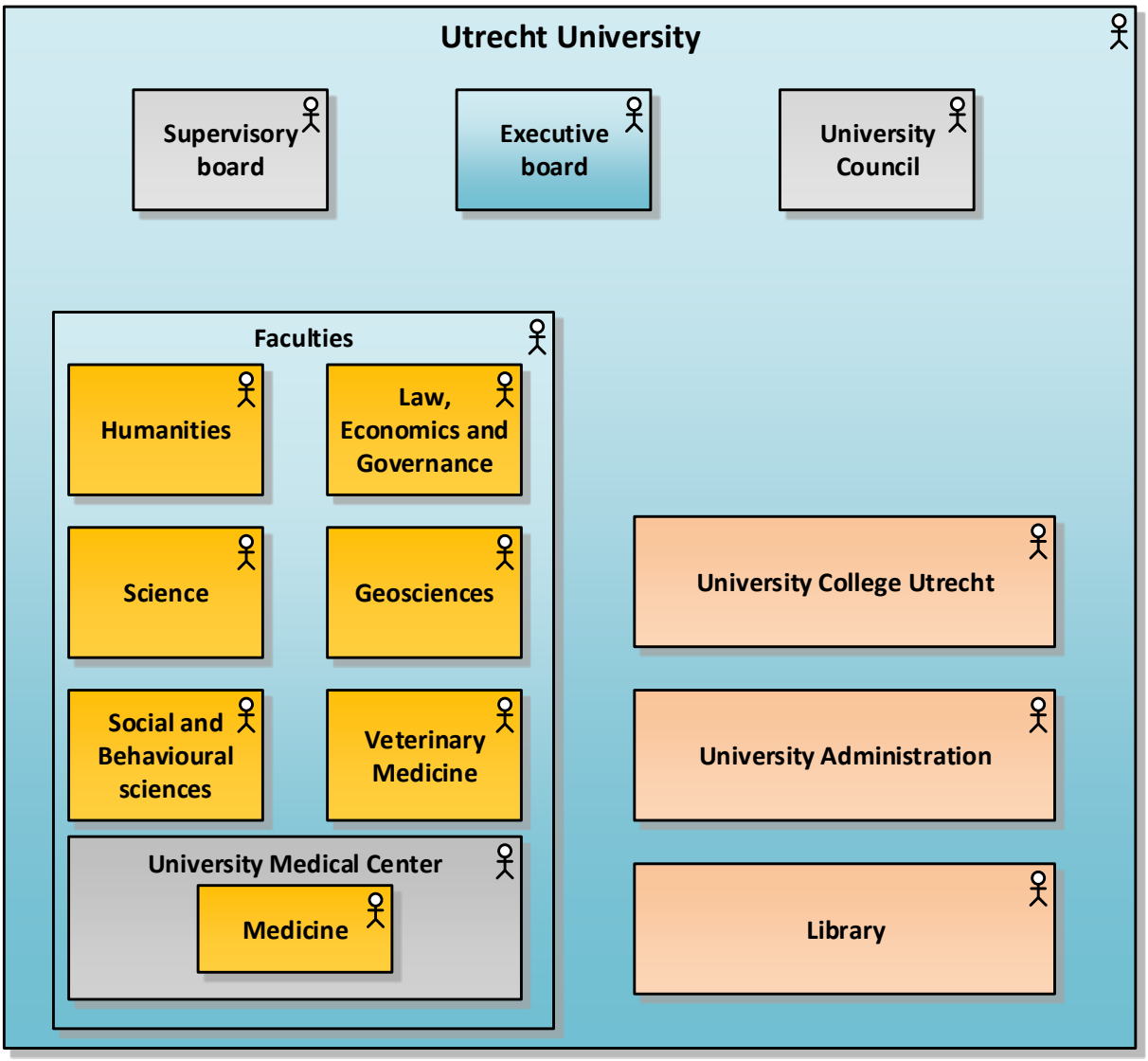


FIGURE 9-1: STRUCTURE OF UTRECHT UNIVERSITY

The components will now be explained in short.

Supervisory board: this is the supervisory body of Utrecht University. The Executive Board requires approval from the Supervisory Board for its Strategic Plan, Annual Report and the Annual Accounts.

Executive board: The highest administrative body within UU. The supervisory board assigns its members.

University Council: The University Council is an elected advisory board representing all staff and students of Utrecht University. The Council has 24 members: 12 staff and 12 student

members. The University Council has regular meetings with the Executive Board about topical issues which it has statutory authority to advise upon

University College Utrecht: University College Utrecht offers a three-year bachelor program in Liberal Arts and Sciences.

University Administration: This component consists of the University Corporate Offices and The University Library (the physical library). The Corporate Offices consist of nine departments in total that support UU in its daily business practices.

Faculties: Each faculty provides education and conducts research in a specific domain.

Library: The collection of all information UU has access to.

The audit of this thesis will be conducted in one of the departments of the University Administration, which is the Information and Technology Services (ITS) department. An overview of the entire University Administration can be seen in Figure 9-2.

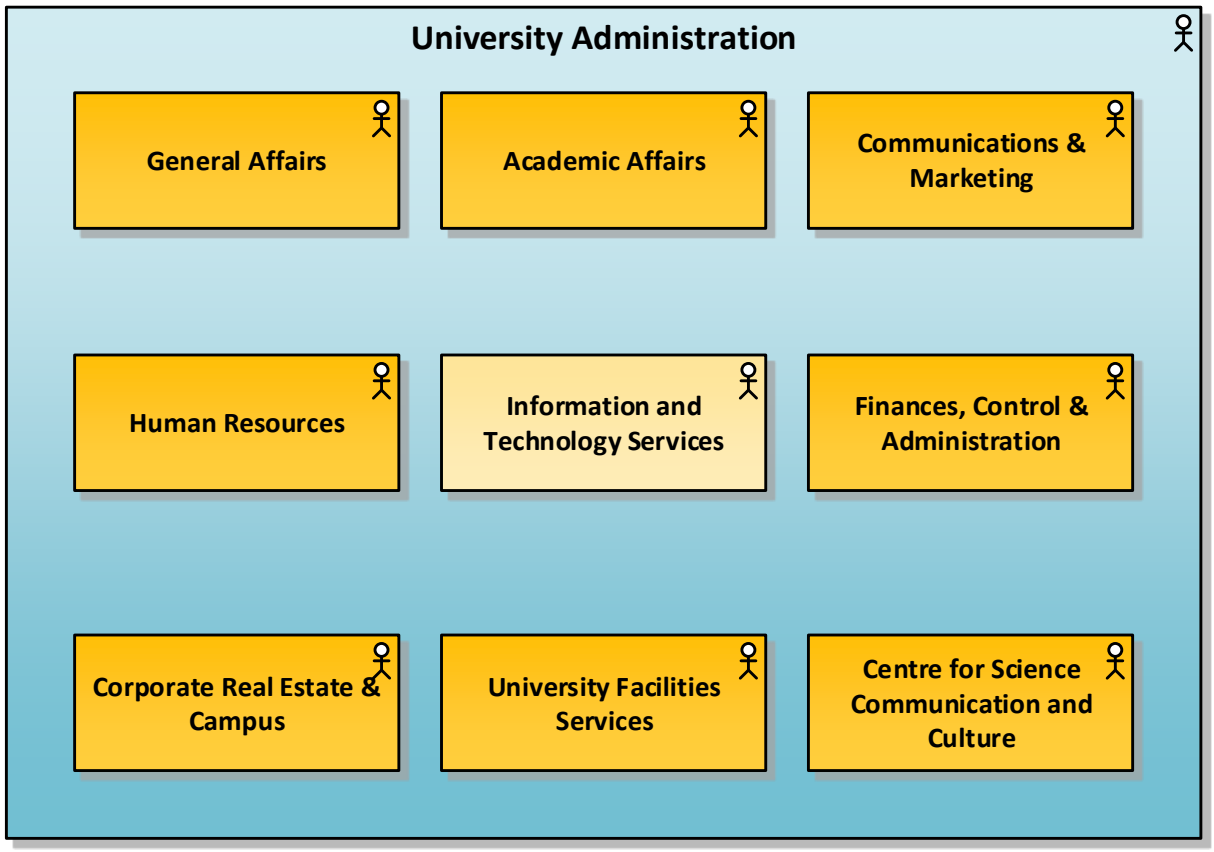


FIGURE 9-2: OVERVIEW OF DEPARTMENTS OF UU ADMINISTRATION

The ITS department is colored differently to sketch where the audit will be conducted.

9.3 The ITS department

This section will contain more information about the ITS department and why it has been chosen as the target for the audit. Due to time constraints, the audit will not be conducted in all departments of UU. Also, since we know some people from the ITS department, we can easily contact people within the ITS department for interviews. Finally, since the ITS department manages a great deal of IT used in UU, it can provide us with a lot of relevant data needed for the sustainability audit.

The ITS department advises the Executive Board on investment in the architecture and use of IT systems. It also formulates the framework of corporate IT policy and is responsible for the program management of IT investment and innovation. Also, the ITS department provides basic IT services for staff, students and visitors of UU; management of UU network infrastructure and finally, management of IT systems for the benefit of operational management.

The ITS department has the following mission: "*Providing a professional IT community for students, lecturers/researchers and other staff members that allow them to perform optimally.* "

There is a focus on:

- Customer focused orientation.
- Management and innovation.
- Reliability and quality.
- Guarantee the safety of UU data.

The ITS department has several extra core values besides the core values of the UU. These general core values are ambition, inspiration, involvement and independence. The ITS department includes the following extra core values: transparency, expertise, collaboration and being a learning organization.

The ITS strives for delivering a solid infrastructure to UU, while also delivering proactive advice to all users in UU. The ITS tries to align the business and IT to the most optimal way possible. They describe in their domain plan that they see that IT will move from the back office to the frontline in the coming years. About ten years ago, the decision was made to centralize the IT support of UU into one central organ. Because of this decision to centralize most IT services into one department, the auditing protocol is most relevant for the ITS department.

9.4 Business functions of ITS

ITS has several business functions that it performs, which can be seen in the model in Figure 9-3. A business function is described as '*a behavior element that groups behavior based on a chosen set of criteria (typically required business resources and competencies). A business function may be triggered by, or trigger, any other business behavior element' (Josey, 2013).*

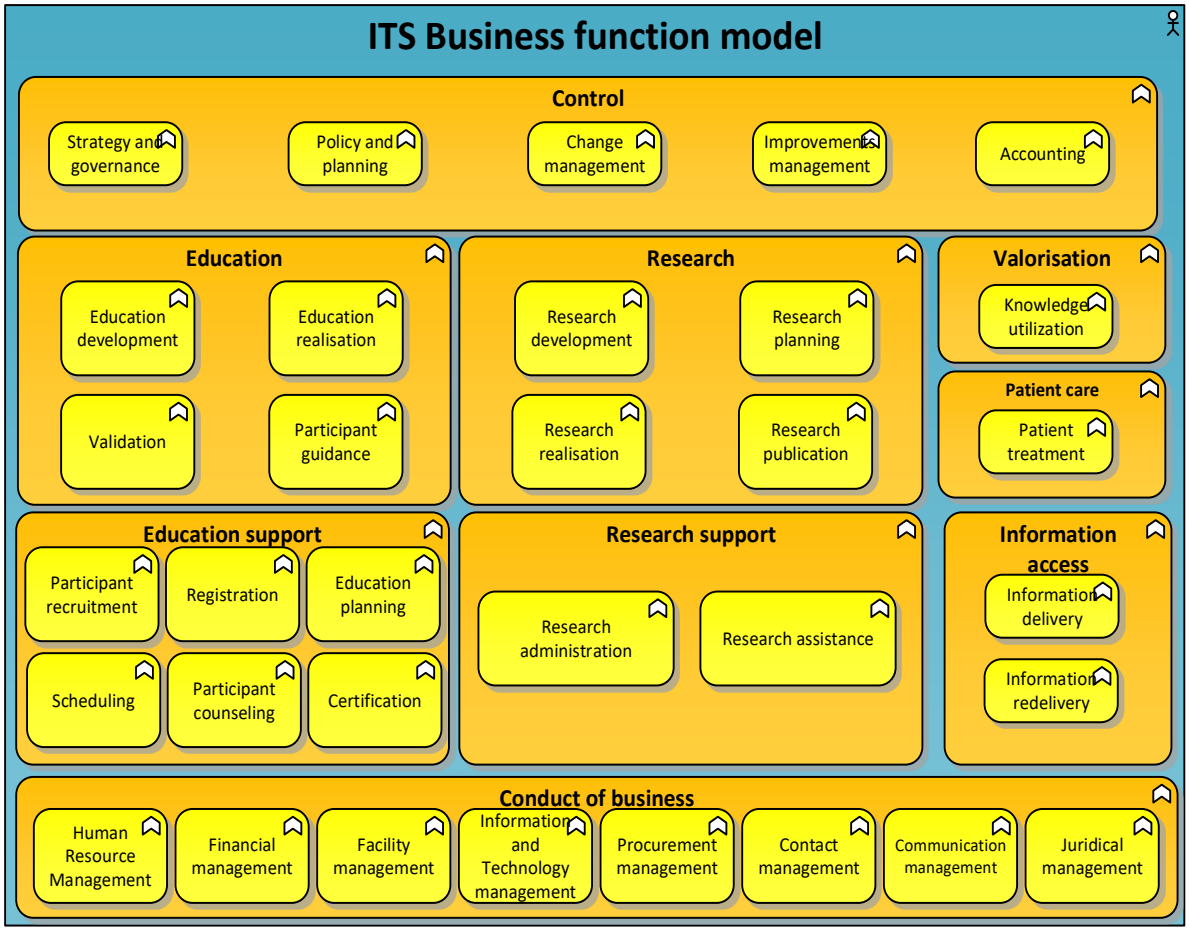


FIGURE 9-3: BUSINESS FUNCTIONS OF ITS DEPARTMENT

It can be seen here, that the business functions in 'Education,' 'Education support,' 'Research,' 'Research support,' 'Valorisation' and 'Information access' are very similar to the constructs which are already present in the SGIMM. Therefore, the focus of specifying constructs which are unique for ITS will not be on these aspects, but more on aspects related to 'Control' and 'Conduct of business.' However, if business issues related to one of these six constructs are deemed to be a valuable addition to the ITS version of the SGIMM, it will still be added to the model.

9.5 Structure of the ITS department

The ITS department recently has had an overhaul and is currently structured as the model in Figure 9-4. below shows. The information was gathered by an interview with two employees of UU and by scanning a few documents concerning the structure of the ITS department. By analyzing this structure and interviewing the employees, the constructs will be defined for the SURF model which will be used in UU.

The following main actors are defined: Strategic, Applications, Infrastructure and Administration. Applications, Infrastructure and Administration each have a few sub-departments.

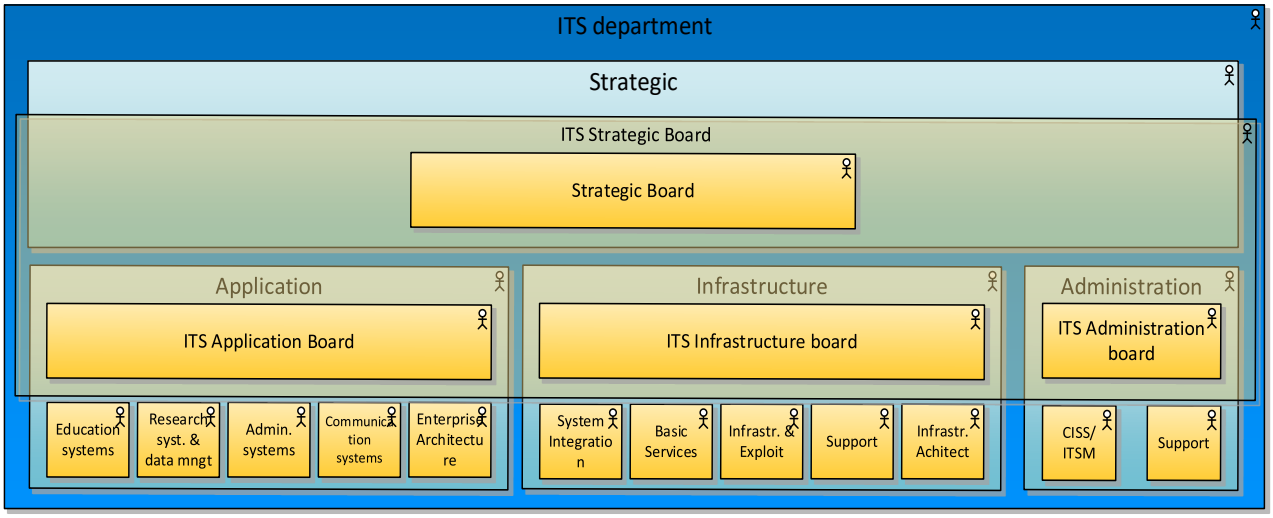


FIGURE 9-4: STRUCTURE OF ITS

Application

- ITS Application Board
- Education Systems
- Research systems & data management
- Administrative systems
- Communication systems
- Enterprise Architecture

Infrastructure

- ITS infrastructure board
- System integration
- Basic Services

- Infrastructure Exploit
- Support
- Infrastructure Architecture

Administration

- ITS Administration Board
- CISS/ITSM (CISS = Contract Management, Procurement Management, Service Level Management Software management, ITSM = IT Service Management)
- Support

The board members of each main actor form the ITS Strategic Board together, which focuses on strategic issues concerning the entire ITS department. Each of the actors in this list can co-operate with other actor and can consist of one or more persons. The ITS will be discussed in more detail on the specific constructs that will be used in the SURF model.

9.6 Tuning the SURF model to the ITS department

This section contains the results of the interviews and the resulting constructs that will be added to the SURF model for the audit. First, the potential constructs will be discussed. These were found by analyzing the description document of ITS as found on the website of UU[3]. They were defined by looking for general issues focusing on issues like products, procurement, meetings and main goals of the ITS department. The following potential ideas for constructs were defined.

Proposed constructs

- **Product matrix:** Involving the product matrix that is defined by ITS to determine the importance and value of goods. An example can be seen in Figure 9-5. The x-axis represents the risks of delivery while the y-axis represents the risks for the goals of UU. The leverage products in the matrix are variable regarding supplier and their procurement costs are not the most important issue. Therefore, sustainable factors can be incorporated in deciding which supplier to choose.

[3] http://www.uu.nl/en/organisation/information-and-technology-services-its/about, click on 'IT Strategic Plan'

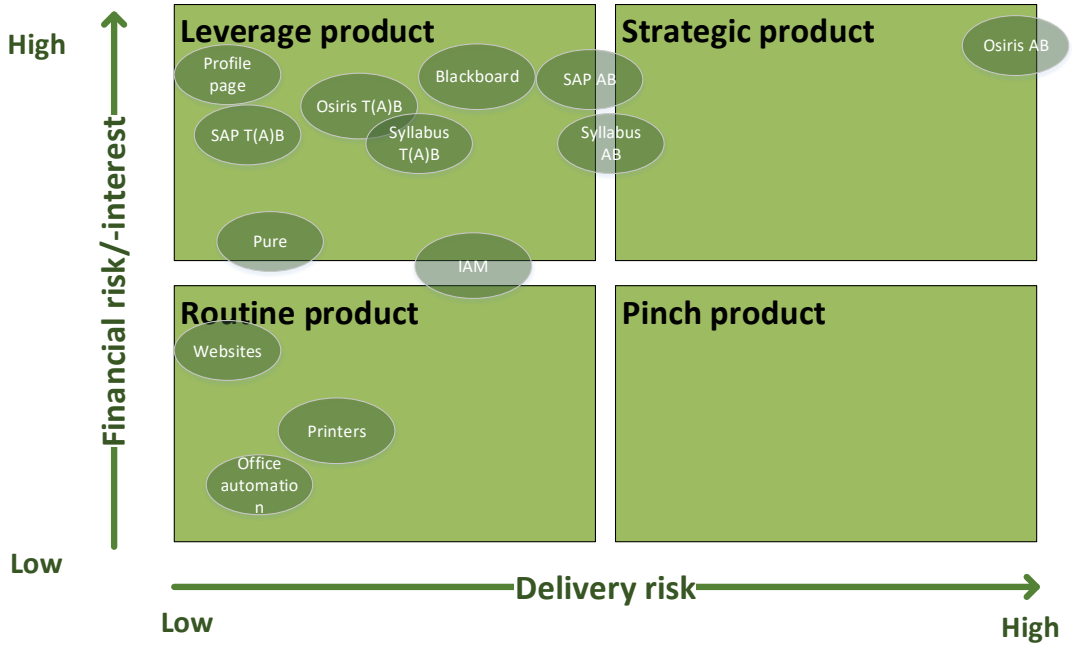


FIGURE 9-5: PRODUCT MATRIX USED IN ITS DEPARTMENT

- **Processing the mission of ITS into sustainable initiatives**: Based on the strategic plan of ITS, the mission involves:
    - Customer focused orientation
    - Management and innovation
    - Reliability and quality
    - Guarantee the safety of UU data.

  In executing these issues, it is possible to try to incorporate sustainability into it as well.
- **Discussing sustainability in standard meetings**: It could form a basis for including sustainable ICT in these meetings. Since ITS has several regular meetings during daily business practices, including sustainability as a standard subject, this could help ITS becoming more aware of sustainability in standard business processes. By reading the domain plan version 1.0 of ITS, the following meetings could involve sustainability issues, with the possibility to be extended:
    - All IT topics: Management Consultation (MO in Dutch) MO and IT consultation, Platform Information Management(PIM)
    - IT portfolios and projects: MO Directed Groups by theme, MO IT consultation and Project Portfolio Board (PPB) on all projects separately and about each other.
    - Information Plan and projects: domain present as the Network for Education and the
      controller talk
    - Functionality of an application: key user consultations, for example using SAP
    - ITS products and services catalog, service level reporting and centrally supported

applications on workstations: Demand Manager Consultation (DMO in Dutch)
    - Architecture, technical coherence and future-proof IT landscape architecture board
    - (ITS internal) , architecture consultation (ITS with faculties)
    - Changes, modifications to the systems change advisory board (ITS internally).
- **Including sustainability issues aimed at optimizing business processes related to IT**:
    - Including potential users to let them use the new possibilities. This can focus on sustainability itself or include it in the new solution.
    - Standardizing the new working approaches.
    - Cleaning redundant data and shutting down systems.
    - Providing high-quality data concerning sustainability.
- **Procurement**:
    - Sustainability is incorporated in the 'Utrechtse onderwijsmodel,' which describes the small-scale and personal education. This requires tools which have to be procured from a supplier.
    - Sustainability is incorporated in procuring tools for Communication and Marketing.

Results of interviews

These items were validated with two employees of ITS to determine if these items were fit for ITS and also if they did not overlap too much with the items already present in SURF to avoid redundancy. Furthermore, the two employees were asked to give their view on what items could be included in the SURF model for the specific items of UU.

- **Product matrix:** This construct was deemed to be valuable for being added to the SURF model. Both interviewed employees agreed on the fact that sustainability could be a valuable factor in choosing suppliers for the quadrant of 'Leverage products.' They also thought it would be valuable because most IT services are deemed to be leverage goods and therefore involving sustainability could influence choosing a supplier for probably at least a few of them.
- **Processing the mission of ITS into sustainable initiatives:** while discussing the four possible items, three of them were deemed to be fit for involving sustainability in them. The only one deemed not fit for including it in the SGIMM was the statement 'Guarantee the safety of UU data'. The reason for this is because UU will not lower the security of UU data if this means becoming more sustainable, safety will receive priority here above all else.
- **Discussing sustainability in regular meetings:** Including sustainability in the regular meetings of ITS mentioned earlier was deemed to be a good addition for the SGIMM. Currently, sustainability is not on the agenda in regular meetings of ITS and

these meetings are a good chance for discussing issues related to sustainability or even only making people more aware of it.

- **Including sustainability issues aimed at optimizing business processes related to IT**:
    - *Including new users:* This issue was deemed to be important for improving, but is expected to be very complex in reality because of people not willing to co-operate or not being aware enough and therefore this potential construct being impossible to improve regardless of improvement actions. It is therefore added in the SGIMM for the audit, but if it is deemed to be too hard to improve or coordinate, it will be removed.
    - *Standardizing business processes:* This issue was deemed to be a valuable addition to the SGIMM in the form of a construct that specifies how well sustainability is incorporated into standard business issues.
    - *The quality of the data:* This issue was deemed to be only relevant for data about sustainable issues itself, like energy consumption and what percentage of consumed energy comes from a sustainable supplier. However, this is already covered at the newly added construct: 'Green standards and metrics.' Therefore, this issue will not be added separately.
    - *Information security and privacy:* This issue will not be incorporated in the SGIMM because as mentioned earlier, ITS will not lower security to become more sustainable.
    - *Cleaning redundant data and shutting off systems when not in use:* This statement was deemed to be valuable because the interviewees thought this is an issue that can be improved very easily but is still not done properly in the current situation. It was believed to be an excellent 'quick win.'
- **Procurement:** The issues mentioned here were cited to be valuable additions, but are part of the constructs 'Procurement' and 'Software services' which are already part of the SGIMM and are therefore not necessary additions to the SGIMM.

There was one extra construct proposed by the interviewees themselves. The construct suggested was:

- **Sustainable procurement criteria:** It was mentioned that sometimes during procurement sustainable issues are not incorporated in the acquisition process because of management 'fears' that there will be no suppliers who can provide the services if the proposed sustainability issues are integrated into a requirement for the service or product procured. The proposed construct was that, should a sustainable requirement be decided to be left out of the procurement process, it has to be motivated by (proven) arguments, else the sustainable requirement may not be left out of the total list of requirements.

Constructs

Based on the results of the interviews, the following constructs are defined:

ITS product matrix – leverage products: The extent to which sustainability is included in the procurement process of goods that are labeled as 'Leverage product' in the product matrix used by ITS.

- **Factors:** *Meetings; Product requirements; Procurement; Supplier*

Sustainability in the mission: The extent to which sustainability is incorporated into daily practices that involve one of the following core mission of ITS:

- Customer focused orientation:
  - **Factors:** *customer relationship management; support; customer collaboration; customer teams.*
- Management and innovation
  - **Factors:** *Innovative sustainable technologies; innovative projects; Management decisions.*
- Reliability and quality
  - **Factors:** *sustainability-related data; standards and metrics.*

Sustainability in standard meetings: The extent to which sustainability is discussed and included in actions during standard meetings which happen in ITS:

- **Factors:** *Meeting agenda; actions; future planning.*

Sustainability in optimizations of business processes:

- Including new users when new IT is implemented or existing IT is changed.
  - **Factors:** *user awareness; user training; knowledge sharing; user requirements.*
- Standardizing business processes to include a sustainability component.
  - **Factors:** *process documentation; employee training; awareness.*
- Cleaning redundant data and shutting off systems when not in use.
  - **Factors:** *Data storage; percentage utilized equipment and data; shutting systems off.*

Argumentation for blocking sustainable procurement: the extent to which argumentation is provided when sustainability issues are not implemented in the procurement criteria.

- **Factors:** *Argumentation; documents; compromises; proof.*

9.7 Results of the audit

The audit was conducted with three employees at the ITS department. The following goals were determined for this audit:

1. Identifying possible improvements for quick wins that can be easily be implemented in the ITS department.
    a. This is the main goal of the audit. This will allow ITS to identify some quick wins that can easily be implemented.
2. Training ITS into using the protocol
    a. If some people are familiar with the protocol, it will be easier to use it again employees are available for performing the audit.
3. Testing the new constructs that were specified in the initial improvement.
    a. There were some doubts about some new constructs related to redundancy. If it is noticed that some constructs result in the same information, they will be merged into one construct.

Due to a busy schedule of the participants, the session was planned for 1,5 hours. Therefore, it was decided to focus on key areas of SGIMM, along with discussing the specific constructs that had differing scores between the participants. This was done to find out why they had filled in different scores and what caused this.
At the start of the session, the participants were asked about their overall opinion of filling in the model.

The participants of the audit stated the following:

- It was a good experience to think about different aspects of Green ICT really; it helped to raise awareness about the various aspects of Green ICT as a concept and in the specific situation of UU. It showed that in the current situation, there is much room for improvement since the scores were rated quite low.

For each domain, the results will be presented here in short.

Green ICT in the organization

The average maturity level given here was 2. During discussions, it was mentioned that these differences were caused by different interpretations of descriptions in the model. Overall, the conclusion was that the maturity level should be 2, which matched the average maturity level. The items that were discussed here had the following overall description: they were described a little bit, but not much or were only implemented ad hoc. The discussion was the most interesting about the strategy. ITS overall follows the main strategy of UU, but ITS itself only has a strategy on the management levels and it is not known if this contains Green ICT. Currently, the participants thought this was not the case.

Greening of ICT

The average maturity level given here was two as well. The most interesting construct here was the construct 'Housing.' Since ITS outsources the housing of most of its servers to a company concerned with sustainability, one of the participants rated this with maturity level 5. The other participants rated this with two since the housing by ITS itself is not being done sustainable. The other constructs of this domain had a score that was mostly 1 or 2, with sometimes 3. One of the arguments by one of the participants for rating the constructs so low was that even if a construct was 2 or 3, it was believed that this was more caused by coincidence than actually being part of standard business processes. The participants agreed that the average maturity level of most constructs was 2 with the comment: there is some work on sustainability, but not consistently, even if the current practices match maturity level 3, this is mostly caused by coincidence.

Greening of operations with ICT

This was the third area with maturity level 2 on average. There was some discussion on what the average maturity level should be since according to the participants, the constructs presented here are being implemented, but only because of organizational demands (matching maturity level 2 in the SGIMM). Furthermore, for feedback and decision support, data was used minimally, matching level 2 as well. However, since some data is only collected through student projects, one of the participants argues it should be maturity level one since it is not done structurally. The data is there, but it is mostly not used, only on demand. For paper reduction, ITS delivers some services (maturity level 3).

Greening of primary processes in higher education with ICT

This field scored pretty low overall (1,3 on average). ITS does provide some services to education through Blackboard and such, but hardly with the focus on sustainability. If a process becomes greener, this is mostly coincidental. For research, it was mentioned that faculties probably are not prioritizing the greening of ICT. Therefore, ITS is barely involved in greening processes here since greening does not often happen if any at all. The same happens for valorization and information access. They stated that they thought that people are probably not interested or aware enough of sustainability for ICT and therefore never invest any time in it. Furthermore, making ICT more sustainable currently has no priority in UU.

People in the organization

This field scored pretty low, along with the previous category. The average maturity level of 'People' was 1,4; meaning that most maturity levels assigned were 1. The participants also stated that the low score overall for ITS originates from this domain. Two participants were concerned with sustainability, being assigned as sustainability-supervisor and were also, according to them, the only ones who actively busy with this issue. Currently, only a small amount of employees is participating in sustainability initiatives. This is caused by

sustainability not being on the priority list and therefore many people (both management and employee level) are not involved in Green ICT initiatives.

ITS specific constructs

This section scored a maturity level of 1,7 overall. It was mentioned here again, that since sustainability is not a high priority currently, most items mentioned here do not include sustainability or only to a minimal extent. It is also not discussed often, as most employees of ITS want to focus on other issues. Although they would not mind sustainable initiatives being implemented, they do not want it to be implemented at the cost of something having a higher priority. ITS currently intends to focus on innovation and therefore sustainability is not considered usually. The only exception in this section were leverage products, in which sustainable issues are already considered to some extent (maturity level 3).

Improvement actions for ITS

At the end of the session, it was discussed what the best actions would be based on these results. The participants agreed on the facts that currently, it would be best to improve the domains 'People' and 'ITS specific.' They believed that starting here will eventually lead to improvement of other fields as well. The following actions were proposed:

1. **Sustainable procurement**: This was mentioned by one employee whose primary function was related to procurement. Even though sustainable criteria were already implemented to some extent during procurement (related to 'leverage products'), it was mentioned that there still were more opportunities to include sustainable criteria even more in the procurement of ICT.
2. **People & Strategy:** Since it was mentioned that the strategy of ITS was not clear for the entire department, a strategy should be defined for ITS and which role sustainability plays in this matter. This would help in making people more aware of what sustainability means for ITS. Even if sustainable initiatives on management level are not implemented due to a low priority, making people more aware could mean a start. For example, this would mean that people would more often switch off their computer at night or print less.
3. **Student projects:** It was proposed to initiate student projects to research the possibilities related to the different aspects presented in 'People.' The participants agreed that this could help present plans for improving the maturity level on these different aspects. Some ideas proposed were related to gamification and serious gaming for example. They believed that if a higher maturity on 'People' would reach, the rest will follow eventually.

It was not specified when the next iteration of the SGIMM would be performed; this would be dependent on when the new projects were finished.

Opinions on the new SGIMM

Reactions to the SGIMM, in general, were quite positive by the participants since it made them aware of their current practices concerning Green ICT and they also believed the model could help making other people more aware of Green ICT. Furthermore, they also stated it did not cost them too much time to fill it in. One of the issues was that the session for discussing the results could take a while, which makes it hard to find a fitting date and time. This was also noticed during the session since 1,5 hours was pretty tight and it was only barely managed to discuss all relevant items. Furthermore, it was not possible in this case to discuss all elements in detail. Still, some valuable actions were defined in the session.

The participants were quite positive about the new section 'People' since they believed this is a very important issue in greening ICT. The actions proposed from the session were also mostly aimed at improving the maturity in this domain to make it easier for other domains to improve as well. Unfortunately, due to the short amount of time in the session, we did not manage to discuss the length of the SGIMM and the value of the new constructs. To determine the value of each separate construct in 'People,' more research has to be performed to make sure no redundant items are present in the mod

10 Discussion & Conclusion

In this master thesis, the goal was to define an environmental auditing protocol for UU, and more specifically, the ITS department. To do this, we first discussed the concept of sustainability and how this regards to business and ICT. We have seen that sustainability has become an important concept for organizations in several ways, which is reflected in the three pillars discussed. Since ICT is a huge consumer of energy through its entire lifecycle and becoming more and more important for organizations in executing crucial business processes. Therefore, greening ICT is important for an organization aiming to become sustainable. We have also seen that ICT has another totally different side related to sustainability, which is using ICT to become more sustainable. This opens up a very interesting domain of research because ICT has two seemingly opposing sides when combined with the concept of sustainability. It would be very interesting to see to what extent ICT hinders a company to become more sustainable and to which extent it can help a company becoming more sustainable.

To define an auditing protocol for the ITS department, we have analyzed and compared several existing frameworks on Green ICT. With the aim to do this in a structured way, we constructed a comparison method in collaboration with Albert Hankel. This comparison method is aimed at comparing frameworks of a certain with each other to determine the conceptual differences. This was very relevant in the field of Green ICT since it is a relatively new field with a lot of inconsistent maturity models and frameworks concerning the important area's they include. Eventually, we decided to take the SGIMM as the basis of the auditing protocol for UU. With the intention to define a new protocol, the existing SGIMM was improved using the constructed comparison method to find out what concepts were missing from the model. Some of these missing constructs were inserted into the model which resulted in a new version of the SGIMM, the most important addition being a section aimed at 'People.' Furthermore, through interviews and documentation, the new SGIMM was provided with constructs specific for the ITS department.

The new SGIMM was tested in a small audit at ITS with three participants, to determine quick wins and introducing them to the SGIMM for future use. The maturity level overall was determined to be quite low because sustainability currently does not have a high priority or people are simply not aware of how they can contribute to more sustainable ICT. The opportunities were determined to be in the 'People' domain and the more business oriented domain, which is about increasing the priority for sustainability in new initiatives. Although this will not be an easy task, plans were proposed for letting students research the possibilities for improving the maturity level for the 'People' domain. The participants believed that once a higher maturity was reached in this aspect, the rest would be easier to improve as well. During the audit, the new SGIMM was received positively, with the new domain 'People' also receiving positive feedback.

Based on the overall results of the thesis, there are some possible follow-up projects. These projects will be aimed towards follow-up projects related to the new SGIMM, ITS and the comparison method.

New SGIMM

1. Test the new SGIMM in more situations to further define the 'People' domain.
2. Complete the explanation sheets explaining the constructs of the SGIMM in more detail.
3. Research on how to include Green standards and metrics in the model as a whole.
4. Research on how to include improvement processes in the SGIMM, focusing on processes that specify *how* to improve the constructs.

ITS

1. Improve the ITS specific constructs and keep them up to date.
2. Set up projects for students to determine how to improve the maturity of the 'People' domain, along with other relevant subjects from the model.
3. Start on projects to include sustainability in the strategy and raise its priority (possibly in combination with focusing on the 'People' domain).
4. Prepare for conducting an audit with more participants, and keep doing this on a regular time interval (phase 4 and 5 of the design science cycle).

Comparison method

1. Test the method in other domains then Green ICT, to test its generalizability.
2. Search for possibilities to further structure the 'Improve framework' phase, both in existing techniques and new techniques.

There were some difficulties during this project. First was due to a job starting in September, some tasks needed to shorten like doing interviews and the size of the audit. Furthermore, due to the short amount of time we had for discussing the audit, we did not manage to research whether the 'People' domain was complete or had unnecessary items. Therefore, there are some opportunities for future research and projects.
Another difficulty was that while writing the thesis, we also decided to propose a method used for comparing frameworks. We had some difficulty in separating the method from the case study because the method was first integrated into the research, and therefore we had to do much extra work in defining the method without any influence from the specific domain of Green ICT. This was needed to make the method applicable to more domains than sustainability.

Some limitations for this project were the limited amount of participants for the interviews and audit, which influenced the amount of valuable data for use. We decided to let the audit be a very general introduction to the audit with very generic recommendations, and we could not go into the details. To go into more detail, another audit needs to be facilitated with the objective to start a series of audits aimed to improve sustainability in IT at UU.

Overall, the comparison method proved to be effective for determining concepts that were not present in the SGIMM. Based on the acquired information from applying the comparison method, we added a new domain and one new construct and got three other ideas for future improvements. However, we think the improvement phase should be structured better, using techniques for improving frameworks. For ITS, the results of the audit can be a good starting point for future projects and give them a foundation for performing the audit in the future to see if anything has improved. The positive feedback from ITS is also promising for when a definitive new version of the SGIMM is going to be developed. We believe that with the insights gained with the comparison method and the audit, a solid foundation has been created for three domains: aiding in the development of maturity models, the improvement of the SGIMM and the greening process of the ITS department of UU.

References

1. (2014). Retrieved from http://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm
2. AG Partnerblog. (2015). IT is crucial for a sustainable energyworld. [IT is cruciaal voor een duurzame energiewereld]
3. Andreopoulou, Z. (2012). Green informatics: ICT for green and sustainability. *Agrárinformatika/Journal of Agricultural Informatics, 3*(2), 1-8.
4. Aral, S., & Weill, P. (2007). IT assets, organizational capabilities, and firm performance: How resource allocations and organizational differences explain performance variation. *Organization Science, 18*(5), 763-780.
5. Benn, S., Dunphy, D., & Griffiths, A. (2014). *Organizational change for corporate sustainability*. Oxford: Routledge.
6. Boudreau, M., Chen, A., & Huber, M. (2008). Green IS: Building sustainable business practices. In R. T. Watson (Ed.), *Information systems: A global text* (pp. 1-17). Athens: GA: Global Text Project.
7. Brown, B. J., Hanson, M. E., Liverman, D. M., & Merideth Jr, R. W. (1987). Global sustainability: Toward definition. *Environmental Management, 11*(6), 713-719.
8. Butler, T. (2003). An institutional perspective on developing and implementing intranet-and internet-based information systems. *Information Systems Journal, 13*(3), 209-231.
9. Butler, T. (2011). Towards a practice-oriented green IS framework. Paper presented at the *Ecis,*
10. Carroll, A. B. (1999). Corporate social responsibility evolution of a definitional construct. *Business & Society, 38*(3), 268-295.
11. Chan, R. Y., & Yam, E. (1995). Green movement in a newly industrializing area: A survey on the attitudes and behaviour of the hong kong citizens. *Journal of Community & Applied Social Psychology, 5*(4), 273-284.
12. Computerworld staff. (2010). **The top green-IT organizations: Green from the ground up**.
13. Curry, E., & Donnellan, B. (2012). Understanding the maturity of sustainable ICT. *Green business process management* (pp. 203-216) Springer.
14. Dahlsrud, A. (2008). How corporate social responsibility is defined: An analysis of 37 definitions. *Corporate Social Responsibility and Environmental Management, 15*(1), 1-13.
15. De Bruin, T., Freeze, R., Kaulkarni, U., & Rosemann, M. (2005). Understanding the main phases of developing a maturity assessment model.
16. De Silva, L. N., Goonetillake, J. S., Wikramanayake, G. N., & Ginige, A. (2012). Towards using ICT to enhance flow of information to aid farmer sustainability

in sri lanka. Paper presented at the *Proceedings of the 23rd Australasian Conference on Information Systems 2012,* Geelong, Victoria. 1-10.
17. de Vrede, T. (2016). Microsoft tests sea-datacenters. [**Microsoft test diepzee-datacenters**]
18. Dedrick, J. (2010). Green IS: Concepts and issues for information systems research. *Communications of the Association for Information Systems, 27*(1), 11-18.
19. Donnellan, B., Sheridan, C., & Curry, E. (2011). A capability maturity framework for sustainable information and communication technology. *IT Professional, 13*(1), 33-40.
20. Doorenbosch, T. (2015). **Google signs megacontract for green energy**. [**Google sluit megacontract voor schone energie**]
21. Dyllick, T., & Hockerts, K. (2002). Beyond the business case for corporate sustainability. *Business Strategy and the Environment, 11*(2), 130-141.
22. Ebner, D., & Baumgartner, R. J. (2006). The relationship between sustainable development and corporate social responsibility. Paper presented at the *Corporate Responsibility Research Conference,* Dublin. 1-17.
23. Elliot, S., & Binney, D. (2008). Environmentally sustainable ICT: Developing corporate capabilities and an industry-relevant IS research agenda. Paper presented at the *12th Pacific Asia Conference on Information Systems,* Suzhou, China. 4-7.
24. Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107-115.
25. Esty, D., & Winston, A. (2009). *Green to gold: How smart companies use environmental strategy to innovate, create value, and build competitive advantage*. New Jersey: John Wiley & Sons.
26. Fettweis, G., & Zimmermann, E. (2008). ICT energy consumption-trends and challenges. Paper presented at the *Proceedings of the 11th International Symposium on Wireless Personal Multimedia Communications, , 2*(4) 6.
27. Gatto, M. (1995). Sustainability: Is it a well defined concept? *Ecological Applications, 5*(4), 1181-1183.
28. Gelenbe, E., & Caseau, Y. (2015). The impact of information technology on energy consumption and carbon emissions. *Ubiquity, 2015*(June)
29. Giddings, B., Hopwood, B., & O'brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. *Sustainable Development, 10*(4), 187-196.
30. Hankel, A. (2014). Understanding higher order impacts of green ICT. Paper presented at the *Ict4s,*
31. Hankel, A., Oud, L., Saan, M., & Lago, P. (2014a). A maturity model for green ICT: The case of the SURF green ICT maturity model. Paper presented at the *EnviroInfo,* 33-40.

32. Hankel, A., Oud, L., Saan, M., & Lago, P. (2014b). A maturity model for green ICT: The case of the SURF green ICT maturity model. Paper presented at the *EnviroInfo*, 33-40.
33. Hart, S. L. (1997). Beyond greening: Strategies for a sustainable world. *Harvard Business Review, 75*(1), 66-77.
34. Hilty, L. M., Page, B., & Hřebíček, J. (2006). Environmental informatics. *Environmental Modelling & Software, 21*(11), 1517-1518.
35. Hilty, L., Lohmann, W., & Huang, E. (2011). Sustainability and ICT—an overview of the field. *Politeia, 27*(104), 13-28.
36. Hitchcock, D. E., & Willard, M. L. (2009). *The business guide to sustainability: Practical strategies and tools for organizations*. London: Earthscan.
37. Humphrey, W. S. (1988). Characterizing the software process: A maturity framework. *Software, IEEE, 5*(2), 73-79.
38. International Chamber of Commerce. (1989). Environmental auditing.*Publication no 468* doi:ICC Publishing SA
39. Jiankang, W., Jiuling, X., Qianwen, L., & Kun, L. (2011). Knowledge management maturity models: A systemic comparison. Paper presented at the *2011 International Conference on Information Management, Innovation Management and Industrial Engineering*, Shenzen. , *3* 606-609.
40. Johnson, R. E. (1997). Frameworks=(components patterns). *Communications of the ACM, 40*(10), 39-42.
41. Josey, A. (2013). *ArchiMate® 2.1-A pocket guide* Van Haren.
42. Junglas, I., & Watson, R. T. (2006). The u-constructs: Four information drives. *Communications of the Association for Information Systems, 17*(1), 26.
43. Khoshgoftar, M., & Osman, O. (2009). Comparison of maturity models. Paper presented at the *Computer Science and Information Technology, 2009. ICCSIT 2009. 2nd IEEE International Conference On*, Beijing. 297-301.
44. Kliazovich, D., Bouvry, P., & Khan, S. U. (2012). GreenCloud: A packet-level simulator of energy-aware cloud computing data centers. *The Journal of Supercomputing, 62*(3), 1263-1283.
45. Lee, J., Kang, S., Lee, D., Ahn, Y., & Park, A. B. (2009). Comparison of vPMM and BPMM. Paper presented at the *Software Engineering, Artificial Intelligences, Networking and Parallel/Distributed Computing, 2009. SNPD'09. 10th ACIS International Conference On*, 321-326.
46. Mettler, T., & Rohner, P. (2009). Situational maturity models as instrumental artifacts for organizational design. Paper presented at the *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology*, 22.
47. Molla, A., Cooper, V. A., & Pittayachawan, S. (2009). IT and eco-sustainability: Developing and validating a green IT readiness model. *ICIS 2009 Proceedings*, , Paper 141.

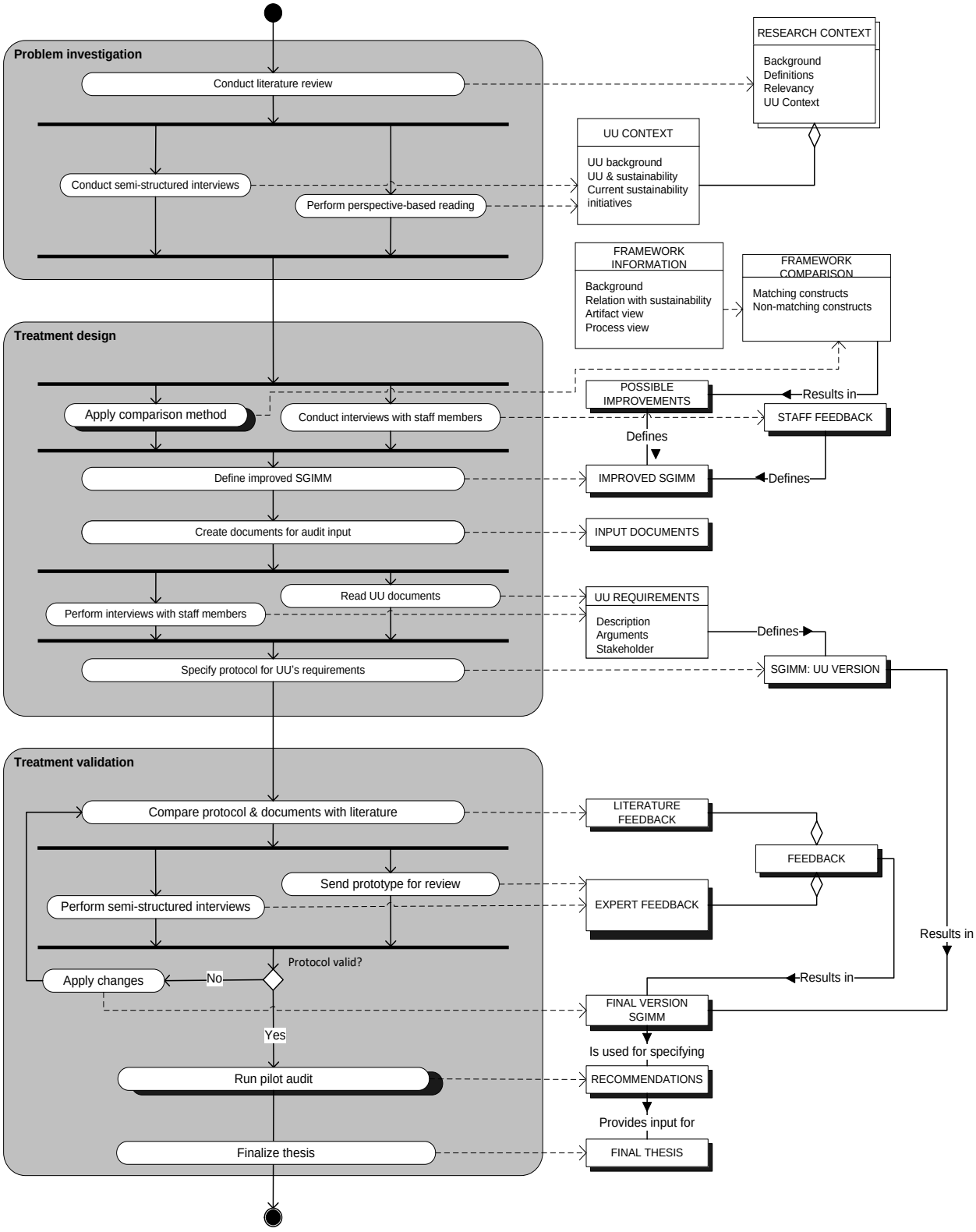
48. Molla, A., Cooper, V., Corbitt, B., Deng, H., Peszynski, K., Pittayachawan, S., & Teoh, S. Y. (2008). E-readiness to G-readiness: Developing a green information technology readiness framework. *ACIS 2008 Proceedings*, , 35.
49. Molla, A., Cooper, V., & Pittayachawan, S. (2011). The green IT readiness (G-readiness) of organizations: An exploratory analysis of a construct and instrument. *Communications of the Association for Information Systems, 29*(1), 67-96.
50. Morelli, J. (2013). Environmental sustainability: A definition for environmental professionals. *Journal of Environmental Sustainability, 1*(1), 2.
51. Murugesan, S. (2007). Going green with IT: Your responsibility toward environmental sustainability. *Cutter Business-IT Strategies Executive Report, 10*(8)
52. Murugesan, S. (2008). Harnessing green IT: Principles and practices. *IT Professional, 10*(1), 24-33.
53. Murugesan, S., & Gangadharan, G. (2012). Green IT: An overview. In S. Murugesan, & G. Gangadharan (Eds.), *Harnessing green IT: Principles and practices* (pp. 25-43). Wiley, Chichester: Wiley-IEEE Press.
54. Pahuja, S. (2013). Environmental audit. *Encyclopedia of corporate social responsibility* (pp. 969-979) Springer.
55. Patel, C. D., Bash, C. E., Sharma, R., Beitelmal, M., & Friedrich, R. (2003). Smart cooling of data centers. Paper presented at the *ASME 2003 International Electronic Packaging Technical Conference and Exhibition,* Maui, Hawaii. 129-137.
56. Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems, 24*(3), 45-77.
57. Philipson, G. (2010). A comprehensive and practical green ICT framework. In B. Unhelkar (Ed.), *Handbook of research on green ICT: Technology, business and social perspectives: Technology, business and social perspectives* (pp. 131-145). New York: Hershey.
58. Porter, M. E., & Kramer, M. R. (2006). The link between competitive advantage and corporate social responsibility. *Harvard Business Review, 84*(12), 78-92.
59. Porter, M. E., & Van der Linde, C. (1995). Green and competitive: Ending the stalemate. *Harvard Business Review, 73*(5), 120-134.
60. Pulparambil, S., & Baghdadi, Y. (2015). A comparison framework for SOA maturity models. Paper presented at the *2015 IEEE International Conference on Smart City/SocialCom/SustainCom (SmartCity),* 1102-1107.
61. Rai, A., Patnayakuni, R., & Seth, N. (2006). Firm performance impacts of digitally enabled supply chain integration capabilities. *MIS Quarterly, 30*(2), 225-246.
62. Ranganathan, P. (2010). Recipe for efficiency: Principles of power-aware computing. *Communications of the ACM, 53*(4), 60-67.

63. Ray, G., Muhanna, W. A., & Barney, J. B. (2005). Information technology and the performance of the customer service process: A resource-based analysis. *MIS Quarterly, 29*(4), 625-652.
64. Slob, B., & Steinweg, T. (2009). Buy IT fair - handleiding voor het duurzaam inkopen van computers.
65. Team, C. P. (2002). Capability maturity model® integration (CMMI SM), version 1.1. *CMMI for Systems Engineering, Software Engineering, Integrated Product and Process Development, and Supplier Sourcing (CMMI-SE/SW/IPPD/SS, V1.1),*
66. Tilt, C. A. (2009). Corporate responsibility, accounting and accountants. In S. O. Idowu, & W. L. Filho (Eds.), *Professionals' perspectives of corporate social responsibility* (pp. 11-32). Berlin: Springer.
67. Uddin, M., & Rahman, A. A. (2012a). Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics. *Renewable and Sustainable Energy Reviews, 16*(6), 4078-4094.
68. Uddin, M., & Rahman, A. A. (2012b). Validation of green IT framework for implementing energy efficient green data centres: A case study. *International Journal of Green Economics, 6*(4), 357-374.
69. van de Weerd, I., & Brinkkemper, S. (2008). Meta-modeling for situational analysis and design methods. *Handbook of Research on Modern Systems Analysis and Design Technologies and Applications, 35*
70. von Alan, R. H., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly, 28*(1), 75-105.
71. Wendler, R. (2012). The maturity of maturity model research: A systematic mapping study. *Information and Software Technology, 54*(12), 1317-1339.
72. Wieringa, R. J. (2014). *Design science methodology for information systems and software engineering*. Berlin: Springer.
73. World Commission on Environment and Development. (1987). *Our common future*. Oxford: Oxford University Press.

Appendices

Appendix A: PDD of thesis

PDD of the full thesis process, from the beginning until the end.

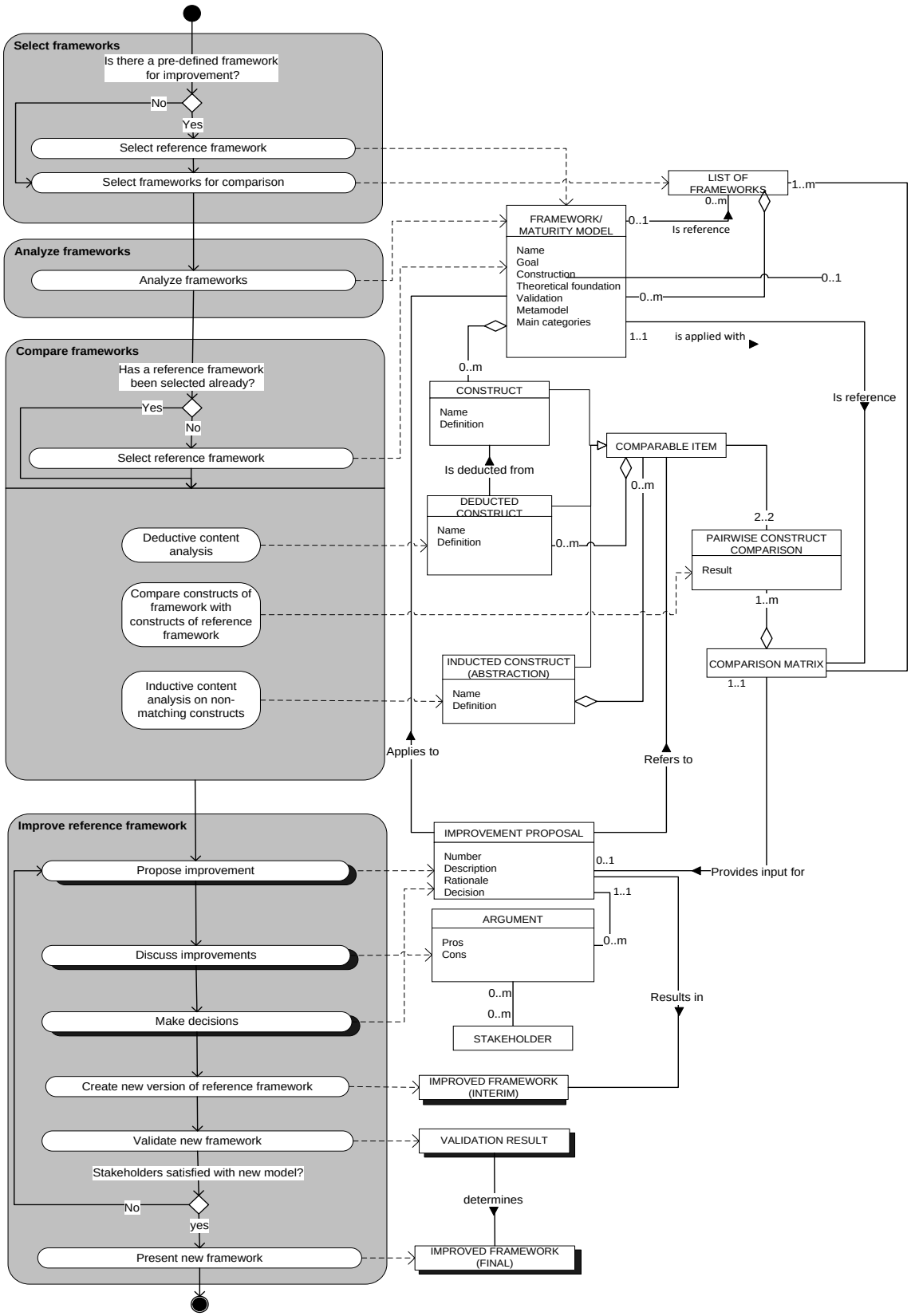


Activity	Sub-activity	Description
Problem investigation	Conduct literature review	A literature review is conducted in order to specify the research CONTEXT of the research in order to specify the research context.
	Conduct semi-structured interviews	Staff members are interviewed in order to determine the specific CONTEXT for UU.
	Perform perspective-based reading	Documents are read in order to help determine the specific CONTEXT for UU.
Treatment design	Apply comparison method	The comparison method is applied. The frameworks are analyzed on their context in order to gather DATA about the framework containing the OBJECTS, PROCESSES and other relevant DATA. Furthermore, the frameworks are compared in order to create FRAMEWORK COMPARISON. Finally, IMPROVEMENTS for the SURF protocol are defined.
	Compare frameworks	The frameworks are compared in order to create a FRAMEWORK COMPARISON.
	Define improvements for SURF procedure	Based on a combination of common sense & literature, possible IMPROVEMENTS are defined for the SGIMM
	Conduct interviews with staff members	Interviews are conducted with staff members in order to collect STAFF VIEWS which are used to help determine the new SGIMM
	Define improved SURFprocedure	Based on the gathered data in the previous steps, an IMPROVED version of the SURF PROCEDURE is defined.
	Create documents for audit input	For preparation of the pilot audit, DOCUMENTS are created required for the INPUT of the audit.
Treatment validation	Validate improved protocol with literature	The new protocol is VALIDATED with literature in order to determine if its satisfies the requirements for an environmental AUDIT.
	Perform semi-structured interviews	New INTERVIEWS are performed in order to help with the VALIDATION.
	Prototype review	The new SURF protocol is send to SURF in order to receive more FEEDBACK
	Perform pilot audit	The new SURF protocol is performed in a pilot AUDIT.
	Apply changes	Changes are applied in the SGIMM
	Write thesis	The thesis is written based on the results.

Concept	Description
CONTEXT	Combination of internal and external issues that can have effect on an organizations approach to developing and achieving its objectives (ISO 9000 2015)
OBJECT	Any entity that is either conceivable or perceivable (ISO 9000:2015)
DATA	Facts about an object (ISO 9000:2015)
INFORMATION	Meaningful data (ISO 9000:2015)
PROCEDURE	specified way to carry out an activity or a process (ISO 9000:2015)
PROCESS	set of interrelated or interacting activities that use inputs to deliver an intended result (ISO 9000:2015)
IMPROVEMENT	Activity to enhance the performance (ISO 9000:2015)
FEEDBACK	Opinions, comments and expressions of interest in a product , a service or a complaints-handling process (ISO 9000:2015)
DOCUMENTS	Information and the medium that it contains(ISO 9000:2015)
REQUIREMENT	Need or expectation that is stated, generally implied or obligatory (ISO 9000:2015)
VALIDATION	Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled (ISO 9000:2015)
AUDIT	systematic, independent and documented process for obtaining objective evidence and evaluating it objectively to determine the extent to which the audit requirements are fulfilled (ISO 9000:2015)

Appendix B: PDD of comparison method

A PDD showing the steps of the comparison method in more detail, along with the relationships between the deliverables



Activity	Sub-activity	Description
Select frameworks	Select reference framework	Based on the goals and wishes of the relevant stakeholder(s), a reference FRAMEWORK or MATURITY MODEL is chosen for improvement or change.
	Select frameworks for comparison	Based on the goals of the relevant stakeholder(s), FRAMEWORKS are chosen for a COMPARATIVE ANALYSIS
Analyze frameworks	Analyze frameworks	The FRAMEWORKS are analyzed to gather INFORMATION about the FRAMEWORKS. The FRAMEWORKS have the following attributes: Name, Goal, Construction, Theoretical Foundation, Validation, Metamodel, Main categories. A framework has several CONSTRUCTS with the following attributes: Name, Definition. Possible, a framework is applied in assessing the maturity of a domain with an AUDIT PLAN.
Compare frameworks	Select reference framework	If no REFERENCE FRAMEWORK has been chosen yet, it is chosen at this moment.
	Deductive content analysis	If the constructs are deemed to be too general, a technique like deductive content analysis is applied to the framework to determine DEDUCTED CONSTRUCTS.
	Inductive content analysis on non-matching constructs	On the CONSTRUCTS that do not appear in the reference framework, inductive content analysis is applied to create an INDUCTED CONSTRUCT out of the CONSTRUCT. Furthermore, if multiple INDUCTED CONSTRUCTS in the MATRIX are the same, they are merged in the same row. To determine this, all INDUCTED CONSTRUCTS are compared with each other
	Compare constructs of frameworks with constructs of reference framework	The CONSTRUCTS (and possibly, DEDUCTED CONSTRUCTS) of the reference framework are compared with all CONSTRUCTS of the frameworks for comparison. This creates one or multiple PAIRWISE CONSTRUCT COMPARISONS which is presented in a COMPARISON MATRIX. The PAIRWISE CONSTRUCT COMPARISON has one attribute: Result

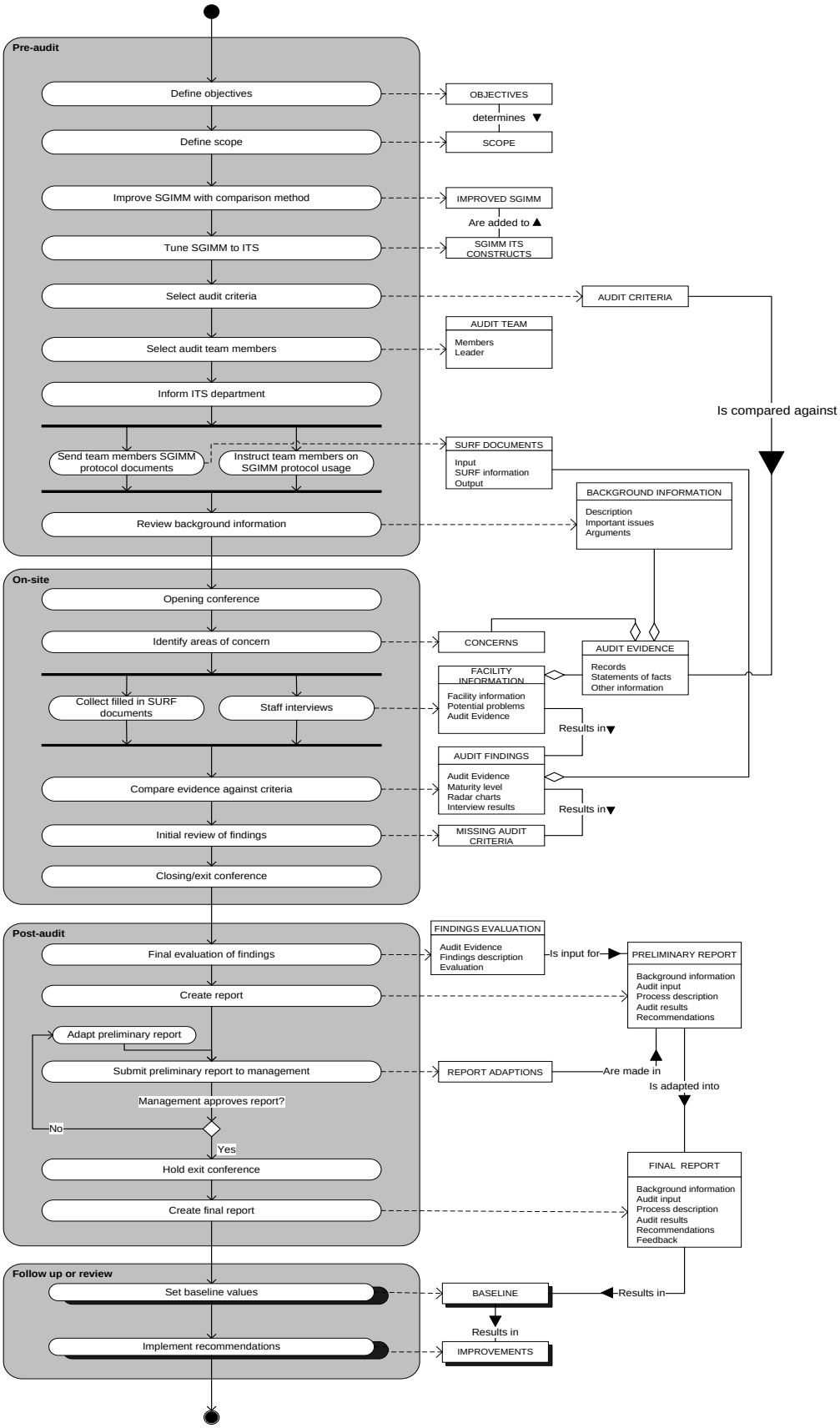
Next part of the activity table can be found on the next page.

Improve framework	Propose improvements	Based on the results of the PAIRWISE CONSTRUCT COMPARISON, a list of IMPROVEMENT PROPOSALS are proposed that will be reviewed and discussed. Possibly, extra information is gathered through sources like literature, interviews and consultants. Each IMPROVEMENT PROPOSAL has the following attributes: Number, Description, Rationale, Decision
	Discuss improvements	In order to determine new CONSTRUCTS and other IMPROVEMENTS to the REFERENCE FRAMEWORK, the IMPROVEMENT PROPOSALS are analyzed by interviewing experts/stakeholders/consultants, reading literature, holding discussions and performing other tasks that might help in this matter. This results in ARGUMENTS for each IMPROVEMENT PROPOSAL. Each ARGUMENT has the attributes 'Pro's' and 'Cons.'
	Make decisions	Based on the ARGUMENTS, decisions are made about the IMPROVEMENT PROPOSALS, so the value of the attribute 'Decision' in IMPROVEMENT PROPOSAL is determined.
	Create new version of reference framework	Based on the ARGUMENTS for each IMPROVEMENT PROPOSAL, an IMPROVED REFERENCE FRAMEWORK is defined. These are implemented, resulting in an IMPROVED FRAMEWORK (INTERIM).
	Validate new framework	The IMPROVED FRAMEWORK (INTERIM) is validated by the practitioners of the method, resulting in a VALIDATION RESULT that will be discussed by the relevant STAKEHOLDERS. If the STAKEHOLDERS are satisfied, the IMPROVED FRAMEWORK is presented to the community. If the STAKEHOLDERS are not satisfied, new IMPROVEMENT PROPOSALS are created, creating a new iteration of phase 4
	Present new framework	The practitioners present the new IMPROVED FRAMEWORK (FINAL) to the stakeholders.

Concept	Description
FRAMEWORK	A broad overview, outline, or skeleton of interlinked items which supports a particular approach to a specific objective, and serves as a guide that can be modified as required by adding or deleting items(Businessdictionairy) . For this method, the framework has the following attributes that are deemed relevant: Name, Goal, Construction, Theoretical foundation, validation, construct, metamodel, main categories, audit plan
MATURITY MODEL	Model derived from one or more specified process assessment model(s) that identifies the process sets associated with the levels of a specified scale of organizational process maturity (ISO/IEC 33001:2015)
COMPARATIVE ANALYSIS	The item-by-item comparison of two or more comparable alternatives, processes, products, qualifications, sets of data, systems, or the like. (business dictionary)
INFORMATION	Meaningful data (ISO 9000:2015)
CONSTRUCT	Concept or 'useful fiction' (which may or may not refer to an objective reality) employed in summarizing multitudes of facts and in formulating explanatory theories (businessdictionairy.com)
DEDUCTION	Method of reasoning from general to particular, it is employed in deriving general laws or principles from the observed phenomenon (businessdictionairy.com)
INDUCTION	Method of reasoning from particular to general; the mental process involved in creating generalizations from the observed phenomenon or principles
LIST	Any enumeration of a set of items (wikipedia)
TABLE	A table is a means of arranging data in rows and columns. (wikipedia)
IMPROVEMENT	Activity to enhance performance (ISO 9000:2015)
ARGUMENT	an argument is a series of statements typically used to persuade someone of something or to present reasons for accepting a conclusion. (wikipedia)
STAKEHOLDER	A stakeholder is a person or an organization that can affect or be affected by a decision or activity. Stakeholders also include those who have the perception that a decision or activity can affect them. (ISO 9000:2015)
REFERENCE	Reference is a relation between objects in which one object designates, or acts as a means by which to connect to or link to, another object. The first object in this relation is said to refer to the second object. The second object, the one to which the first object refers, is called the referent of the first object (wikipedia).
VALIDATION	Validation is the process of using objective evidence to confirm that the requirements which define an intended use or application have been met (ISO 9001 2015)

Appendix C: PDD of auditing protocol

A PDD showing the auditing protocol tuned to using the SGIMM in ITS.



Activity	Sub-activity	Description
Pre-audit	Define objectives	OBJECTIVES are defined for the audit
	Define scope	Based on the OBJECTIVES, a SCOPE is determined.
	Select audit criteria	The CRITERIA are determined against what the facility will be audited
	Select audit team members	The TEAM members are determined who will conduct the audit
	Inform ITS department	The ITS department will be informed about the audit
	Send team members SURF protocol documents	The TEAM members will receive the DOCUMENTS needed for conducting the audit
	Instruct team members in SURF protocol	The TEAM members are instructed in how to use the SURF PROTOCOL
	Review background information	the BACKGROUND INFORMATION is reviewed in order to identify issues that might be relevant to the audit
On-site	Opening conference	The OBJECTIVES and used PROTOCOL is communicated to the ITS department
	Identify areas of concern	The ITS department will be inspeced and reviewed to see if there are any AREAS OF CONCERN
	Collect SURF documents	The SURF DOCUMENTS are collected from all staff personnel who have participated in the audit
	Interview staff members	Staff members are interviewed in order to gather INFORMATION about the facility, including EVIDENCE for the results of the CRITERIA.
	Record and document data in SURF	All gathered information is processed into the SURF protocol, which delivers several AUDIT FINDINGS
	Initial review of findings	The initial findings are reviewed in order to determine the MISSING CRITERIA.
	Closing/exit conference	The audit findings are introduced to the facility.
Post-audit	Final evaluation of findings	The findings are EVALUATED in order to back them up with evidence and give them a label for prioritization
	Create report	A PRELIMINARY REPORT is created based on the findings
	Submit preliminary report to management	The PRELIMINARY REPORT is sent to management of ITS department
	Submit final report	The FINAL report is delivered to management.
	Adapt preliminary report	If management does not approve the PRELIMINARY REPORT, the report is ADAPTED
	Hold exit conference	The facility is informed about the end of the audit.
	Lessons learned interview	An interview in order to receive FEEDBACK from the problem owners
Follow-up	Set baseline values	Based on the findings in the report, a BASELINE is set for using the protocol in the future
	Implement recommendations	The recommendations are implemented at the ITS department.

Concept	Description
OBJECTIVES	A specific result that a person or system aims to achieve within a time frame and with available resources (businessdictionairy.com)
SCOPE	The division of work to be performed under a contract or subcontract in the completion of a project, typically broken out into specific tasks with deadlines (businessdictionairy.com)
AUDIT CRITERIA	set of policies, procedures or requirements used as a reference against which objective evidence is compared (ISO 9000:2015)
AUDIT TEAM	one or more persons conducting an audit, supported if needed by technical experts (ISO 9000:2015)
DOCUMENT	information and the medium on which it is contained (ISO 9000:2015)
OBJECTS	Anything perceivable or conceivable (ISO 9000:2015)
DATA	Facts about objects (ISO 9000:2015)
INFORMATION	Meaningful data (ISO 9000:2015)
CONCERN	Interest in a system relevant to one or more of its stakeholders (ISO 42010:2011)
AUDIT EVIDENCE	records, statements of fact or other information, which are relevant to the audit criteria and verifiable (ISO 9000:2015)
AUDIT FINDINGS	results of the evaluation of the collected audit evidence against audit criteria(ISO 9000:2015)
EVALUATION	Measuring the extent to which targets are being met, and detecting the factors that hinder or facilitate their realization. It also involves establishing cause-effect relationships about the extent to which a particular policy (or a set of policies) produces the desired outcome. (businessdictionairy.com)
REPORT	A document containing information organized in a narrative, graphic, or tabular form, prepared on ad hoc, periodic, recurring, regular, or as required basis. Reports may refer to specific periods, events, occurrences, or subjects, and may be communicated or presented in oral or written form (businessdictionairy.com)
ADAPTION	Modification of a concept or object to make it applicable in situations different from originally anticipated. (businessdictionairy.com)
BASELINE	Clearly defined starting point (point of departure) from where implementation begins, improvement is judged, or comparison is made. (businessdictionairy.com)
FEEDBACK	The information sent to an entity (individual or a group) about its prior behavior so that the entity may adjust its current and future behavior to achieve the desired result.

Appendix D: Matching and non-matching constructs

The resulting table from the comparison method applied on the SGIMM and several frameworks in the field of Green ICT. The table with matching constructs is split into two parts.

Matching constructs						
SGIMM (SURF)	**G-readiness (Molla)**	**Green IS framework (Butler)**	**Holistic Approach to Green IT (Murugesan & Gangadharan)**	**Data Center framework (Uddin & Rahman)**	**SICT (Donnellan et al.)**	**Envirability (Philipson)**
General/business issues						
Green ICT strategy	X	Green Business and IS Strategy & Business model/Online channels	Green IT Strategies and policies	x	Strategy and planning	Governance & compliance
Governance of ICT services	Governance	Organisational Governance (umbrella term)	X	x	Corporate policies	
Green ICT procurement	Attitude, Policy, Practice	Procurement/IT Outsourcing	X	Procurement	Operations and life cycle	Procurement
E-waste Policy	Attitude, Policy, practice, technology	Waste/disposal recycling	Green disposal of IT systems	Recycle and disposal		Disposal, recycle & reuse
Green ICT in Information Management and Architecture	X	X	x	X	ICT enabled business processes& Performance and reporting	x
Community Collaboration	X	X	x	X	External compliance	x
Green ICT supply Chain Management	Policy	Supply Chain Management	x	x	ICT enabled business processes	Business process management
Greening of ICT (Green IT)						
Housing	Attitude	Buildings management systems	Green use of IT systems	X	Operations & life cycle, Performance & reporting	Data center environmentals
Computing Infrastructure	Policy, practice, Technology	Data center & IT infrastructure		Revamp architecture & infrastructure		
Network Infrastructure	Attitude, practice, Technology					Networking & communications
Storage infrastructure	Attitude, practice, Technology					Data center environmentals
End user ICT Equipment (PC's, printers, etc.)	Policy, Technology	Front Office IT		X		End User Computing
Software and ICT services	Technology	Procurement/IT Outsourcing		Identify virtualization & cloud computing, Implement Virtualization & Cloud Computing with Outsourcing		Outsourcing & Cloud

Matching constructs						
Greening of operations with ICT (Green IS)						
Travel reductions with ICT	X	Teleconferencing & teleworking	Green use of IT systems	x	ICT enabled business processes	Teleworking & Collaboration
Area reductions with ICT	X	X		x		X
Energy reductions with ICT	Attitude, Policy, Technology	Environmental management system		x		x
Paper reductions with ICT	Practice, Technology	Office processes & printing		x		Printing & Consumables
Feedback and decision support	Attitude, Policy, Practice	Buildings management system & Product/Service operations		Analysis phase	Performance and reporting	Metrics
Greening of primary processes in higher education with ICT						
Education	Policy, Practice (more general)	Product/service processes (more general)	Green use of IT systems (more general)	x	ICT enabled business processes (more general)	Business process management & Business Applications (more general)
Education support				x		
Research				x		
Research Support				x		
Valorisation				x		
Information Access				x		

Non matching constructs						
SGIMM (SURF)	**G-readiness (Molla)**	**Green IS framework (Butler)**	**Holistic Approach to Green IT (Murugesan & Gangadharan)**	**Data Center framework (Uddin & Rahman)**	**SICT (Donnellan et al.)**	**Envirability (Philipson)**
People		People			People and culture	
GHG emissions	Attitude, GHG emissions			Governance & Compliance to lower CO2, Carbon Emission Management, Measure CO2 Emissions		Carbon emission management
Energy sources	Policy, Green sources of energy					
Extra waste caused by IT	Practice, extra waste (paper, batteries, etc.)	Smaller product & packaging, packaging				
Green standards and metrics			Green standards and metrics	Identify green metrics & set benchmarks		
Green production			Green manufacturing of IT systems			
Green design			Green design of IT systems			
Green data centers	Policy, green data center					
Shorten refreshment	Practice, shorten refreshment of equipment to gain more efficient equipment					
Corporate Social Responsibility	Policy, CSR					
Data center specific technologies				Identify virtualization & cloud computing		
Categorization of data centers				Categorize data centers		
Software Architecture						Software Architecture
Planning				Planning phase		
Equipment for waste		Equipment				
Product take-back		Product-takeback				
Social clauses (SOMO)	x	x	x	x	x	x