A Maturity Model for Green ICT: The Case of the SURF Green ICT Maturity Model

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published in
EnviroInfo 2014 - 28th International Conference on Informatics for Environmental Protection
2015

document version
Publisher's PDF, also known as Version of record

A Maturity Model for Green ICT: The case of the SURF Green ICT Maturity Model

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Abstract

This paper discusses the development and evaluation of a maturity model for Green ICT. We describe how the model was developed with the input of a number of Green ICT experts before it was released to the general public. The model consists of three domains with attributes on Green ICT that encompass both Greening of ICT as well as Greening by ICT. The quality of the model and its accuracy to capture the full scope of Green ICT has been evaluated through an online survey. We evaluated the quality of the model on relevancy of attributes, whether the attributes were well defined and whether the domains were complete. Twenty participants contributed meaningfully. Two attributes were considered to be irrelevant and six new attributes were suggested. With these results the quality of the maturity model can be improved. Our next step is to test the usefulness of the model by seeing how it is used in practice. We hope this paper inspires more work on testing the quality and usefulness of models and frameworks on Green ICT.

1. Introduction and motivation

There is a clear need to transform our society into one that is environmentally sustainable. One of the factors in this transformation is avoiding too much global warming, which is associated with the amount of CO_2-particles in the air. To avoid a higher than 2° C warming, we need to reduce our Greenhouse Gas (GHG) emissions to zero before 2050 and maybe even earlier.

The field of Green ICT is associated with minimizing the negative environmental impacts of ICT and optimizing the positive impacts of ICT. However, most Green ICT activities are often only focused on reducing the negative impacts of ICT. Even within these activities there is a narrow focus: data centers receive disproportionate attention because these are such large energy consumers; yet, data centers are only responsible for 20% of the total ICT footprint with end user devices being responsible for the largest part (60%) [1]. In addition, from a lifecycle perspective, most efforts in Green ICT reduce the impact of the use phase and its associated energy consumption, but for many ICT devices and components, the largest part of their footprint is in production [2].

The main reason for this narrow focus is that such Green ICT actions are the most visible and most easy to take. In addition, optimizing the positive impacts of ICT often leads to disassociated benefits and split incentives, between organizations and within organizations: a common case is that ICT departments must make the investments while others, such as Facilities departments, reap the benefits, both from an economic and environmental perspective. To overcome the narrow focus on both the solution space and collaboration options, organizations need to have insight into how Green ICT actions affect a wider scope of environmental impact and a way to understand their progress in opening up the narrow focus.

This paper describes and evaluates the SURF Green ICT Maturity Model (SGIMM) that has been designed for the purpose of giving organizations insights in and understanding of the total

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environmental impact of Green ICT. We will describe how the model was created with the input of a number of Green ICT experts before it was released to the general public. The quality of the model and its accuracy to capture the full scope of Green ICT has been evaluated through an online survey.

2. Methods used to create the maturity model

SURF, the Dutch higher education and research partnership for ICT, decided to develop a maturity model on Green ICT after interviewing a number of Dutch higher education and research institutions. In these interviews the institutions expressed a clear need for some way to know how well they are doing in terms of Green ICT. SURF wanted to develop a maturity model based on expert views and opinions and validate this through a survey spread amongst practitioners. The SGIMM was developed by SURF and a number of Green ICT experts, both from the Dutch higher education and research community as well as outside it. Responsibility for ICT in organizations part of this community is typically delegated to an ICT department. The SGIMM was therefore designed from the ICT department's perspective

The outline of the model was created in a workshop with nine Green ICT experts. During this workshop domains were set and attributes were discussed (see section 3 for a detailed description of the maturity model). Based on this input we designed a first draft model that was evaluated by the expert group in an elaborate survey. The draft that followed on the feedback from the survey was tested in a pilot with a higher education institution, the Hogeschool van Arnhem en Nijmegen. The results were discussed again with the expert group leading to a maturity model that was published after this discussion[3].

3. Description of the SURF Green ICT Maturity Model

The concept of the maturity model is based on the Capability Maturity Model, representing a framework with five maturity levels for quality and process improvements. The five levels are (1) initial, (2) repeatable, (3) defined, (4) managed and (5) optimizing. At the lowest level, the initial level, the organization does not provide a stable environment for the activity. At this level the process is ad hoc. However, at the highest level, which is the optimizing level, the entire organization is focused on continuous process improvement [3].

The SGIMM conceptually consists of four domains covering negative and positive impacts and aspects of ICT. Each domain consists of attributes that have a definition and a description of a level five maturity. Three domains and attributes are summarized in Table 1.

The three domains mentioned in Table 1 are generically applicable to any organization. The fourth domain is sector specific and covers 'Greening of primary processes with ICT'. For the higher education sector, the primary processes would relate to education and research. This domain is not yet included in the currently published model.

The SGIMM is designed to give organizations insights into the maturity of Green ICT of the organization. It is set-up as a self-assessment and enables organizations to have an internal dialogue, to gain agreement on the status quo and to define actions for improvement. By letting several individuals within an organization score the attributes and discussing theses scores with the participants (average, minimum, maximum scores, etc.), an organization can identify weak and strong Green ICT aspects. SURF published a manual that guides users through this process of self-assessment together with the model itself.

[3] http://www.surf.nl/en/knowledge-and-innovation/knowledge-base/2014/surf-green-ict-maturity-model.html

Green ICT in the organization	Greening of ICT	Greening of operations with ICT
Green ICT Strategy	Computing Infrastructure	Travel Reductions with ICT
ICT Governance	Network Infrastructure	Space Reductions with ICT
Green ICT Procurement	Storage Infrastructure	Energy Reductions with ICT
E-waste policy	Housing	Paper Reductions with ICT
Green ICT Architecture Principles	End User ICT Equipment	Other Reductions with ICT
Information Management	ICT Services	Environmental Awareness and Decision Support
Community Collaboration	Green Software Development	
Green ICT Supply Chain Management		

Table 1. The domains and attributes of the SURF Green ICT Maturity Model.

4. Evaluation of the SURF Green ICT Maturity Model

While the SGIMM was grounded in the opinions of the Green ICT experts and should therefore theoretically be of sufficient quality, this needed to be validated by practitioners. In order to validate the model, we designed an online survey[4] in which questions were asked on the quality of the model. These questions were based on Wand and Wang [4], who identified four generic dimensions to evaluate Intrinsic Data Quality using the most cited quality dimensions in their literature study: (1) complete, (2) unambiguous, (3) meaningful and (4) correct. They defined complete as a set of data that includes all necessary values; unambiguous (accuracy and precision) as representing the correct data; meaningful was defined as being able to use data in a useable way; and correct as containing the right information. To apply these dimensions to the questions we wanted to ask we chose to ask about the relevancy of attributes (meaningfulness), whether they were well-defined (correct and unambiguous) and whether a domain was complete or missing an attribute (complete).

The survey was set-up online and spread mainly amongst people from the Dutch higher education sector. It was also promoted outside of the sector and internationally (mainly UK higher education) for comparison purposes, but this was only a small part of the response. Because the entire survey was time consuming participants could choose one or more domains (Table 1) to answer questions about. Motivation was required for most answers. In addition we collected information on each participant on where they were from (country, sector) and whether they were familiar with Green ICT, their maturity.

We did a trial run with the survey amongst the Green ICT experts who helped us with the maturity model. Their feedback, such as to add an 'I don't know' option to each question, was incorporated in the published version of the survey which was available for four weeks during February 2014.

[4] The survey content is available upon request at the authors.

5. Results of the evaluation

In total, 68 participants started the survey but only 20 of them contributed meaningfully. 80% of the participants were working in the Netherlands. The response for each domain was as follows:

- Green ICT in the organization 8
- Greening of ICT 13
- Greening of operations with ICT 8

Because the response was so low, it was hard to draw any quantitative-based, representative conclusions. Nevertheless, we found some interesting results.

First, we used the self-rated maturity on Green ICT of participants and of their organizations as a weighting factor to calculate relevancy scores. As can be seen in Figure 1, more than half of the participants rated themselves mature, whereas they rated their organization of lower maturity than themselves. We assumed opinions of mature participants and/or working for mature organizations are more important than opinions of immature participants and/or working for immature organizations. The maturity levels were converted to a 1-5 scale and each participant's relevancy score on an attribute was weighted by their fraction of the sum of maturity levels of all participants who scored that attribute.

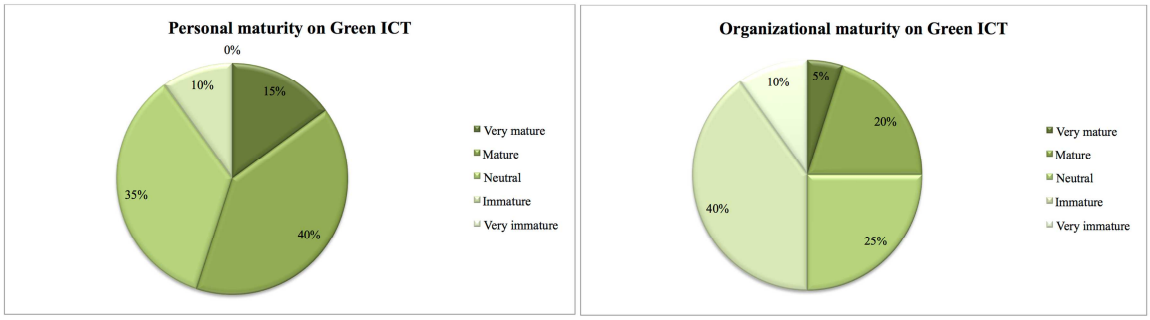

Figure 1. Personal and organizational maturity of the survey participants.

By weighting the average relevancy of attributes we amplified differences between attributes that were difficult to see otherwise. Participants had to agree or disagree with the relevancy of an attribute on a Likert scale of 1 to 5, where a score of 5 was the highest relevancy option. A neutral position towards relevancy was indicated by a score of 3. We considered an attribute relevant if its weighted average relevancy is 3 or higher. Figure 2 shows the results for all attributes of the model. Almost all attributes are considered relevant except two, being: 'Information Management' and 'Other reductions with ICT'.

We also asked participants to motivate their score. If we just zoom in on the two low-scoring attributes we see for 'Information Management' that the participants were triggered by the use of the word *redundancy* in the attribute description: they do not believe information management can be used to reduce excessive redundancy in ICT resources. For 'Other reductions with ICT' it seems that this attribute does not appeal to participants because it is too broadly defined: it is described as a catchall, covering everything not mentioned by the other five attributes in the domain 'Greening of operations with ICT'.

The second quality aspect we were interested in was whether attributes were well defined. In the survey this was a yes/no question where participants had to motivate if they disagreed. The results are shown in Table 2.

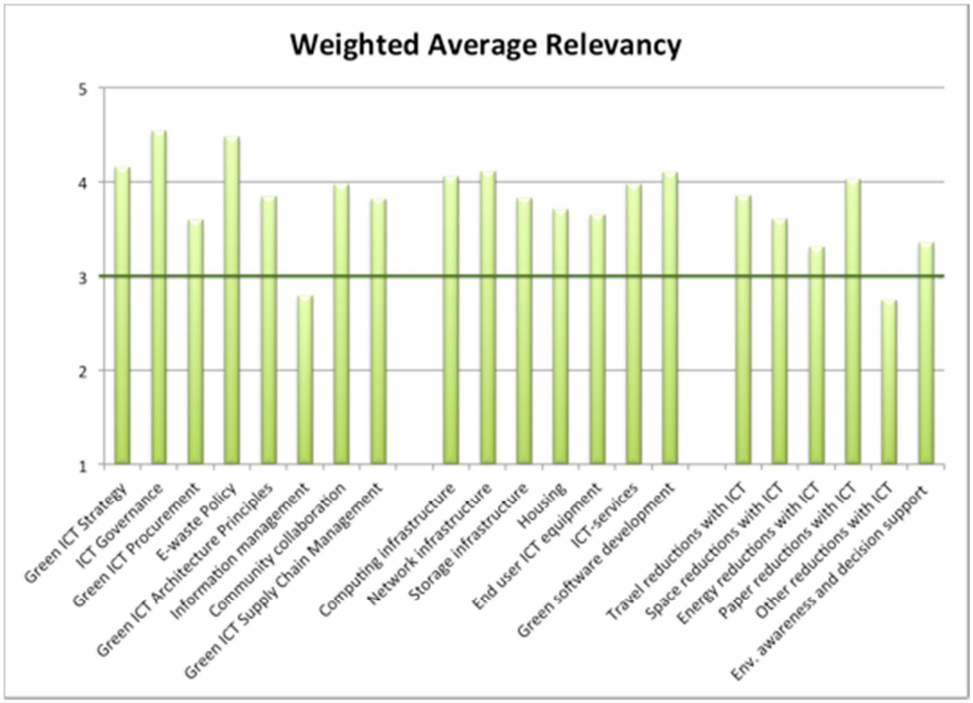

Figure 2. Weighted average relevancy scores for all attributes of the maturity model.

Attribute	Participants	Agreement	IDK: Participant does not know	Agreement excluding IDK
Green ICT in the organization				
Green ICT Strategy	8	6	1	85,71%
ICT Governance	8	6	0	75,00%
Green ICT Procurement	8	6	1	85,71%
E-waste Policy	8	5	1	71,43%
Green ICT Architecture Principles	8	4	1	57,14%
Information management	8	2	3	40,00%
Community collaboration	8	4	2	66,67%
Green ICT Supply Chain Management	8	4	3	80,00%
Greening of ICT				
Computing infrastructure	13	10	2	90,91%
Network infrastructure	13	10	1	83,33%
Storage infrastructure	13	7	4	77,78%
Housing	13	10	1	83,33%
End user ICT equipment	13	9	1	75,00%
ICT-services	13	7	2	63,64%
Green software development	13	8	1	66,67%
Greening of operations with ICT				
Travel reductions with ICT	8	4	1	57,14%
Space reductions with ICT	8	7	1	100,00%
Energy reductions with ICT	8	7	0	87,50%
Paper reductions with ICT	8	7	1	100,00%
Other reductions with ICT	8	6	1	85,71%
Env. awareness and decision support	8	7	0	87,50%
Green ICT Strategy	8	6	1	85,71%

Table 2. This table shows whether participants agreed with the definition of attributes.

A strict definition of being well defined would be that all participants agreed with the definition of an attribute. This would translate into a 100% score in the last column of Table 2 and the

observation that only two attributes are well defined. If we look into the motivation participants gave us, we see a clear difference between high scores (above 80%) and low scores. In general the high scores have small comments for improvement often adding something local from their own experience. The low scores show comments relating to the need for more examples (too abstract), ambiguousness and scoping and focus issues.

The final aspect of the survey concerned completeness of the maturity model. We asked participants whether they were missing an attribute in a domain. In each domain two participants made suggestions. These were: Maintenance management; People and culture; Mind-set and experience of staff; Sustainable offices; Savings in productions and logistics; Improving work inefficiencies with ICT. As participants were often only evaluating one domain, some suggestions do overlap with each other or attributes were already present in the model. Second, for the domains 'Green ICT in the organization' and 'Greening of ICT' a high percentage of participants answered "I don't know"; three out of eight and five out of thirteen respectively. It seems that this question was difficult to answer.

While it is difficult to draw any definitive conclusions from this survey, overall it seems that the maturity model is covering most aspects of Green ICT within the three domains. The results suggest that two attributes can be removed and six suggestions for new attributes are offered. Most descriptions of the attributes need small revisions, whereas some need more work, based on the feedback from the participants.

6. Related work

Many models, frameworks and tools on assessing the environmental impact of ICT have been released over the past years from both research and practice. In addition, there are general impact assessment tools that can also be applied to ICT, such as life cycle analysis or green house gasses audits (see Ecofys et al. [5] for an overview of general tools applied to ICT).

Most of the specific models and tools focus on energy efficiency and reducing the negative impacts of ICT, such as those developed by the Green Grid[5] and the OpenDCME model[6]. While these are mostly focused on data centres, others such as those developed by Gartner [6] and Molla et al. [7] capture the entirety of ICT but are still only limited to the direct impacts in scope or are very general/abstract. A few tools have been developed that also include the positive impacts of ICT, such as those by UK HM Government [8], deMonsabert et al. [9] and Donnellan et al. [10]. Still those mostly focus on the negative impacts, too. From a system perspective or the total global footprint of human society this seems strange since the negative impacts are responsible for 2% of that footprint, while the positive impacts have the potential to reduce the global footprint by 16% [1].

As far as we can derive from research literature and practice, there is a lack of works on assessing the quality of the tools, if and how they are being used and whether they achieve their intended effects. While such questions might be trivial for other assessment topics, as it will quickly follow from use, this is not the case for the environmental impact of ICT. Environmental sustainability is typically multi-dimensional and prone to local optimizations and it is therefore complex to assess progress.

[5] www.thegreengrid.org

[6] www.opendcme.org

Model	Problem description	Goal	Target audience	Comparison with SGIMM
Data Center Energy Efficiency Maturity Model [11]	Organizations have problems managing data centers due to complexity and rapid evolution.	Help to improve the energy efficiency management in data centers.	Organization who manage data centers.	Both are maturity models. Limited scope – only data centers.
ICT Capability Maturity Framework [10]	ICT is responsible for a major percentage of the organizational footprint.	Manage sustainable ICT within an organization to reduce the organizational footprint.	Organization who would like to reduce their ICT footprint.	Both are maturity models. Focus is more on strategic level (similar to [6]).
SustainaBits [9]	Challenges to define and achieve sustainability goals.	Provide a reliable and industry accepted framework to guide organizations within the IT sector to a sustainable future.	Organizations within the IT sector.	Not a maturity model but a broad set of criteria. Focus is on comparison between IT organizations.
UK HM Government Green ICT Maturity Model [8]	ICT has a key role both as a contributor to the government's carbon footprint and as an enabler for the business and behaviour changes required to meet the significant Greening Government targets.	This model provides the means for UK government to demonstrate the progress being made with embedding Green ICT into its business processes and practices.	All UK public sector bodies.	Very similar to SGIMM, but targeted at governmental organizations. Seems based on practice alone (vs. research).
Green IT Readiness Framework [7]	Pressure on organizations to implement sustainable business practices. Critical capability of organizations to measure their G-readiness.	Help organizations to evaluate their maturity on Green ICT based on their Green IT readiness.	Researcher to establish cause-and-effect relationship models. Practitioners to use as a decision tool.	Focus on Greening of ICT. Uses five components (similar to SGIMM domains) that can be scored 1-7. Based mainly on literature.
Gartner Green and Sustainable IT Infrastructure and Operations Maturity Model [6]	Many organizations do not necessarily acknowledge sustainable development priorities explicitly. This model focuses on these priorities from an IT I&O perspective.	The model is intended to help identify where your organization is on the maturity curve, and how to get to where you want to be.	CIOs	High level descriptions (aimed at strategic & tactical level), few examples, little attention for enabling aspects.

Table 3. A comparison of Green ICT models and frameworks.

7. Conclusion

In this paper we have explained how we have developed a Green ICT maturity model that goes beyond the energy efficiency of ICT. To evaluate the quality of the model, we defined three quality aspects: relevancy of attributes, well-defined attribute descriptions and completeness of the domains. We created a survey where participants had to evaluate these aspects. Twenty participants contributed meaningfully to the survey.

From the participants' response, it seems that the maturity model is covering most aspects of Green ICT within the three domains. Two attributes were considered not relevant and six suggestions were made for new attributes. Most descriptions of the attributes need small revisions, whereas some need more work, based on the feedback from the participants. While it is difficult to draw any definitive conclusions from this survey, with these results the maturity model can still be improved.

8. Discussion

The results of the survey are indicative on the quality of the model, but they are not conclusive. We will continue to find ways to assess the quality, because we think it is important to ground this in science and in practice. This is not only useful for the model itself, but conclusions can also be used in other models. Similarly, we want to learn from other work as well and we think it would be good to see more work on quality assessment of Green ICT models.

One of the quality aspects we did not look at is whether the model is actually used and how it is used. Our next step is therefore to continue the evaluation of SGIMM through following its use in practice. We want to see how organizations use the model as a baseline, what they do with the results and if anything has changed in the organization after a period of time.

While the survey results can be used to improve the maturity model, the response was too low to draw any quantitative conclusions that can be generalized to meaningful statements for other Green ICT models or statements on attitudes towards Green ICT. For example, it would be interesting to find out what aspect of Green ICT is found most relevant in the Dutch Higher Education sector compared to those in the UK. The high dropout of participants (20 out of 68 completed the survey) indicates that it was difficult to complete the survey, probably because of its length and depth. It would be interesting to do a shorter survey to find out more about what aspect of Green ICT is considered important, based on topics such as the attributes in the SGIMM.

We hope the way we approached the development and evaluation of the SGIMM will attract follow-up for research on other Green ICT models and frameworks, as we believe it is necessary to ground these models in practice and to evaluate these scientifically. In the end, the goal of such models is that they are used in practice and that will only happen if they are of sufficient quality.

Acknowledgements

We would like to thank SURF for facilitating and publishing the SURF Green ICT Maturity Model, as well as supporting our research. Special thanks also go out to the Green ICT experts and the Hogeschool van Arnhem en Nijmegen for their help in developing and refining the maturity model.

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