

Green ICT Maturity Models

Towards a general approach

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Abstract—A lot of effort is still required in greening ICT and the use of ICT to green organisations. However, Green ICT initiatives are hard to sustain. In this context, Green ICT maturity models help by providing a benchmarking tool and a roadmap. However, several Green ICT maturity models have been proposed by different researchers over the years with no clear justification. This makes it difficult for companies to choose which Green ICT maturity model to adopt. This research aims at comparing the different Green ICT maturity models. This could help companies manage their Green ICT initiatives in a more sustainable way. It will analyse the evolution of Green ICT maturity models and provide cues for further research in this area.

Keywords—Green ICT, maturity models, sustainable development

I. INTRODUCTION

Much effort has been put so far in sustainable development and at least the rate of unsustainable growth has slowed down in recent years. Nevertheless, a lot still remains to be done in sustainable development as the world is getting less and less sustainable. It is the duty of everyone to bring his contribution to make the world a better place for ourselves and our future generations. Research on the link between Information and Communication Technologies (ICT) and sustainable development has shown that ICT does account for 2% of global carbon emissions [1] with its power consumption and e-waste on the upper trend. However, ICT could also be used to reduce the impact of human activities on the environment by 15% by 2020 [2] especially with applications geared towards dematerialisation use such as electronic transactions, video conferencing and e-commerce amongst others. However, ICT can have a positive or negative impact on the environment depending on how it is used [3]. There has been considerable research on prescriptive directives on how to reduce the impact of ICT on the environment such as in [4]–[7] amongst others which are focused on reduced resource use. However,

getting reliable data for such assessments is a daunting task [8]. Initial enthusiasm easily dies out in such cases. Thus, there is need for a carefully devised Green ICT strategy to craft an organisation's way to a harmonious development [4]. In this context, maturity models are very helpful. They can help in assessing the current status of companies with respect to best practices and they can also support in planning a roadmap for promoting environmental sustainability initiatives.

However, a number of Green ICT maturity models have been developed over the years, for example in [9]–[13]. They are based on different expectations, ambitions and assessment criteria and it can therefore be difficult to choose which model to adopt. An inappropriate choice could either not be motivating enough for a company or further discourage it and kill new Green ICT initiatives in the bud itself. In order to overcome this difficulty, we set off to compare and contrast several existing Green ICT maturity models in order to understand the functioning and limitations of these models through a cross comparative analysis. Subsequently, a generic approach to Green ICT maturity is developed and presented herein.

II. GREEN ICT MATURITY MODELS

Maturity models are not new. Way back in 1993, the Software Engineering Institute of Carnegie-Mellon University presented the Capability Maturity Model (CMM) for process maturity [14] which over the years evolved in the Capability Maturity Model Integrated (CMMI). It defined maturity in a number of levels each characterised by a specific behaviour. Organisations were encouraged to assess the level at which they were and then follow the characteristics of the next level to define initiatives for process improvement in their organisation. The advantage of the maturity model was that it allowed benchmarking across different organisations and also

provided the framework for a roadmap for process improvement.

This approach seems to have inspired Graeme who proposed a Green ICT maturity model [9]. This model (referred to as Model 1) is based on the estimation and optimisation of attitude, policies, practice, technology and metrics in the effort of the organisation towards Green ICT. It also looks at different categories such as equipment life-cycle, end user computing, enterprise & data centre and ICT as a low carbon enabler. The proposed maturity levels and their characteristics are:

- 0 – No Intention : No awareness
- 1 – Initial : Some awareness but no implementation
- 2 – Replicable: Ad-hoc implementation
- 3 – Defined: Formal but immature programs
- 4 – Managed: Methodical implementation with proper measurement
- 5 – Optimisation: All activities managed for optimal performance

Desai & Bhatia also proposed another Green IT maturity model (referred to as Model 2) [10]. It measures several aspects of an organisation's "operations, behaviour and achievements". It is centred on data centre and facilities, end user computing, asset lifecycle, IT service management and people activities. The different maturity levels are:

- Level 1 - Deficient : The company is evaluating green IT benefits but has no proven implementations yet
- Level 2 - Monitored: The company measures the carbon emissions of the IT activities in the organisation and effectively reduces them by 10%
- Level 3 - Optimised: Carbon emissions from IT in the organisation are reduced by at least half.
- Level 4 - Dynamic: The IT department is almost carbon neutral and reports about it
- Level 5 - Sustainable: IT is expected to help the business reduce its carbon footprint

The model prescribes a series of requirements for each pillar for each maturity level. Moreover, it uses carbon footprinting to assess maturity.

Donnellan, Sheridan & Curry proposed a Sustainable ICT Capability (SICT) Framework (referred to as Model 3) [11]. The framework consists of the following actions:

- define the scope and objectives of ICT
- appraise the existing sustainable ICT maturity
- grow and monitor SICT capability building blocks
- evaluate and monitor evolution of SICT capability

The different maturity levels are:

- Initial - Little awareness of sustainable ICT
- Basic - Limited sustainable ICT strategy but implementation is immature
- Intermediate - Presence of sustainable ICT strategy but although it is included in life cycle of systems, it is restricted to project level

- Advanced - Sustainability is a central theme of business and IT life cycles.
- Optimising - Sustainable ICT practices are applied across the whole supply chain for the organisation.

Hankel, Oud, Saan & Lago defended the need for a Green ICT Maturity model because most Green ICT initiatives are focused on reducing negative impacts of ICT [12]. They pointed out that, on one hand, a large part of ICT carbon emissions are with the end users and that, on the other hand, the production of ICT equipment accounts for the majority of their carbon footprint. They blamed current initiatives which focus too much on low hanging fruits which can be good for the short term but which prevents an optimal use of Green ICT. They therefore built a Green ICT maturity model by interacting with ICT experts over a workshop and then validated the model through a survey. The feedback allowed them to improve the model qualitatively although it did not allow quantitative conclusions.

The model (referred to as Model 4) is based on CMM and includes the following levels:

- Level 1: Initial
- Level 2 : Repeatable
- Level 3: Defined
- Level 4: Managed
- Level 5: Optimising

The model is centred on Green ICT in the organisation, Greening of ICT and Greening of operations with ICT. Although the model was built after consultation with Dutch higher education, the model can be used for all types of organisations.

DeMonsabert, Odeh & Meszarros defended the need for a framework to avoid inconsistencies in Green ICT initiatives and to enable an evaluation of same across organisations [15]. The authors built their model with objectives of environmental protection, economic feasibility, social responsibility and innovation. Their effort was a joint collaboration between a university and a Green ICT Non-Governmental organizations. They then embedded an evolutionary approach in their model - the first release was implemented in a company and feedback sought to build the second version of the model. The second version was oriented along the different dimensions of sustainability, namely social, environmental, economic and innovation.

This model is new in terms of its coverage of non-environmental aspects of sustainability. Its social sustainability criteria assess sustainability governance, workforce, consumers and suppliers, local community and society. However, it does not provide a maturity model per se and thus was excluded from this study.

The UK Government proposed a model (referred to as Model 5) which is based on CMMI model and is in line with the Green ICT strategy of the UK government [13]. The maturity levels are:

- Foundation - evidence and intelligence gathering to inform actions, agreed plans

- Embedded - show commitment and basic initial development, basic processes in place
- Practised - moving forward taking actions to improve, repeatable actions
- Enhanced - pushing for new opportunities, adoption of best practice, improving capability
- Leadership - taking control, having own vision, optimising performance

They also defined 2 additional levels of ‘ad-hoc’ (where there is no clear strategy) and ‘not applicable’ (where it is not worth or not possible to have an assessment). It focuses on the following areas (with a subdivision into further subcategories):

- Manage ICT Services
- Manage ICT Technology
- Changing ICT Services
- Exploiting ICT

It can be seen that the different Green ICT maturity models have some features in common but are at first glance not identical. However, none of the proposed models (except in [12] which gave a superficial overview of the different maturity models) compare their work with previous work nor justify the need for a new maturity model. There is thus need for a comparison between the different Green ICT maturity frameworks to assess their quality and their appropriateness to an organisation.

III. RESEARCH METHODOLOGY

We adopted a multiple case study approach for our research. After a review of the materials on the available Green ICT maturity models, it was obvious that it was not easy to assess a company as per a maturity model. This was because many of the models required assessments by consultants although in some cases such as in [12], [13], there were detailed guidelines to perform the assessment while in others, third-party self-assessments such as in [16] were available. We thus set out to devise a way to carry out a quick preliminary assessment. The approach followed was to first select a Green ICT maturity model and devise questions which would allow us to verify if the company met the lowest maturity level in that model. If this was the case, then same would be applied for the next higher maturity level and so on and so forth until the company did not match up to a certain maturity level. The final assessment was the maturity level just below the one which the company failed to meet.

We then prepared a list of fictitious companies with different experiences with Green ICT generated from each level of all the selected Green ICT maturity models. These companies were then assessed with all the other Green ICT maturity models to compare the different assessments. The results were then analysed.

We are aware that the ideal situation would have been to apply the Green ICT maturity model assessment with the proper consultants on selected real companies with different Green ICT experiences. However, for various reasons such as lack of resources and time, we had to resort to an alternative

approach which would still be appropriate for our research objectives.

IV. RESULTS & ANALYSIS

The assessment criteria devised for the different Green ICT maturity models are as follows:

- Model 1 [9]

Level 0: Basic question on general Green ICT awareness. Qualifies for the level if displays no awareness of Green ICT.

Level 1: Some questions on Green ICT awareness and implementation. Qualifies for the level if company has some awareness but has not implemented any Green IT initiatives.

Level 2: Question on any formal Green ICT strategy. Qualifies for the level if company has implemented some Green ICT initiatives but has no formal Green ICT strategy.

Level 3: Questions on implementation of Green ICT strategy. Qualifies for the level if company has a Green ICT strategy but is still immature in its approach.

Level 4: Question on measurement and management of Green ICT strategy. Qualifies for the level if makes use of metrics in the implementation and control of the Green IT strategy.

Level 5: Question on overall activity of the organisation. Qualifies for the level if the impact on the environment is optimised for all activities.

- Model 2 [10]

Level 1: Questions on Green ICT awareness and any initiatives taken in this direction. Qualifies for the level if company has no Green ICT implementations.

Level 2: Questions on measurement of achievement of Green ICT initiatives. Qualifies for the level if company is able to reduce the carbon emissions of the ICT activities by 10%.

Level 3: Questions on governance of Green ICT initiatives. Qualifies for the level if there is a dedicated organisation for driving Green ICT initiatives and if these result in a reduction of 50% of the carbon emissions of the ICT activities of the company.

Level 4: Questions on carbon emissions reporting due to Green ICT initiatives. Qualifies if the ICT department is almost carbon neutral and reports on it.

Level 5: Questions on carbon emissions reductions for the whole organisation. Qualifies if Green ICT initiatives help reduce carbon emissions for the whole organisation.

- Model 3 [11]

Initial: Questions on Green IT awareness and any implementations. Qualifies for the level if company has only little understanding and a few policies.

Basic: Questions on Green IT strategy and its implementations. Qualifies for the level if company has a

Green IT strategy but implementation is immature with no clear accountability.

Intermediate: Questions on sustainable IT strategy and on the control of its implementation. Qualifies for the level if the company has a full sustainable IT strategy with targets and metrics at the individual project level.

Advanced: Questions on the importance of sustainability in IT and business life cycles. Qualifies for the level if the company puts sustainable ICT at the heart of IT and business planning and both IT and the business drive the efforts together.

Optimising: Questions on sustainable ICT across the extended enterprise. Qualifies for the level if the company adopts sustainable ICT practices across its full supply chain.

- Model 4 [12]

Level 1 – Initial: Questions on Green ICT awareness and practice in the organisation. Qualifies for the level if there is little awareness /practice, for example, in terms of e-waste and energy efficiency and there is no Green ICT strategy for the organisation.

Level 2 – Repeatable: Questions on Green ICT strategy and scope of its implementation. Qualifies for the level if there is only a basic Green ICT strategy and the scope of implementation is restricted to the ICT department.

Level 3 – Defined: Questions on Green ICT strategy and scope of its implementation. Qualifies for the level if there is a clear Green ICT strategy geared towards resource consumption and the ICT department is a regular partner in greening of some processes across the organisation.

Level 4 – Manageable: Questions on the inclusion and review of Green ICT strategy in the organisation and the role of ICT department in greening of the organisation. Qualifies for the level if the Green ICT policy is taken into consideration in all business processes and it is itself reviewed regularly.

Level 5 – Optimising: Questions on the role and scope of the Green ICT strategy. Qualifies for the level if the Green ICT strategy is broad, allows participants to moderate their actions to optimise their impact on the environment and is applied beyond the frontiers of the organisation to reach the whole supply chain.

- Model 5 [13]

Level 0a – Not applicable: This is a decision by the organisation that it is not worth or possible to carry out an assessment.

Level 0 – Ad-hoc: Questions on Green ICT strategy. Qualifies for the level if there is no agreed Green ICT plan in place in the organisation.

Level 1- Foundation: Questions on Green ICT strategy. Qualifies for the level if there is an agreed Green ICT plan in

the organisation and environmental issues are considered in business decisions.

Level 2 – Embedded: Questions on Green ICT strategy and committed resources. Qualifies for the level if there are resources committed on the Green ICT strategy and initial actions have started.

Level 3 – Practised: Questions on implementation of Green ICT strategy across the organisation. Qualifies for the level if the Green ICT strategy is agreed upon and its implementation is growing across the organisation.

Level 4 – Enhanced: Questions on control of the implementation of Green ICT strategy in the organisation. Qualifies for the level if there is a consistent application of Green ICT strategy with an emphasis to improve and learn across the organisation.

Level 5 – Leadership: Questions on inclusion of Green ICT strategy within the organisation strategy. Qualifies for the level of effectiveness of Green ICT strategy is measured and if sustainability concerns form part of business strategy.

We used the selected Green ICT maturity models to generate the list of fictitious companies as follows:

- Model 1 – companies A-E
- Model 2 – companies F-J
- Model 3 – companies K-O
- Model 4 – companies P-T
- Model 5 – companies U-Y

This approach gave the following list of fictitious companies with different experiences in Green ICT:

- A. Company has no Green ICT awareness.
- B. Company has some Green ICT awareness but has not initiated any Green ICT actions
- C. Company has implemented some Green ICT actions but has no formal Green ICT strategy
- D. Company has a formal Green ICT strategy and has started only started implementing it.
- E. Company has implemented its Green ICT strategy and makes use of metrics to control its implementation
- F. Company has no implemented any Green ICT initiatives
- G. Company has implemented a few Green ICT initiatives resulting in a reduction of carbon footprint of its ICT activities by 10%
- H. Company has a dedicated organisation for Governance of Green ICT and achieves a reduction of carbon footprint of its ICT activities by 50%
- I. Company's ICT department is carbon neutral and reports its carbon footprint
- J. Company uses Green ICT to reduce carbon footprint across the organisation systematically

- K. Company has little awareness and no policies on Green ICT
- L. Company has a Green ICT strategy but implementation has just started
- M. Company has a Green ICT strategy and has proven implementations with metrics to control it - Green ICT is a concern in ICT projects.
- N. Company has implemented its Green ICT strategy and Green ICT concerns are at the heart of decisions across the whole business. Green ICT is driven by the business and ICT departments together.
- O. Company applies its Green ICT strategy across its entire supply chain
- P. Company has little awareness / practice in Green ICT and does not have a Green ICT strategy
- Q. Company has a basic Green ICT strategy but the scope of its implementation is restricted to the ICT department
- R. Company has a clear Green ICT strategy geared towards resource consumption and the scope of this implementation has gone outside the ICT department (but not yet the whole organisation)
- S. Company has a practice of including Green ICT policy in all business decisions and reviews its Green ICT policy regularly as well.
- T. Company has a practice to include Green ICT policy in all its actions across its entire supply chain
- U. Company has no green ICT plan
- V. Company has an agreed Green ICT plan and environmental issues are generally considered in the company
- W. Company has an agreed Green ICT plan and has committed resources to it with some initial results
- X. Company has an agreed Green ICT plan and its implementation is growing across the company
- Y. Company measures the effectiveness of the implementation of its Green ICT strategy and sustainability is considered as part of all business strategy

For the analysis, the results of the assessment of each Green ICT maturity model was slightly modified for comparison sake. As all the models used a five level scale, all assessment levels were coded in the number range 0-4 to facilitate comparison. A colour coding was also used to show the difference in assessment of the same company by the different Green ICT maturity models. The colour coding followed is red, amber, yellow, blue and green for levels 0 to 4 respectively.

The table below shows the results of this analysis:

TABLE I. COMPARISON OF GREEN ICT MATURITY ASSESSMENTS

COMPANY	ASSESSMENT				
	Model 1	Model 2	Model 3	Model 4	Model 5
A	0	0	0	0	0
B	1	0	0	0	0
C	2	0	0	0	0
D	3	1	1	1	1
E	4	2	2	2	2
F	1	0	0	0	0
G	2	1	1	1	1
H	3	2	2	2	2
I	4	2	2	2	2
J	1	1	1	1	1
K	2	0	0	0	0
L	3	1	1	1	1
M	4	2	2	2	2
N	4	4	3	3	4
O	4	4	4	4	4
P	1	0	0	0	0
Q	1	1	1	1	1
R	3	2	2	2	2
S	4	4	4	4	4
T	4	4	4	4	4
U	0	0	0	0	0
V	1	1	1	1	1
W	1	1	1	2	2
X	3	3	3	3	3
Y	4	4	4	4	4

The results show that the different models may agree on low Green ICT maturity companies near the 0 level. However, they differ on the medium to high Green ICT maturity companies. The increasing expectations of all stakeholders in recent times probably explains the difference in the models. Indeed, the oldest model in [9], although encouraging for low achieving (from the Green ICT maturity perspective), is less ambitious and discerning as the other models. There is however agreement on the need for a Green ICT strategy or plan and for a rigorous control of its implementation across the different models. There is also increasing use of metrics and quantitative ways of controlling Green ICT initiatives for higher maturity levels. Models such as the one in [10] include carbon footprinting throughout as a means of assessment. Although most of the models are ICT department centric with many initiatives starting from the ICT department itself, they also recognize that Green ICT cannot be restricted to the ICT department and reward those that take it across the whole organization. Some like in [11], [12] even expect high maturity companies to extend Green ICT initiatives to the full supply chain. All the different models focus mostly on the environmental aspect of Green ICT with rare exceptions such as the one in [15] which was unfortunately excluded from the study. It is clear though that Green ICT maturity cannot focus solely on the environmental aspect of sustainability any longer.

V. GENERAL GREEN ICT MATURITY MODEL

In light of the above, we propose a general Green ICT model encompassing the different models reviewed. The model should be discerning at the lower levels to differentiate

between those who are not doing anything and those trying to devise and implement initial Green ICT initiatives. We feel that this is important to encourage those starting on the journey of Green ICT. However, it should also set more ambitious goals such as the inclusion of metrics at higher maturity levels. Finally, Green ICT mature companies are expected to promote Green ICT values not only within their companies but rather across their full supply chain. Our proposed general Green ICT model thus includes the following maturity levels:

0. Reckless: At this level, companies have little or no awareness of Green ICT and especially believe that nothing can be done at the company level.
1. Ad-hoc: At this level, there is recognition of Green ICT but initiatives are ad-hoc and not sustainable.
2. Conscious: At this level, the company has a Green ICT plan and is committed to its implementation across the ICT department
3. Responsible: At this level, the company has a Green ICT plan and is committed to its implementation across the whole organization. It is important for metrics to be defined and monitored at this level.
4. Role model: At this level, the company includes Green ICT issues at all levels of business decision making and strives to implement it across its full supply chain. Companies here are in a virtuous improvement mode for sustainable development of the business.

This model regroups the main directions and the levels from several models and will help to provide a standard guidance for companies wishing to properly manage their Green ICT initiatives.

VI. CONCLUSION AND FUTURE WORK

The comparison attempted was not a statistical one and as such, it is difficult to make far reaching generalising claims. However, a qualitative assessment shows that there is some agreement as well as clear differences among the different Green ICT models.

Future work would involve confirming our results through more quantitative approaches. It would also be interesting to further develop and test the generic Green ICT maturity model. There is also need for a taxonomy of Green ICT maturity models which would give a direction for future development of Green ICT maturity models.

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