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A Revised Framework for the Governance and Management of Green IT

J. David Patón-Romero
(AQCLab Software Quality Laboratory, Ciudad Real, Spain
JoseDavid.Paton@gmail.com)

Maria Teresa Baldassarre
(Department of Informatics, University of Bari "Aldo Moro" (UniBa), Bari, Italy
mariateresa.baldassarre@uniba.it)

Moisés Rodríguez
(AQCLab Software Quality Laboratory, Ciudad Real, Spain
mrodriguez@aqclab.es)

Mario Piattini
(Alarcos Research Group, Institute of Technologies and Information Systems
University of Castilla-La Mancha (UCLM), Ciudad Real, Spain
Mario.Piattini@uclm.es)

Abstract: Sustainability is not an option; it has become a primordial necessity in our nearest future and in the base of the growth of our society in all aspects and areas. Information Technology (IT) is playing a leading role in the field of sustainability. Organizations around the world realize the importance of Green IT and the great benefits it generates at an ecological, social, and economic level. That is why more and more organizations advocate for a sustainable environment *in* and *by* IT and demand standards and guidelines in this regard. However, this transformation towards the Green IT is not simple, it is a profound change that must be approached in stages, and the first one is the level of governance and management. For this reason, after developing, applying, and validating a first version (obtaining a series of lessons learned and points of improvement), we have carried out the development of the second version of a *"Governance and Management Framework for Green IT"*. With this revised framework, we intend to offer a more complete and solid guide that helps organizations to gradually implement, evaluate, and improve all those aspects and characteristics of governance and management that are the basis of the processes, practices, and activities of Green IT. The results obtained after validating the revised framework demonstrate a stronger validity, usefulness, and applicability, offering a solid guide to organizations in their efforts to gradually implement, evaluate, and improve Green IT.

Keywords: Governance, Management, Audit, Green IT, Sustainability, Framework, Maturity Model, ISO/IEC 33000
Categories: H.0, J.0, K.0, K.4, K.6

1 Introduction

Sustainability is transforming our world. Since the well-known "Brundtland Report" [Brundtland et al., 1987] appeared in 1987, advocating for the first time in the history

of humankind for a sustainable development, sustainability has evolved from an idea of a few to a need of many.

Such is the importance of sustainability that has become one of the main objectives of governmental organizations around the world, which have committed themselves at the United Nations (UN) to achieve a sustainable development in all areas through an Agenda for the year 2030 (with 17 goals and 169 targets for the sustainable development) [United Nations, 2015], in which they declare:

"We are determined to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations"

One of the areas that organizations around the world have put in their sights to implement sustainability is the area of Information Technology (IT).

Gartner, Inc., one of the most important advisory firms in this area of IT, estimates that *"global carbon emissions attributable to IT have been calculated at 2% to 2.5% of world totals - about the same as the airline industry - and as high as 5-6% of developed nation totals"* [Mingay, 2007]. In addition, the advisory firm McKinsey & Company, Inc., dedicated to strategic management issues, has predicted that *"carbon footprint of the IT sector will triple during the period from 2008 to 2020"* [Webb, 2008], following the same idea of the Ericsson organization that stipulates in this period an increase of almost 60% of the total electricity consumption of the IT sector, owing this to the increasing number of devices, as well as to the network expansion [Ericsson, 2013].

That is why the field of Green IT has emerged, responding to the following definition: *"the study and practice of design, build and use of hardware, software and information technologies with a positive impact on the environment"* (definition adapted from [Calero and Piattini, 2015]).

From this definition we can see that the main objective of Green IT is not only to reduce the impact that IT has on the environment, but also to serve as a bridge to reduce the environmental impact of the rest of the areas through the use or application of IT. That is why Green IT can and must be understood from two perspectives (as defends the idea proposed by [Erdélyi, 2013]):

- ***Green by IT*:** in which IT is understood as a capacitator or enabler (in the sense of [Unhelkar, 2011]), providing the tools needed to allow tasks of diverse nature in diverse areas to be carried out in a sustainable manner for the environment.
- ***Green in IT*:** in which IT is understood as a producer; that is, when IT itself has an impact on the environment due to its energy consumption and the emissions it produces, which impact must therefore be reduced.

Fortunately, Green IT is more than a trend, and more and more organizations are realizing the importance and necessity of this area, implementing some form of sustainable solutions within their processes and daily operations [Brodkin, 2008] [Deng and Ji, 2015]. In fact, large part of society nowadays is willing to pay more for a sustainable product [Cazier and Hopkins, 2011], what mainly and together with other reasons has led to Green IT and, in general, sustainability have become in a competitive business advantage [Wimmer et al., 2010] [Simmonds and Bhattacherjee, 2014].

However, organizations have a great handicap against them to carry out the implementation, evaluation, and improvement of Green IT practices in an organized and standardized way, due to the non-existence of studies, standards and/or best practices (among others) that are specific to Green IT [Patón-Romero and Piattini, 2016] [Calero and Piattini, 2017] [García-Mireles et al., 2018] [García-Berna et al., 2018] [Naumann et al., 2011].

In fact, many organizations already have programs for corporate social responsibility, energy saving, contribution to ecological issues, etc., but they do not know how to approach the Green IT issue. An example of this is the university of the authors of the present study, the University of Castilla-La Mancha (UCLM), as well as some software factories close to it, which, although they have some implementations of Green IT (carried out under its own criteria), they want but they do not know/cannot govern and manage such implementations in an appropriate and accurate manner.

Therefore, with the foregoing in mind, we developed a first version of the *"Governance and Management Framework for Green IT"* (from now on, GMGIT) [Patón-Romero et al., 2017]. In this first version, we established the necessary characteristics to define, implement, and audit the basic characteristics of governance and management of Green IT in the organizations.

After carrying out different validations with the GMGIT 1.0, we obtained a series of lessons learned that helped us improve, refine, and expand the framework, obtaining a new and more solid version, the GMGIT 2.0. As so, in the present study, we present a revised framework for the governance and management of Green IT, through which we intend to show the progress that is being made in this area, as well as the new characteristics and main changes performed in the GMGIT 2.0.

Likewise, the GMGIT 2.0 represents a significant advance with respect to the previous version and the area in which it is framed. This is due to the inclusion of new processes, which allow covering all business processes in organizations in relation to Green IT (the previous version only covered the most related to the Green IT); the differentiation made between *Green by IT* and *Green in IT*, which helps to better understand the practices in this regard and to establish more specific contexts; and the adaptation and inclusion of an ISO/IEC 33000-based maturity model developed specifically for the GMGIT 2.0, which helps to carry out the whole process of implementation, evaluation, and improvement of Green IT in a systematic and progressive manner; among other changes.

The rest of the present study is organized as follows: Section 2 contains the background about the governance and management of Green IT and the maturity models in this context, as well as the lessons learned we have obtained from the validations of the GMGIT 1.0; Section 3 presents the main and new characteristics of the revised *"Governance and Management Framework for Green IT"*; Section 4 describes the validation performed with this revised framework; finally, Section 5 shows the conclusions and the proposals for future work.

2 Background

2.1 Governance and Management of Green IT

The governance and management are the fundamental basis of all business areas [Bader, 2008]. While governance is responsible for establishing the set of rules and practices that ensure that the organization is meeting the expectations of all its stakeholders, management is responsible for planning, directing, and controlling all processes and assets to achieve the objectives and goals of the organization. Therefore, without having established the governance and management of an area, it is impossible to carry out in a correct and efficient way the implementation, control, and improvement of all the aspects of this area, as well as to obtain the expected results and benefits in this regard.

From the point of view of IT, one of the most complete frameworks in this regard is COBIT 5 (*Control Objectives for Information and related Technology*) [ISACA, 2012], a framework developed by ISACA (*Information Systems Audit and Control Association*). Through this framework, a guide is established for the implementation and, mainly, the control and audit of the governance and management of different areas of IT (such as security, risks, etc.). However, COBIT 5 does not take sustainability into account as another area (and increasingly important area) within IT.

Taking into account this deficiency in the COBIT 5 framework, in [Patón-Romero and Piattini, 2016] we carried out a systematic mapping study (SMS) [Budgen et al., 2008] [Kitchenham, 2007] [Petersen et al., 2008] in order to know the state of the art of the area of governance, management, and auditing of Green IT.

This SMS demonstrates the novelty of the field of Green IT and the practically non-existence of frameworks, standards, studies, and/or research in this area of governance, management and auditing of Green IT. In fact, this SMS highlights only two studies as closely related to this area: first, study [Gabriel, 2008] contains an analysis of the state of the art of the Green IT and highlights the importance of conducting audits in this regard; and, second, study [Gray et al., 2014] shows a survey conducted to internal auditors from different organizations in relation to their opinions and professional experiences about Green IT.

Also, as gray literature we have found two other studies not included among the studies found in the SMS that are relevant in this area of governance, management, and auditing of Green IT: on the one hand, study [Gray, 2011] carries out an analysis about the Green IT practices that organizations carry out nowadays, through which the lack of experience of the organizations in this respect is demonstrated and it is identified what they should do in the future and the opportunities that exist in this respect, especially for auditors, and, on the other hand, study [Ambtman, 2011] identifies and proposes different characteristics that auditors should consider within a Green IT audit and also highlights the non-existence of frameworks and/or standards to implement and audit the Green IT.

That is why, keeping in mind all of the above and seeing the need to develop a common framework to help organizations implement, evaluate and improve best practices of Green IT, we developed the first version of the *"Governance and Management Framework for Green IT"* (GMGIT 1.0) [Patón-Romero et al., 2017]. Currently, after carrying out several validations with the GMGIT 1.0, we have

reinforced and improved the framework, obtaining a more solid and useful new version, the GMGIT 2.0, whose novelties and main changes are presented in the present study.

2.2 Maturity Models of Green IT

Maturity models are one of the most useful tools used by organizations in their search for greater efficiency and effectiveness in different business areas, as well as to generate greater benefits and an increase in business value.

A maturity model is a structured set of elements (best practices, measurement tools, analysis criteria, etc.) that allows to evaluate the degree of which an organization implements best practices in a specific business area, comparing them with standards, identifying those gaps and/or weaknesses in which an organization must focus to improve and to establish a process of continuous improvement. From the point of view of the organizations it offers a guide for the implementation and improvement of best practices in a determined area, following a roadmap of evolutionary improvement, through evolutionary steps, from the most basic to the most mature and innovative processes.

That is why the development of any framework that establishes characteristics for the implementation, control and improvement of activities, practices and/or processes in any business area, must be accompanied by the development of a maturity model that allows to carry out all these actions in a simpler, organized, and progressive way.

Therefore, with the aim of developing a maturity model for the GMGIT, first of all, we carry out an SMS to know the maturity models that currently exist in the area of Green IT (and sustainability in general), which is included in [Patón-Romero et al., 2018].

This SMS shows the novelty of this field of Green IT maturity models and the non-existence of a solid and validated maturity model for Green IT. Analyzing the 27 studies related with sustainability maturity models found through this SMS, only 9 of them are related with the area of Green IT. Of these 9 Green IT-related maturity models studies, only 3 are validated and highlighted as the most complete and applicable proposals [Buchalcevova, 2015] [Curley et al., 2016] [Hankel et al., 2014]. However, it is not possible to adapt or use these 3 outstanding proposals, since each one deals with a different problem that is not applicable to the characteristics of the GMGIT.

Thus, once we analyzed the state of the art of the Green IT maturity models area, and based on the results obtained, we developed a first maturity model for the GMGIT 1.0 [Patón-Romero et al., 2018] based on the ISO/IEC 15504 [ISO, 2003]. Currently, after carrying out several validations with both the GMGIT 1.0 and the ISO/IEC 15504-based maturity model for the GMGIT 1.0, we have developed an updated version of the maturity model for the GMGIT 2.0 following the new ISO/IEC 33000 family of standards, as explained in more detail in Section 3.3.

2.3 Lessons Learned from the First Version of the *"Governance and Management Framework for Green IT"*

One of the most important and significant results when some kind of validation is done, are the lessons learned. Thanks to the lessons learned, we can find and solve deficiencies or problems that from a theoretical point of view were not considered or were wrong, as well as refining and improving the object of the validation.

During the validations that we carried out with the GMGIT 1.0, through a series of focus groups and a couple of case studies [Patón-Romero et al., 2017], we obtained a set of lessons learned that have helped us both to solve problems and cover deficiencies of the framework, as well as to refine, expand and improve it.

The first lesson we learned was based on the difficulty for organizations to correctly understand and interpret some concepts of the enablers of the framework, especially those of the process enabler. This is due to the novelty of Green IT and the lack of standards, frameworks, and/or best practices in this regard that standardize and strengthen the concepts of Green IT, avoiding that each organization applies this area according to its own criteria. This lesson learned together with its solution is discussed in detail in Section 3.4.

Second, when we carried out the case studies, conducting audits of Green IT following the audit questions that we established in GMGIT 1.0, we realized the need for a maturity model. This maturity model is necessary since, until now, we evaluated all the processes without any distinction between them, that is, without considering that some processes depended on more basic ones that had to be analyzed beforehand and with those that had to be fulfilled in the first place. Therefore, thanks to the development of a maturity model, the whole evaluation phase of Green IT would be simplified and carried out in a gradual and organized way, focusing on those basic processes in the first place and going up towards more specific and complex processes as these first processes were being fulfilled. Section 3.3 describes in detail the maturity model based on the ISO/IEC 33000 developed for the GMGIT 2.0.

Third, related to the first lesson learned obtained, we realized that the members of the organizations we interviewed had many problems in correctly understanding and interpreting the activities specific to Green IT of each of the processes of the framework. The organizations did not know if they actually fulfilled a certain activity or not, as they were disoriented and confused with practices that they carried out on whether it was to reduce the impact of the IT itself or if it was to use IT to reduce the impact of different areas of the business, which meant that they did not correctly interpret the scope of each activity. Therefore, we realized the need to differentiate between *Green by IT* and *Green in IT* in the activities of each of the processes of the framework. Details on the solution regarding the differentiation between *Green by IT* and *Green in IT* are shown in Section 3.2.1.

Finally, the validations made also reinforced our idea that we had from the beginning to include more processes in the framework. Initially we only decided to adapt and include in the GMGIT 1.0 the 15 processes of the COBIT 5 framework [ISACA, 2012] that we consider most closely related to the Green IT (as explained in [Patón-Romero et al., 2017]), in order to obtain a first contact as proof of concept and to obtain the necessary experience to include the rest of the processes of COBIT 5 in the GMGIT 2.0. The validations carried out with the GMGIT 1.0 showed us the viability of the framework, which supposed a solid starting point with the basic characteristics to be considered in Green IT. For its part, the lessons learned made us reaffirm the need to include the rest of the processes of the COBIT 5 framework to reinforce and expand the scope of the GMGIT towards more complex and elaborated processes. In Section 3.2.2 the inclusion of these 22 new processes in the GMGIT 2.0 is shown in detail.

3 A Revised *"Governance and Management Framework for Green IT"*

The changes made in this second version of the *"Governance and Management Framework for Green IT"* (GMGIT 2.0) are shown in the following sub-sections.

3.1 Updated Structure of the Framework

In the GMGIT 2.0 a new section has been added (Section IV), so the updated structure is as follows:

- **Section I:** which contains the necessary concepts to understand the rest of the framework. On the one hand, an overview of the Green IT is defined, and, on the other hand, the basic architecture of COBIT 5 is described and how it can be adapted to the specific needs of Green IT.
- **Section II:** it is the main part of the framework and it follows the guidance of the enablers established by COBIT 5 to establish and describe the specific enablers for Green IT, specifying in detail the governance and management characteristics of Green IT. These enablers are the following:
  - Principles, policies and frameworks that are specific to Green IT.
  - Processes related to Green IT.
  - Organizational structures that are specific to Green IT.
  - Culture, ethics and behavior that are specific to Green IT.
  - Information that is specific to Green IT.
  - Services, infrastructure and applications that are specific to Green IT.
  - People, skills and competencies that are specific to Green IT.
- **Section III:** this section proposes a guide or framework for conducting Green IT audits, which includes all the phases to follow to perform a Green IT audit, as well as the aspects to be considered and the audit questions to be asked, taking as a basis the enablers defined in Section II of the framework (mainly, the processes enabler).
- **Section IV:** this is the new section that has been included in the second version of the framework and includes a maturity model based on the ISO/IEC 33000 to assess the governance and management of the Green IT. In this maturity model, the maturity levels of Green IT are established, the processes related to Green IT are categorized in each of these maturity levels, each of the attributes of the different processes are described, and the capability dimension of the processes are established (cf. Section 3.3).

3.2 Changes in the Enabler of Processes of Green IT

3.2.1 Differentiation between Green by IT and Green in IT

One of the main and most important changes is the differentiation that has been made in the activities of each practice of the processes (which determine the compliance or not of each process) between *Green by IT* and *Green in IT*.

First of all, it is important to remember each of these definitions of *Green by IT* and *Green in IT*, now applied specifically to the processes of governance and management:

- ***Green by IT*:** when IT is understood as Green IT tools, that is, when governance and management characteristics to help perform tasks of different kinds in different areas of the business in an environmentally sustainable way using IT are identified, define, establish, etc.
- ***Green in IT*:** when in IT elements are considered Green IT issues, that is, when a specific IT element includes/adopts Green IT characteristics to help reduce its impact on the environment.

So, based on the lessons learned we obtained from the validations carried out with the GMGIT 1.0, we realized that the term Green IT is very broad to apply in a general way through the framework in an audit or when implement sustainable practices. In most cases, the organizations were confused, they did not see clearly if they were dealing with Green IT practices or not and it was very tedious to understand the scope of this term. Once we explained to the managers of the organizations the Green IT from the point of view of these two terms (*Green by IT* and *Green in IT*), they began to understand everything better and they found the whole process easier. Thus, the main recommendation we obtained from organizations was to differentiate these two terms in the processes and make specific audits and/or implementations of *Green by IT* or of *Green in IT*.

That is why we decided to establish a specific differentiation between *Green by IT* and *Green in IT* in the different processes of the GMGIT. To do this, we divided each of the specific Green IT activities of the different practices of the processes in *Green by IT* activities and *Green in IT* activities. In the Figure 1, as example, this differentiation carried out in the activities of the EDM01.01 practice of EDM01 process is shown (EDM – Evaluate, Direct and Monitor).

As we can see in the Figure 1, this differentiation between *Green by IT* and *Green in IT* has not been done in the specific inputs and outputs of each practice. This is so because we believe that, although it is true that an organization needs to have a clear distinction between these two terms in the activities to correctly evaluate each practice of the processes, this differentiation in the inputs and outputs is not necessary, because these can be treated in a generic way, since an organization may have established, for example, a general "Principles of Green IT", although they only deal with specific Green in IT practices. In addition, these inputs and outputs would be the same for both *Green by IT* and *Green in IT*.

EDM01: Practices, Inputs/Outputs and Activities of the Process that are specific to Green IT

Governance Practice	Inputs specific to Green IT		Outputs specific to Green IT	
	From	Description	Description	To
EDM01.01 Evaluate the governance system Identify the stakeholders and commit to them continually, document the understanding of the requirements and project the current and future design of governance of Green IT.	Outside the scope of the *Governance and Management Framework for Green IT*	Legal, regulatory and contractual requirements, as well as trends and factors that affect Green IT	Principles of Green IT	EDM01.02 APO01.01 APO01.03 APO01.04 APO02.01 APO02.05

Activities specific to Green By IT

1. Analyze and identify the internal and external factors of the context of the organization (legal, regulatory and contractual requirements, trends…) that might have an influence on the design of the governance of Green by IT.
2. Evaluate and determine the role and relevance of Green by IT, and compliance with it, as regards the needs of the organization and the legal and regulatory requirements.
3. Define the principles of Green IT that will guide the design of the enablers of Green by IT.
4. Understand the organizational culture of the decision-making and establish an optimal model in the decision-making of Green by IT.

Activities specific to Green In IT

1. Analyze and identify the sustainability factors (legal, regulatory and contractual requirements, trends...) that might have an influence on the design of the IT governance.
2. Evaluate and determine the role and relevance of Green in IT, and compliance with it, as regards the needs of the organization and the legal and regulatory requirements.
3. Define the principles of Green IT that will guide the design of the enablers IT.
4. Understand the organizational culture of the decision-making and establish an optimal model in the decision-making of IT that takes into account the Green IT.

Figure 1: Differentiation between Green by IT and Green in IT in the activities of the EDM01.01 practice of EDM01 process

3.2.2 Inclusion of New Processes

Another remarkable change is the inclusion of 22 new processes that, together with the 15 processes already existing in the GMGIT 1.0, allow covering all business areas from the point of view of governance and management of Green IT.

In the GMGIT 1.0 [Patón-Romero et al., 2017] we decided to include and adapt to Green IT only those processes (15 in total) of the COBIT 5 framework that, together with a group of experts in the area, we consider more closely related to the Green IT. We did this in order to avoid that the first version of the framework was too complex and unmanageable without the necessary experience and to be able to carry out a first contact and a proof of concept in order to determine if a framework with these characteristics was really applicable and necessary in this area.

After the validations that we carried out with the GMGIT 1.0, we could observe the usefulness and necessity of a framework of these characteristics, at the same time that we obtained lessons learned and the necessary experience to, on the one hand, refine the existing characteristics in the framework, and, on the other hand, expand the framework with new characteristics.

Therefore, in the GMGIT 2.0, again taking as a basis the 37 processes established by the COBIT 5 framework [ISACA, 2012], we have decided to include and adapt to the Green IT 22 new processes, through which we intend to cover all the business areas that affect and may be affected by the Green IT. Therefore, the GMGIT 2.0 is composed

of a total of 37 processes (5 governance processes and 32 management processes) as shown below (the new processes included have been marked with an asterisk):

- **Governance processes:**
  - EDM01. Ensure governance framework setting and maintenance.
  - EDM02. Ensure benefits delivery.
  - EDM03. Ensure risk optimization.
  - EDM04. Ensure resource optimization.
  - EDM05. Ensure stakeholder transparency.
- **Management processes:**
  - APO01. Manage the IT management framework.
  - APO02. Manage strategy.
  - APO03. Manage enterprise architecture. *
  - APO04. Manage innovation. *
  - APO05. Manage portfolio. *
  - APO06. Manage budget and costs.
  - APO07. Manage human resources. *
  - APO08. Manage relationships.
  - APO09. Manage service agreements. *
  - APO10. Manage suppliers. *
  - APO11. Manage quality. *
  - APO12. Manage risk. *
  - APO13. Manage security. *
  - BAI01. Manage programs and projects. *
  - BAI02. Manage requirements definition.
  - BAI03. Manage solutions identification and build.
  - BAI04. Manage availability and capacity. *
  - BAI05. Manage organizational change enablement. *
  - BAI06. Manage changes. *
  - BAI07. Manage change acceptance and transitioning. *
  - BAI08. Manage knowledge. *
  - BAI09. Manage assets.
  - BAI10. Manage configuration. *
  - DSS01. Manage operations.
  - DSS02. Manage service requests and incidents. *
  - DSS03. Manage problems. *
  - DSS04. Manage continuity. *
  - DSS05. Manage security services. *
  - DSS06. Manage business process controls. *
  - MEA01. Monitor, evaluate and assess performance and conformance.
  - MEA02. Monitor, evaluate and assess the system of internal control. *
  - MEA03. Monitor, evaluate and assess compliance with external requirements.

The acronyms of the processes stand for: EDM – Evaluate, Direct and Monitor; APO – Align, Plan and Organize; BAI – Build, Acquire and Implement; DSS – Deliver, Service and Support; MEA – Monitor, Evaluate and Assess.

3.3 Adaptation to ISO/IEC 33000

As we were validating the GMGIT 1.0 we realized the need for a maturity model that would allow us to carry out the phases of evaluation/audit, implementation, and improvement of the Green IT in a gradual and organized way. That is why we developed a first maturity model for the GMGIT 1.0 based on the ISO/IEC 15504 family of standards [Patón-Romero et al., 2018].

We chose the ISO/IEC 15504 [ISO, 2003] to carry out a first contact because it is one of the default standards most used in different fields, such as aerospace [Cass et al., 2001], software engineering [Ardimento et al., 2008] [Fernández-Sáez et al., 2016] [Garzás et al., 2013], government [Gökalp and Demirörs, 2016], risk management [Ivanyos and Sándor-Kriszt, 2015], automotive [Automotive SIG, 2015] [Lami et al., 2016], information security [Mesquida and Mas, 2015], health [Mc Caffery and Dorling, 2010] [Söylemez and Tarhan, 2016], nuclear energy [Varkoi et al., 2014], among others. It was also selected due to our experience with this standard in the development of other maturity models [Garzás et al., 2013] and related support tools for harmonizing multiple reference models [Baldassarre et al., 2009] [Pardo et al., 2011a] [Pardo et al., 2011b].

However, the ISO/IEC 15504 is being replaced by the new ISO/IEC 33000 [ISO, 2015a]. This change or update does not bring great news much beyond the change of numbering and a reorganization and extension of the standard. The main characteristics of the maturity model defined by the standard, such as maturity levels and attributes of the processes, are maintained, only changes are made in some concepts in order to make the ISO/IEC 33000 more open and to have a wider range of applications than its predecessor for the evaluation and improvement of the capability and maturity of the organization's processes.

That is why, following this update, we have also decided to update the maturity model of the first version, developing the ISO/IEC 33000-based maturity model for the GMGIT 2.0.

Therefore, in this new maturity model, in addition to updating the concepts according to the ISO/IEC 33000, we have carried out the inclusion of the 22 new processes added to the GMGIT 2.0 (2 new processes in the maturity level 2, 8 in level 3, 9 in level 4, and 3 in level 5), as well as we have reviewed the adequacy in the different maturity levels of the 15 existing processes.

For the inclusion of each of the processes in the different maturity levels we have followed our own experience as experts in the area, since the authors are CISA (*Certified Information Systems Auditor*) by ISACA and Chief Auditors of AENOR (*Spanish Association for Standardization and Certification*) for Software Engineering, with large experience applying the best practices and audit guides established by the ISO/IEC 33000. Thus, the inclusion of the processes in the different maturity levels has been conducted considering the feedback obtained by the organizations audited with the GMGIT 1.0 regarding the practices they carry out and consider during the different stages of Green IT implementation, as well as considering the dependencies between the 37 processes of the GMGIT 2.0.

On the other hand, the adequacy of the processes in the different maturity levels is being evaluated and verified through the validations that have been carried out and are being carried out in this regard (cf. Section 4).

So, in the Figure 2 this ISO/IEC 33000 based maturity model is shown graphically, in which we can see the different maturity levels of the model, as well as the description of each level and the categorization of the GMGIT 2.0 processes in the different levels. It is important to highlight that, in addition to the maturity levels shown in Figure 2, there is another maturity level, i.e. level 0 (incomplete), in which the organization does not consider the sustainability, and no Green IT practice is defined.

Figure 2: Description of the maturity levels of Green IT and categorization of the processes in the ISO/IEC 33000-based maturity model for the GMGIT 2.0

Likewise, for each of the 37 processes included in the ISO/IEC 33000-based maturity model for the GMGIT 2.0, we have identified and described each of the process attributes defined by the ISO/IEC 33000 in order to evaluate and analyze the compliance with each process. As way of example, the Figure 3 shows the description of the attributes of the DSS03 process according to the ISO/IEC 33000.

DSS03: Attributes of the Process with respect to the ISO/IEC 33000-based Maturity Model for Green IT		
Attribute	**Description**	
Process ID	DSS03	
Process name	Manage problems	
Process description	Identify and classify problems and their root causes and provide resolution in time to prevent recurring incidents. Provide recommendations for improvement.	
Process purpose	Increase availability, improve service levels, reduce costs, and improve customer comfort and satisfaction by reducing the number of operational problems.	
Process outcomes	As a result of successful implementation of "Manage problems": 1. The problems related to the Green IT are solved in an effective, efficient and sustainable way.	
Base practices	**DSS03.PB1: Identify and classify problems.** Define and implement criteria and procedures to report the problems identified, including classification, categorization and prioritization of problems. [Outcome: 1] **DSS03.PB2: Investigate and diagnose problems.** Investigate and diagnose problems using experts in the relevant issues to evaluate and analyze the root causes. [Outcome: 1] **DSS03.PB3: Raise known errors.** As soon as the root causes of the problems have been identified, create records of known errors and an appropriate temporary solution, and identify potential solutions. [Outcome: 1] **DSS03.PB4: Resolve and close problems.** Identify and initiate sustainable solutions by referring to the root cause, raising requests for change through the established change management process if it is required to resolve errors. Ensure that affected staff are aware of the actions taken and plans developed to prevent future incidents from happening again. [Outcome: 1] **DSS03.PB5: Perform proactive problem management.** Collect and analyze operational data (especially records of incidents and of changes) to identify emerging trends that may indicate problems. Register problems to allow valuation. [Outcome: 1]	
Work products	**Inputs**	**Outputs**
	Root causes of the problems related to the Green IT. [Outcome: 1]	Classification structure for problems related to the Green IT. [Outcome: 1]
	Record of known errors and solutions of the problems related to the Green IT. [Outcome: 1]	Root causes of the problems related to the Green IT. [Outcome: 1]
	Problems related to the Green IT solved. [Outcome: 1]	Record of known errors and solutions of the problems related to the Green IT. [Outcome: 1]
		Problems related to the Green IT solved. [Outcome: 1]
		Lessons learned about problems related to the Green IT. [Outcome: 1]

Figure 3: Description of the attributes of the DSS03 process according to the ISO/IEC 33000

On the other hand, this ISO/IEC 33000-based maturity model also includes the necessary elements to evaluate the capability of each of the 37 established processes. The capability of a process is used to determine the degree to which a process complies with certain objectives and/or expectations. These objectives/expectations are evaluated through a series of Process Attributes (PAs), which are organized into 5 capability levels. For this, we have adopted the same capability levels, PAs, and Process Attributes Results (PARs) established by the ISO/IEC 33000 [ISO, 2015a].

Thus, to reach a certain maturity level on an organization, it is first necessary to determine the capability level of each of the processes corresponding to the maturity level(s) of that are intended to be evaluated. In this sense, Figure 4 shows the relationship between the capability and maturity levels of Green IT.

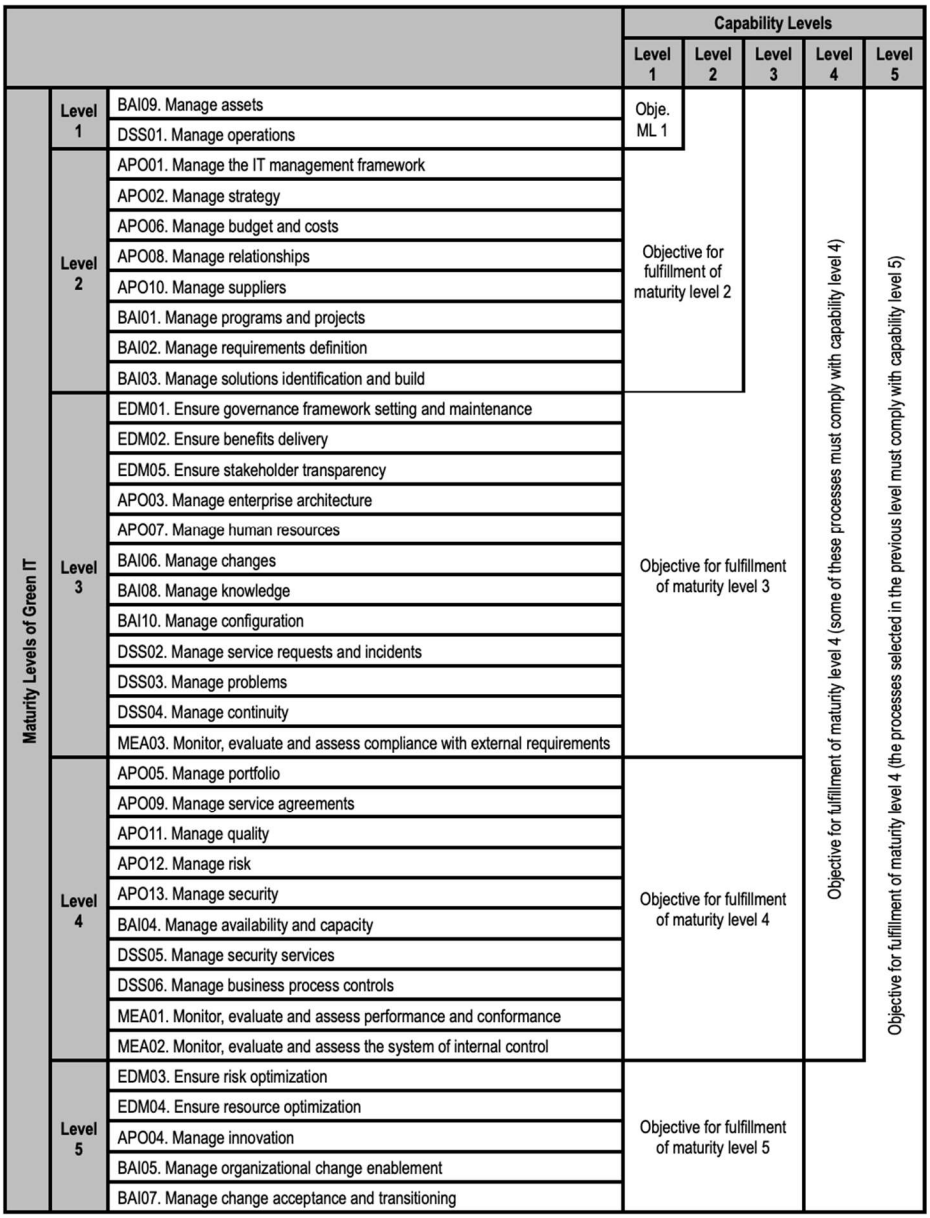

Figure 4: Relationship between the capability and maturity levels of Green IT in the ISO/IEC 33000-based maturity model for the GMGIT 2.0

Thus, this maturity model will help both auditors and organizations when taking the GMGIT as a guide to carry out its specific objectives in Green IT.

On the one hand, from the point of view of the auditors, this maturity model simplifies their work because it allows them to focus on the processes in an organized way, since it avoids the evaluation of too complex and/or advanced processes without first evaluating those basic and necessary processes according to each level.

While, on the other hand, from the point of view of the organizations, the maturity model allows them, first, to know at what maturity level they are in order to cover the deficiencies found at that level in a simple and feasible way with respect to their situation, and, second, to carry out a progressive and appropriate implementation and improvement following the processes according to the maturity level they intend to achieve.

3.4 Other General Changes/Improvements

In addition to the major changes that have been defined in the previous sections, we have also made other minor changes that have arisen either from the lessons learned from the validations performed with the GMGIT 1.0 or due to the inclusion of new characteristics to the framework.

From the point of view of the lessons learned, we realized during the validations with the GMGIT 1.0 that some definitions of the different enablers (mainly the processes enabler) were not understood correctly, since the managers of the organizations were slow to understand their meaning or were mistaken in their interpretation. That is why we carry out a complete revision of the framework to improve and clarify the concepts and descriptions of all the enablers and, in particular, the processes enabler.

On the other hand, due to the inclusion of the 22 new processes in the framework, the number of audit questions has increased, since these processes are through which all the governance and management aspects of Green IT are audited. Therefore, of the 122 audit questions that GMGIT 1.0 had, the GMGIT 2.0 has a total of 600 audit questions of Green IT. It should be noted that the differentiation between the *Green by IT* and *Green in IT* made in the processes has led us to also distinguish between specific audits of *Green by IT* and of *Green in IT*, so that the 600 audit questions can be found divided in half between both types of audit.

3.5 Overview of Changes between GMGIT 1.0 and GMGIT 2.0

Table 1 shows an overview of the changes that have been made between the different versions of the GMGIT. These changes are organized according to the type of change, what includes/affects each version, and an approximate percentage of change.

Likewise, through the changes made in the existing characteristics in GMGIT 1.0 and the new inclusions of different aspects in the GMGIT 2.0, we have estimated that the GMGIT 2.0 has led to an evolution in content between 70-80% compared to the GMGIT 1.0.

Type of Change	GMGIT 1.0	GMGIT 2.0	Percentage of Change
Structure	Section I. Green IT: • Definition of Green IT • Principles of COBIT 5 applied to Green IT Section II. Enablers of COBIT 5 adapted to Green IT: • Enabler: Principles, polices and frameworks • Enabler: Processes • Enabler: Organizational structures • Enabler: Culture, ethics and behavior • Enabler: Information • Enabler: Services, infrastructure and applications • Enabler: People, skills and competencies Section III. Framework for auditing the Green IT: • Evaluation stages • Auditing questions *(122 questions)*	Section I. Green IT: • Definition of Green IT • Principles of COBIT 5 applied to Green IT Section II. Enablers of COBIT 5 adapted to Green IT: • Enabler: Principles, polices and frameworks • Enabler: Processes • Enabler: Organizational structures • Enabler: Culture, ethics and behavior • Enabler: Information • Enabler: Services, infrastructure and applications • Enabler: People, skills and competencies Section III. Audit framework of Green IT: • Evaluation stages • Auditing questions of *Green by IT (300 questions)* • Auditing questions of *Green in IT (300 questions)* Section IV. ISO/IEC 33000-based maturity model for Green IT: • Maturity levels of Green IT • Categorization of the processes • Description of the processes • Assessment of the process capability	~35%

Type of Change	GMGIT 1.0	GMGIT 2.0	Percentage of Change
Processes	• 15 processes: EDM01; EDM02; EDM03; EDM04; EDM05; APO01; APO02; APO06; APO08; BAI02; BAI03; BAI09; DSS01; MEA01; MEA03	• Differentiation between *Green by IT* and *Green in IT* in the activities. • 37 processes: EDM01; EDM02; EDM03; EDM04; EDM05; APO01; APO02; APO03; APO04; APO05; APO06; APO07; APO08; APO09; APO10; APO11; APO12; APO13; BAI01; BAI02; BAI03; BAI04; BAI05; BAI06; BAI07; BAI08; BAI09; BAI10; DSS01; DSS02; DSS03; DSS04; DSS05; DSS06; MEA01; MEA02; MEA03	~150%
Maturity model	ISO/IEC 15504-based maturity model with: • 5 maturity levels • 15 processes	ISO/IEC 33000-based maturity model with: • 5 maturity levels • 37 processes • 5 capability levels • Update of concepts	~70%
Other general changes	• Empirical validations through case studies at Spanish organizations.	• Improvement and clarification of the concepts and descriptions of all the enablers. • Empirical validations through case studies at international level.	~30%

Table 1: Overview of changes between GMGIT 1.0 and GMGIT 2.0

4 Validation

As with the first version of the framework, once the GMGIT 2.0 has been developed, it must be validated in order to, on the one hand, verify the consistency and applicability of both the changes and new characteristics introduced, as well as the framework in general, and, on the other hand, refine it and improve its applicability in real contexts.

For this purpose, in [Patón-Romero et al., 2019] we present a case study [Yin, 2017] [Runeson et al., 2012] performed in an IT services center of a university in Spain; for confidentiality reasons this center is identified as USC (*University Services Center*). Through this case study, we conducted an audit in the USC applying the GMGIT 2.0, making special emphasis on the changes and new characteristics included (such as the ISO/IEC 33000-based maturity model for the framework).

We have chosen the USC to carry out this case study due to the high involvement and commitment of this organization with sustainability and Green IT. This can be seen in the Green IT initiatives that the USC carries out, such as:

- Use of virtualization to reduce the number of hardware devices needed to offer the services.
- Redesign of the data center to improve cooling and, therefore, energy efficiency.
- Sustainable IT acquisitions, acquiring only IT that comply with regulations (such as EU Energy Star v5, ISO 14001 or ISO 779/9296) and acceptable levels of consumption.
- Recycling and withdrawal of obsolete electronic and electrical material.
- Reduction of the number of printers through a centralized printing service.
- Printing software that identifies and records the printouts of each user of the system and forces users to carry out a double confirmation (one on the originating computer and another on the printing station).
- Automatic shutdown of computers.
- Maintenance of IT by remote control.
- Use of an electric car for travel related to IT maintenance (whenever such displacement is necessary).
- Shared carts with laptops for practical classes.

After auditing the USC following the GMGIT 2.0 and, in particular, the ISO/IEC 33000-based maturity model for the framework (auditing in depth the processes of the first two maturity levels and superficially the levels 3, 4, and 5), we have identified several shortcomings (especially in the definition and formalization of policies, plans, objectives, strategy, etc., of Green IT) and possible solutions to comply with each process (whose results and principal findings are discussed in more detail in [Patón-Romero et al., 2019]).

Thus, analyzing the audit results following the audited processes of the GMGIT 2.0 and taking into account the ISO/IEC 33000-based maturity model for the framework, we can determine that the USC is partially in the Level 1 of maturity of Green IT (as can be seen in Figure 5).

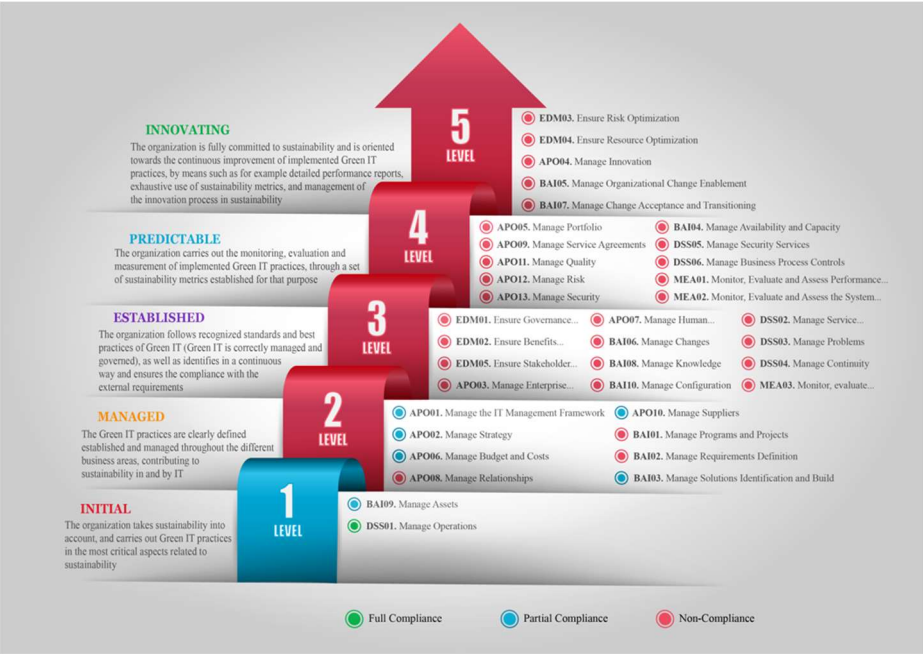

Figure 5: Compliance of the USC with respect to the processes of the maturity levels of Green IT

Therefore, thanks to the results and principal findings obtained through this case study, we can determine that we have solved the problems (lessons learned) found in the validations performed with the GMGIT 1.0 and the changes and new characteristics of the GMGIT 2.0 are consistent, coherent, and applicable. In general terms, we improved the framework, obtaining a proposal of the GMGIT 2.0 very useful to organizations as a complete and solid guide in their quest to gradually implement, evaluate, and improve the Green IT within their business.

On the other hand, the USC has been very satisfied with this case study, since it has served them, in the first place, to know its current status with respect to Green IT (shortcomings, problems, strengths, opportunities, etc.), and, second, to obtain a guide to continue and gradually improve, and implement Green IT practices. In fact, we are currently working with the USC to reach the Level 1 of maturity of Green IT and start to work on the following levels, and, thanks to the GMGIT 2.0, the USC has already obtained promising first results and aims to accomplish an increase in the efficiency and a substantial improvement in the area of Green IT and sustainability in general.

5 Conclusions and Future Work

Sustainability has ceased to be a simple idea with purely marketing purposes, to be a necessity for the survival of organizations and, mainly, of humankind. This has led to

global governmental organizations such as the United Nations (UN) [United Nations, 2015] and the European Commission [European Commission, 2017] have set their sights on sustainability, setting the guidelines to be followed in this increasingly important and indispensable area.

From the point of view of the business, more and more organizations in pursuit of their survival are joining this "green revolution", given the enormous potential and impact of sustainability in their areas and business models [Jenkin et al., 2011]. It is proven (and these organizations have realized and recognize it) that perform investments in sustainability (to implement sustainable practices and guarantee and improve their correct performance) generates great and multiple benefits at different levels of the business; such as improved quality and increased effectiveness and efficiency of organizational processes and products, risk reduction, better reputation, and greater profitability, among others [Epstein and Buhovac, 2014] [Hertel and Wiesent, 2013].

Therefore, with our goal of bringing and contributing to sustainability in and by the area of IT and help organizations in this respect, we developed the first version of the *"Governance and Management Framework for Green IT"* [Patón-Romero et al., 2017], with the necessary characteristics to define, implement, and audit the governance and management of Green IT in organizations. After validating this GMGIT 1.0 through a set of focus groups and case studies, we obtained different lessons learned that have helped us improve, refine and extend it, obtaining a new and more solid version, the GMGIT 2.0.

In the present study we have presented this revised framework for the governance and management of Green IT, showing the new characteristics and main changes performed in the GMGIT 2.0, as well as the results and principal findings we obtained through the first validation that we carried out with the GMGIT 2.0.

Analyzing the results obtained, we can determine that we have solved the problems found in the GMGIT 1.0 and we have obtained a reliable and solid GMGIT 2.0, in our goal of simplify and expand the adoption of Green IT by organizations, offering them a guide to gradually implement, evaluate, and improve the Green IT. Likewise, from these results, it is important to highlight the contributions and implications of the most important changes.

On the one hand, in the GMGIT 1.0 we included only 15 processes closely related to Green IT in order to make a first contact and proof of concept. Now, thanks to the inclusion of 22 new processes to GMGIT 2.0, an important advance has been achieved for the context of the framework. It is no longer just covering business processes that have a direct relationship with Green IT, but all those that, in some way, may be affected or affect the Green IT.

On the other hand, the differentiation that has been performed between *Green by IT* and *Green in IT* not only helps to better understand all the established processes and practices, but also allows to establish more specific contexts, which in turn will allow obtaining better results in this regard.

And, finally, the adaptation and development of the ISO/IEC 33000-based maturity model for the GMGIT 2.0 supposes a clear declaration of intentions of a framework that is updated and aligned with the wide adopted and recognized international standards, so that the whole theoretical base of the GMGIT 2.0 can be put into practice in a much simpler, more convincing, and affordable manner.

All this has undoubtedly allowed the GMGIT to evolve from a proof of concept, as GMGIT 1.0 supposed, to a solid, empirically validated, and complete framework thanks to the GMGIT 2.0. Thanks to this, organizations can cover all the aspects they need to implement, control, and improve the Green IT throughout the whole business, obtaining better results and benefits in this regard. And the research and the scientific field are also benefited, since, once all the theoretical basis and how to put into practice the governance and management of the Green IT has been established, a large number of research fields are opened. Some of these fields are, for example, the analysis of the behavior of the Green IT in different types of organizations after the application of the best practices defined in the GMGIT 2.0, or the research on specific indicators of Green IT and of sustainability (performance, adequacy, alternatives, etc.) in specific aspects of the different processes and practices established in the GMGIT 2.0, among others.

However, we are at the halfway point and we have a lot of work to do in this regard, as we have obtained new lessons learned about the GMGIT 2.0 that we must further investigate and overcome.

First, we have to improve the external validity and continue refining and improving the GMGIT 2.0. For this purpose, we have planned to carry out more validations through case studies in different types of organizations at an international level.

Second, we are currently working on adapting and incorporating international standards such as the ISO 14000 family of standards [ISO, 2015b] in the GMGIT 2.0. With this end, we intend to improve and expand the scope of the framework, in order to standardize it towards other standards and, mainly, provide a guide to organizations seeking to obtain certifications in this respect.

On the other hand, so far we have not made the GMGIT available since we want to finish validating it and confirm even more that all the characteristics we have established are consistent and adequate to avoid possible risks to organizations when they use it. But, we are working hard to further refining and improving the GMGIT 2.0 and obtain a new version of this framework, the GMGIT 3.0, which we intend to make it available publicly by the end of 2019.

We are in the middle of a revolution, a “green revolution” for our planet, for our lives and for those of our future generations. It is our duty as members of humankind to continue protecting our environment, to continue working towards an increasingly sustainable development, to continue this way towards the victory of the life.

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