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# Auditing the Governance and Management of Green IT

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**ABSTRACT**

Sustainability is not a trend; more and more areas of knowledge defend it and apply it among their main characteristics. The area of Information Technology (IT) has not been left behind and, through the so-called Green IT, advocates for a more sustainable environment. Organizations around the world are realizing that Green IT is an important asset that produces great benefits at ecological, social, and economic level. For this reason, we have developed a revised version of the *"Governance and Management Framework for Green IT"*. With this new version we intend to offer a more complete and solid guide that helps organizations to gradually implement, assess, and improve those characteristics of governance and management that are the basis of the processes and practices of Green IT. This proposal has been empirically validated through a case study and the results obtained demonstrate the validity, usefulness, and applicability of the framework for organizations.

**KEYWORDS**

Governance; management; Green IT; sustainability; case study

## Introduction

In recent years, there has been an increasing activity in studying and putting into practice sustainability[1] of Information Technologies (IT). This interest has been further strengthened because the IT sector contributes to about 2% of global $CO_2$ emissions, and is responsible for approximately 8% of the EU's electricity use. The total electricity consumption of the IT sector is forecasted to increase by almost 60% from 2007 to 2020, owing this to the increasing number of devices, as well as to the network expansion.[2]

That is why the field of Green IT has emerged, referring to it as *"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.[3])

Fortunately, Green IT is not only a trend; it is becoming a must,[4] as more and more organizations are implementing some form of sustainable solutions within their processes and daily operations.[5,6] Most people claim that they are willing to pay more for a sustainable product,[7] and sustainability has been recognized as a competitive business advantage.[8–10]

But, as it happens in all areas at their initial phase, the existence of studies, standards and/or best practices (among others) that are specific to Green IT is almost nil.[11–14] This is a problem for organizations in their efforts to implement and evaluate Green IT practices in an organized and standardized way.[15]

With the foregoing in mind, we have developed a first version of the *"Governance and Management Framework for Green IT"* (from now on, GMGIT),[16] through which we have established the necessary characteristics to define, implement and audit the governance and management of Green IT in an organization. In addition, we also developed a maturity model[14] based on the standard ISO/IEC 15504[17] for the developed framework. It is important to highlight that a maturity model is a tool that helps to conduct the evaluation/assessment of the current state of a certain area in a progressive and systematic way through different levels, in order to detect weak points and generate a continuous improvement plan.

In order to validate and refine both the GMGIT and the maturity model, in the 1.0 version we performed a set of focus groups and case studies. Through these validations, we obtained a series of lessons learned that have helped us improve, refine and expand both the GMGIT and the maturity model.[18] Consequently, we have performed the following:

- Improvement and clarification of the definitions of the existing processes and the rest of the enablers of the GMGIT 1.0.

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- Inclusion of 20 new processes to the GMGIT.
- Differentiation between *Green by IT* and *Green in IT* in the practices of all processes (existing and new) of the GMGIT.
- Update of the maturity model from ISO/IEC 15504 to ISO/IEC 33000.[19]
- Inclusion of the 20 new processes in the maturity model (2 in level 2, 8 in level 3, 7 in level 4, and 3 in level 5).

However, this new version of the GMGIT and the maturity model must be validated in order to reinforce the changes made. That is why, in the present study, we present the first case study that we have conducted with the 2.0 version.

Therefore, the main goal of the present case study is to: *achieve that the 2.0 version of the GMGIT and the maturity model is a valid and useful reference guide for organizations, i.e., a complete roadmap to gradually implement, evaluate and improve Green IT*.

The rest of the present study is organized as follows: Section 2 contains the background about the governance and management of Green IT, as well as maturity models in this context; Section 3 describes the research methodology performed; Section 4 presents the main results obtained through the case study; Section 5 discusses the principal findings, as well as the implications for research and practice, limitations and threats to validity; finally, Section 6 shows the conclusions and the proposals for future work.

## Background

### Governance and management of Green IT

In relation with the governance and management of Green IT and, in particular, on the evaluation/audit of these areas, in Patón-Romero and Piattini[13] a systematic mapping study (SMS) is performed. An SMS aims to *"map out and categorize existing literature on a particular topic, identifying gaps in research literature from which to commission further reviews and/or primary research"*.[20]

This SMS demonstrates the practically nonexistence of studies or research related to this area of governance, management and auditing of Green IT. Only two studies are highlighted in this SMS as closely related to the area: the first study[21] performs an analysis of the state of the art of Green IT and shows the relevance of conducting audits in this area; and the second study[22] presents a survey about the opinions and professional experiences of internal auditors from different organizations in relation to Green IT.

Also, as gray literature we have found two other relevant studies in the area of governance, management and auditing of Green IT: the first one[23] analyzes what organizations are currently doing in Green IT, showing the lack of experience and involvement in this area and identifying what they should do in the future and, in particular, the opportunities for auditors in this regard; and, the second one[24] proposes different characteristics that should be considered within an audit of Green IT and also highlights the nonexistence of frameworks to implement and audit Green IT.

Thus, we can observe the novelty of the Green IT area and the need to develop common frameworks that help organizations to implement, evaluate and improve best practices in this regard. That is why, with this in mind, we have developed the GMGIT[16,18] and, currently, we are strengthening and improving it to make it a solid and useful framework for organizations.

### Maturity models of Green IT

In relation with the maturity models that currently exist to gradually evaluate and improve Green IT (and sustainability in general), a SMS has been performed.[14]

This SMS demonstrates the novelty of the area and the lack of a solid and validated maturity model for Green IT. Through the SMS, 27 studies have been found in relation with the sustainability-related maturity models, and only 9 of these studies are related to maturity models of Green IT, of which only 3 are validated as the most complete and applicable proposals (Buchalcevova,[25] Curley et al.,[26] and Hankel et al.[27])

However, the studies found through this SMS relate to specific problems and it is not possible to adapt them to the GMGIT. For this reason, we have developed a maturity model specific for the GMGIT,[14] and, as for the framework, we are currently working to validate and improve it in order to obtain a valid maturity model to gradually evaluate and improve Green IT in organizations.

## Case study research

### Case study approach and case selection

A case study is *"an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"*.[28]

The case study methodology is especially appropriate for all new research fields.[29] For this reason, we decided

to conduct a case study, following the guidelines proposed in Runeson et al.,[30] with the 2.0 version of the GMGIT and the maturity model,[18] since we are still in an exploratory phase and, also, due to the youth of the Green IT area in general.

Through the case study, in our research goal to validate and refine both the 2.0 version of the GMGIT and the maturity model, we have aimed to answer the following exploratory research questions:

- **RQ1**: Is the improvement and clarification of the existing processes and the inclusion of the 20 new processes consistent and adequate?
- **RQ2**: Is the differentiation between *Green by IT* and *Green in IT* convenient when conducting an audit?
- **RQ3**: Does the updating of the maturity model to the ISO/IEC 33000 maintain the suitability of all its characteristics?
- **RQ4**: Are the processes (the new ones mainly) at a correct maturity level with respect to the organizational initiatives?
- **RQ5**: Have the deficiencies and problems found in the lessons learned from the previous validations been solved?
- **RQ6**: Are both the GMGIT and the maturity model applicable in real life?

In order to answer these questions correctly and conduct a case study, we have selected an organization that is most appropriate and representative. In the previous validations we performed a case study in an IT Services Center of a university.[14,16] Therefore, we wanted to continue with the same type of organization, to maintain a certain level of coherence and parallelism, and we have chosen another IT services center of a university in Spain (different from the first one); for confidentiality reasons this center is identified as USC (*University Services Center*).

In the same way, the size of this organization (Large Company, due to its inclusion together with the university to which it provides its services), as well as its commitment and prior implementation of sustainable practices, as shown below, make it a very representative and appropriate case to achieve our research goal. The background and experience of the USC in the implementation of Green IT practices in a large and complex context helps us to evaluate a fairly diverse and broad casuistry.

As indicated in its organizational statutes, the main objective of the USC is to *"design, plan, manage, and ensure infrastructures and services based on Information and Communication Technologies (ICT) provided to the* university *community in the areas of teaching, research and administrative management"*.

The USC has more than 100 employees and is responsible for IT services of a university of more than 30,000 students and more than 2,000 teachers and researchers. It is important to highlight the importance that this university gives to sustainability. Indeed, it has a Vice-Rectorate of Sustainability. For its part, the USC is committed to sustainability implementing some initiatives related to Green IT, 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 energy efficiency.
- Sustainable IT acquisitions, acquiring only IT that comply with regulations (such as EU Energy Star v5, ISO 14001 o 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 and forces users to perform 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.

Through these initiatives we can observe the involvement of the USC with sustainability and Green IT, which makes it a representative case study in our research goal to validate and refine the 2.0 version of the GMGIT and the maturity model.

However, the USC has been implementing these initiatives without any guide or standard that would allow them not only to implement best reliable practices in an organized and adequate way, but also to control that the implemented practices work according to what was expected and to be able to improve performances. Thus, the application of the GMGIT through this case study is a great opportunity for the USC in order to know their current status in Green IT and to improve in this regard, implementing new practices and improving existing ones.

### Data collection

For data collection we used a qualitative methodology based on interviews, observations, and collection of documents. We have chosen this methodology instead of a quantitative methodology (based on surveys,

mainly) since the nature of case studies based on audits does not give rise to another type of data collection other than through interviews, observations and collection of documents for further qualitative analysis.

So, a Green IT audit was performed during November-December 2017, following the audit guide included in the GMGIT and the maturity model developed (of course, applying the 2.0 version of both.[18])

At first, we conducted a series of interviews both with senior management and main IT managers. It is important to highlight the first interview, since we analyzed the mission, vision and activity of the organization and established the scope of the audit. Through this scope we determined to conduct a specific audit of *Green in IT*, since, being an IT organization, the Green IT initiatives implemented are based on improving the efficiency of IT to reduce its environmental impact. The terms of *Green in IT* and *Green by IT* are described below for further clarification:

- ***Green in IT***: when the IT itself has an impact on the environment, due to its energy consumption and to the emissions it produces, and this impact should be reduced (i.e., IT as producer).
- ***Green by IT***: in the sense that the IT provides the tools needed to allow different kinds of tasks to be performed in a sustainable way with the environment (i.e., IT as capacitator or enabler.[31])

In the scope of the audit, we also determined to analyze in detail only the processes of the first two maturity levels. We discussed and analyzed all the GMGIT processes and the maturity levels of Green IT with the managers of the USC and we concluded that from level 3 the organization did not comply with any process. For this reason, in the detailed analysis and audit report we only analyzed the processes of the first two levels, although the rest of the processes were also analyzed, but in less detail.

Finally, regarding the collection of documents, we collected general information about the USC (policies, goals, infrastructures, services, staff, etc.). About the specific information of Green IT, through the interviews we filled out a checklist on the compliance or not of each specific practice of the processes of the GMGIT, following the audit questions established. In the same way, through the interviews and on-site observations, we collected relevant comments and evidence to verify the correct application of the Green IT initiatives and to detect problems and risks in this regard.

### *Data analysis*

The analysis of the data was conducted as the data were collected. For this, it is important to highlight three main phases in the data analysis step:

- **Preparation**: in this first phase, a preliminary meeting was held with senior management, in which the mission, vision and activities of the organization were analyzed in order to establish the plan and scope of the audit, as well as making a first official contact with the organization.
- **Conducting the audit**: during the audit phase, different interviews with senior management and main IT managers were conducted, the evidence and veracity of the organization's Green IT practices were analyzed in situ, and relevant documentation was collected. To analyze all the information collected during the audit in detail, we filled out and evaluated a checklist with the Green IT audit questions made (with possible answers: yes, no and N/A), considering the comments included in each of these questions and the evidence obtained. From the analysis of this information, we obtained the audit report in which we identified, on the one hand, the strengths and main opportunities for improvement in Green IT for the USC, and, on the other hand, the compliance with the processes of Green IT (analyzing the problems encountered and possible solutions).
- **Presentation of results**: finally, the results obtained (illustrated through the audit report) were presented to the USC and analyzed together in order to obtain feedback from the organization verifying their correctness.

## Case study results

After auditing the processes of the maturity levels of Green IT at the USC (in depth the first two levels and superficially the levels 3, 4, and 5), we have identified the problems found in the different processes, as well as the possible solutions to comply with each process (as shown by way of example in Table 1).

So, by analyzing the results obtained during the audit performed at the USC, we can observe the high involvement of said organization with sustainability through the different sustainable practices in IT. However, several deficiencies have been found, especially in the definition and formalization of policies, plans, objectives, strategy, etc., of Green IT (as can be seen in more detail in Table 2 through the main strengths and opportunities for improvement identified).

**Table 1.** Problems encountered and possible solutions in the BAI09 process of Level 1 of maturity of Green IT.

| Problems encountered | Possible solutions |
|---|---|
| The assets of *Green in IT* are not identified, registered and classified according to their criticality. | • Identify and record all *Green in IT* assets, as well as the requirements they cover and the relationships and dependencies between them.<br>• Identify the critical assets of *Green in IT* and classify them according to the level of criticality that each one has. |
| There is a software license management system, but the software related and/or affected by the *Green in IT* is not labeled as such. | • Label as "Green" (sustainable) the software related and/or affected by the *Green in IT*. |

**Table 2.** Strengths and opportunities for improvement with respect to Green IT for the USC.

| Strengths | Opportunities for improvement |
|---|---|
| • High level of commitment and awareness of the members of the board of directors and senior management with sustainability, both by the USC and the university.<br>• Large number of Green IT practices implemented:<br>◦ Virtualization.<br>◦ Improvement of CPD cooling.<br>◦ Sustainable IT acquisitions.<br>◦ Recycling of obsolete electronic material.<br>◦ Reduction of the number of printers through a service of centralized printing.<br>◦ Printing software that identifies and records the printouts of each user of the system and forces users to perform a double confirmation.<br>◦ Automatic turning off of computers.<br>◦ Maintenance of IT by remote control.<br>◦ Use of an electric car for travel related to IT maintenance.<br>◦ Shared carts with laptops for practical classes. | • Absence of official documents regarding policies, strategies, objectives and other enablers of Green IT. Therefore, the formalization of these aspects is necessary, through which the bases of governance and management of Green IT will be strengthened, which will allow a more effective and efficient implementation of the practices in this regard.<br>• No specific metrics are established to evaluate the correct performance of Green IT practices (beyond the energy consumption metrics). So, it is necessary to implement a greater number of metrics (such as tons of recycled electronic material, amount of water consumed and saved relative to the consumption of printing ink, CO2 levels, cost and economic savings that the measures implemented imply, etc.) and use them to evaluate periodically and improve the performance of Green IT, which will help achieve greater benefits in this regard.<br>• The implementation of the practices of Green IT has been conducted following the own criteria of the organization. So, it is highly advisable to adopt some framework or standard to guide these implementations throughout their whole life cycle, which will increase the level of success and the improvement of the practices implemented in this regard. |

Thus, following the audited processes of the GMGIT and considering the maturity model developed for these processes, we can determine that the USC it is partially in the Level 1 of maturity of Green IT (as can be seen in Figure 1).

## Discussion

### *Main findings*

The present case study has as research goal to validate and refine the 2.0 version of the GMGIT and the maturity model that we have developed.

After analyzing the results and the feedback obtained through this case study, we have reached the following principal findings, based on our experience and subjective analysis of the entire procedure and results obtained:

- From the point of view of the 2.0 version of the GMGIT and the maturity model,[18] this is valid and very useful to conduct the implementation, evaluation and improvement of the Green IT in organizations. By applying this 2.0 version in real life through this case study, we have observed that both the existing elements and processes (improved in this 2.0 version) and the new ones maintain the coherence and are reflected in the processes and practices implemented, in this case, by the USC.
- From the point of view of the organizations, in this case based on the example of the USC, there is still a lot of work to do in Green IT. It is true that organizations are increasingly aware of the need to implement sustainable practices due to different ecological, economic and social reasons. However, organizations are still disoriented in this topic of Green IT, due to its novelty and the absence of reliable standards in this regard. That is why they demand standards and/or frameworks such as the GMGIT that will serve as a guide for them, first, to know their current status in Green IT (since most of the interested organizations are already implementing practices in this regard, although in a disorganized way and following their own criteria), and second, to conduct a gradual implementation and improvement of the Green IT in the processes, practices and daily activities of the organization.
- From the point of view of Green IT and sustainability in general, these topics are increasingly relevant and necessary. In recent years, ecological awareness has changed from a trend and an ideal that few followed to an important and indispensable asset for both business and society.

Also, as lessons learned we have identified the need to include and/or relate international standards with the

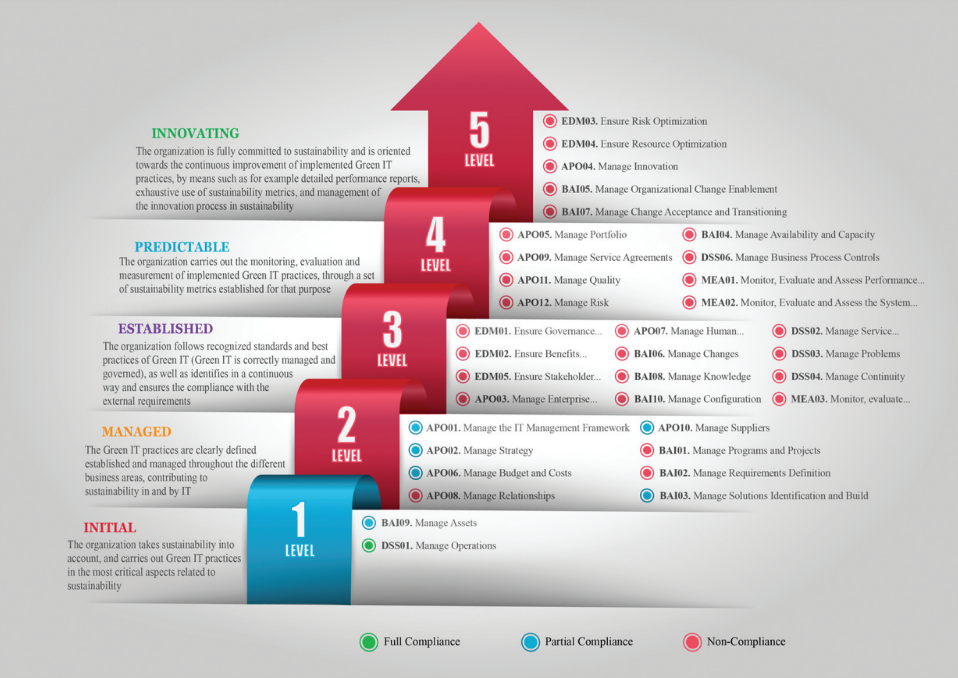


**Figure 1.** Description of the maturity levels of Green IT and compliance of the USC with respect to the processes of these levels.

framework. Although the framework is very broad and covers different aspects of governance and management of Green IT, the inclusion of standards such as ISO 14000[32] would allow to reinforce and further expand the scope of the framework, obtaining reference points on, for example, the implementation of an effective Environmental Management System (EMS). Likewise, the inclusion of these international standards would greatly help organizations to obtain valuable certifications in this regard.

Finally, the exploratory research questions established for this case study are analyzed and answered in detail below, based on the results and feedback from the USC that we have obtained.

### *RQ1: Is the improvement and clarification of the existing processes and the inclusion of the 20 new processes consistent and adequate?*

On one hand, the improvement and clarification of the concepts and descriptions of the existing processes and practices of the GMGIT 1.0 has helped the organization, in this case, the USC, to better understand what each process is about and what is being evaluated (in comparison to the case studies that we have performed previously, in which organizations had some problems to understand some concepts and processes). Likewise, regarding our work as auditors, it has also helped us to be more concise and better understand the processes when evaluating them (improving said evaluations and the results).

On the other hand, the inclusion of the 20 new processes to the GMGIT is consistent, since they follow the logic of the already existing processes, and, at the same time, very adequate, since, analyzing the framework and the results in conjunction with the USC, we have come to the conclusion that, although the 15 processes of the GMGIT 1.0 are the basis of good governance and management of Green IT, the 20 new processes reinforce and cover necessary features that were missing from the 1.0 version.

To obtain these findings we have relied on our experience as auditors applying both versions of the GMGIT. In the audits performed with the GMGIT 1.0, organizations constantly had doubts about the evaluated processes, due to the lack of certain details and ambiguity in some descriptions, and the lack of other more specific processes that were not included. With the GMGIT 2.0 we have realized that, in this case, the USC has not had as many doubts about the different processes and elements of the framework, which has streamlined the audit process. Likewise, the feedback obtained from the USC has been very positive in this regard, since they have easily recognized and identified the characteristics, practices, and activities of the different processes.

### *RQ2: Is the differentiation between Green by IT and Green in IT convenient when conducting an audit?*

First, based on the feedback obtained from the managers of the USC, the differentiation between *Green by IT* and *Green in IT* in the practices of the processes is not only

adequate, but also necessary. For organizations it is very important to work with specific terms, which help to properly understand the concepts in this regard, correctly evaluate their processes and simplify their work when conducting implementations in this sense.

Likewise, based on our experience conducting the audit, we can say that it greatly simplifies the work of the auditors. This differentiation allows the auditors to be more specific when explaining the concepts and processes to be evaluated, as well as to greatly improve the evaluation performed, since it is easier and more direct to identify and analyze the processes and practices of each type.

These findings are based on the comparison between the established and understood scope of the audits conducted with both versions. With the GMGIT 1.0, organizations were not entirely clear on the scope of the audit and it took them a long time to identify all the Green IT practices they had in place (especially *Green by IT* practices). With the GMGIT 2.0, in this case, the USC has understood the scope of the audit in a much clearer way and has been able to identify in a much easier, faster, and more direct way the implemented *Green in IT* practices.

### RQ3: Does the updating of the maturity model to the ISO/IEC 33000 maintain the suitability of all its characteristics?

Updating the maturity model from ISO/IEC 15504[17] to ISO/IEC 33000[19] has not been a problem, since ISO/IEC 33000 is the evolution of ISO/IEC 15504 and the base is identical. The 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. In the same way, when applying the new ISO/IEC 33000-based maturity model in practice, the adequacy with respect to the previous model is maintained, and we have not had any problems of interpretation or understanding in this regard with the USC.

### RQ4: Are the processes (the new ones mainly) at a correct maturity level with respect to the organizational initiatives?

First, after presenting the maturity model to the USC, we analyzed together the different processes of the maturity levels in order to obtain feedback from the USC that would help us determine if the processes were at a correct maturity level or not. To do this, we have relied mainly on two questions: 1) Do you consider appropriate the maturity levels established? 2) Do you consider that each of the processes is at the appropriate maturity level?

The feedback obtained from the USC coincided with our proposal, helping us reinforce it. Also, as we exploited the case study, we have reinforced the maturity level of the processes of the first levels, since we have concluded that the organizations begin to work on these processes (implementing characteristics/practices and obtaining results in these) when they start in the implementation of the Green IT. While the processes of the first levels are the basis on which to start working and do not depend largely on other processes, the processes of higher levels are more specific when it comes to improving the base and depend on the results of the processes of the lower levels.

### RQ5: Have the deficiencies and problems found in the lessons learned from the previous validations been solved?

The deficiencies and problems found in the lessons learned from the previous validations were based on the difficult understanding by organizations of certain concepts related to the processes and practices of Green IT. Green IT is a topic that is often abstract and quite broad, because it is easy to get confused between practices of *Green by IT* and of *Green in IT*. That is why in the GMGIT 2.0[18] we have made two main changes to solve these problems: the first has been the improvement and clarification of the concepts and descriptions of the existing processes and practices; and the second has been the differentiation between *Green by IT* and *Green in IT* in the practices of the processes. Thanks to these changes, we have managed to solve the deficiencies and problems found in the lessons learned from the previous validations, since, in this case, at the USC we have not identified major problems of understanding in this regard.

### RQ6: Are both the GMGIT and the maturity model applicable in real life?

As we can observe through the results obtained, principal findings and the other research questions, both the GMGIT and the maturity model are applicable in real life. In fact, we have received a very positive feedback from the USC, which has seen very useful the GMGIT, seeing reflected in the best practices that they implement and others that they recognize as necessary to implement. The USC has felt satisfied with the expectations that they had about getting a first vision of its current state in Green IT and obtain a guide to gradually implement and improve best practices of Green IT.

## Implications for research and practice

The findings of this case study have huge transcendence for researchers and practitioners in the area of

governance, management and auditing of Green IT and of sustainability and IT in general.

On the one hand, thanks to this 2.0 version of the GMGIT and the maturity model,[18] researchers have a reinforced and validated starting point to conduct innovative research in this new field of Green IT. The scope of the GMGIT is very broad, so researchers can go in depth and perform detailed research of different aspects of governance, management and/or auditing/evaluation of Green IT. In the same way, the applicability of the GMGIT in different types of organizations favors the appearance of new studies and lines of work.

On the other hand, practitioners and organizations not only have a solid guide on which to base their implementations of Green IT, but also a model that allows evaluating such implementations in a gradual and simple way, obtaining great benefits in this area. Also, IT auditors and managers, mainly, will be able to expand their range of operations, including Green IT among their new competencies, and more and more new organizations will start to implement sustainable practices through Green IT.

## Limitations of the case study

The main limitation of this case study has to do with the application of the 2.0 version of the GMGIT and the maturity model in a single organization in an only specific context (Spain as a country, organization within the IT sector).

As a starting point, initiating the validation of this 2.0 version in a single organization and in a specific context helps us to determine if the changes made maintain the coherence and applicability in a real environment. But it is necessary to conduct more cases in multiple contexts in order to reinforce the validation by reviewing in detail all aspects to find possible problems overlooked and/or not found by the scope of this case study, as well as refine and improve the 2.0 version through different points of view and problems of various organizations.

Therefore, and bearing in mind the research goal and main limitation of this case study, we plan to conduct more case studies at international level and in organizations whose business models are not only based on IT.

## Threats to validity

The four aspects of validity defined by Runeson et al.[30] applied to the present case study are analyzed in detail below.

### Construct validity

To perform the development both the framework and the maturity model, we have taken as a basis two well-known standards. On the one hand, for the GMGIT we have adopted the structure of enablers and followed the definitions and concepts of governance and management defined in the COBIT 5 framework.[33] While, on the other hand, for the maturity model developed for the GMGIT we have embraced the maturity levels, necessary attributes for the processes and main definitions and characteristics of the ISO/IEC 33000.[18] In this regard there are no discrepancies between practitioners and researchers. However, the concepts, definitions and main characteristics of Green IT may not be interpreted in the same way by practitioners and researchers (mainly due to the novelty of this area). That is why in these aspects we have tried to make more emphasis, defining and explaining them in detail to avoid such discrepancies (which can be seen, for example, in the differentiation between *Green by IT* and *Green in IT*).

### Internal validity

The problems that can affect the internal validity from the point of view of an audit-based case study are those related to the problems or drawbacks that the organization may have to conduct the audit and, in this case, to gradually implement the GMGIT following the maturity model developed. These problems or drawbacks can be, for example, lack of time and/or resources, lack of involvement and commitment from senior management and IT managers, internal discrepancies, etc. That is why, in order to mitigate this threat, during the preliminary meeting held with the senior management (as commented above in Section 3), we performed a formal presentation of the GMGIT and the maturity model to obtain the commitment and predisposition of the organization. We also made a preliminary analysis of the organization in order to determine if they had the appropriate time and resources to conduct all the process of evaluation/audit and implementation of the GMGIT (as well as to assess their level of interest and associated risks and to establish the plan and scope of the audit).

### External validity

In relation to external validity, the threats that exist are related to the type of the organization and the geographic location. The case study has been performed in an organization dedicated to the management of IT services, so it is limited to a single business model and there may be discrepancies with respect to other types of organizations and even in similar business models. It is also a Spanish organization, which

does not have an international presence, so that aspects such as culture, way of working, etc., can also generate discrepancies. For these reasons, in order to mitigate these threats, we will conduct more case studies of this 2.0 version of the GMGIT and the maturity model in different types of organizations at an international level. In this way, we intend to generalize and standardize both the GMGIT and the maturity model, as well as continue to refine and improve both.

### *Reliability*

The analysis and transcription of results of the data collected through the interviews, observations, and collection of documents (data collection techniques defined by Lethbridge et al.[34]) has been performed independently by each author, in order to reduce the bias among each other. However, the authors collaborate closely on these topics, so in the future we plan to prepare detailed documentation so that external researchers and practitioners can apply and validate both the GMGIT and the maturity model developed.

## Conclusions and future work

More and more organizations from all over the world are joining the sustainable movement, seeing the enormous potential and impact that this idea has within their areas and business models.[35] Organizations have realized and recognize that carrying out investments in sustainability (implementing sustainable practices and evaluating, guaranteeing and improving their correct performance) is generating multiple benefits in terms of improved quality of organizational processes and products, increased efficiency and effectiveness in the production and/or service delivery, risk reduction, better reputation and greater profitability, among others.[36]

Therefore, in order to bring and contribute to sustainability in the area of IT and help organizations in this respect, we developed the first version of the *"Governance and Management Framework for Green IT"*[16] and of the ISO/IEC 15504-based maturity model[14] for the framework. After validating this 1.0 version through a series of focus groups and case studies, we obtained a set of lessons learned that have helped us extend and improve them, obtaining a 2.0 version of the GMGIT and an update of the maturity model to the ISO/IEC 33000.[18]

Following the same route of the 1.0 version, once the second version were developed, our objective was to validate them to demonstrate their usefulness and continue improving them. That said, as presented in this paper, we have conducted a first case study in a Spanish organization dedicated to providing IT services to a university.

Analyzing the results obtained through the case study in question, we can determine that we have solved the problems found in the 1.0 version and that the 2.0 version of both the framework and the maturity model is consistent and coherent, being very useful and offering a complete and solid guide to organizations in their work to implement, evaluate and improve Green IT within their processes and daily operations.

In addition, from the point of view of the audited organization, the USC has been very satisfied, since this case study has served them to organize, from a governance and management point of view, the Green IT practices that they have already implemented and to start the improvement and implementation of new practices once they know their current status in this area. In fact, thanks to the GMGIT 2.0, the USC has already obtained promising first results and aims to achieve an increase in the efficiency and a substantial improvement of the Green IT and sustainability in the organization.

However, the work does not end here, as we have obtained new lessons learned about this 2.0 version that we must further investigate and overcome.

First, in order to reinforce the validity and continue refining and improving the 2.0 version, we intend to conduct more validations through case studies in different types of organizations at an international level.

Second, we are working on adapting and integrating international standards such as the ISO 14000 family of standards[32] in the GMGIT, in order to improve and expand the scope of the framework, mainly, to help organizations to obtain certifications in this respect.

It is our duty, as either researchers, practitioners and organizations, to defend and keep on working on this idea, protecting the environment and creating a sustainable future, as our life and that of future generations depends on it.

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## Declaration of interest statement

No potential competing interest was reported by the author(s).

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