

Application of ISO/IEC TR 33014 to the improvement of Green IT processes

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ABSTRACT

Sustainability has become an important engine of change for both society and organizations. The latter have realized that sustainability goes far beyond preserving the environment and the implementation and improvement of sustainable practices is helping them to be increasingly effective and efficient in their processes and operations. One of the business areas that is evolving the most and taking on the most relevance regarding sustainability is Information Technology (IT). The well-known as Green IT not only defends the idea of sustainable IT, but also of using IT to help other areas to be sustainable. However, organizations are still disoriented regarding Green IT, since they do not have the frameworks and/or standards to properly implement and improve Green IT in their processes and operations. That is why this study addresses the problem of improving Green IT processes by applying the ISO/IEC TR 33014 standard to this area, based on a case study in a Colombian organization. The results and findings obtained through this application demonstrate the usefulness and importance of conducting improvement plans for Green IT processes when best practices are implemented in this regard. Likewise, following standards such as the ISO/IEC TR 33014 for the improvement of processes help to obtain more reliable results, as well as more effective and efficient practices and processes.

1. Introduction

Sustainability is not optional. Since the well-known "Brundtland Report" was published [1], society, organizations, and governments around the world have been increasingly committed to achieving sustainable development [2,3]. This has led, mainly in recent years, to the fact that most organizations change their way of thinking and acting and understand that they have economic, social, and environmental responsibilities and obligations, launching themselves to make a difference through sustainability [4].

Nowadays the area of Information Technology (IT) has become a target for organizations regarding sustainability [5–9]. Through the so-called Green IT practices [10,11], organizations aim to bring eco-sustainability not only towards IT but also from IT to the rest of processes and business areas [12]. In fact, the adoption of Green IT is already demonstrating the great benefits it brings to organizations

[13–16].

However, the Green IT adoption is a long and complex process, in which organizations often do not have enough tools/guides to face this challenge [17–19]. That is why, due to this lack of standards and/or frameworks, we have developed the "Governance and Management Framework for Green IT" (GMGIT) [20,21].

The GMGIT is a framework through which a guide is established with all the necessary characteristics to implement, control/evaluate, and improve Green IT in organizations in a progressive and systematic manner, all from the point of view of the governance and management of this area. After carrying out the validation of the GMGIT through different case studies in several organizations [22,23], we are conducting various improvement plans in these organizations, following the ISO/IEC TR 33014 standard [24]. Through these improvement plans we not only intend to continue refining and validating the GMGIT, but we also intend to help organizations improve their Green IT processes

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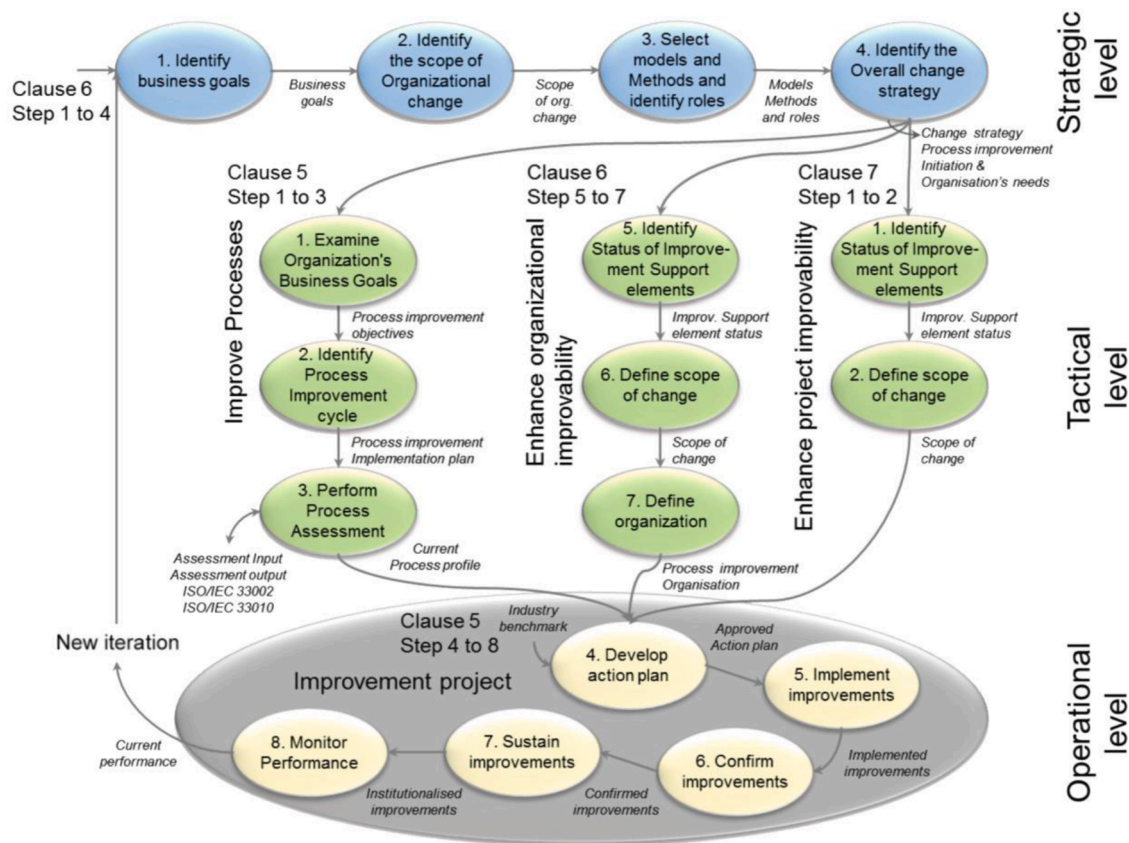


Fig. 1. Levels and steps for improvement according to ISO/IEC TR 33014 [24].

following an appropriate guide and methodology.

Thus, in this article we present an application of the ISO/IEC TR 33014 standard to the improvement of Green IT processes [25], based on a case study we have performed in a Colombian organization, and show how we have conducted the improvement plan in this regard, as well as the results obtained. Additionally, it is important to highlight that thanks to this application the organization is very satisfied, as it has achieved an improvement in the management of Green IT, as well as a greater commitment and involvement in this regard from the relevant members and stakeholders.

The rest of the present study is organized as follows: Section 2 contains the background about ISO/IEC TR 33014 and the GMGIT; Section 3 presents the application of ISO/IEC TR 33014 to Green IT, based on the case study on which the improvement plan has been conducted; Section 4 discusses the lessons learned from the application performed; finally, Section 5 shows the conclusions and lines for future work. Likewise, Appendix A includes the general results of compliance with Green IT processes at the Colombian organization.

2. Background

2.1. ISO/IEC TR 33014

The ISO/IEC TR 33014 [24] is an international standard that belongs to the ISO/IEC 33000 family of standards [26,27] and establishes how to conduct the improvement of processes and business management functions following a plan of continuous improvement based on the use of process evaluation as part of a complete framework. For this improvement, the standard establishes three levels (see Fig. 1): 1) Strategic (what goals of improvement to achieve); 2) Tactical (how to achieve the goals of improvement); and 3) Operational (how to perform the improvement). The standard also identifies three different perspectives

to perform the improvement:

- **Process perspective.** Improvement of the process as a program or project for different business goals, application domains, and organization sizes.
- **Organizational perspective.** Improvement of organizational ability to improve (improvability) to ensure success with improvement projects.
- **Project perspective.** Improvement of the quality of a project to achieve the success of the improvement.

Likewise, some of the aspects that this standard includes and develops are the use of the results of a process evaluation/assessment, the principles of continuous improvement of processes, the roles in improvement, the strategies and scope of change, etc.

Thus, thanks to the ISO/IEC TR 33014 standard, the continuous improvement of different business areas can be conducted through the processes improvement, following a systematic and progressive methodology based on the use of process evaluation as part of a complete framework to perform and ensure the success of the improvement.

2.2. Governance and management framework for Green IT

The lack of standards, frameworks, and/or best practices related to Green IT [19,28-32], led us to consider the need to develop a common framework that would help organizations to implement, evaluate, and improve the Green IT. And that is why we developed the "Governance and Management Framework for Green IT" (GMGIT, from now on) [20, 21], with the aim of establishing the governance and management bases that organizations must follow to properly implement Green IT practices in their processes and daily operations.

The latest version of the GMGIT is based on COBIT 2019 (Control

Objectives for Information and related Technology) [33] [34], an ISACA (Information Systems Audit and Control Association) framework. This is the most widely used framework for the governance, management, and evaluation/audit of IT and its different areas [35].

Thus, considering the structure of the 7 governance and management components established by COBIT 2019 (1. Principles, policies and frameworks; 2. Processes; 3. Organizational structures; 4. Culture, ethics and behavior; 5. Information; 6. Services, infrastructure and applications; 7. People, skills and competencies), in the GMGIT we have defined and developed the elements, characteristics, and aspects of Green IT that must be applied when addressing each of these components.

Likewise, the GMGIT also includes other important elements, such as: the application of the ISO 14000 family of standards [36] in each of the framework's processes [37], to align industry-defined sustainability best practices with the framework; a Green IT audit guide/framework with 648 audit questions (324 to audit the *Green in IT* and 324 to audit the *Green by IT*), to assist during the Green IT assessment/audit process; and a maturity model [21] based on the ISO/IEC 33000 family of standards [26], to systematically and gradually implement and evaluate the Green IT.

On the other hand, it is important to highlight that in order to validate, refine, and improve the GMGIT, we conducted a series of audits [22,23] based on the case study methodology [38–40]. Therefore, the GMGIT is a framework that has been put into practice and has proven useful for organizations in implementing and evaluating the governance and management of Green IT.

2.3. Related work

In recent literature there is no example of the application of the ISO/IEC TR 33014 standard to a field related to sustainability, such as Green IT. In fact, it is difficult to find applications like the one performed in the present study in other areas/contexts. After a general search, only one study that deals with the application of this standard in the automotive sector has been identified [41]. However, there are several studies that analyze different specific aspects of the standard and propose new ideas to improve the application of these aspects [42–45].

3. Application of ISO/IEC TR 33014 to Green IT

When conducting a Green IT improvement plan, we decided to take as a basis the methodology established by the ISO/IEC TR 33014 standard [24]. This standard provides all the characteristics and generic steps necessary to apply improvement plans in any context (as shown in Fig. 1), so its adaptation to the context of the GMGIT [20,21] has not been any inconvenience.

Thus, to show the application of ISO/IEC TR 33014 to Green IT (through the GMGIT), the following subsections explain the actions we have conducted in each of the three levels established by the standard (strategic, tactical, and operational). In the same way, we are going to take the case study and improvement of Green IT processes performed at the Central Unit of Valle del Cauca (UCEVA, from now on).

3.1. Strategic level

In this first level, we interviewed the UCEVA managers to analyze and understand the organization as a whole (mission, vision, main activities, etc.), as well as its specific Green IT objectives and the motivation to achieve them. This is a very important step since it allowed us to identify the context of the organization and to have a first approach to its processes, practices, and operations, being able to establish an adequate scope and action plan. Likewise, this also allowed us to present the GMGIT and its most important characteristics, helping the UCEVA to have a more accurate vision of the framework, as well as motivating and obtaining the commitment of the managers and main stakeholders.

So, it is important to highlight and understand the organization and

its objectives and motivations regarding Green IT. The UCEVA is a Colombian public university institution of higher education that has about 6000 students and 500 professors and researchers. The department/area that provides IT services to this organization is working on several projects whose purpose is to apply Green IT practices to reduce its carbon footprint. At the strategy level, the implementation of these practices responds to the need to comply with environmental requirements and regulations related to the Colombia's National Environmental Policy, which not only leads to a reduction in taxes, but also to access to certain national tenders, programs, and projects. Likewise, the strategy goes beyond simply complying with these regulations, since it is intended to implement more sustainable measures to achieve greater competitiveness, improve quality, and fulfill its commitment to the society and the environment, in accordance with the provisions of the organization's Mission.

However, they began to implement this kind of sustainability practices without any control, without first establishing an adequate basis for its governance and management, and without following a standard or framework in this regard. Following their own criteria, they simply decided to adopt those "most famous" practices and implement them without further ado. That is why, once they knew about the GMGIT, they decided to contact us and begin to follow the framework in order to have a guide throughout the implementation, evaluation, and improvement of the Green IT processes and practices. Likewise, it is also important to highlight that, from the point of view of the UCEVA managers, during this first contact they told us that their expectations regarding the evaluation/assessment and improvement were based on: first, knowing their current status and how they were doing in this regard; and, second, being able to establish a more organized and reliable plan and strategy, following a framework of best practices, and with external and independent supervision from the organization itself.

Therefore, from this first approach and after knowing in more detail different aspects of the organization, together with the UCEVA we determined to go ahead and conduct an entire improvement plan for the Green IT processes. To do this, following the ISO/IEC TR 33014 standard, we determined that the next step would be to perform an audit in order to know in detail the current status/situation of the organization in this regard (Tactical Level) before conducting the implementation and improvement of the processes (Operational Level).

3.2. Tactical level

From a tactical level perspective, first of all, it is important to highlight that we focused on the process improvement perspective, since the context of the GMGIT and the scope of the plan developed with the UCEVA is specific for the improvement of Green IT processes. For this reason, we have not performed any action on the clauses relating to "Enhance organizational improvability" and "Enhance project improvability" defined in the ISO/IEC TR 33014 standard (see Fig. 1).

Thus, at this level the main objective was to know the current status/situation of the UCEVA, in order to identify the starting point from which to start making the appropriate improvements. For this reason, we decided to conduct an audit, which took place between October–November 2018. The methodology followed, main characteristics, results obtained, and discussions and conclusions reached in this audit conducted at the UCEVA, have been published and can be consulted at [22].

Anyway, as a general summary of the audit, together with the UCEVA we decided to conduct a *Green in IT* audit (since they are focusing on practices to reduce the impact of IT itself). Likewise, as a first contact and due to the fact that they were still in the initial stages of implementation of Green IT, we also established the scope of evaluating only the processes corresponding to the first two maturity levels, as established in the GMGIT [21]. During the audit itself, a series of interviews were performed, as well as the necessary evidences and documents were collected, in order to carry out a qualitative analysis of all

Table 1

Scope and timeline of the Green IT improvement cycles performed at the UCEVA.

Cycle	Processes scope	Improvements implementation period	Evaluation period
First cycle	DSS01. Manage Operations APO01. Manage IT Management Framework APO02. Manage Strategy APO06. Manage Budget and Costs APO08. Manage Relationships	03/2019 – 10/2019	11/2019 – 12/2019
Second cycle	APO10. Manage Vendors BAI01. Manage Programs BAI02. Manage Requirements Definition BAI03. Manage Solutions Identification and Build BAI11. Manage Projects	01/2020 – 08/2020	08/2020 – 09/2020

this information and generate an audit report about the current situation of the UCEVA regarding the audited Green IT processes. And about the results obtained, despite the involvement and predisposition of the UCEVA with sustainability and the application of best practices in this regard, everything implemented so far had been performed in a rather disorganized manner and lacked a formalisation, a control, and a base that would allow a correct governance and management. In fact, of the 2 processes evaluated in the *Green in IT* Maturity Level 1, the UCEVA fully complied with the BAI09 (Manage Assets) process and partially with the DSS01 (Manage Operations) process; while with the *Green in IT* Maturity Level 2 processes, they did not comply with any. Therefore, the final result was that the UCEVA was partially in the *Green in IT* Maturity Level 1.

Finally, it is important to highlight that thanks to this audit we were able to know the current status of the UCEVA regarding Green IT, which was reflected in the audit report that we presented to said organization. After explaining the results and findings found to the UCEVA, we decided to establish an action plan to start implementing and supervising the improvement of Green IT processes (Operational Level).

3.3. Operational level

Once the current situation and the specific problems of each of the Green IT processes evaluated at the UCEVA were known, in this last level we performed the definition and application of an action plan for the improvement, in order to solve the problems found and implement the Green IT processes of the first two maturity levels evaluated.

Thus, we first identified with the UCEVA the available resources and other relevant characteristics in order to adequately define both the scope and the timeline for the action plan. Based on this, we agreed to conduct two improvement cycles, dividing the processes between them, with a duration per cycle of between 6 and 8 months for the implementation of improvements. Likewise, we also agreed to perform an overall evaluation after each cycle to verify the improvements and ensure that they continued to comply with all the previous practices before moving on to the next cycle or ending the current improvement plan. It is also important to highlight that, in the specific plan of each of the cycles, we not only included the scope of the action plan in terms of processes and the timeline, but also all the problems/non-conformities found in each process, as well as the possible solutions to address them and the work products resulting from the application of the improvements. Table 1 shows the scope in terms of processes and the timeline established in the two Green IT improvement cycles performed at the UCEVA.

After each of the defined cycles, the evidence and results obtained from the application of the improvements were collected, in order to

Table 2

Implementation of the *Green in IT* practices for the DSS01 (Manage Operations) process at the UCEVA.

Base practice	Actions/Measures implemented
DSS01.BP1: Perform operational procedures. Maintain and execute operational procedures and tasks of <i>Green in IT</i> reliably and consistently.	The UCEVA already complied with this practice before conducting the improvement. However, we have reviewed that the following measure has been maintained and remains consistent with the rest of the practices: The general strategy of the organization is oriented towards <i>Green in IT</i> , so that it is considered at all times for its analysis, application, and management (the latter two, when applicable) in all the operational procedures of the UCEVA. Accompanying this practice, a constant and important work of dissemination and awareness is conducted to all members and relevant stakeholders of the organization about the strategy and characteristics adopted in relation to <i>Green in IT</i> .
DSS01.BP2: Manage outsourced services. Manage the operation of outsourced services so as to maintain their reliability and their consistency with the <i>Green in IT</i> .	As in the previous case, the UCEVA already complied with this practice, so we have reviewed the adequacy and consistency of the following: The acquisition and management of outsourced IT services includes as a contractual obligation the compliance at all times with the <i>Green in IT</i> requirements established by the UCEVA in its policy, principles, and strategic plan, as well as with the applicable legal requirements. Likewise, periodic evaluation methods are established to verify compliance with these characteristics before, during, and after the acquisition, as well as throughout the entire life cycle of the service provision.
DSS01.BP3: Monitor IT infrastructure. Monitor the IT infrastructure and events related to it, in an effort to ensure the alignment of all of them with the Green IT. Store enough chronological information in the operations logs of the organization to allow the reconstruction, review and examination of the time sequences of the operations, as well as of the activities associated with the support to those operations.	A method of constant monitoring and evaluation of the IT infrastructure performance has been established, in order to verify that both the IT infrastructure in general and the sustainable practices implemented not only generate the expected results, but also allow achieving the <i>Green in IT</i> objectives established by the UCEVA. This method is automated based on resource consumption thresholds, warning when a value is reached above a set limit. Likewise, the indices are periodically monitored to verify their correct operation.
DSS01.BP4: Manage the environment. Maintain measures for protection against environmental factors. Install specialized equipment and devices to monitor and control the environment from a <i>Green in IT</i> perspective.	The <i>Green in IT</i> has been included within the characteristics and parameters of the management of the environment. Likewise, related to monitoring the performance of the IT infrastructure, a series of parameters have been established to evaluate the environmental impact of said infrastructure, in order to take corrective actions to meet the <i>Green in IT</i> objectives in this regard.
DSS01.BP5: Manage facilities. Manage the facilities according to the laws, regulations, guidelines and other requirements related to <i>Green in IT</i> .	The management of the facilities at the UCEVA has incorporated the <i>Green in IT</i> as a characteristic to consider in the elements of said facilities. Thus, a method has been established to evaluate and incorporate new <i>Green in IT</i> practices that may be applicable in current facilities, as well as to analyze and consider practices in this regard when expanding, renovating, or constructing new facilities.

Table 3
Compliance with the processes and their practices of Maturity Level 1 at the UCEVA.

Processes and their Base Practices of Maturity Level 1	Yes	Partially	No
BAI09. Manage Assets	X		
BAI09.BP1: Identify and record current assets	X		
BAI09.BP2: Manage critical assets	X		
BAI09.BP3: Manage the asset life cycle	X		
BAI09.BP4: Optimize asset costs	X		
BAI09.BP5: Manage licenses	X		
DSS01. Manage Operations	X		
DSS01.BP1: Perform operational procedures	X		
DSS01.BP2: Manage outsourced services	X		
DSS01.BP3: Monitor IT infrastructure	X		
DSS01.BP4: Manage the environment	X		
DSS01.BP5: Manage facilities	X		

evaluate them and verify their suitability and consistency both in particular and with respect to the rest of existing processes and practices. It is important to highlight that in order to properly analyze these results and evaluate the improvement made, they have been analyzed and compared with the results obtained in the first audit performed at the UCEVA, which are published in [22].

Thus, as a specific example of one of the processes included in the scope of the action plan, Table 2 shows the actions/measures that have been conducted to implement the *Green in IT* practices of the DSS01 (Manage Operations) process. As we can see, each of the practices of the process have been correctly addressed and, together with the evaluation of the evidence, it has also been verified (both after the first and second cycle) that there is no conflict with any of the other processes and all the implemented practices maintain the suitability and consistency.

On the other hand, Appendix A includes the general results of compliance with the Green IT processes evaluated and under the action plan for the improvement conducted at the UCEVA.

Therefore, as a conclusion to the results obtained, the UCEVA has successfully implemented the vast majority of the practices of the different processes included in the action plan, reaching the Maturity Level 2 of *Green in IT*. The improvement is substantial and very relevant, since in the first audit performed [22], the UCEVA was at Maturity Level 1, with a full compliance with the BAI09 (Manage Assets) process, a partial compliance with the DSS01 (Manage Operations) process, and a total non-compliance of the rest of the processes.

4. Discussion

4.1. Main findings from the improvement plan at the UCEVA

The main findings we have obtained from the improvement plan conducted at the UCEVA are presented and discussed below, divided into different points of view:

- **Application of the ISO/IEC TR 33014 to Green IT.** The methodology that we have performed to apply the ISO/IEC TR 33014 standard to Green IT through the GMGIT has been adequately adapted to the context of both the framework and the organization and has not generated any problem or inconvenience. We believe that the most important thing when conducting a successful improvement plan is, first, to evaluate and know in detail what the current status of the organization is in the area in question, and then to define an action plan for the improvement together with the organization in order to determine a realistic and feasible scope and timeline. Likewise, we also believe that, whenever possible, it is better to divide the action plan for the improvement into several cycles, since this helps organizations, on the one hand, to better organize and focus work on more specific aspects (achieving a more comfortable, affordable, systematic, and progressive improvement), and, on the other hand, to be able to conduct more periodic

Table 4
Compliance with the processes and their practices of Maturity Level 2 at the UCEVA.

Processes and their Base Practices of Maturity Level 2	Yes	Partially	No
APO01. Manage IT Management Framework	X		
APO01.BP1: Design the management system of IT in line with the Green IT	X		
APO01.BP2: Communicate management objectives, direction and decisions made	X		
APO01.BP3: Implement management processes	X		
APO01.BP4: Define and implement the organizational structures	X		
APO01.BP5: Establish roles and responsibilities	X		
APO01.BP6: Optimize the placement of the function of <i>Green in IT</i>	X		
APO01.BP7: Define information and system ownership	X		
APO01.BP8: Define target skills and competencies	X		
APO01.BP9: Define and communicate policies and procedures	X		
APO01.BP10: Define and implement infrastructure, services and applications	X		
APO01.BP11: Manage continual improvement of the management system of IT in line with the Green IT	X		
APO02. Manage Strategy	X		
APO02.BP1: Understand organization context and direction	X		
APO02.BP2: Assess current capabilities, performance and maturity of <i>Green in IT</i> of the organization	X		
APO02.BP3: Define the target of the capabilities of <i>Green in IT</i>	X		
APO02.BP4: Conduct a gap analysis	X		
APO02.BP5: Define the strategic plan and roadmap	X		
APO02.BP6: Communicate the strategy and direction of <i>Green in IT</i>	X		
APO06. Manage Budget and Costs	X		
APO06.BP1: Manage finance and accounting	X		
APO06.BP2: Prioritize resource allocation	X		
APO06.BP3: Create and maintain budgets	X		
APO06.BP4: Model and allocate costs	X		
APO06.BP5: Manage costs	X		
APO08. Manage Relationships	X		
APO08.BP1: Understand business expectations	X		
APO08.BP2: Identify opportunities for <i>Green in IT</i> to enhance the business	X		
APO08.BP3: Manage the business relationship	X		
APO08.BP4: Coordinate and communicate	X		
APO08.BP5: Provide input to the continual improvement of services	X		
APO10. Manage Vendors		X	
APO10.BP1: Identify and evaluate vendor/supplier relationships and contracts	X		
APO10.BP2: Select vendors/suppliers	X		
APO10.BP3: Manage vendor/supplier relationships and contracts	X		
APO10.BP4: Manage vendor/supplier risk		X	
APO10.BP5: Monitor vendor/supplier performance and compliance		X	
BAI01. Manage Programs			X
BAI01.BP1: Maintain a standard approach for program management	X		
BAI01.BP2: Initiate a program	X		
BAI01.BP3: Manage stakeholder engagement	X		
BAI01.BP4: Develop and maintain the program plan	X		
BAI01.BP5: Launch and execute the program	X		
BAI01.BP6: Monitor, control and report on the program outcomes	X		
BAI01.BP7: Manage program quality		X	
BAI01.BP8: Manage program risk		X	
BAI01.BP9: Close a program	X		
BAI02. Manage Requirements Definition			X
BAI02.BP1: Define and maintain business functional and technical requirements	X		
BAI02.BP2: Perform a feasibility study and formulate alternative solutions	X		
BAI02.BP3: Manage requirements risk		X	
BAI02.BP4: Obtain approval of requirements and solutions	X		
BAI03. Manage Solutions Identification and Build			X

(continued on next page)

Table 4 (continued)

Processes and their Base Practices of Maturity Level 2	Yes	Partially	No
BAI03.BP1: Design high-level solutions	X		
BAI03.BP2: Design detailed solution components	X		
BAI03.BP3: Develop solution components	X		
BAI03.BP4: Procure solution components	X		
BAI03.BP5: Build solutions	X		
BAI03.BP6: Perform quality assurance		X	
BAI03.BP7: Prepare for solution testing		X	
BAI03.BP8: Execute solution testing		X	
BAI03.BP9: Manage changes to requirements	X		
BAI03.BP10: Maintain solutions	X		
BAI03.BP11: Define services of <i>Green in IT</i> and maintain the service portfolio	X		
BAI03.BP12: Design solutions based on the defined development methodology	X		
BAI11. Manage Projects		X	
BAI11.BP1: Maintain a standard approach for project management	X		
BAI11.BP2: Start up and initiate a project	X		
BAI11.BP3: Manage stakeholder engagement	X		
BAI11.BP4: Develop and maintain the project plan	X		
BAI11.BP5: Manage project quality		X	
BAI11.BP6: Manage project risk		X	
BAI11.BP7: Monitor and control projects	X		
BAI11.BP8: Manage project resources and work packages	X		
BAI11.BP9: Close a project or iteration	X		

evaluations (redirecting the course more easily and reducing the risks of implementing erroneous or incompatible measures). That is why we performed a first case study to know the current status of the UCEVA in this regard [22]; we defined an action plan together with said organization, adapting and being flexible at all times to its context; and we divided said action plan into two cycles to be able to

approach the processes bit by bit and to evaluate the measures implemented before reaching a full implementation of the improvements (in which one any problem or inconvenience would have been more complicated and costly to solve). All this has meant that both the UCEVA and we have not had any problem when applying the ISO/IEC TR 33014 standard in this context and we have obtained very satisfactory results and better than expected.

- **The GMGIT.** In this regard, we continue to reinforce and validate the applicability and consistency of the GMGIT through applications such as the one performed, demonstrating, in this case, its usefulness and suitability for organizations to progressively and systematically improve the processes and practices related to the governance and management of Green IT. The feedback we have obtained throughout the implementation and improvement process has been very satisfactory, since the UCEVA has recognized that the practices included in the GMGIT are adequate and fit in a very useful and efficient manner in the context in which they are found. However, as in any situation, there is always room for improvement and feedback from UCEVA has highlighted that a great step forward would be to include specific and successful examples of different elements (e.g., policies and strategies) from other organizations. This would help make the GMGIT a much more detailed and useful guide, as new organizations in this area could adopt these specific examples that are already working in other organizations. We think it is a good recommendation and we are going to work on it. However, we also consider that including these examples is not going to be an easy task, since we will have to deal with organizations for confidentiality issues, and, in addition, it can be a double-edged sword, since each organization has a context and variables different from the other in many respects and these examples may not be so easy to adopt and, more importantly, not generate the expected results.

Table 5

Compliance of the audited processes with the Process Attributes (PA) and their results (PAR) of Capability Levels 1 and 2 at the UCEVA.

Process Attributes (PA) and their Process Attributes Results (PAR) of Capability Levels 1 and 2	BAI09	DSS01	APO01	APO02	APO06	APO08	APO10	BAI01	BAI02	BAI03	BAI11
PA 1.1: Process performance	F	F	F	F	F	F	P	P	P	P	P
<i>The PARs of PA 1.1 correspond to the results of the process on which it applies</i>											
PA 2.1: Process performance management	F	F	F	F	F	F	P	P	P	P	P
PAR 2.1.1: Determine and communicate the results to be achieved	F	F	F	F	F	F	F	F	F	F	F
PAR 2.1.2: Determine and address the risks that may affect the performance of the process	F	F	F	F	F	F	P	P	P	P	P
PAR 2.1.3: Plan, monitor, measure, evaluate, and adjust the performance of the process	F	F	F	F	F	F	P	P	P	P	P
PAR 2.1.4: Define, assign, and communicate those responsible and authorities to perform the process	F	F	F	F	F	F	F	F	F	F	F
PAR 2.1.5: Determine, provide, and maintain the necessary resources to perform the process	F	F	F	F	F	F	F	F	F	F	F
PAR 2.1.6: Determine the competencies to perform the process	F	F	F	F	F	F	F	F	F	F	F
PAR 2.1.7: Ensure the competences of the people who perform the process on the basis of an appropriate education, training or experience	F	F	F	F	F	F	P	F	F	P	F
PAR 2.1.8: Manage the interfaces between the parties involved to ensure effective communication and level of control expected	F	F	F	F	F	F	P	F	F	F	F
PA 2.2: Work products management	F	F	F	F	F	F	F	F	F	F	F
PAR 2.2.1: Determine the requirements for work products	F	F	F	F	F	F	F	F	F	F	F
PAR 2.2.2: Define the requirements for the control of work products	F	F	F	F	F	F	F	F	F	F	F
PAR 2.2.3: Identify, document, and appropriately control work products	F	F	F	F	F	F	F	F	F	F	F
PAR 2.2.4: Review and approve the suitability and adequacy of the work products in accordance with the defined plans and adjust them as necessary to meet the requirements	F	F	F	F	F	F	F	F	F	F	F
PAR 2.2.5: Determine, maintain and preserve work products to provide confidence that the process is carried out in the manner established and thus ensure the compliance of work products and/or services with their requirements	F	F	F	F	F	F	F	F	F	F	F

F: Full compliance; P: Partial compliance; N: Non-compliance.

- Organization involved (UCEVA).** The application of the GMGIT through an improvement plan based on the ISO/IEC TR 33014 standard has been very successful for the UCEVA. On the one hand, thanks to the established methodology, they have been able to implement the GMGIT practices and processes included in the scope in an orderly, progressive, and systematic manner, reducing the complexity of implementation and associated risks, as well as controlling and reviewing all in a more constant and effective manner. On the other hand, thanks to this implementation, they have been able to get out of the predicament they were in, due to the lack of a specific guide/framework that would not only help them to identify and implement specific Green IT practices in a much more reliable, effective, and efficient manner, but also to have an extra motivation to advance and improve in this area, as well as to make the entire organization aware that this is important and needs to be done. However, we have identified that, in these early stages of implementation, the UCEVA has had problems in identifying and addressing risks related to Green IT and also establishing an adequate method to evaluate the quality of both the measures and practices implemented and the results obtained. We cannot determine that this is always the case, since the work is ongoing and we must conduct more improvement plans to evaluate and verify this. Even so, it is something that we are going to emphasize in the next improvement plans and we have in mind to develop guides and specific examples in this regard to help organizations in these controversial, abstract, and difficult to understand and apply aspects (especially at the beginning of the development of a certain area).

4.2. Lessons learned from applying ISO/IEC TR 33014

One of the most important and critical aspects during a process of applying an improvement plan such as the one that concerns us, is obtaining and analyzing the lessons learned. Thanks to this, problems can be identified (often applicable to any context), through which the methodology followed can be refined and improved.

Thus, from the point of view of the application of the ISO/IEC TR 33014 standard to the improvement of Green IT processes performed in this study, this standard has been a fairly adequate guide to conduct the entire process of the improvement. Thanks to this, we have been able to divide the work according to the levels and steps established by the standard, conducting a more organized and direct process. Likewise, it has helped us not to ignore or forget to conduct specific actions to consider important aspects such as identifying and analyzing what the organization's objectives are regarding change/improvement or developing an action plan to conduct a more progressive and affordable improvement.

However, the main drawback that happens with all the standards is that they are just a guide, i.e., in our case, the ISO/IEC TR 33014 standard has very well defined what has to be done (the steps that must be followed and their order), but it does not specify how it should be done. It would be appropriate to have at least one guide or proposal that includes different options and recommendations on how the different levels and steps can be performed in specific contexts. For example, in our specific case, for each of the levels we established and followed (according to our own criteria) a strategy based on: first (Strategic Level), hold a meeting with the organization to broadly analyze its context, objectives, motivations, etc., and try to collect all the information that will help to establish the basis for defining and following an adequate plan and methodology at the next levels; second (Tactical Level), conduct an audit in order to know the current status/situation of the organization's processes in relation to Green IT and to identify the starting point from which to perform the improvement; and, third (Operational Level), establish a progressive action plan divided into two cycles for the implementation of the improvements in the different processes, performing evaluations, based on follow-up audits, after each cycle to verify the adequacy of said improvements.

From our point of view, we believe that the strategy and methodology we have followed has been correct and is adequate when conducting a successful process improvement plan (whether it is Green IT processes or from another context). But the ISO/IEC TR 33014 standard should provide at least examples of these strategies and methodologies to follow, in order to avoid biases and/or abstract or erroneous interpretations that lead to an unsuccessful or even harmful application of an improvement plan.

4.3. Limitations of the study

From the outset, it has sought to conduct this study mitigating or avoiding possible limitations or risks that could affect its validity. However, there are always limitations of various kinds that are beyond the control and can affect the results and findings obtained.

For example, in order to mitigate possible risks or limitations in relation to interpretations and discrepancies that may exist between researchers and practitioners, from the outset frameworks (such as COBIT 2019) and standards (such as ISO/IEC 33000, ISO/IEC TR 33014, ISO 14000...) that are recognized and extended have been taken as a basis. However, despite following these guides and the validations performed in this regard, there may always be discrepancies in certain concepts or best practices that are specific to Green IT, since these come from the analysis, experience in practice, and perspectives of the authors.

Likewise, a limitation of this study is the application of the proposal in a single organization. Although it is true that what the study intends is to take a single and first application example to demonstrate the applicability of the ISO/IEC TR 33014 standard to the improvement of Green IT processes and from there continue the development and improvement in this regard, the specific context of said organization poses a risk of applicability to other types of organizations and contexts. For this reason, work is being done to conduct this application in other organizations in different contexts, as well as to prepare detailed documentation so that other researchers and practitioners can conduct their own studies and obtain new conclusions and findings from their points of view.

4.4. Implications for research and practice

The present study has a high implication and transcendence both at the level of research and practice. From the research perspective, the progress made through the application of the ISO/IEC TR 33014 standard to the improvement of Green IT processes allows researchers in the areas of sustainability, Green IT, IT in general, and process management conduct further research in this regard. These can go from the application of the GMGIT and/or the proposal of this study in new and different contexts to continue its validation and identification of findings and possible gaps to address; until the development of a more specific research in characteristics related to the governance, management, and improvement of Green IT, based on the advances made through the GMGIT and this study.

Likewise, from the practice perspective, this study represents a great advance for organizations, since they finally have a guide that helps them not only in Green IT in general, but also to conduct an implementation and improvement in this regard in a progressive and systematic manner. Until now organizations were afraid to embark on this field due to the lack of guidelines and empirical evidence. Therefore, proposals such as the one presented in this study are of great help and will allow more and more organizations to implement Green IT practices in their daily processes and operations.

5. Conclusions and future work

Nowadays, nations, organizations, and institutions around the world seek the formula for growth. Many have already realized that a large

part of the solution to this formula lies in the sustainable innovation and development.

The implementation of sustainable practices and processes has become a very common activity, especially in areas as scalable and important as IT [4–9]. The well-known as Green IT is reporting important and substantial benefits for the organizations that implement it [15, 16]. However, the implementation of these Green IT practices or processes is usually conducted without performing a continuous improvement plan, which generates an important handicap in terms of effectiveness and efficiency, due to the obsolescence of what has been implemented and the lack of a real management.

For this reason, in this study we decided to conduct the implementation of an improvement plan for Green IT using the widely adopted ISO/IEC TR 33014 standard [24] for improvement plans, as well as the “Governance and Management Framework for Green IT” (GMGIT) [20,21] (the specific framework for the governance and management of sustainability in and by IT).

The results obtained through the application of an improvement plan for Green IT in the processes of a Colombian organization demonstrate the importance of constantly evolving and improving the sustainable practices implemented, as well as following guides, frameworks, and/or standards that help to perform this work. Before conducting this application, the organization in question had a series of disjointed and poorly managed Green IT practices, which were not producing the expected results. Now, thanks to the improvement performed, they have everything much better established and managed, improving the effectiveness and efficiency of the Green IT function in their processes and daily operations, as well as obtaining adequate results regarding their expectations.

On the other hand, from the point of view of the GMGIT, this improvement plan continues to demonstrate the validity, usefulness, and applicability of this framework for organizations when implementing, evaluating, and improving the governance and management practices and processes required in Green IT.

For all these reasons, we continue to develop and refine the GMGIT, as well as applying it through improvement plans in more organizations in different contexts and internationally. The lessons learned and feedback obtained from applications such as the one presented in this study are not only helping us to improve the GMGIT, but also to increasingly help organizations to obtain better and greater benefits in this regard. Similarly, from the feedback obtained through this study we have identified and we are working on incorporating specific and successful examples of application of different aspects of Green IT, as well as on expanding the scope of the GMGIT from considering only the environmental sustainability to also considering the social and economic sustainability [46–48].

The situation is very clear, we are very close to reaching the point of no return and to the fact that the sustainable practices and processes implemented are of no use. We must continue working, and, above all, constantly evolving and improving regarding sustainability. There is no other plan, we cannot continue leaving the defense of our environment half done.

CRediT authorship contribution statement

J. David Patón-Romero: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Maria Teresa Baldassarre:** Conceptualization, Validation, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Moisés Rodríguez:** Conceptualization, Validation, Formal analysis, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition. **José Gabriel Pérez-Canencio:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing. **Mary Luz Ojeda-Solarte:** Conceptualization, Methodology, Validation,

Resources, Writing – review & editing. **Andrés Rey-Piedrahita:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing. **Mario Piattini:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. General Results of Compliance with Green IT Processes at the UCEVA

Table 3 and Table 4 show the general results of compliance with each of the processes and their practices, corresponding to the first two maturity levels [21] included in the scope of the action plan for the improvement conducted at the UCEVA.

Likewise, Table 5 shows the evaluation of the capability of each one of these processes of the first two maturity levels, which also demonstrates the evolution/improvement of the processes.

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