sustainability

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A Framework Proposal to Assess the Maturity of Green IT in Organizations

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Abstract: Green IT has been gaining relevance in organizations that seek to mature their IT projects, processes and strategies in a sustainable way, encompassing the set of strategies, practices and policies related to Information Systems, IT infrastructure, acquisition, use and disposal with a focus on economic and socio-environmental performance. Thus, this article aims to propose a Green IT Maturity framework. A systematic literature review led to the development of a Green IT practice checklist, which was qualitatively analyzed and categorized into six dimensions, culminating in a Green IT maturity framework proposal. The results provide a structured instrument to facilitate the Green IT identification and implementation of practices in organizations. The findings can guide the Green IT implementation and sustainable initiatives across the organization from six dimensions: organizational, technological, economic, environmental, social and marketing. The framework enables the development diagnosis and assessment of Green IT practices present in the organization. It also works as a guide in the search and monitoring of Green IT practices that can be used, improving the sustainability levels of organizational operations.

Keywords: Green IT; framework; maturity; practices; sustainability

Citation: Salles, A.C.; Lunardi, G.L.; Thompson, F. A Framework Proposal to Assess the Maturity of Green IT in Organizations. *Sustainability* **2022**, *14*, 12348. https://doi.org/10.3390/su141912348

Academic Editor: Shintaro Sengoku

Received: 31 August 2022
Accepted: 22 September 2022
Published: 28 September 2022

1. Introduction

Companies from all sectors and sizes are under increasing pressure from green movements and regulatory bodies to reduce their environmental footprint. Answers to these challenges include corporate social responsibility (CSR) and corporate sustainability initiatives [1,2]. From this perspective, organizations have sought alternatives to implement sustainability in their business processes, whether in production/operation or in conducting the business, through the strategy definitions that bring the organization closer to its goals in a more sustainable way and with less socio-environmental impact [1–4].

From a strategic point of view, Information Technology (IT) is considered essential for any organization that wants to operate efficiently and effectively in its markets, successfully conducting and managing its operations [5]. This greater technological dependence has made investments in the acquisition and maintenance of technological devices continue to grow at an accelerated rate. However, if on the one hand IT has provided organizations with competitive advantages—or at least avoided a competitive disadvantage—on the other hand, it has been responsible for a significant part of the environmental problems faced by society [6], such as high energy consumption (which also contributes to the emission of greenhouse gases), the amount of non-renewable inputs used in its production and the disposal of obsolete equipment [7].

In this context, Green IT can be considered an alternative to conventional technologies, based on organizational strategies that aim at both the production and use of high-tech hardware and software, considering sustainability principles to reduce the carbon footprint and environmental impacts [8]. Studies related to Green IT include, for example, the IT Life

Cycle Analysis (LCA), which involves measuring the environmental impacts caused by its conception, production, consumption and, subsequently, disposal, either by end-users or by organizations [3].

In this sense, the study and practice of Green IT contribute to humanity's future, by encouraging the adoption of more sustainable practices by people and the development of policies focused on IT sustainability within organizations [8,9]. To achieve effective results in terms of sustainability, Green IT must assume centrality, being considered the first step towards achieving organizational sustainability and contributing to sustainable development. Green IT is considered the latest indicator of sustainable business practices because it improves global energy productivity while keeping the economics dynamic [8,10–12].

The future points to a latent demand from companies that provide IT services from a broader perspective, incorporating sustainability objectives in other business areas and not just in the organization's technology sector, associated with the development and support of the IT infrastructure [10,11,13]. Thus, analyzing the maturity of Green IT can serve as an important indicator to assess the predisposition and potential of companies to improve and/or develop sustainable innovations that cover not only their technological area but, more broadly, the entire company from an institutional perspective [13]. In fact, the IT literature focusing on how to assess the level of sustainable development of organizations in the IT area is limited [14]. Santos et al. [15], analyzing different sustainability maturity models found in the literature—including two IS models—concluded that most maturity models focus on only one aspect or are excessively broad—not including in detail the elements necessary to measure the level of maturity in sustainability. In this sense, this study mitigates these gaps by mapping the state-of-the-art of Green IT practices in organizations, considering their application in different categories of analysis (dimensions and areas) and proposing a specific maturity framework for Green IT in organizations.

The study intends to answer the following research question: How to systematize Green IT practices in order to support organizations to address and diagnose the development of IT sustainability in specific organizational areas? So, in this paper we propose a theoretical framework to assist organizations in the assessment of their maturity concerning Green IT practices, expanding the analysis perspective until then considered by the literature, covering organizational, technological, economic, environmental, social and marketing aspects. Besides, we understand this framework can be seen as a guide to orientate the search and monitoring of Green IT practices that can be used by the organizations, improving their operation's sustainability levels.

2. Building a Green IT Maturity Framework

2.1. Green IT

The term Green Information Technology, more commonly called Green IT [6], is a socio-technical movement related to the need to innovate the way organizational resources are combined, aligning them with sustainability and economic policies, to the detriment of global discussions on sustainability and corporate social responsibility [16]. From this perspective, Green IT provides benefits for the environment, society, and business by seeking ways to interrelate and implement IT policies, practices, strategies and products that can help improve and foster the environmental dimension of sustainability, and, consequently, influence its economic and social dimensions in a holistic process [7].

One of the most common interpretations of sustainability is the triple bottom line (TBL) concept, which states that sustainable development must include social, environmental and economic dimensions [17]. When applied to the organizational area, the TBL aims to analyze sustainability beyond traditional measures of profit, return on investment and generation of value for shareholders, to include social and environmental issues [16]. The environmental dimension encompasses the concern about production and consumption considering that ecosystems can maintain their self-repair or their capacity for resilience [17]. The social dimension involves eradicating poverty and setting the standard for a dignified life, with fair and equitable distribution of income, and consumption of natural goods

and services among all inhabitants [17]. The economic dimension, in turn, includes the formal and informal economy, in the sense of providing services to individuals and groups, increasing individuals' income and their standard of living [18]. In this sense, it is possible to believe in the beginning of a business management new paradigm, driven by sustainability and the integrated economy, which includes the environment and society from the sustainable awareness perspective [18].

In this integrated perspective of sustainability, Green IT corresponds to the sum of energy savings with resource management ranging from production chains, and lifecycle assessment that goes from raw material extraction to the end of the equipment's useful life, including its disposal [6]. Therefore, Green IT comes to be understood as the study and practice related to the design, production, operation and disposal of IT equipment, such as computers, servers and associated subsystems (monitors, printers, storage and network and communication devices) with maximum efficiency and with minimal or no impact on environment. It also includes the development of strategies and tools to control, guide and communicate the green practices adopted by organizations [10,19,20].

It is necessary to analyze Green IT comprehensively and consider aspects such as efficient energy consumption and management, manufacturing design and operation of IT equipment, concerns about the complete life cycle of information and communication technologies, the total cost of ownership, micro and macroeconomic issues, systems use and performance as well as environmental, social and ethical practices related to the acquisition, use and disposal of IT [17]. Taking this under consideration, for IT adopted by managers and users in organizations to be considered "green", in addition to the economic feasibility and operational performance of the system, it is needed to consider environmental, social and ethical aspects in the process of technology acquisition, use and disposal. Thus, the organization will have a holistic view of the adopted Green IT implementation and evaluation [10,21]. On that account, IT intelligent management can be seen as an alternative for organizations not only to minimize the damage caused by their activities to the environment or reduce the operating costs of the business but also for them to develop a sustainable organizational environment in harmony with the aspirations of today's society [9].

2.2. Green IT Practices

Green IT has dealt with and assumed a strategic role in the incorporation of environmentally correct practices in organizations, inducing a process of incorporation of sustainability in a transversal way, since it deals with issues such as the integration of greener computing practices. These practices translate into the energy efficient equipment design; personal computers replacement with thin clients; virtualization software use to run multiple operating systems on the same server; cooling technology improvement; print optimization regimes; carbon offset program adoption; Network-Critical Physical Infrastructure (NCPI) system/device efficient scaling for IT load; energy management; reduced energy consumption in data centers; electronic waste reduction/recycling/proper disposal generated by obsolete computing equipment; teleworking and videoconferencing; web-based business services; IP telephony; remote computer administration to reduce CO_2 emissions among other IT infrastructure optimization practices to meet sustainability requirements [21–23].

Organizations can also adopt other sustainability initiatives and practices related to the use of renewable energy sources and/or clean energy generation, mercury-based lighting replacement with sodium-based lamps that are more efficient, conventional LCD monitors replacement with LED, air conditioners resizing, documents and administrative routines computerization, which consume a lot of resources, such as fuel for people/processes, energy and physical space [9]. Additionally, Green IT can be associated with the IT equipment purchase practices, as well as the supplier's selection and contracting that meet the environmental/ecologically correct prerequisites, that is, giving preference to equipment/companies considered "green" [9]. This involves analyzing the environmental

footprint present in the IT supply chain, assessing the track record of software, hardware and IT service providers, incorporating green issues (such as recyclable design and packaging) in the supplier's evaluation and including social concerns (such as the use of child labor and the presence of harmful materials in the supply chain) in acquisition decisions [21,24]. It also covers an environmental performance assessment of products in addition to the clear environmental policy development to guide the technological equipment purchase that is sustainable [21,24]. Specific initiatives serve as a basis for creating an organizational culture focused on environmental awareness and management, increasing the proportion of green/clean energy supply for intensive IT operations, which reduces consumption and waste rates of inputs as well as waste generation [25].

In this context, the most common categories of Green IT practices in the organizational context can be extracted from the literature, such as: Energy Efficient Computing (Hardware and Software), Energy management, Green Equipment Projects, Disposal and Recycling guided by environmental responsibility, Green Labeling and Acquisition of green products, and Development of Corporate Green IT Policies that take into account the organization's environmental strategy globally [19,20]. Despite the benefit of these practices is presumed and valid, these initiatives refer to green practices that include "corporate-level" strategies and argue that such a strategy has a potentially positive impact on the environment. However, in terms of sustainability, the strategy needs to consider the commercial (economic) and ecological (environmental) aspects to allow the benefits identification in favor of a company's revenue and/or cost, enabling the strategy at the institutional level [10]. In this sense, IT is expected to play a leading role in supporting the company's sustainability initiatives [26]. Examples of such initiatives include the development of analytical tools and information systems that support energy consumption reduction, the emission management systems implementation and the supplanting of carbon-emitting business practices [27]. The Green IT systems adoption that integrates information from supply and operation technologies for managerial decision-making, for example, is an institutional-level initiative [27].

2.3. IT and Green IT Maturity Models

A significant amount of studies presented in the literature have been concerned with the need to suggest models or frameworks that can help professionals make decisions and provide support on how to implement green practices [28]. Several models, frameworks and tools for assessing the environmental impact of IT have been released in recent years [29,30]. Consequently, there are more generic impact assessment tools that can also be applied to IT, such as life cycle analysis or greenhouse gas audits [31]. Most models and tools focus on energy efficiency and reducing the negative impacts of IT. In addition, studies focused on providing sustainability-related maturity models stand out, which take into account processes and/or operations, as well as the management of the organization [31–33]. However, to develop a management structure focused on Green IT, it is desirable to have specific maturity models that allow guiding and carrying out activities related to the management of Green IT gradually and systematically [34].

A maturity model is intended to be used as a basis for evaluating different organizations, analyzing practice development patterns, projects and results, as well as establishing comparisons [35]. From the maturity level, it is possible to predict the future performance of an organization in a given area or set of disciplines. The maturity analysis results serve as a guide for organizations to prioritize actions and strategies to reach higher maturity levels, seeking their evolution. Thus, organizations can use maturity concepts and models to accelerate their development, concerning practices, processes and actions in the most diverse strategic areas. The benefits associated with achieving higher organizational maturity levels are associated with shorter completion times, better cost control, better strategic management for decision making, sustainable growth and long-term profitability, higher level of project management maturity, better performance in all domains of the organiza-

tion, increased global maturity of the organization directly responsible for improving risk management, followed by contract management and cost management [35].

There are several models that focus their theorizing and measurement efforts in different disciplines, according to the type of organization or set of processes in question. However, a limited number of specific maturity models are found in the literature to assess Green IT [36]. The study carried out by Patón-Romero and Piattini [37] showed that sustainability maturity models tend to focus on the areas of processes/operations and organization management. In addition, they highlighted attention to a large number of sustainability and IT maturity models that present inconsistencies and lack of scientific validation. The researchers also highlighted that the CMMI (Capability Maturity Model Integration) is the most used model in the development of maturity models in the Green IT area since it is a model that appears to be very complete. Patón-Romero and Piattini's [37] discoveries also represent great relevance and opportunity for researchers and managers of organizations in the sustainability and Green IT areas. This is because they show a new field of work, in which researchers in the area of technology, management and sustainability can develop and test new maturity models focused on Green IT, helping to advance and consolidate this study field. Maturity models in the IT area work as mechanisms to help managers administrate technical activities, standardize and maintain the quality of information generated and stored in organizations' systems. The models also have strategic importance, as they work as a tool for IT Governance [34,38].

Among the Green IT maturity patterns, structures or models found in the literature, a good part is based on the CMM (Capability Maturity Model) and CMMI (Capability Maturity Model Integration), whose concept of software process maturity was inspired by the techniques of Total Quality Management (TQM) [34,39]. Other models use the COBIT methodology of IT Governance (Control Objectives for Information and Related Technology) as a basis for proposing new instruments to measure the Green IT maturity in organizations [5]. Nonetheless, despite including stakeholders and presenting objectives and approximate analysis dimensions with a holistic sustainability perspective in organizations, both CMM and COBIT have some limitations. Among them, the lack of emphasis on the organization's attitude towards sustainability stands out; IT policies involving the origin, use and disposition of IT assets that are not sustainable; a lack of emphasis on implementing sustainable IT policies in day-to-day operations within a company; the lack of emphasis on the importance of sustainable IT practices to ensure environmental safety; the lack of consideration of the organization's social responsibility to act sustainably; the lack of emphasis on the interdependencies between business and the environment in which it operates; and, finally, not considering sustainability as a corporate management problem [38].

Hence, it is clear that there is still a gap in the literature when it comes to more robust Green IT maturity models, capable of providing information for maturity assessment, organizational situational diagnosis, comparison measures and support in the definition of short and long-term to achieve corporate sustainability goals, induced, in this case, by the organization's IT area.

3. Materials and Methods Used to Create the Green IT Maturity Framework

The research was developed under a qualitative approach as it allows the identification of multiple meanings attributed to a certain complex reality. It included exploratory and descriptive steps. The exploratory stage sought to explore the problem aiming at developing, clarifying and modifying concepts and ideas, favoring a new understanding of the problem, indicating clear concepts, priorities and operational definitions [40] that serve as basis for further research. The descriptive stage sought to report how the phenomenon was observed during the research, in addition to describing the characteristics/evidence found in a given organization when confronting the theory with the studied context.

As data collection procedures, the Systematic Literature Review (SLR) and Content Analysis were used. The purpose of the SLR is to map and assess existing intellectual

territory to further expand existing knowledge, contributing to the research evidence base development in a given area of knowledge by identifying the main scientific contributions to a field or question [41]. In turn, content analysis is a systematic coding and categorization approach used to explore large amounts of textual information to determine trends and patterns of words used, their frequency, their relationships and the structures and discourses of communication [42]. This technique consists of organizing the data, dismembering it through different nuclei of meaning and, later, regrouping these parts into analytical categories, that is, classes that bring together common elements, allowing inferences to be made about the data obtained [42]. So, it is understood that from the analysis of the collected data, it will be possible to reconstruct meanings that present a deeper understanding of what is being investigated.

To fulfill the proposed objective, the carrying out of the methodological steps of this research started with the Systematic Literature Review (SLR), where it was possible to map what has been addressed in the research on the adoption of Green IT practices and maturity models for the evaluation of IT/Green IT in organizations. The development of the SLR led to a mapping of several Green IT practices. First, a research protocol was elaborated guiding the conduction of data collection, so that the results could contribute to identifying the state-of-the-art of the most applied Green IT practices in organizations. The research protocol comprises the databases, the quality criteria for data selection and for the inclusion/exclusion of the collected data definition. After the research protocol application, we performed a bibliometric study on Green IT and Green IT Practices in the selected databases. The analysis and interpretation of data considered eligible allowed for the results synthesis and description (Table 1).

Table 1. Systematic Review Process.

Research Question	*Analyze the Green IT practices used by organizations*
Research Protocol	
Database	SciELO and Science Direct
Research Strategy	In conducting the bibliographic research, two databases were used with their respective search engines: Scientific Electronic Library On-line (SciELO) and Science Direct.
Inclusion/Exclusion Criteria	Articles published between 2008 and 2019 that dealt with the Green IT and sustainability topic in organizations. The publications review considered the literature on Green IT, guided by IT professionals and academics in the IT area, management and sustainability, as well as the maturity of Green IS/Green IT and Green IT practices adoption in organizations. The objective was to identify variables/categories of analysis consistent with the research question. Articles that did not meet the quality assessment criteria, articles that were not peer-reviewed and articles that were not published in indexed journals were excluded.
Quality Criteria	Five quality criteria were defined, considering the rigor, credibility and relevance of the studies identified in the review, based on the research problem in question. They are as follows: 1. Is the article research-based? 2. Does the article have a clear relationship with the research objectives? 3. Do the collected data address/have adequacy to the research question? 4. Does the data analysis have sufficient methodological rigor? 5. Does the study have value for practice and research?
Literature review	Bibliometric Study
Data analysis and interpretation	Content analysis

The study carried out a survey of articles in two databases: Science Direct and SciELO, taking into account several areas of knowledge that have or could be related to the proposed research question, such as Applied Social Sciences, Engineering, Science Environmental, Computer Science, Decision Sciences, Economics, Econometrics and Finance, Energy, Business, and Management and Accounting. The keywords were used as search requirements, both in the title, in the abstract and in the keywords themselves, identified by the authors

as the main ones to report the theme of the published article. The keywords used were: Green IT, Green IT Practices, Sustainable IT, Green Information Technology Practices, Green Information Technology and Sustainable Information Technology.

Review articles and research articles, citable, indexed, published in all peer-reviewed journals, in all countries, in the period comprised between 2008 and 2019, were selected. Of the total number of articles collected in the two databases (3127), 1226 articles (representing 39.21%) were discarded because they addressed Information Technology (green or not) in their content but were not related to the topic of the present research. Additionally, 848 articles were discarded due to non-suitability to the research topic or due to duplication, representing 27.12% of the portfolio initially identified. A total of 586 articles (18.74%) were analyzed which, although they did not directly answer the research question itself, allowed an analysis of the field of research and the subject studied, contributing to theoretical and practical findings, deepening knowledge about the state-of-the-art of the researched topic. A total of 396 articles, representing 12.66% of the initial portfolio, addressed the topic of Green IT and, of these, 71 articles were analyzed in their entirety, as they clearly addressed one or more Green IT practices in their content, representing 2.27% of the total identified articles.

In addition to the most widespread Green IT practices in organizations, which were extracted from the SLR, the application of the content analysis methodology [42] allowed extracting a categorization of the results found, applying the themes dismemberment and identification or meaning nuclei and, later, performing a new grouping or categorization through coding processes. The Content Analysis stage was fundamental for the research because it allowed the analysis of the data collected in the systematic review stage, verifying the speeches' compatibility with the categories/dimensions of the proposed intermediate analyses. It also facilitated the codes, elements, criteria and intermediate categories identification that resulted in the definition and categorization of the dimensions of the Green IT application, from a holistic and transversal perspective in the organization.

Consequently, several more widespread Green IT practices were identified in organizations, which brought elements of analysis that resulted in the identification of commonsense cores between the practices raised, making the presence of Green IT more evident in organizations from the perspective of six dimensions: organizational, technological, economic, environmental, social and marketing. The grouping of Green IT practices into six dimensions reinforced the relevance and existence of their respective elements and categories of analysis. The data crossing from the literature review culminated in the framework proposal to assess the maturity of Green IT in organizations.

The methodological application selected for the research has provided the necessary answers to enable the analysis of the relationship between different types of Green IT practices and the application area of these practices in organizations. The results obtained in the SLR provided conceptual foundations that were fundamental for the proposition of the Green IT Maturity assessment framework, whose objective is to be able to assess the level of adoption and maturity of practices and initiatives related to Green IT. The systematic review combined with content analysis made it possible to make inferences about the effective implementation of Green IT practices and superior performance in organizations, according to the results indicated by the researched literature.

4. Results

To enable the assessment of the maturity of Green IT in organizations, through a broad (holistic) perspective, this study proposed to develop a FRAMEWORK OF MATURITY OF GREEN IT. The framework allows for diagnosing and evaluating the existing Green IT practices' level of development in the organization, as well as the Green IT maturity level in specific areas, improving the operation sustainability levels.

4.1. Framework Proposition

The broad perspective of the proposed framework allows for assessing the maturity of Green IT practices, from the top-down and bottom-up perspectives of the organization [43,44], in terms of organizational related to the process, IT strategy and governance, technological related to technology, economic related to financial capacity, economic viability and level of risk exposure, environmental related to environmental proactivity, social related to community collaboration, sharing sustainable values and articulation with stakeholders, and marketing related to Green IT innovation, green supply chain, leveling the competition, competitive advantages, commercial networking and legal/regulatory aspects to which the organization is bound. This maturity framework proposition was especially relevant, as although there is an expectation that Green IT will reduce organizational costs and the company's impact on the environment, there has been much less attention to understanding the strategic benefits of IT services in a broader perspective and that meets sustainability objectives, including, in addition to environmental aspects, the incorporation of, for example, analysis variables in terms of customer value creation, business value and social value [22].

From the perspective of Green IT, the maturity framework proposed here was inspired by the "Green IT Adoption Model" or GITAM (Green IT Adoption Model), developed by Molla [27], based on static variables, context variables and dynamics of adoption/readiness to adopt Green IT practices, combined with the model proposed by Molla and Abareshi [45], which examined the influence of eco-sustainability motivations on Green IT adoption, focusing on four eco-motivations at the locus (internal versus external) and focus (economic versus socio-political) intersection of motives. It is noteworthy that the construction of the model to assess the Green IT maturity includes additional analysis categories that emerged from the literature review and that are not included in the models proposed by Molla [27] and Molla and Abareshi [45]. In this way, new dimensions of analysis were raised, being considered relevant to analyze the phenomenon from a broader and strategic perspective, which considers, for example, not only the adoption of Green IT practices but also aspects related to the adoption, maintenance and sustainability initiatives evolutionary development applied to the IT area in organizations.

That said, the framework proposal focused on the construct alignment and readjustment that corroborate both the Green IT adoption/performance models proposed by Molla [27] and Molla and Abareshi [45], as well as the constructs proposed by the main IT governance maturity models, widely used by organizations such as COBIT, CMM and CMMI. Then, the different models contribute to the expansion of the framework dimensions and analysis elements, confirming, excluding or developing categories based on the model validation in the field, since these models consider different analytical dimensions. Thus, it is possible to add to the framework each model/method of management/measurement contributions of IT results, as well as to develop new categories of analysis, overcoming the models with their specific limitations. Such analysis dimensions are associated, for example, with meeting the stakeholders' demands; end-to-end organization coverage; a single and integrated model application; holistic approach; the distinction between governance and IT management concepts, among others.

The framework and possible Green IT maturity levels are outlined by category (construct) and corresponding analysis elements (block) as well as the final analysis estimate (resulting maturity), considering the general/organizational level of Green IT maturity. The framework representation is illustrated in Figure 1, below.

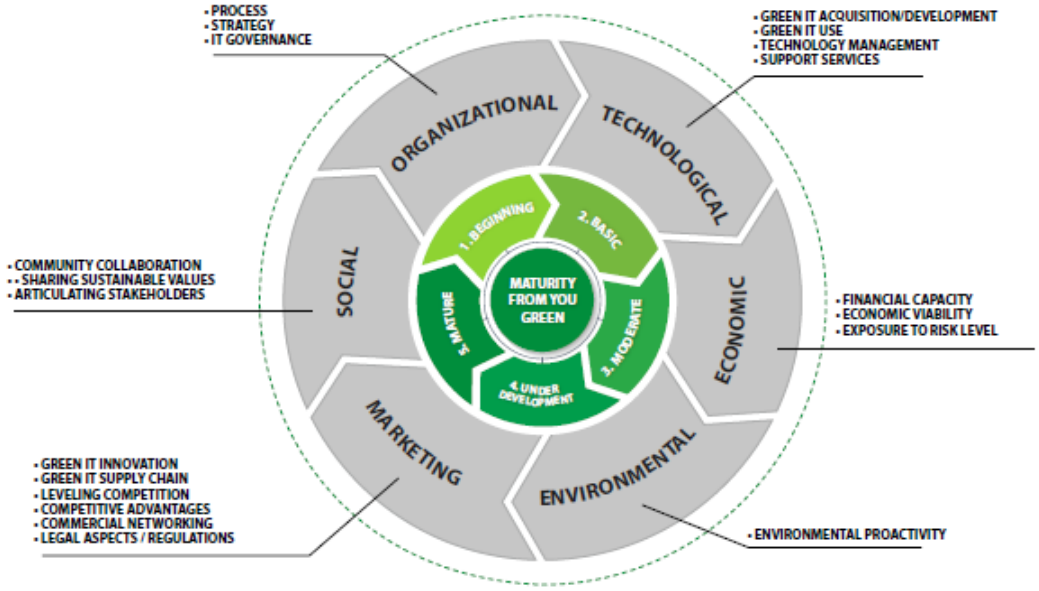

Figure 1. Green IT Maturity Framework.

The Green IT maturity framework is intended to be an instrument to assess the degree of organizations' maturity concerning the development of Green IT practices in a broad and transversal perspective, from a top-down and bottom-up view. In this sense, the categories and analysis elements defined by the Green IT maturity framework assume the scope of the IT concept, proposing constructs that emerged from the Green IT literature and the main IT governance and maturity models, widely used by organizations in IS/IT management. The framework proposal considered elements that can contribute to the development of Green IT maturity internally in organizations, in a bottom-up and top-down logic, as well as a relationship logic with the environment beyond organizational boundaries, that is, from the inside out and the outside in [28,46].

4.2. Theoretical Conceptualization of the Framework

The analysis categories identification shows how Green IT is present in organizations as a whole, which facilitates the identification, adoption and use of such practices, making the incorporating sustainability process in organizations more tangible, as well as facilitating the focus areas' identification for the strategies' application for the Green IT practices development and inclusion in a more transversal and holistic way, maximizing the efforts of different organizational areas in favor of sustainability. From the framework proposal, it is possible to identify the practices and initiatives related to each category of analysis as well as their elements/requirements, as a way of mapping and diagnosing different Green IT practices that can be implemented and evaluated in organizations.

The *organizational dimension* is related to the business objectives and strategic alignment focused on sustainability with traditional business objectives; IT objectives alignment with strategic business sustainability objectives; development, adoption, use and diffusion level of Green IT; Green IT management and governance; role of IT, and how it can activate a company's green strategy/sustainability strategy; the available organizational structure use to outline different strategies to make your IT greener/ environmentally correct; development of both quantitative and qualitative indicators (quality, productivity, innovation and organizational learning, environmental and social performance) for the evaluation of Green IT, aiming at understanding the complex and transversal relationships that involve the decision-making process to evaluate benefits versus costs; multidimensional perspective of Green IT (environmental balance, policy, technology, acquisition and consumption of products/services (IT and others), marketing, manufacturing and resources used by the organization); IT broad perspective, when analyzing IT/IS, which includes,

in addition to technology resources (hardware and software), organizational resources (human, information, capital, formal and informal infrastructure, among others) that allow IT to support individual, group and business goals; organizational behavior (systemic view) in relation to the way in which technologies are adopted and/or developed and how they are used; refers to additional resources that need to be mobilized, such as: training, qualified staff; support services, development of organizational arrangements, policies and incentives to enable effective management and use of new technologies; institutional and organizational forces that drive the adoption of Green IT and influence user behavior; and different organizational actions that can stimulate or inhibit the implementation of Green IT practices in companies. The organization's commitment to the adoption of Green IT and the development of engagement measures can lead to a change in the working method so that environmental sustainability initiatives can be favored, forming and developing positive beliefs and attitudes towards Green IT that can mitigate the negative impact of IT on the organization.

The Green IT *technological dimension* comprises the adoption of practices and technologies (Green IS/IT) with an emphasis on efficiency and environmental impact reduction; acquisition, adoption, use and management of Green IT (clean and efficient IT); adoption of other green practices and technologies in interrelated business processes that enable and encourage the development of Green IT; incorporation of Green IT principles in hardware and software architecture development; diffusion of Green IT practices at all organizational levels (operational/tactical/strategic); and the application extension of the Green IT concept beyond organizational boundaries, including the supply chain articulation and development, the IT life cycle management and the definition of new premises for the competitive market.

The *environmental dimension* is related to the use and management of new or improved technologies with an emphasis on sustainability, adoption of practices to make existing IT more sustainable, IT products/services linking environmental problems and demands in business strategy, predisposition to green consumption (adoption of Green IT procurement policies with clear ecological and environmental guidelines for purchasing IT and other devices and services); concern/sensitivity with environmental demands and the impact of organizational operations in the environmental context; environmental problems/issues influence on strategic and operational decisions around the acquisition, adoption, use and development of IT; measurement of environmental impact (monitoring practices adoption through the use of IT in monitoring energy consumption and environmental footprint); sustainability application in business processes (IT products/services incorporate environmental concerns/demands considered in the organization's sustainability strategy); comprehensive Green IT policy; product lifecycle management to minimize the environmental footprint (policies, practices and technologies combination); emphasis on the consolidation/development of Green IT practices adopted by the organization; environmental auditing through the use of IT to monitor and control the consumption of natural resources used by the organization; pollution prevention/reduction; the clean technologies use that do not use polluting materials; and the technical skills development oriented towards sustainability and the efficient use of information technology resources.

The *economic dimension* consists of the business opportunities transformation and generation from the adoption of Green IT. It assumes a certain level of risk exposure and availability of investments to implement Green IT initiatives aimed at cost reduction in the medium and long term. It is associated with the cost/level of investment to Green IT; IT cost reduction considerations; the need for greater IT efficiency and the pursuit of tangible cost savings in operations, both at the IT and organizational levels; considerations about the possibility of meeting customer demands, ensuring efficiency and sustainability (favorable perception/positive image in relation to green operations/processes) and financial results expansion (profit, return on investment, increase in market value); considerations on the availability of financial resources to innovate, develop and acquire technologies, as well as implement practices that help in measuring and monitoring the environmental and social

impact of operations; motivations for investing in Green IT and business strategies that emphasize not only environmental considerations but also cost savings; level of investment and risk exposure related to the percentage of Green IT adoption; and willingness to invest in Green IT and sustainability, driven by broader socio-environmental concerns, even if the economic benefits are not tangible in the short term.

The *social dimension* refers to equity objectives that focus on people's equal rights to environmental resources, as well as a company's social responsibility for future generations. This dimension analyzes the environmental equity objectives achievement with a focus on people's equal rights to environmental resources; a company's social responsibility for future generations; business objectives alignment with those of corporate social responsibility; articulation with stakeholders from global and local communities regarding environmental demands (direct and indirect); organization's contribution to sustainable development goals, including Green IT as a strategy to green businesses and minimize social impacts in addition to environmental ones; development of a collective socio-environmental awareness that presupposes concern for the demands of stakeholders and articulation/engagement to meet them through a shared effort; use of collaborative technologies for social mobilization around environmental demands among non-governmental organizations (NGOs) to achieve goals shared by society; and value generation for society and recognition/social acceptance by generating benefits/qualitative results reconciled with economic performance, meeting the expectations shared by local and global communities around environmental concerns.

The *marketing dimension* is associated with the organization's external environment that includes political, economic, social and environmental dimensions. It relates to the actions of organizations that need to execute leveling strategies, driving the development and adoption of Green IT, competitor actions, inter-organizational relationships and market incentives for the adoption of Green IT, supply and demand dynamics that give rise to new suppliers of Green IT, consulting professionals and engineering branches focused on sustainability goals associated with IT and absorption level of Green IT products/services by the market. It also includes the performance of supervisory/regulatory bodies that foster a Green IT market, networking to develop innovations and competitive advantages, and a green supply chain development. This dimension analyzes Green IT/Sustainability practices that expand the organizational boundaries (ecosystem/market/external environment); competitor actions (adoption of sustainability/Green IT practices by the organizations ecosystem); pressure from IT suppliers and/or suppliers (sustainability practices/Green IT adoption by the supply/distribution chain ecosystem —green supply chain); pressure from customers/consumers (environmentally friendly product demands); pressures from the regulatory environment (public policies and regulations that can pressure organizations to adopt a more sustainable posture—recycling programs, product lifecycle management, correct disposal of electronic equipment); government incentives (policies and benefits that encourage sustainability practices); implementation of Green IT by more and more organizations; industry associations for the development of Sustainable Technologies (articulation with stakeholders); innovation level, green supply chain development and inter-organizational collaboration for the development of green, efficient and cost-effective products, processes and technologies; and development of competitive advantages from the organizational capacity to develop market opportunities in an environmentally correct/sustainable way. Table 2, below, presents a summary of the practices surveyed and grouped into each of the six categories identified through the qualitative analysis performed.

The identification of these categories of analysis shows how Green IT is present in organizations as a whole, which facilitates the identification, adoption and use of such practices, making the process of incorporating sustainability in organizations more tangible, as well as facilitating the identification of focus areas for the strategies applied for development and inclusion of Green IT practices in a more transversal, synergistic and holistic way, maximizing the efforts of different organizational areas in favor of sustainability.

Table 2. Categories of most widespread Green IT practices in organizations.

Category	Green IT Practices
Organizational	Product management and sustainable development in IT management; IT systems that integrate information from Green IT supply and operation technologies for managerial decision making; assessment tools and a methodology (ISO 14001) for efficient and effective use and practice; projects and strategies for environmental sustainability in the IT area; corporate environmental strategy; specific Green IT policies; internal IT audit; approaches and methodologies for incorporation of Green IT in the organization; an organizational culture creation focused on environmental awareness and management; institutional Green IT policies; evaluation of the products environmental performance such as the adoption of the electronic product environmental assessment tool; analytical tools for green supply chain management, environmental management and carbon footprint analysis.
Technological	IT products and services (Hardware and Software) focused on environmental sustainability; eco-efficiency of computer systems and operational data centers; Green IT systems that integrate information from Green IT supply and operation technologies for managerial decision making; Green design and Green manufacturing; projects and strategies for environmental sustainability, including data center design and location; energy efficient computing, including power management and virtualization (Cloud computing, Grid Computational and SaaS); Green IT metrics; power management, virtualization, improving cooling technology, optimizing IT infrastructure for sustainability requirements; energy efficient chip and disk drive design; personal computers replacement with energy efficient Thin Clients; use of virtualization software to run multiple operating systems on one server; reduce the data centers energy consumption; server consolidation and virtualization, data center energy efficiency optimization, print optimization, data center data flow management, IT equipment scaling, ecological considerations in provisioning and Request For Proposal (RFP); liquid cooling for IT equipment; direct current (DC) powered IT equipment; ICTs based on low-carbon business solutions such as video conferencing, thin clients and web-based business services, virtual collaboration and IP telephony; desktop virtualization and policies and practices for enterprise PC power management, PC usage, and print optimization regimes.
Economic	Carbon offset policy; purchase of carbon credits, cost reduction with the adoption/generation of clean energy; cost reduction with the use of energy-efficient equipment; cost savings at scale by integrating green computing practices such as power management, virtualization, improving cooling technology, recycling, e-waste disposal, and optimizing IT infrastructure to meet sustainability requirements; financial losses savings/reduction with equipment recycling; budget allocation for Green IT projects; carbon offsetting; improvement in organizational performance by removing old systems and designing energy-efficient systems.
Environmental	Disposal of IT in a sustainable/ecologically correct way; disposal and recycling practices that are responsible, sustainable and comply with applicable regulatory requirements; Green metrics; Green IT metrics; energy efficient computing; approaches and methodologies for incorporation of Green IT in the organization; renewable energy sources use to power data centers; alternative energy sources use; reduce e-waste from obsolete computing equipment; promote teleworking and remote computer administration to reduce transport emissions; supplying green/clean energy for intensive IT operations, using paper as well as other office equipment that are recycled, increasing recycling rates, reducing consumption and inputs waste rates and, consequently, waste generation; environmental impact reduction with the adoption of practices that contribute to the generation reduction of residues and consumption reduction of natural resources such as virtualization; use of LCD monitors; documents digitization; corporate MSN; Eco source; Screen saver; Print reduction; VoIP; Call center; Paper reuse; consumption control tools; Thin Clients; prints outsourcing; paper reuse; cartridge recycling; print control; equipment donations; selective collect; recovery of parts; printers outsourcing; servers outsourcing; electronic invoice.
Social	Corporate responsibility; analyzing the IT hardware supply chain environmental footprint, assessing the track record of software and IT service providers, incorporating green issues (such as recyclable design and packaging) into the supplier assessment, and including social concerns (such as labor child use and the presence of harmful materials in the IT supply chain) in IT procurement decisions; taking out old systems, using efficient NCPI devices, and designing energy-efficient systems.
Marketing	Green IT Consulting; IT Audit; Environmentally preferable IT purchases; outsourcing practices; analysis of the environmental footprint of an IT hardware supply chain, assessment of the track record of software and IT service providers, incorporating green issues (such as recyclable design and packaging) into vendor assessment; analytical tools for green supply chain management, environmental management and carbon footprint analysis; ICTs based on low-carbon business solutions such as video conferencing, thin client and web-based business services.

4.3. Levels of Green IT Maturity

A maturity model consists of an evolution-level sequence for a given class of objects. It represents an anticipated, desired, or typical path of evolution in the form of stages or levels to classify organizations or processes. According to Hevner et al. [46], maturity models can be understood as artifacts that serve to solve the company's problems and determine its status quo and its capabilities in a given space and time.

The lower stage of a maturity model represents an initial state that can be, for instance, characterized by an organization with few capabilities in a given domain. On the other hand, the highest stage of maturity represents the full development of the organization in this domain, that is, a total-maturity [35]. To advance on the evolution path between these two extremes, a continuous progression of the organization's capabilities or the performance of its processes is necessary. Thus, a maturity model helps organizations to position themselves and assess their position on this path. Therefore, a maturity model provides domains, criteria, elements and characteristics that need to be analyzed and met to reach or define a certain level of maturity. From there, continuous improvement measures are derived as well as the methodologies and tools development and applications focused on problem-solving. This way, it is possible to assume that the development of maturity models is relevant to help companies in the situational diagnosis as well as in the search and monitoring of solutions from certain categories and dimensions of analysis with a focus on the problem or development stages that are desired to be achieved.

In this study, the Green IT maturity levels of the proposed framework were defined based on the constructs' alignment and readjustment, dimensions and attributes that corroborate the main IT governance maturity models, widely used by organizations such as COBIT, CMM and CMMI, since these are the most used models in the IT area and they are very complete. Therefore, the Green IT maturity framework presents five levels of maturity for quality and process improvements with a focus on the use of sustainable technologies in organizations. The Green IT maturity levels are summarized in Table 3. The analysis dimensions of the Green IT maturity framework are generally applicable to any organization.

Table 3. Green IT Maturity Levels.

Maturity Level	Description
1. Incipient	There is some or no awareness of the importance of Green IT issues related to the activity. No monitoring is performed. No existing documentation. Sustainability issues may even be considered, but not implemented. No improvement activities or actions take place.
2. Basic	There is some ad hoc implementation, but no strategy. Immature implementation. The organization adopts some basic Green IT activities and procedures. There is some documentation on the adoption of certain practices and procedures. No monitoring is performed. There are no improvement actions.
3. Moderate	Institutional (formal) programs and policies are defined and required, but implementation is at an intermediate level. It follows trends (monitors) and adopts some technologies and good organizational practices in certain areas. It has Green IT strategies focused on operational areas of the business (IT and/or Operations). There is activity documentation (histories and records). Directly affected personnel are trained in the use of the technology. Indirectly affected personnel are not included in the procedures review or training related to the activity. The organization has an average (moderate) percentage of use of green technologies and tools. It does not seek or develop improvement actions.
4. Developing	The implementation of Green IT practices follows a methodology and is managed. It develops sustainability and Green IT programs. Performs adequate measurement and regular management of indicators associated with the activity. It monitors and seeks to develop improvement actions for institutionalized formal programs and policies. There is documentation of the activity (histories and records). The affected personnel is trained on Green Technology (activity) resources and objectives. The activity is constantly improving (internal and external focus).

Table 3. *Cont.*

Maturity Level	Description
5. Mature	All activities are monitored and managed for optimal and planned performance. Affected personnel directly or indirectly related to the activity are trained/enabled about the resources and objectives of Green Technology (activity). Activity documentation (histories and logs) is constantly updated. The results of the activities developed are evaluated and monitored with a focus on the continuous improvement of processes and the review of the resources used by the organization. The organizational processes and activities developed and used are aligned with the organization's stakeholders. Tools and methodologies are used in an integrated manner to improve the quality, efficiency and effectiveness of organizational processes and results with a focus on sustainability.

The five levels are (1) incipient, (2) basic, (3) moderate, (4) developing, and (5) mature. At the lowest level, the incipient level, the organization does not provide a stable environment for activity. At this level, the process is ad hoc. However, at the highest level, which is the mature level, the entire organization is focused on continuous process improvement. The Green IT maturity framework conceptually consists of six categories or domains of analysis (organizational, technological, economic, environmental, social and marketing) that cover various aspects related to Green IT across the organization. Each category is composed of analysis dimensions and elements that have a conceptual definition to provide a clear understanding of the object analyzed and the consequences of each dimension/category analyzed in the process of assessing the maturity of Green IT (see previous Section 4.2).

In the maturity assessment process, a situational diagnosis of the organization is carried out concerning the dimensions, categories and elements covered and analyzed by the proposed framework. The characteristics and percentages of adoption of Green IT practices adopted by the organization are raised and from that, it is sought to qualitatively evaluate and identify the appropriate Green IT maturity level for a given organization. Hence, the Green IT maturity framework was designed to provide organizations with insights into the maturity of green technology practices that can be applied and developed in the organization considering an internal dialogue and alignment with various dimensions and areas of the organization, as well as with the market and the society in which it operates and with which it transacts in its business, improving the sustainability levels of its operations.

5. Conclusions

Although it is still considered a recent and not very widespread area, Green IT proposes the development of IT products and services aligned with sustainability and corporate strategy, being a pioneering initiative of some organizations that provide technology services in the world, such as Accenture, Deloitte and EDS [8]. Therefore, the future points to a latent demand that lacks companies that provide technology services from a broader perspective of IT (IT sector itself, sustainable objectives incorporation by other areas, through Green IT, aspects related to strategies, practices, policies and management) and not just restricted to the organization technological area, while developing and supporting the hardware and software infrastructure. Thus, as Green IT is considered a socio-technical movement that refers to the need to innovate the way organizational resources are combined, this work can be used by numerous companies and researchers.

Besides that, although the presented research is descriptive, conceptual and qualitative, its value is significant to the field of knowledge in sustainability and IT operations. Even though it is still considered a recent and not very widespread area, Green IT could be understood as a proposal to develop IT products and services that are more sustainable. So, the framework proposal to assess the maturity of Green IT is a great starting point for further research since companies from all sectors and sizes are under increasing pressure from green movements. Organizations need to focus their goals on sustainability in a holistic and transversal way since IT permeates all organizational areas. Therefore, this study can be considered as a preliminary attempt to advance research on Green IT, through

the theorization and construction of a framework capable of helping managers in the maturity assessment of Green IT practices in their organizations.

The literature review and qualitative analysis made it possible to identify, in addition to relevant scientific contributions for a theoretical deepening of the field, relevant contributions to the practice of organizations, based on a possible categorization of practices that can contribute to future studies. Such studies could enable a more detailed practice analysis identified about each dimension, helping researchers/managers in the impact studies of Green IT in organizations, in enhancers/inhibitors studies of Green IT practices adoption, in the analysis related to the maturity of certain practice categories, and why some practices are more present than others in organizations and considered more in the decision-making process for the adoption of Green IT.

Thus, intelligent IT management can be an alternative for organizations to minimize the impacts of their activities, improve energy efficiency, reduce the amount of disposal and associated operating costs, and increase recycling and the use of recycled materials, so that a sustainable organizational environment can be developed in harmony with the aspirations of today's society. It is concluded that the IT literature lacks research focused on how to assess the level of sustainable development of organizations in the IT area, which is generally reflected in their environmental strategies and green practices. As previously mentioned, several studies have analyzed different aspects of the adoption of green practices in the IT area and their correlations, impacts and benefits to improve the performance of organizations, testing and demonstrating their usefulness to study the determinants, antecedents and consequences of the adoption of Green IT, from different perspectives of the concept.

By proposing the Green IT Maturity framework, this research contributes to the theory and practice of organizations in this field of knowledge. The proposed framework aims to help managers and specialists with a tool capable of evaluating in a systemic and in-depth way, from various perspectives (organizational, technological, economic, environmental, social and marketing), the maturity of Green IT in organizations. The study also provides a tool to address and diagnose the development of IT sustainability in specific areas of the organization, as well as guide the implementation of new Green IT practices available in the market. The framework can be seen as a guide to orientate the search and monitoring of Green IT practices that can be used in the organization, improving the operations' sustainability levels.

In this sense, this study fills a gap in the literature by mapping the state-of-the-art of Green IT practices in organizations, considering their application in different categories of analysis, dimensions and several focus areas, contributing to a theorization of application dimensions of Green IT and the proposition of a specific maturity framework for Green IT in organizations. This framework is based on maturity levels related to evolutionary limits correlated with the presence of practices, processes, programs, tools and performance/sustainability indicators in each analysis category. In addition, it contributes with a contextualized theoretical framework of Green IT practices that, when explicitly identified, can help to minimize barriers to their implementation, increasing the dimension awareness of analysis and making the forms of application of Green IT more tangible in different areas, until then little researched in academia and practice, but necessary to promote sustainable changes in the business context.

Consequently, the Green IT maturity framework can contribute to the review of the organization's sustainability strategy, focusing on saving financial resources, reducing CO_2 emissions, developing transversal sustainability policies and programs, and reducing the consumption energy of IT devices, among other possible practices. So, the adoption of several possible Green IT practices requires raising the levels of Green IT maturity and increasing the business value of the company. As a research limitation, it is highlighted that the framework still lacks empirical validation of its use/application, which could reinforce and reassess some dimensions and categories of analysis. Furthermore, the framework application in different contexts and sectors of the economy is suggested, to verify its

external validity and possible similarities or differences between the companies studied, seeking its improvement and expansion of the application potential.

Author Contributions: This article is the result of teamwork. A.C.S., G.L.L. and F.T. conducted the research together. A.C.S. carried out the preparation of the manuscript. G.L.L. designed the research methodology. A.C.S. and G.L.L. analyzed the data and drafted the final version of the manuscript. F.T. contributed to data analysis and manuscript review. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable for this article as it does not involve human or animal subjects.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This research was partially supported by the National Council for the Improvement of Higher Education—CAPES. We gratefully acknowledge their support.

Conflicts of Interest: The authors declare no conflict of interest.

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