



UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO



DIPARTIMENTO DI
INFORMATICA

**PhD Program in Computer Science and Mathematics
XXXII Cycle**

Research Project

PhD Student: José David Patón Romero

Supervisor: Prof.ssa Dr. Maria Teresa Baldassarre

Coordinator: Prof.ssa Dr. Maria Francesca Costabile

PhD student signature _____

Supervisor signature _____

1. Research title

A Framework for Green IT Governance, Management and Auditing.

2. Research area

Software Engineering

3. Research motivation and objectives

Our planet is suffering; it faces new and different problems every day that unfortunately cannot be resolved alone. Most (if not all) of these problems have been caused by mankind, and this has led society, and organizations in particular, to increasingly rethink the effectiveness, efficiency and consumption of their activities in the quest to remedy or mitigate their harmful impacts on the environment.

From the point of view of Information Technology (IT), the constant and unstoppable advancement and adoption of technology in all areas is leading to an exponential growth in the impact that IT has on the environment. That is why the concept of Green IT has come about, the intention of which is to contribute to eco-sustainability in and by IT.

Green IT can be defined as *“the study and practice of design, build and use of hardware, software and information technologies with a positive impact on the environment”*.

This idea of Green IT has been gaining increasing relevance as a strategy to add value to business, and more and more organizations are adopting Green IT practices within their processes and daily operations.

However, Green IT is a field with a short history, and although the number of best practices is increasing, there are no specific standards or frameworks to help organizations implement and verify that these Green IT practices are sufficient and correct, and that they work as expected.

Therefore, the development of this doctoral dissertation aims at the creation and validation of a framework for the governance, management and auditing of Green IT, to establish the bases and characteristics necessary to ensure that the adoption of Green IT on behalf of organizations are sufficient and correct with expected performance. To achieve this main objective, we have established different secondary objectives:

- To know the state of the art in the area of governance, management and audit of Green IT, as well as the frameworks and models related to this area and to the area of sustainability.
- To develop a “Governance and Management Framework for Green IT”, in which the characteristics of governance and management of Green IT are established and a guide to carry out audits based on these characteristics is offered. In addition, international standards such as ISO 14000 should be adapted to this framework, in order to standardize the framework and assist organizations in obtaining some type of certification in this field
- To develop a maturity model for the “Governance and Management Framework for Green IT”, through which an organization can gradually implement the developed framework and improve its maturity level in this area of Green IT.
- To apply the “Governance and Management Framework for Green IT” in different organizations at national and international level, in order to validate and refine through case studies the proposed framework.

The first results obtained through different validations demonstrate the validity and usefulness of the framework developed in the field of Green IT, providing a complete guide to the organizations in their efforts to implement, control and/or improve the practices of Green IT in their processes and day-to-day operations.

4. State of the art

At the present time, there are practically no studies related to the governance and management of Green IT and, in particular, to the area of Green IT audits.

In [36] we carry out a systematic mapping study related to the field of Green IT audits, and in [35] the systematic mapping study makes particular emphasis on the indicators used in this type of audits. This systematic mapping study demonstrates that studies or research related to the area of Green IT audits are practically non-existent; Green IT audit frameworks, in which the governance and management characteristics of Green IT required to carry out implementations in this area are defined, are also conspicuous by their absence.

In fact, and only two studies stand out as being closely related to the area of Green IT audits: on the one hand, [14] shows an analysis of the state of the art of Green IT and notes the importance of carrying out audits in this area; and, on the other hand, [17] deals with a survey on the experiences and opinions of the internal auditors of different organizations in relation to the area of Green IT.

In addition, as gray literature we have found two very relevant studies in this area of Green IT audits, which are important to highlight:

- The first study [16], developed by *The Institute of Internal Auditors Research Foundation* (IIARF), deals with a survey conducted on a group of organizations and, in particular, on its internal auditors. The intention is to see the level of involvement with Green IT on the part of the organizations, analyzing what they are currently doing in this area, in order to identify what they should do in the future. The survey throws into relief the lack of experience and involvement of organizations in the area of Green IT; this in turn provides multiple opportunities for internal auditors to offer a wide variety of services in this area of Green IT, thereby adding value to the business.
- The second study [1] is about a thesis carried out at *Vrije Universiteit Amsterdam*, which contains, on the one hand, an investigation about what Green IT is, as well as what its advantages and disadvantages are. Furthermore, it contains a proposal on what characteristics should be considered within an audit of Green IT. This thesis also highlights the absence of any framework related to Green IT and to audits in this field.

We can therefore observe how novel this field is, and appreciate the need to develop a framework for Green IT that will serve as a guide for establishing governance and management of Green IT in organizations, as well as for controlling/auditing that the Green IT implementations are sufficient and correct, and that they work as expected.

5. Problem approach

In order to achieve the main objective of this doctoral dissertation, an action research methodology [15] will be carried out, through which the work to be performed will be organized and managed on the basis of cycles as established by this methodology.

On the other hand, as a methodology to know the state of the art in the area in question, the Systematic Mapping Study (SMS) technique will be used, that is a method for investigating about a specific area, in order to collect and categorize all the information that exists on it [5] [15] [31] [41].

Likewise, to validate and refine empirically the results obtained, case studies will be used as a method [43].

6. Expected results

As results of this doctoral dissertation, we aim to obtain a validated “Government and Management Framework for Green IT”, through which organizations of any type, size, etc., not only

be able to carry out the implementation of a correct governance and management of Green IT, but also to audit their Green IT implementations, evaluate their maturity level, achieve certifications on international standards related to sustainability, etc.

Therefore, thanks to the framework that is intended to be developed in this doctoral dissertation, the adoption of Green IT in organizations will be greatly optimized/improved, increasing further if it is possible the advance of this area so indispensable in our nearest future.

7. Phases of the project

Following the methodology of action research, we intend to perform three cycles (three academic years) that would be composed as follows:

- **First cycle (years 2016/2017):** in this cycle, the “Governance and Management Framework for Green IT” (based on COBIT 5 framework [19]) will be developed, as well as the maturity model for this framework (based on ISO/IEC 15504 [22]), obtaining a first version of the framework. This first version of the framework will be validated and refined through several case studies at the University of Castilla-La Mancha (UCLM), as well as expert judgments and presentations at conferences.
- **Second cycle (years 2017/2018):** in this cycle, it is intended to make a 6-month stay at the University of Bari Aldo Moro (UniBa), which aims to extend the “Governance and Management Framework for Green IT” with new standards such as, for example, ISO 14000, obtaining the second version of the framework. In addition, this second version of the framework will be validated and refined through various case studies, expert judgments, presentations at conferences, etc.
- **Third cycle (years 2018/2019):** in this cycle, another stay at the University of Bari Aldo Moro will be carried out and the validation and refinement of the “Governance and Management Framework for Green IT” in various case studies is intended to finish, in order to obtain a final version of the framework.

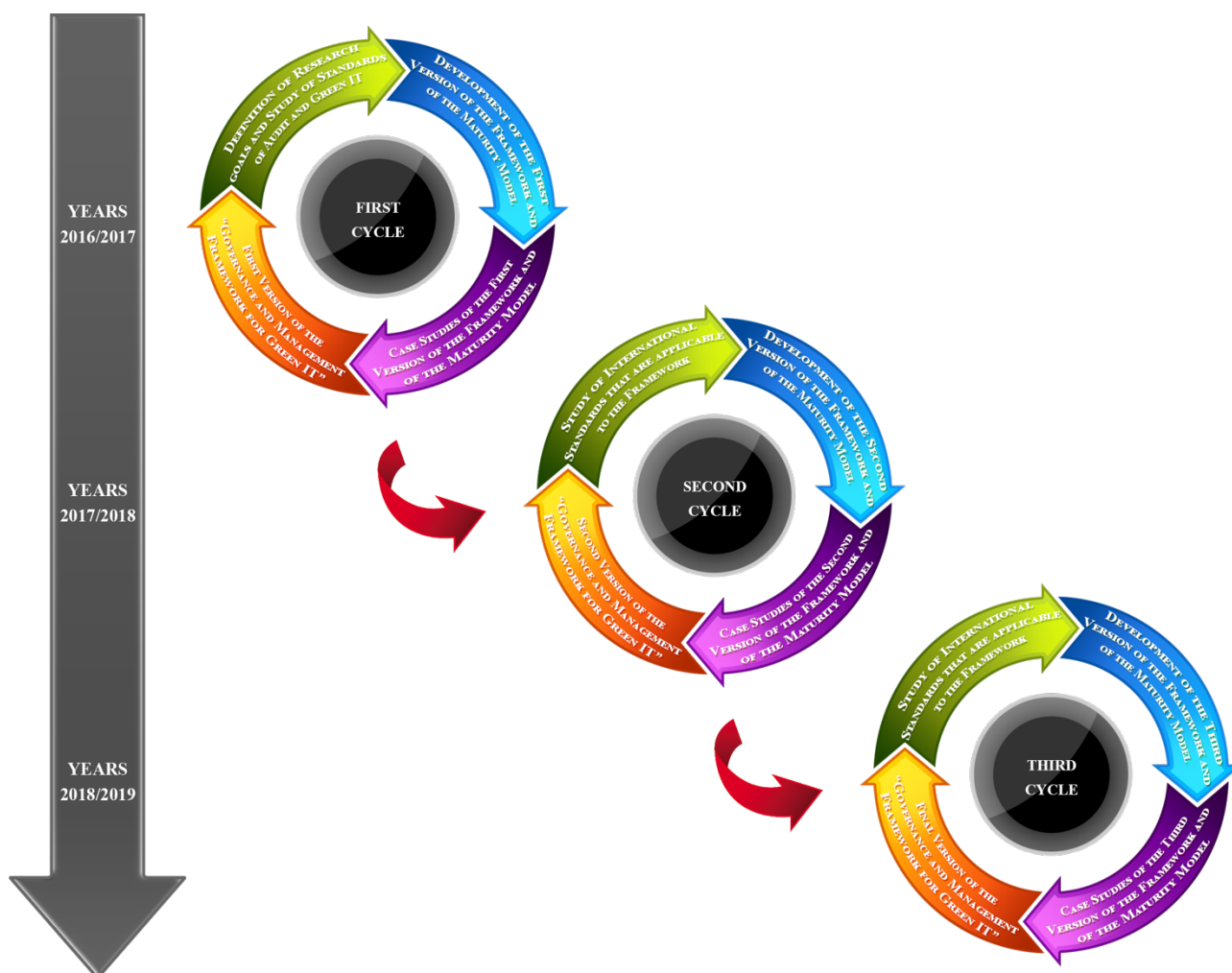


Figure 1: Phases of the doctoral dissertation.

8. Result evaluation

All the results of the research will be evaluated through case studies [43] (in order to validate and refine these results empirically) carried out in collaboration with national and international organizations. Moreover, we will carry out two different types of approaches in planning and executing case studies:

- **Analytical Approach.** The case study is examined in order to attempt and understand what has happened and why. It is not necessary to identify problems or suggest solutions.
- **Problem-Oriented Method.** The case study is analyzed to identify the major existing problems and to suggest solutions to these problems.

All case studies will be defined according to the experimental guidelines outlined by Wohlin et al. [45].

9. Possible reference persons external to the department

A co-supervised doctoral dissertation will be carried out between the University of Castilla-La Mancha (under the direction of Prof. Dr. Mario Gerardo Piattini Velthuis) and the University of Bari Aldo Moro (under the direction of Prof.ssa Dra. Maria Teresa Baldassarre) through a co-tutele agreement, based on current existing Memorandum of Understanding between Spain and Italy. Therefore, it is planned to carry out several stays of different duration in Bari (Italy) in the second and third cycles (years 2018 and 2019), based on the temporary planning of the development of the doctorate.

10. References

Next, the fundamental bibliography used during the development of this doctoral dissertation is presented. This bibliographic list will be updated during the period of the doctoral dissertation.

- [1] E. L. Ambtman, “Green IT Auditing,” Thesis, Vrije Universiteit Amsterdam, Amsterdam, Netherlands, 2011.
- [2] L. Ardito and M. Morisio, “Green IT – Available data and guidelines for reducing energy consumption in IT systems,” *Sustainable Computing: Informatics and Systems*, vol. 4, no. 1, pp. 24-32, 2014. DOI: <https://dx.doi.org/10.1016/j.suscom.2013.09.001>
- [3] G. Brundtland, M. Khalid, S. Agnelli, S. Al-Athel, B. Chidzero, L. Fadika, ..., and S. Okita, *Our Common Future (“Brundtland Report”)*. Oxford University Press, Oxford, OX, United Kingdom, 1987.
- [4] A. Buchalcevova, “Green ICT Maturity Model for Czech SMEs,” *Journal of Systems Integration*, vol. 6, no. 1, pp. 24-36, 2015. DOI: <https://dx.doi.org/10.20470/jsi.v6i1.220>
- [5] D. Budgen, M. Turner, P. Brereton, and B. Kitchenham, “Using Mapping Studies in Software Engineering,” in *20th Annual Meeting of the Psychology of Programming Interest Group (PPIG 2008)*, Lancaster, UK, 2008, pp. 195-204.
- [6] C. Calero and M. Piattini (Eds.), *Green in Software Engineering*. Springer International Publishing AG, Cham, ZG, Switzerland, 2015.
- [7] Carnegie Mellon University, *CMMI for Development (Version 1.3)*. Carnegie Mellon University, Pittsburgh, PA, USA, 2010.
- [8] M. Curley, J. Kenneally, and M. Carcary, *IT Capability Maturity Framework (IT-CMF). The Body of Knowledge Guide – Second Edition*. Van Haren Publishing, Zaltbommel, GE, Netherlands, 2016.
- [9] M. Dastbaz, C. Pattinson, and B. Akhgar, *Green Information Technology: A Sustainable Approach*. Morgan Kaufmann, Waltham, MA, USA, 2015.
- [10] K. Erdélyi, “Special factors of development of green software supporting eco sustainability,” in *IEEE 11th International Symposium on Intelligent Systems and Informatics (SISY 2013)*, Subotica, Serbia, September 26-28, 2013, pp. 337-340. DOI: <https://dx.doi.org/10.1109/SISY.2013.6662597>
- [11] F. J. Esteve Zarazaga, “Las “TIC verdes” en el Horizonte 2025,” *Novática*, no. 234, pp. 80-84, 2015.
- [12] European Commission, “Future Brief: Green Behaviour,” *Science for Environment Policy*, iss. 4, 2012.
- [13] European Commission, *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of the Circular Economy Action Plan*. European Commission, Brussels, Belgium, 2017.
- [14] C. Gabriel, “Why it’s not naive to be green,” *Business Information Review*, vol. 25, no. 4, pp. 230-237, 2008. DOI: <https://dx.doi.org/10.1177/0266382108098865>
- [15] M. Genero, J. A. Cruz-Lemus, and M. Piattini, *Métodos de investigación en ingeniería del software*. Ra-Ma Editorial, Madrid, Spain, 2014.
- [16] G. L. Gray, *Green IT Opportunities for Internal Auditors*. The Institute of Internal Auditors Research Foundation (IIARF), Altamonte Springs, FL, USA, 2011.
- [17] G. L. Gray, W. G. No, and D. W. Miller, “Internal Auditors’ Experiences and Opinions Regarding Green IT: Assessing the Gap in Normative and Positive Perspectives,” *Journal of Information Systems*, vol. 28, no. 1, pp. 75-109, 2014. DOI: <https://dx.doi.org/10.2308/isy-50694>

- [18] A. Hankel, L. Oud, M. Saan, and P. Lago, "A Maturity Model for Green ICT: The case of the SURF Green ICT Maturity Model," in *28th EnviroInfo 2014 Conference*, 2014, pp. 33-40.
- [19] ISACA, *COBIT 5: A Business Framework for the Governance and Management of Enterprise IT*. ISACA, Rolling Meadows, IL, USA, 2012.
- [20] ISACA, *COBIT 5 for Assurance*. ISACA, Rolling Meadows, IL, USA, 2013.
- [21] ISACA, *Maximizing the Combined Effects of COBIT 5 and CMMI: A Guide to Using the Practices Pathways Tool*. ISACA, Rolling Meadows, IL, USA, 2017.
- [22] ISO, *ISO/IEC 15504 (Information technology — Process assessment)*. International Organization for Standardization, Geneva, Switzerland, 2003.
- [23] ISO, *ISO 37120 (Sustainable development of communities — Indicators for city services and quality of life)*. International Organization for Standardization, Geneva, Switzerland, 2014.
- [24] ISO, *ISO 14000 (Environmental management systems)*. International Organization for Standardization, Geneva, Switzerland, 2015.
- [25] ISO, *ISO/IEC 33000 (Information technology — Process assessment)*. International Organization for Standardization, Geneva, Switzerland, 2015.
- [26] ITU, *ITU-T L.1400: Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*. International Telecommunication Union, Geneva, Switzerland, 2012.
- [27] ITU, *ITU-T L.1420: Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations*. International Telecommunication Union, Geneva, Switzerland, 2012.
- [28] ITU, *ITU-T L.1300: Best practices for green data centres*. International Telecommunication Union, Geneva, Switzerland, 2015.
- [29] ITU, *ITU-T L.1325: Green ICT solutions for telecom network facilities*. International Telecommunication Union, Geneva, Switzerland, 2017.
- [30] ITU, *ITU-T Y.4903/L.1603: Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals*. International Telecommunication Union, Geneva, Switzerland, 2017.
- [31] B. Kitchenham, *Guidelines for Performing Systematic Literature Reviews in Software Engineering, Version 2.3*. EBSE Technical Report, Keele University, UK, 2007.
- [32] T. C. Lethbridge, S. E. Sim, and J. Singer, "Studying Software Engineers: Data Collection Techniques for Software Field Studies," *Empirical Software Engineering*, vol. 10, no. 3, pp. 311-341, 2005. DOI: <https://dx.doi.org/10.1007/s10664-005-1290-x>
- [33] S. Murugesan and G. R. Gangadharan, *Harnessing Green IT: Principles and Practices*. John Wiley & Sons, Chichester, United Kingdom, 2012.
- [34] J. D. Patón-Romero and M. Piattini, "GreenITAudit: A Tool to Audit the Green IT," in *2nd Green in Software Engineering Workshop (GInSEng 2016)*, Amsterdam, The Netherlands, August 29, 2016.
- [35] J. D. Patón-Romero and M. Piattini, "Indicators for Green in IT Audits: A Systematic Mapping Study," in *3rd International Workshop on Measurement and Metrics for Green and Sustainable Software Systems (MeGSuS'16)*, Ciudad Real, Spain, September 07-09, 2016, pp. 4-12.
- [36] J. D. Patón-Romero and M. Piattini, "Auditorías de Green in IT: Un Mapeo Sistemático," in *XXI Jornadas de Ingeniería del Software y Bases de Datos (JISBD 2016)*, Salamanca, Spain, September 13-16, 2016, pp. 577-590.
- [37] J. D. Patón-Romero and M. Piattini, "Modelos de Madurez de Green IT: Un Mapeo Sistemático," in *12ª Conferência Ibérica de Sistemas e Tecnologias de Informação*

(CISTI'2017), Lisboa, Portugal, June 21-24, 2017, pp. 2110-2115. DOI: <http://dx.doi.org/10.23919/CISTI.2017.7975693>

- [38] J. D. Patón-Romero, M. Rodríguez, and M. Piattini, "A SPICE-Based Maturity Model for the Governance and Management of Green IT," in *17th International SPICE Conference (SPICE 2017)*, Palma de Mallorca, Spain, October 04-05, 2017, pp. 143-155. DOI: http://dx.doi.org/10.1007/978-3-319-67383-7_11
- [39] J. D. Patón-Romero, M. T. Baldassarre, M. Piattini, and I. García Rodríguez de Guzmán, "A Governance and Management Framework for Green IT," *Sustainability*, vol. 9, no. 10, pp. 1761, 2017. DOI: <http://dx.doi.org/10.3390/su9101761>
- [40] J. D. Patón-Romero, M. Piattini, and M. T. Baldassarre, "A Framework for Green IT Governance, Management and Audit," in *VII Jornadas Doctorales de la UCLM*, Albacete, Spain, November 11, 2017.
- [41] K. Petersen, R. Feldt, M. Shahid, and M. Mattsson, "Systematic Mapping Studies in Software Engineering," in *12th International Conference on Evaluation and Assessment in Software Engineering (EASE 2008)*, Bari, Italy, 2008.
- [42] M. Piattini, E. del Peso, and M. del Peso, *Auditoría de Tecnologías y Sistemas de Información*. Ra-Ma Editorial, Madrid, Spain, 2008.
- [43] P. Runeson, M. Höst, A. Rainer, and B. Regnell, *Case Study Research in Software Engineering: Guidelines and Examples*. John Wiley & Sons, Hoboken, NJ, USA, 2012.
- [44] B. Unhelkar, *Green IT Strategies and Applications: Using Environmental Intelligence*.
- [45] C. Wohlin, P. Runeson, M. Höst, M. Ohlsson, B. Regnell, and A. Wesslén, *Experimentation in Software Engineering*. Springer-Verlag Berlin Heidelberg, Berlin, Germany, 2012. DOI: <https://dx.doi.org/10.1007/978-3-642-29044-2>