A Maturity Model for Energy Management

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Abstract

Energy management is becoming a priority as organizations strive to reduce energy costs, conform to regulatory requirements, and improve their corporate image. Despite the upsurge of interest in energy management standards, a gap persists between energy management literature and current implementation practices. This gap can be traced to the lack of an incremental improvement roadmap. In order to close this gap, we propose an Energy Management Maturity Model that can be used to guide organizations in their energy management implementation efforts and to incrementally achieve compliance with energy management standards, such as ISO 50001. The proposed maturity model is inspired on the Plan-Do-Check-Act cycle approach for continual improvement, and covers well-understood fundamental energy management activities common across several energy management texts. We evaluate our proposal by combining the following methods: *(i)* the use of a questionnaire in energy management related groups to assess the model's utility, according to industry experts; *(ii)* mapping between ISO 50001 and our maturity model, in order to assess whether it can be used to help ISO 50001 implementation; *(iii)* evaluate the achieved mapping using Wand and Weber's method to identify ontological deficiencies. Our proposal helps organizations gradually implement energy management efforts with a well known set of activities and helps them achieve compliance with ISO 50001, the latest energy management systems standard, providing them financial and consumer image benefits.
Keywords: Energy Management, Maturity Model, ISO 50001, Plan-Do-Check-Act

1. Introduction

Energy management has been defined as the systematic use of management and technology to improve an organization's energy performance [6] or, in academic research, as the control, monitoring and improvement activities for energy efficiency [5]. Regardless of definition, the topic has become of utmost importance for organizations worldwide, many of which are currently deploying energy management solutions to improve their energy use, to comply with legislation, energy standards and their requirements, and to enhance the organization's reputation among customers. By implementing energy management programs, organizations can save up to 20% on their energy bill, and can also achieve savings up to 5%-10% with minimal investment, effectively cutting operational costs [6].

Energy management and its associated practices vary greatly mainly because there is no well-understood energy management model, as evidenced by the disparity in the reviewed literature. As will be clear later, despite the existence of several guides to assist companies in implementing energy management activities [6, 27], case-studies show that real-world implementations of energy management programs fail to cover the breadth of energy management activities defined in these guides [13, 8]. In summary, there is a gap between theory and real-world implementation practices of energy management that needs to be closed.

This thesis proposes and conducts a preliminary evaluation of an Energy Management Maturity Model, meant for energy managers in all kinds of organizations, that organizes the essential energy management activities across five maturity levels, therefore contributing to bridge the gap between theory and real-world practice.

Overall, for an organization, an Energy Management Maturity Model will: *(i)* structure and improve the understanding of energy management practices, *(ii)* provide a roadmap towards continuous improvement, *(iii)* provide an understanding of the steps required towards successful energy management, *(iv)* enable benchmarking the current energy practices against other organizations, and *(v)* guide investment efforts.

This translates into benefits according to three pillars, as shown in Figure 1: *(i)* environmen-

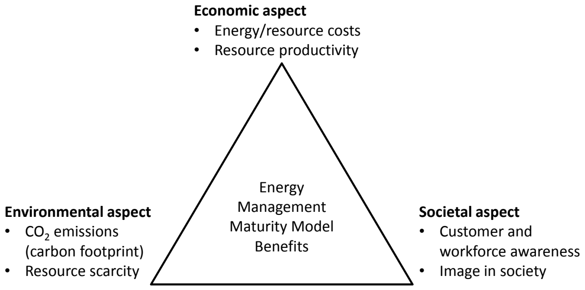


Figure 1: Energy management maturity model main benefits

tal benefits, such as reduced CO_2 emissions due to lower energy consumption; *(ii)* economic benefits, translated into lower energy costs and increased resource productivity; and *(iii)* societal benefits, such as customer and workforce awareness and organizational image in society.

1.1. Problem

According to the International Organization for Standardization (ISO), Energy Management stands out as one of the top five areas that require the development and promotion of international standards. The adoption of a standard, such as ISO 50001, increases energy efficiency by more than 20% in industrial facilities [22]. To further emphasize the relevance of this topic, a study made by Lawrence Berkeley National Labs about energy efficiency projects in the United States concluded that the total project spending in energy service companies, from 1990 to 2000, increased from US$500 million to US$2 billion [29].

Another study has identified that, out of the 3,749 respondents, 85% state that energy management was very important to their organizations and 63% have actually invested in energy efficiency projects [15]. Regarding legislation, for example, the EU has also established an energy improvement target of 20% by 2020 [33].

Energy efficiency can be improved through investments in energy technologies and promoting energy management practices [2]. While energy management shares some common practices across the literature, there is still a great diversity in these practices: some activities are neglected while others are more common. For example, existing solutions for measurement, analysis and control of energy do not address all the requirements of energy management at the organization or process level because they do not adequately develop workforce awareness of the energy used in their business [30]. Some common energy management activities include ensuring management commitment, appointing individuals or teams responsible for energy management, defining energy policies and action plans, as well as reviewing implemented measures by management, or metering of energy use.

In an analysis of the Swedish industrial energy efficiency programs [28], energy audits allow a potential energy performance increase between 16-40% and an electricity savings potential between 20-60%, and have been identified as very important for the identification and implementation of cost-effective energy-efficiency opportunities [26].

The approaches taken to implement such activities can vary greatly in terms of practices and technological sophistication: an organization might use energy-saving practices based on the experience of the facility manager and/or users, while another may employ a computerized Energy Management System, which is by definition a management system that provides a framework for managing and continually improving organizational policies, processes and procedures [14]. However, the use of these energy management systems isn't a very commonly adopted practice [19].

On one hand, the recently published ISO 50001 standard [16] enables organizations to establish energy management systems and processes necessary for energy performance improvement to reduce energy costs, greenhouse emissions and other environmental impacts. However, standards such as IS393 [24], ANSI/MSE 2000 [1], BS EN 16001 [4], and more recently ISO 50001, only define the requirements for organizations to establish, maintain, implement and improve energy management systems. These standards do not provide organizations with a model to assess their current situation against other organizations, except for a final certification, or allow them to plan their energy management implementation in an incremental way along an established improvement roadmap.

On the other hand, maturity models have been extensively studied and utilized in multiple engineering domains as an instrument for continuous improvement [32]. Following the success of the Capability Maturity Model (CMM) for Software [21], there has been significant interest in this field across multiple areas, both from an academic and professional point of view. CMM has evolved into the Capability Maturity Model Integration (CMMI), which has been adopted by thousands of organizations worldwide.

Maturity models can be used as a tool to assess the as-is situation of a company, derive and rank improvement measures, and control implementation progress [10]. They consist of a sequence of maturity levels that represent a desired organizational evolution path, in which the initial maturity level represents a state that can be characterized by an organization having few capabilities in the chosen domain, while the highest maturity level represents a stage of total maturity [3]. Maturity, in this case, can be defined as a metric to evaluate capabilities of an organization regarding a certain discipline [11]. Advancing through this evolution path indicates that organizations are improving their capabilities step by step [17].

According to a recent survey on maturity models, out of the 237 studied articles, only 3 efforts focused on the topic of sustainability [32], showing that research regarding maturity models in the energy field is still at its inception. Up to now, no maturity model has been created specifically for energy management. However, maturity models have been created for Smart Grid implementation [25], for data center efficiency [9], and initial efforts have been reported regarding energy management maturity models [20].

Furthermore, the approach taken by international standards is different from the approach taken by maturity models. In order to reach compliance with a standard such as ISO 50001, organizations need to show evidence about every single defined requirement, in the form of a final certification. Maturity models have the same ultimate goal of process improvement but they establish several levels of organizational maturity as organizations increase their improvement efforts and implement the required processes at their own pace, providing them with an implementation roadmap not included in ISO standards.

In view of the arguments presented above, we may say that "organizations do not have a systematic approach, e.g., maturity models, to energy management implementation." Developing a Maturity Model is a significant research problem related with the importance of guidelines and best practices, e.g., maturity models and frameworks. Indeed, the solution for the presented problem will provide a set of best practices, providing organizations with a systematic means of improving their energy usage.

1.2. Methodology

The aim of this work is the design of an energy management maturity model that will further drive improvements in energy management in organizations. In order to assess the current state of energy management practices, design the proposed maturity model and perform its evaluation, we conducted our research as follows:

- Review of several sources related to energy management (such as energy management systems, energy management guides, energy management standards and case studies), and also of sources related to maturity models.
- Comparative analysis contrasting the current state of energy management in organizations, obtained from the reviewed case studies, energy management guides and other energy management articles.
- Identification of a set of energy management activities that will be the basis for the proposed maturity model based on the previous analysis.
- Evaluation of the proposal for completeness by performing an ontology mapping to the requirements of ISO 50001.
- Evaluation of the achieved mapping using Wand and Weber's method to identify ontological deficiencies.
- Evaluation of the utility and difficulty of implementation of the proposed activities, and overall utility of the proposed maturity model through questionnaires.

1.3. Document structure

This document is organized as follows: Section 2 presents the related work associated with this thesis, namely energy management guides, energy management systems, energy management standards, energy management scientific articles, and maturity models. Section 3 details the proposed maturity model and Section 4 describes the evaluation method performed to validate this work and the results obtained. Finally, Section 5 presents the conclusions of this work, along with its limitations, lessons learned, and future work.

2. Related Work

Energy management activities are somewhat similar across energy management literature. Although there are no authoritative sources defining what are the essential energy management activities, all the analysed literature points to the idea of performing initial reviews to understand how energy is being used and to establish a baseline of organizational energy performance. The creation of an energy policy and strategy is mostly established in good practice guides, and most texts also establish an action plan.

The commitment of senior management appears as a cross-cutting aspect required to ensure resources for promoting energy programs, and backing the creation of energy management roles. The communication of energy improvement results inside the organization as well as staff training is also considered relevant across most texts.

Metering, monitoring and analysis is relevant across virtually all texts, and must be backed up by energy management systems. Overall, the functionalities of Energy Management Systems support activities of metering, monitoring and analysis, benchmarking, understanding energy usage, and assist in communicating the results of improvement actions, which can be framed into the Energy Strategy and Review steps prescribed by energy guides.

The completeness and level of detail also varies across energy management texts, with some offering a more complete description of what are considered good energy management practices, such as the CarbonTrust guide. However, analysis of case studies and scientific papers shows that organizations often do not follow the same activities as good practice guides in their implementation of energy efficiency programs, as evidenced by Table 1. Most importantly, no guide or paper explores how to implement energy management in an incremental way for all the activities.

Activities	SEI	CarbonTrust	Van Gorp	Dusi and Schultz	Gonzalez et al.	Coppinger
Management commitment	•	•	•	•		•
Create energy management roles	•	•		•		•
Understand energy usage	•	•	•		•	•
Benchmark current performance		•	•			
Identify opportunities	•	•			•	•
Establish policy	•	•				
Define energy performance indicators		•			•	
Set objectives and targets	•	•	•			
Create action plan	•	•	•	•		
Assign responsibilities	•	•				
Prioritise investments	•	•				
Procurement		•				
Training	•	•				
Documentation				•		
Communicate results	•	•	•	•		
Allocate resources		•				
Regulatory compliance		•				
Metering, monitoring and analysis	•	•	•	•	•	
Management review	•	•				
Audit process		•		•		•
Plan continuous improvement		•				•

Table 1: Comparison table of the energy management activities in all of the analysed energy management texts, from good practice guides to case studies and other scientific articles [27, 6, 29, 12, 13, 8]

Despite the fact that a large number of organizations are motivated to pursue energy efficiency and are informed in this matter, very few have the capabilities to actually implement energy efficiency measures or can actually demonstrate the results of their improvement actions [7]. Energy management efforts are frequently hindered by a number of factors [18] such as *(i)* lack of information, *(ii)* limited awareness of the benefits of energy efficiency measures, *(iii)* inadequate skills, *(iv)* cultural or financial constraints leading to investment in production capacity instead of energy efficiency measures, and *(v)* larger importance on addressing upfront costs instead of overhead energy costs.

As previously mentioned, we can clearly see a gap between energy management theory and implementation, which is supported by scientific literature. The energy efficiency gap, referring to the fact that energy improvement measures are not always implemented despite the need for increasing energy efficiency, is due to three categories of barriers: economic, behavioral and organizational [23]. The first category (economic) describes barriers such as *(i)* hidden costs, which translates to collecting and analyzing information costs, *(ii)* limited access to capital, representing tight energy budgets that may affect the ability to invest in energy efficiency measures, and *(iii)* risk aversion, caused by fear of production disruption. Behavioral barriers refer to the lack of credibility and trust of information, therefore impeding improvement efforts. Finally, factors such as organizational culture can be described as organizational barriers.

Regarding energy management maturity models, there have been recent developments in this area. The Sustainable Energy Authority of Ireland has reported some preliminary work on the Energy Management Maturity Model [20]. Their research follows a different approach from our proposed maturity model, as each process is assessed individually, following a continuous representation, while our model is based on a staged representation that provides a global vision of the main processes that an organization should implement for managing energy more efficiently. Finally, the fact that national energy authorities are developing a maturity model further underscores the relevance of our work.

3. An Energy Management Maturity Model

Our Maturity Model is based on a representative set of well-defined and well-understood energy management activities. As discussed previously in Section 2, existing energy management guides share common activities but the implementation of energy management programs and efforts varies greatly.

To obtain such a set of energy management activities, as illustrated in Figure 2, we refer not only to the energy management literature previously analysed as our basis, but have also taken inspiration in CMMI, taking into account other activities that are deemed as good management practices. For example, CMMI process areas Work Planning, Supplier Agreement Management, Configuration Management, Measurement and Analysis and Organizational Training can be coarsely mapped to our 'Create action plan', 'Procurement', 'Documentation', 'Metering, monitoring and analysis' and 'Training' activities.

The energy management activities derived from the literature were organized into five maturity levels following the Plan-Do-Check-Act cycle framework on which most maturity models and standards are based.

In the five-level Energy Management Maturity Model, shown in Figure 2, the first maturity level, **Initial**, depicts the stage that organizations start at and is characterized mostly by ad-hoc processes and efforts. Energy usage is not being monitored, organizations don't have defined policies or established improvement goals, roles are not defined and energy efficiency efforts are not being regularly reviewed. In this initial stage, the success of energy management efforts in organizations depends on certain individuals and on their previous experience.

The second maturity level, **Planning**, represents a point where organizations are undertaking the first organizational efforts to understand energy usage: how is energy being consumed, how is it related to the core business, and how and what kind of external constraints, such as legislation, apply to energy efficiency. This is done by gathering and analysing data to understand current energy performance in the organization, and creating a baseline for future comparison that will assist the identification of problematic areas where improvements can be made. This maturity level is defined by activities such as:

An initial review, that uses measurement and monitoring data to *(i)* identify energy sources and assess past and present energy use, *(ii)* identify major areas of energy use by reviewing facilities, equipment, systems, processes and other factors that will play a part in energy use, *(iii)* create forecasts on future energy use and consumption, and *(iv)* identify opportunities for improvement.

A commitment activity, where top management helps in *(i)* defining an energy policy, *(ii)* assigning an energy manager role or team, *(iii)* promoting energy management inside the organization, *(iv)* regularly reviewing objectives and project status, and *(v)* providing the essential resources (human, financial, technological and others) to improve energy performance.

Laying out an energy policy, detailing the commitment to energy performance, availability of the necessary resources, compliance with legislation, as well as regular and formal reviews. The energy policy will also help define goals, objectives, and performance indicators. An action plan is then created to establish how the organization will achieve the proposed goals, and what actions are prioritised and assigned to individuals, with clear responsibilities, budgets and time. This policy will also guide the organization in the procurement of energy related services, equipment and resources.

The third maturity level, **Implementation**, is characterised by organizations where intentional action is being taken to overcome detected inefficiencies. This maturity level defines activities required for the implementation of energy improvement measures, with procurement and investment also playing an important role. Without ensuring financial backing, projects and teams are unable to implement defined measures. Energy procurement will invest these financial funds with suppliers that will ensure the achievement of energy policy goals.

Training and communication are also important inside an organization at this point. Staff must be trained to understand energy management and acquire the required skills to understand the subject and work with energy management systems. Everyone inside the organization must also be aware of the benefits and goals of the proposed energy efficiency measures to promote user cooperation.

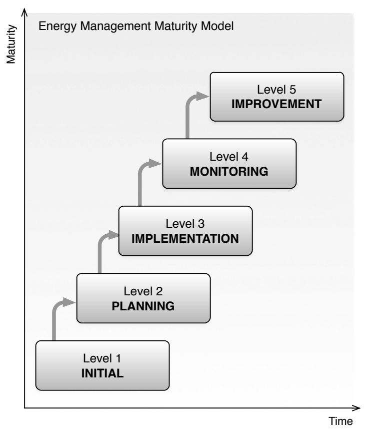
In the fourth maturity level, **Monitoring**, organizations actively and routinely collect, process and analyse energy data and energy performance indicators, achieved with the help of identified functionalities of energy management systems, to ensure that the defined goals are met and to identify further improvement opportunities, providing management with reports on the success of energy management efforts. This assessment of the effectiveness of taken measures is verified by the organizational program audit activity.

The final maturity level, **Improvement**, is where organizations ensure that implemented measures are reviewed by senior management, to correct possible identified flaws and introduce adjustments in the previously defined energy policy, action plans, and objectives.

4. Evaluation

The evaluation method consisted in the following steps:

- **ISO 50001 mapping**: mapping of proposed activities to latest energy management systems standard, which enables us to validate the set of proposed energy management activities.
- **Wand and Weber method**: assess mapping between proposed maturity model and energy management standard ISO 50001 in terms of ontological deficiencies.
- **Questionnaire**: gather proposal feedback from industry experts to *(i)* address the validation and relevance of the research problem and the proposed work, and *(ii)* evaluate proposed key activities in terms of utility, difficulty of implementation and overall utility of this maturity model.



Maturity Level	Activities
1 - Initial stage	No defined activities
2 - Planning stage	Energy review Benchmark current performance Identify improvement opportunities Ensure management commitment Establish energy management roles Establish energy policy Set objectives and targets Establish energy performance indicators Create action plan Check regulatory compliance
3 - Implementation stage	Investment Procurement Training Communication Documentation
4 - Monitoring stage	Metering, monitoring and analysis Program audit
5 - Improvement stage	Management review

Figure 2: Proposed maturity model, with five levels of increasing maturity, representing the initial, planning, implementation, monitoring and improvement levels as depicted on the left side of the figure and an overview of the five levels of energy management, and their corresponding activities, as seen on the right side of the figure.

4.1. ISO 50001 mapping and evaluation using Wand & Weber method

The mapping between our proposed maturity model and ISO 50001 aims at validating if the proposed model supports ISO standard activities. Every defined activity in our model can be mapped to an ISO requirement, as shown in Table 2.

To evaluate the achieved mapping between our model and ISO 50001, we will perform an analysis according to the Wand and Weber method [31]. Wand and Weber define an ontological evaluation of grammars method, where two sets of concepts are compared in order to identify four ontological deficiencies, as shown in Figure 3:

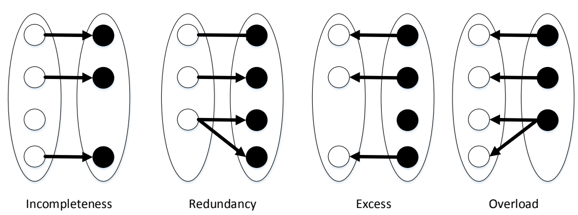


Figure 3: Illustration of ontological deficiencies as proposed by Wand and Weber

Incompleteness Can every first set element be mapped to an element in the second set? If there isn't a total mapping, it is considered incomplete.

Redundancy Are there elements in the first set mapped to more than one element in the second set? If so, the mapping is considered redundant.

Excess Is every element from the second set mapped to a first set element? The mapping is considered excessive if there are elements without a relationship.

Overload Is every element of the second set mapped only to one element in the first set? The mapping is considered overloaded if any element in the second set has more than one mapping to the first one.

The ontological evaluation of the mapping of our proposal to ISO 50001 is presented in Table 2. A first observation is that the mapping is **complete**, since every proposed activity in our model can be mapped to an ISO 50001 requirement. For the next defined attribute, **redundancy**, there is one activity in our maturity first model that is mapped to more than one activity in ISO 50001. As for **excess**, we have identified several ISO 50001 requirements that couldn't be mapped to our proposal. Regarding **overload**, there are two ISO 50001 requirements that are mapped to more than one activity in our model.

In terms of the four analysed ontological deficiencies, using this method, our model can indeed be considered as **complete**, since every activity can be mapped to a requirement established in the standard. This evaluation however, clashes with the knowledge that our model does not fully cover ISO 50001.

Regarding **excess**, despite the assessment of this mapping as complete, there are a few ISO requirements which could not be mapped to our proposal. Requirement *Operational control* in ISO 50001 states that the organization needs to identify and plan all operations related to energy use

Maturity model activities	ISO 50001 requirements	Wand and Weber ontological deficiencies
Planning		
Energy review	Energy review	Overload
Benchmark current performance	Energy baseline	Complete
Identify improvement opportunities	Energy review	Overload
Ensure management commitment	Top management	Complete
Establish energy management roles	Management representative	Complete
Establish energy policy	Energy policy	Complete
Set objectives and targets	Energy objectives, energy targets and energy management action plans	Overload
Establish energy performance indicators	Energy performance indicators	Complete
Create action plan	Energy objectives, energy targets and energy management action plans	Overload
Check regulatory compliance	Legal and other requirements	Complete
Implementation		
Investment	Design	Complete
Procurement	Procurement of energy services, products, equipment and energy	Complete
Training	Competence, training and awareness	Overload
Communication	Communication	Redundant/Overload
	Competence, training and awareness	
Documentation	Documentation	Complete
N/A	Operational control	Excess
Monitoring		
Metering, monitoring and analysis	Monitoring, measurement and analysis	Complete
Program audit	Internal audit of the EnMS	Complete
N/A	Evaluation of legal requirements and other requirements	Excess
N/A	Nonconformities, correction, corrective, and preventive action	Excess
N/A	Control of records	Excess
Improvement		
Management review	Management review	Complete

Table 2: Mapping of the activities in the proposed maturity model and ISO 50001 requirements, and the corresponding evaluation according to the Wand and Weber method, regarding ontological deficiencies

to guarantee that they are carried out according to policy, and is a missing activity from the proposed model but nevertheless is a valuable process in energy management and should be object of further study. Other requirements such as *Control of Records* (which establishes the need to maintain documentation that expresses conformity to the ISO standard), *Evaluation of legal requirements and other requirements* and other general ISO requirements are not mapped to our model explicitly. Through our analysis of energy management texts, we did not find any explicit mention to these activities since a few are specific to the ISO standard, so they were not included in our model, but further development of this model can accommodate other relevant missing activities.

For **redundancy**, there is only one activity in our model that is mapped to two different requirements. In our model, *Communication* establishes internal communication of energy management efforts and promotion of their awareness, which is coarsely split between two ISO requirements. Finally, we do not consider **overload** a problem since our model establishes several 'finer-grained' activities in comparison with ISO's approach of grouping some requirements.

Our model was established through the analysis of several energy management texts, and therefore, is not an all-encompassing model, i.e., it does not feature every conceivable energy management activity. However, we learned that, despite our model being based on energy management texts, it is possible to achieve an almost complete mapping to ISO 50001, with the exception of three requirements, proving the proposed model is fairly complete. As a result, organizations can use our maturity model and rise through the maturity levels by implementing the proposed activities and, as they do so, they will be automatically working towards ISO 50001 compliance.

4.2. Questionnaire

In this section we will detail how the questionnaires were performed, and present and discuss the results. We divulged a questionnaire for the evaluation of our work through several Linkedin groups, related to energy management or ISO 50001, and obtained 31 responses.

In this questionnaire, we have evaluated several parameters, such as: *(i)* utility and difficulty of implementation of each proposed activity; and *(ii)* overall utility of the proposed maturity model.

Regarding the assesment of utility and difficulty of implementation, the proposed scale is shown in Table 3.

Value	Utility	Difficulty of implementation
1	Lowest utility	Lowest difficulty
2	Low utility	Low difficulty
3	High utility	High difficulty
4	Highest utility	Highest difficulty

Table 3: Scale used to assess utility and difficulty of implementation in the questionnaire

Regarding the **utility and difficulty of implementation of each proposed activity**, the obtained results reveal an overall positive evaluation of the utility of the proposed activities, as seen in

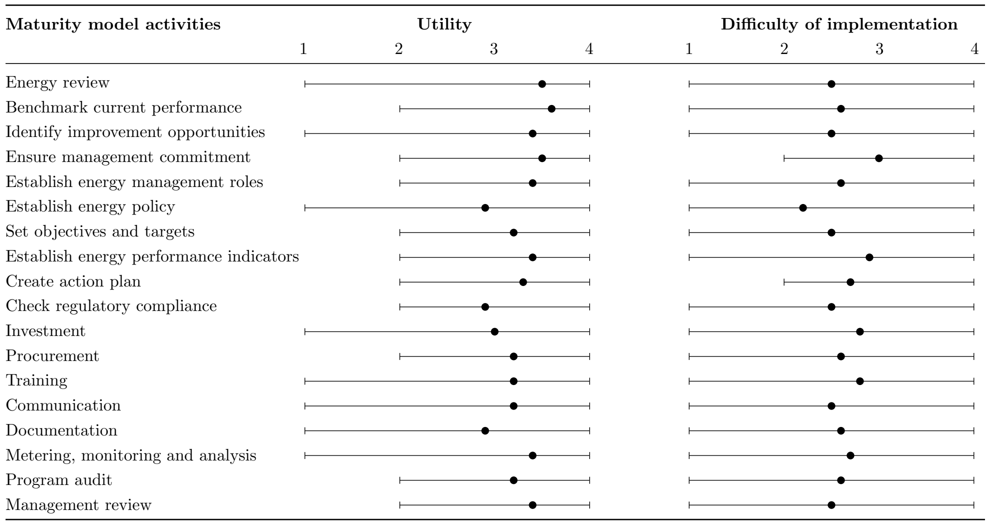


Table 4: Illustration of maturity model activities and questionnaire results, showing the maximum, minimum and average values for both evaluated parameters, utility and difficulty of implementation

Table 4. Results show that the utility of most activities averages between 3 and 4, with an overall average of 3,3 between all activities, with the only three activities with an average value of utility below 3 being *Establish energy policy*, *Check regulatory compliance* and *Documentation*. The utilized scale represented 3 as *high utility* and 4 as *highest utility*, and as such, the obtained results represent a positive opinion to our proposal in terms of utility, further underscoring the importance of the proposed activities.

Regarding difficulty of implementation, activities settle between *low difficulty* and *high difficulty* of implementation. The activity with the highest average, management commitment, matches respondents opinion as one of the biggest challenges to ISO 50001 implementation and identified barriers to energy management, according to studied research.

We also asked participants if they would consider implementing an energy management maturity model in their organizations. Out of the 31 respondents, only six responded they would not consider implementing it, representing a positive response of approximately 81%.

In terms of overall utility of the proposal, the results obtained are very positive. Regarding scores, we did not obtain any result classified as *lowest utility*, eight people classified it as *low utility*, 19 classified it as *high utility* and four people classified it as *highest utility*. Despite obtaining an average slightly lower than three, the vast majority of respondents classified our proposal as positive, with the obtained results shown in Figure 4.

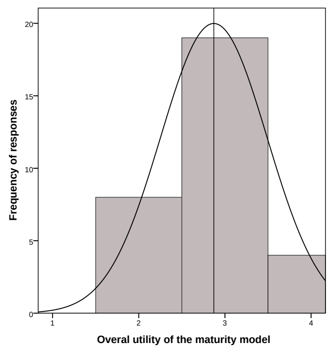


Figure 4: Histogram and distribution curve of the questionnaire results regarding the overall utility of the proposed maturity model as assessed by the 31 respondents, with the middle line representing an average utility value of 2,9

5. Conclusions

In order to cope with the rising energy costs and comply with environmental regulations, organisations need to improve their energy management practices. Yet, despite the creation of energy management guides and standards by several entities, the gap between theory and real world implementation still persists. International standards, like ISO 50001, opt for an improvement strategy of defining a set of necessary requirements to achieve a final stage of compliance.

As such, in order to achieve certification, organisations must comply with every single defined practice. Maturity models, in contrast, also define a set of activities but establish several levels of maturity, grouping these activities into specific levels. This approach is not only compatible with the final goal in the mentioned standards, but also alleviates the implementation of said practices by providing organisations with a defined incremental path and systematic approach for energy management.

To address these concerns and to help to close this gap, this thesis proposes an Energy Management Maturity Model. The proposed model consists of several energy management activities, derived from energy management guides, case studies and scientific articles and is organized into five maturity levels. Its completeness is then evaluated against ISO 50001, demonstrating that virtually every requirement of this industry standard is covered, and the perceived utility of this work was also evaluated through questionnaires aimed at industry experts.

5.1. Impact

The impact of our proposal is manifold. An Energy Management Maturity Model will enable organizations to pursue an incremental improvement path, providing them with a roadmap for achieving higher energy efficiency. Indeed, the proposed maturity model aims at streamlining the approach of energy management, making it easily understood and able to be implemented in a staged and gradual approach. This work will also guide further research as we believe the analysis of several topics regarding energy management and the achieved results can guide further efforts in this field.

Maturity models have been used in distinct domains and are prevalent in the IT industry, enabling organizations to continually improve their processes. Expectably, energy management will benefit, as did other fields, from the adoption of maturity models to achieve continuous process improvement and enabling organizations to better manage their energy management practice.

Ultimately, an Energy Management Maturity Model guides organisations in improving their energy management performance, leading to further energy performance improvements, which translate to economic gains, customer image improvement and a reduction of ecological footprint.

5.2. Retrospective/Lessons Learned

During the evaluation stage, we received several comments regarding the utility of the proposed model. From the gathered feedback, a few respondents highlighted that the proposed model could benefit from adopting a continuous representation, assessing the capability level of individual activities in organizations, instead of only defining what processes to implement at each stage of improvement. The questionnaire responses have also improved our knowledge of the real world situation of energy management in organizations, further cementing the barriers identified in scientific literature as concrete obstacles.

5.3. Future Work

In terms of future work and limitations of this proposal, we have identified the following points:

- The proposed model can be further developed in order to achieve complete compliance with ISO 50001 requirements. By achieving full compliance with this standard, the proposed maturity model can further improve energy management in organizations.
- The scope of this research only includes which activities must be performed but does not describe how to perform them. As such, each proposed activity can be studied with more detail in order to offer a more detailed description, along with a description of relationship between activities and the definition of roles.
- The maturity model can also be further developed by establishing capability levels for each activity, therefore creating a continuous representation of the maturity model, alongside the staged representation already present in this work, as identified by some questionnaire responses.
- This work can also be further evaluated by performing interviews and through a demonstration of its application in organizations, further assessing the utility and real life application of this work.
- Regarding academic research, the work repeated herein, together with the evaluation method and results, can be used in the publication of a scientific article.

References

[1] ANSI. *ANSI/MSE 2000:2008 A Management System for Energy*, 2008.

[2] S. Backlund, P. Thollander, J. Palm, and M. Ottosson. Extending the energy efficiency gap. *Energy Policy*, 51:392–396, 2012.

[3] J. Becker, R. Knackstedt, and D.-W. I. J. Pöppelbuß. Developing maturity models for IT management. *Business & Information Systems Engineering*, 1(3):213–222, 2009.

[4] BSi. *BS EN 16001:2009. Energy Management Systems – Requirements with guidance for use*, 2009.

[5] K. Bunse, M. Vodicka, P. Schönsleben, M. Brülhart, and F. O. Ernst. Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature. *Journal of Cleaner Production*, 19(6):667–679, 2011.

[6] CarbonTrust. Energy Management – A comprehensive guide to controlling energy use, 2011.

[7] K.-H. Chai and C. Yeo. Overcoming energy efficiency barriers through systems approach: A conceptual framework. *Energy Policy*, 46:460–472, 2012.

[8] S. Coppinger. Developing a corporate-wide strategic energy management program. In *52nd IEEE-IAS/PCA Cement Industry Technical Conference*, pages 1–8. IEEE, 2010.

[9] E. Curry, G. Conway, B. Donnellan, C. Sheridan, and K. Ellis. A maturity model for energy efficiency in mature data centres. In *SMARTGREENS*, pages 263–267, 2012.

[10] T. De Bruin, R. Freeze, U. Kaulkarni, and M. Rosemann. Understanding the main phases of developing a maturity assessment model. 2005.

[11] T. De Bruin and M. Rosemann. Towards a business process management maturity model. 2005.

[12] B. Dusi and R. Schultz. Energy management and efficiency – a systems approach. In *53rd IEEE-IAS/PCA Cement Industry Technical Conference*, pages 1–8. IEEE, 2012.

[13] A. J. Gonzalez, R. Castrillón, and E. C. Quispe. Energy efficiency improvement in the cement industry through energy management. In *Cement Industry Technical Conference, 2012 IEEE-IAS/PCA 53rd*, pages 1–13. IEEE, 2012.

[14] R. Hipkiss. Energy Management Systems and Energy Saving Projects, 2011.

[15] IBE. 2012 Energy Efficiency Indicator: Global results. Technical report, Institute for Building Efficiency, 2012.

[16] ISO. *ISO 50001:2011 Energy Management Systems Standard – Requirements with guidance for use*, 2011.

[17] Jörg Becker et al. Maturity Models in IS Research. In *Proceedings of the 18th European Conference on Information Systems (ECIS 2010)*, 2010.

[18] A. McKane, D. Desai, M. Matteini, W. Meffert, R. Williams, and R. Risser. Thinking Globally: How ISO 50001-Energy Management can make industrial energy efficiency standard practice. Technical Report LBNL-3323E, LBNL, 2009.

[19] A. Molla, M. T. Ijab, and V. Cooper. Information Systems Based Energy Management Practices at Telecom Acadia. *Green IT Working Paper Series*, 2012.

[20] J. O'Sullivan. Energy Management Maturity Model (EM3) - A strategy to maximise the potential for energy savings through EnMS, 2012.

[21] M. C. Paulk, B. Curtis, M. B. Chrissis, and C. V. Weber. Capability Maturity Model, version 1.1. *Software, IEEE*, 10(4):18–27, 1993.

[22] E. Piñero. ISO 50001: Setting the standard for industrial energy management. *Green Manufacturing News*, pages 21–24, 2009.

[23] P. Rohdin, P. Thollander, and P. Solding. Barriers to and drivers for energy efficiency in the Swedish foundry industry. *Energy Policy*, 35(1):672–677, 2007.

[24] SEAI. *I.S. 393:2005 Energy Management Systems Standard*, 2006.

[25] SGMM Team, Software Engineering Institute. *Smart Grid Maturity Model v1.2*. Carnegie Mellon University, 2011.

[26] B. Shen, L. Price, and H. Lu. Energy audit practices in china: National and local experiences and issues. *Energy Policy*, 46:346–358, 2012.

[27] Sustainable Energy Ireland. Energy management - A guide for small business, 2008.

[28] P. Thollander, M. Danestig, and P. Rohdin. Energy policies for increased industrial energy efficiency: Evaluation of a local energy programme for manufacturing SMEs. *Energy Policy*, 35(11):5774–5783, 2007.

[29] J. C. Van Gorp. Enterprising energy management. *IEEE Power and Energy Magazine*, 2(1):59–63, 2004.

[30] K. Vikhorev, R. Greenough, and N. Brown. An advanced energy management framework to promote energy awareness. *Journal of Cleaner Production*, 43:103–112, 2012.

[31] Y. Wand and R. Weber. On the ontological expressiveness of information systems analysis and design grammars. *Information Systems Journal*, 3(4):217–237, 1993.

[32] R. Wendler. The maturity of Maturity Model research: A systematic mapping study. *Information and Software Technology*, 2012.

[33] B. Wesselink, R. Harmsen, and W. Eichhammer. Energy Savings 2020 - How to Triple the Impact of Energy Saving Policies in Europe, 2010.