Address risk and opportunities in Energy Management Systems according to ISO 50001: methodology and application for a production plant

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Abstract: The ever-increasing importance of energy efficiency and continuous improvement of energy performance has led Energy Management Systems (EnMSs), especially in the industrial sector, to spread rapidly in recent years.
The international reference for EnMS is represented by the ISO 50001 standard, published for the first time in 2011 and now in its second edition (August 2018). To allow easier integration with other management systems, the new edition of the standard follows the High-Level Structure of the most famous ISO standards relating to management systems (as ISO 9001, ISO 14001, and ISO 45001), usually widespread in organizations. As for the other management systems, it introduces the concept of Risk Management.
Risk management is a widely discussed issue, but its contextualization to the energy scenario is not always immediate and straightforward. Although the scientific literature may support the identification of sources of energy risks, it does not provide useful tools for their analysis and management.
By defining a structured methodology, this work aims to propose a tool that can provide real support to companies in the identification, evaluation, and planning actions to address risk and opportunities for the introduction of an EnMS according to ISO 50001 standard. The methodology developed follows the guidelines suggested by the international standard ISO 31000:2018 (Risk Management - Guidelines), contextualizing them in the energy scenario. The method consists of three main steps: definition of the reference context, risk assessment, and risk treatment. Furthermore, the methodology's application allows understanding the effects that the introduction of an energy management system has on the management of the energy risks of an industrial site.
The proposed methodology has been successfully applied to a real case study of a company operating in the industrial sector with an ISO 50001:2011 certified EnMS to transition to the new edition of the standard.

Keywords: Energy Management Systems; ISO 50001; Risk Management.

1.Introduction

Adopting an Energy Management System (EnMS) means establishing and implementing a set of systems and processes necessary to continually improve energy performance. Among the main benefits are reducing energy costs, improved energy security and legislative compliance, and increasing staff motivation to achieve specific energy objectives.

The international reference for EnMS is represented by the ISO 50001 standard, published for the first time in June 2011 (ISO, 2011), revised and updated in the recent second edition of August 2018 (ISO, 2018a).

The latest survey published by the International Organization for Standardization (ISO) in 2019 reports a standard diffusion estimation of 18'227 certificates and 42'215 sites, especially in the industrial sector. As shown in Figure 1, ISO 50001 certification is widespread in various countries, with a high concentration in Europe.

Thanks to the high benefits of introducing an Energy Management System, the spread of the ISO 50001 standard has seen an ever-growing trend, as shown in Figure 2 for the Italian scenario.

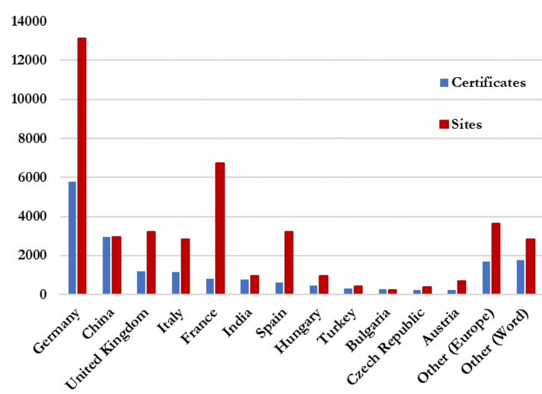

Figure 1: Companies and sites certified ISO 50001 in the world in 2019 (ISO Survey, 2021)

In Italy, according to research carried out annually by the authors (with the last update in January 2021) through the databanks available on the Accredia website (the Italian accreditation body), there is an ever-increasing diffusion of certification. At the end of 2020, 2'519 certified sites have been registered.

As shown in figure 2, in the last two years, many companies have adapted their EnMS to the standard's new requirements, but there is still a significant percentage of companies that have yet to make the transition.

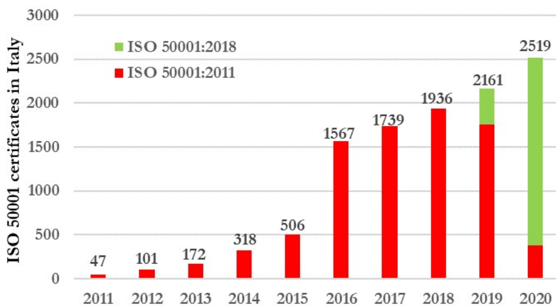

Figure 2: Evolution of ISO 50001 certificates in Italy (Accredia, 2021)

The new edition of the ISO 50001 standard follows the High-Level Structure of the most famous ISO standards relating to management systems and introduces Risk Management (RM).

A risk is an effect of uncertainty on objectives. It can be positive, negative or both, and can address, create, or result in opportunities and threats.

The concept of RM is not new in the industrial sector. All organizations of various types and sizes are faced with internal and external factors that can influence the achievement of set goals. For these reasons, ISO set out to achieve consistency and reliability in RM by creating a standard that would apply to all forms of risk (Purdy, 2010). The ISO 31000 standard, published for the first time in November 2009 (ISO, 2009) and revised in February 2018 (ISO, 2018b), provides guidelines for managing the risks that organizations face and applying to any activity, including decision-making at all levels. The standard approach suggested by the document is suitable for managing any risk, is not dedicated to a particular sector or industry, and can be adapted to any organization and its context.

As the norm is very general, it is not always easy to apply. In fact, in the scientific literature, it is possible to find different approaches and methodologies to favor using the guidelines proposed for different contexts, especially about the integration with other management systems.

In (Sitnikov et al., 2017) and (Cagnin et al., 2019), two different approaches are proposed to introduce risk management in ISO 90001 standard (quality management). In (Muzaimi et al., 2017), the introduction of ISO 31000 in the integrated management system (quality ISO 9001, environment ISO 14001, and occupational health and safety management system OHSAS 18001), usually widespread in organizations, is discussed.

The paper proposed by (Barafort et al., 2017) analyzes risk management activities in various selected ISO standards as quality management ISO 9001, project management ISO 21500, IT service management ISO/IEC 20000-1, and information security ISO/IEC 27001, to provide the basis to improve, coordinate and interoperate risk management activities in IT.

There are also more general methodologies such as those proposed by (Scannell et al., 2013) and (de Oliveira et al., 2017) to integrate ISO 31000: 2009 and Supply Chain RM.

Due to the most recent publication of the standard on energy management systems, only a few works have as their object the management of energy risk in the scientific literature. For example, in (Poveda-Orjuela et al., 2020), the author presents a conceptual model for comprehensive risk and opportunities management and the tools to facilitate its application. This model, although well structured, is complex and addressed, above all, to organizations characterized by a comprehensive management system with an emphasis on energy and performance; it can therefore be difficult to apply to all organizations.

In conclusion, risk management is a widely addressed issue, but its application in the energy scenario is not sufficiently discussed. The scientific literature may support identifying energy risk sources, but it does not provide useful tools for their analysis and management.

This work aims to propose a structured methodology that can provide real support to companies in identifying, evaluating, and planning actions to address risk and opportunities to introduce an EnMS according to the ISO 50001 standard. The methodology developed follows the guidelines suggested by ISO 31000:2018, contextualizing them in the energy scenario.

This methodology is aimed at all those companies that intend to introduce an EnMS according to the current edition of the ISO 50001 standard or that, as shown in figure 2, have yet to transition to the new edition.

This paper is structured as follows. Section 2 *Material and methods* describes all the proposed methodology phases, how to configure and implement them. Section 3 *Case Study* describes the application of the proposed approach to a case study to test its effectiveness, while section 4 *Results and Discussion* contains the experimental results and the main issues encountered during the methodology application. Finally, in section 5 *Conclusion*, future research directions are delineated.

2.Material and methods

This work aims to structure an easy-to-use methodology to help companies implement a risk management system within their EnMS. In order to develop a method in line with the international reference standards, the proposed methodology follows the principles and the terms defined by the ISO 30001 standard on risk management and integrates it with the ISO 50001 standard on EnMSs.

The proposed approach consists of three main steps: Defining the context, Risk assessment, and Risk treatment. Each of these phases is made up of sub-phases. Figure 3 shows a graphical representation of the proposed methodology.

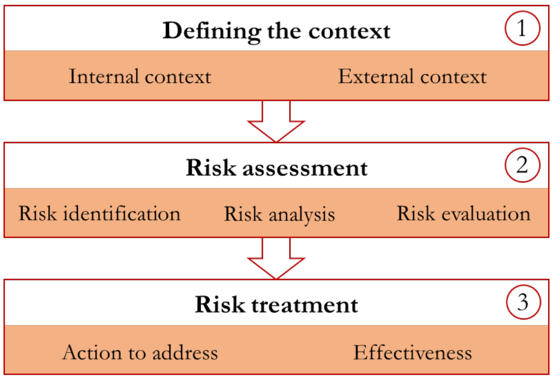

Figure 3: Flow chart of the proposed methodology

2.1 Defining the context

Defining the context of an organization is essential in providing a high-level conceptual understanding of the risk sources that can affect energy performance, both positively (opportunities) and negatively (threats).

External context

The external context includes three macro-groups:

- Stakeholders;
- External environment;
- Social and economic context.

Stakeholders can cause substantial impacts on the performance of the EnMS. These include suppliers (energy, maintenance, and raw material suppliers), customers, authorities, shareholders, partners, etc. For example, changes in energy supply or the introduction of new laws or regulations can influence the achievement of the objectives defined by the company.

The external environment can significantly affect the energy goals. The organization must monitor its environmental impact (climate change, greenhouse gas emissions, etc.). Moreover, if the organization is also a self-producer of energy, its energy source may depend on environmental conditions, such as temperature, presence or absence of sun or wind, etc.

The social and economic context implies risks associated with sudden changes in the market, for which demand peaks may occur, with consequent energy overload, changes in the price of energy, the introduction of new technologies, compliance with regulations and laws to avoid penalties.

Internal context

The internal context, in the same way, comprises four macro-groups:

- Staff;
- Machinery and technologies;
- Organization of production;
- Direction.

Staff can significantly impact the performance of the EnMS; it is necessary to foresee, define, and implement training plans on the management, safety, and use of energy.

Machinery and technologies must be tested and maintained to make them as efficient as possible and examine their obsolescence.

Also, it is necessary to consider how variation in production needs (e.g., scheduling) may affect the performance of the EnMS. Finally, analyzing the Directions is crucial to identify how the company stands with respect to the achievement of the defined objectives.

For each macro-group (external and internal), the user will have to analyze all the sources from which positive or negative risks may arise. Subsequently, for the identified risk sources, the user must identify the *main issues* (the aspects to which the risks will refer) and, for each of them, the *needs and expectations* that will be addressed based on three defined levels:

1. Not affected (N.A.): the need does not affect the EnMS;
2. "+": the need affects the EnMS;
3. "++": the need significantly affects the EnMS.

2.2 Risk assessment

Risk assessment consists of three stages: identification, analysis, and evaluation.

Risk identification

The identification of risks is one of the most important phases; any risk not identified in this phase cannot be the subject of the subsequent steps. The hierarchical structure proposed presents five macro-processes:

- Supplying;
- Self-production;
- Transformation;
- Energy use;
- Energy transfer.

Each of them is divided into specific processes that refer to context analysis. In "Supplying", there are all the items of supply and raw materials; "Self-production" and "Energy transfer" are fields that only concern companies in which there is energy production. "Transformation" includes all those processes in which an energy transformation occurs for the production of an energy vector such as process steam, hot water for heating, production of compressed air, cold water for cooling, etc. This category also includes the opportunities related to using techniques to early detect system anomalies to avoid interruptions in the energy supply to the servomechanisms (Benedetti et al., 2019; Santolamazza et al., 2018). Finally, "Energy use" concerns the actual use of energy, not only regarding the core business but also attributed to auxiliary services.

In this phase, for each specific process, it is necessary to identify all the sources from which the risks may derive; these are reported and, for each of them, with reference to the main topic found in the context analysis, the potential effect is described.

Risk analysis

Risk analysis involves developing knowledge of risk. It provides input to risk evaluation aimed at identifying the most appropriate treatment strategies and methods. An event can have multiple consequences and can affect various objectives. Each company will have different objectives that may concern energy performance (efficiency improvement, consumption reduction, etc.) and other aspects such as cost reduction or corporate reputation improvement. In this phase, it is necessary to analyze the impact that the risk event has on achieving the company's objectives. Besides, for each risk event, any processing operations already present in the EnMS are analyzed. If well established, these actions will be the starting point for defining subsequent steps.

Risk evaluation

The last stage of risk assessment is the evaluation. At this point, the goal is to define which risks and opportunities assess and with what priority. Two crucial factors need to be evaluated: the probability of occurrence of the risk and the intensity of its impact. These two factors will define the degree of acceptability of the risk. The risk assessment is structured on a 5x3 matrix (Table 1).

Table 1: Risk assessment matrix

Rating scale		Impact		
		Low	Medium	High
Probability	Neglectable	1	2	3
	Very low (1-5%)	4	5	6
	Low (5-40%)	7	8	10
	Medium (40-70%)	9	11	13
	High (70-100%)	12	14	15

On the rows of the matrix, we have the probability divided into five levels from "Neglectable" (probability about zero, an event that has never occurred at least since the EnMS is present) to "High" probability. On the columns, we find the potential impact that the occurrence of the risk can have on the objectives of the EnMS. This field is divided into three levels, from "Low" (does not prejudice/ensures the achievement of objectives) to "High" (can prejudice/ensure the achievement of objectives).

The values present on the matrix in Table 1 do not have a calculation purpose. However, they allowed to better identify the classes of the assessment matrix. The risk rating scale is calculated by crossing the probability of occurrence of the risk and the intensity of its impact and returning the degree of acceptability. The evaluation of probability and impact is based on a detailed analysis of the risks and past experience for those events that have already occurred (when historical data are available).

Table 2 and Table 3 show the legends respectively related to threats and opportunities actions to be adopted to treat the risk according to its acceptability.

Table 2: Threat legend

Acceptable	No action required
Optional action	Optionally provide for an action
To improve	Corrective action required
Not acceptable	Preventive action required

Table 3: Opportunity legend

Not convenient	No action required
Optional action	Optionally provide for an action
To monitor	Plan an action
Not acceptable	Priority action required

It is important to underline how, in a management system, even if the risk events are classified as acceptable/not convenient, they will be subject to continuous monitoring to evaluate their evolution.

2.3 Risk treatment

The last phase of the methodology is the treatment of risk, which involves selecting one or more options to modify the risks and gives the possibility to implement these options. Treatment plans must be integrated with the organization's management processes and discussed with the appropriate stakeholders. Decision-makers and other stakeholders need to be aware of the nature and extent of residual risk after treatment. The residual risk must be documented and subjected to monitoring, review, and, where appropriate, further treatment.

Risk treatment consists of two aspects:

- *Action to address*, or the actions to be addressed to a specific risk in order to increase its degree of acceptability; according to the level of acceptability, each action will be stated as optional or mandatory, corrective or preventive.
- *Effectiveness,* or the level of efficiency theoretically achievable by applying the action identified. The "Effectiveness" determines how the company would like to be concerning that risk.

3.Case Study

The methodology presented in the previous chapter was applied to a case study of an industrial plant in the manufacturing sector in Central Italy. At the time of applying the methodology, the company already had an ISO 50001: 2011 certified EnMS and the aim to update its certification to the new edition of the standard.

The chosen case is a product industry with self-production of energy (equipped with a cogenerator using palm oil). For a correct application of the risk management model, the work was carried out with the plant Energy Manager's support. The various phases of the study conducted and the results obtained are presented below.

Defining the context

As foreseen by the methodology, the most representative subgroups have been identified for all macro-groups. For each of them, the *main issues* and the *needs and expectations* have been identified.

Among the most representative subgroups identified for the external context are electricity suppliers, fuel suppliers (palm oil, biodiesel, methane), external maintainers, authorities, and local communities; while, for the internal context, these are compressed air, cogeneration, thermal power plant, refrigeration plant, water treatment, maintenance, and production lines.

Table A1 in Appendix A shows an example of some of the *main issues* and their respective *needs and expectations* identified.

Risk assessment

After defining the context, we move on to identifying the risks. In this regard, the most representative risks and opportunities have been determined for each macro-process (Supplying, Self-production, Transformation, Energy use, and Energy transfer).

For the subsequent phase of risk analysis, in collaboration with the company, three main objectives, based on which to conduct the risk analysis, have been identified: costs, energy efficiency, and corporate reputation. For each risk event, the impact on each of these three factors was analyzed. Furthermore, since the company is already equipped with an EnMS, the actions provided for in its system were reported.

Finally, risk evaluation was conducted. This phase required various actors involved in the processes to adequately evaluate each event's probability and impact.

As shown in Figure 4, twenty-five scenarios (twenty-one risks and four opportunities) have been assessed.

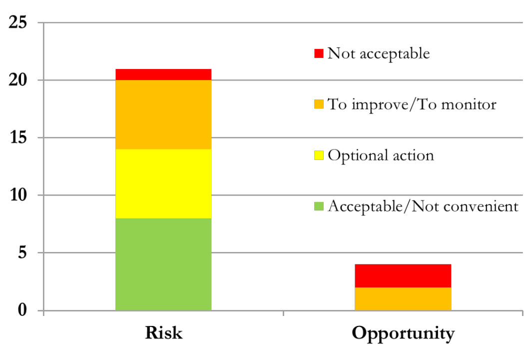

Figure 4: Risk and opportunities identified

Table A2 in Appendix A shows an example of the risk assessment phase for each macro-process.

Risk treatment

The last phase of the methodology involves the treatment of the identified risk events. The company is already in possession of the ISO 50001: 2011 certification, and therefore, although no explicit risk management is envisaged, there are various treatment actions. These actions, already reported in the previous phases, have been further investigated and, when necessary, modified. Based on the risk assessment carried out for each event, the action to address and the expected level of effectiveness were defined.

Table A3 in Appendix A shows the risk treatment step for the risk previously assessed.

4.Discussion

The case study under investigation shows twenty-five risk events divided into twenty-one risks and four opportunities. Of twenty-one risks, eight are "Acceptable", or no actions are needed; six require "Optional action"; six are "To improve"; only one risk is "Not acceptable". As for the opportunities, instead, two have resulted from "To monitor", i.e., corrective action is required to exploit them effectively; two are "Not acceptable", therefore to be managed with absolute priority to obtain a significant improvement on the objectives of the EnMS.

As can be seen, the assessment of these risks ended with a single "Not acceptable" risk. This situation is because the company in question was already in possession of its certified EnMS, so although the risk analysis was not explicitly provided, many actions implemented to obtain certification automatically mitigated the identified risks.

Note that the level of probability "Neglectable" is usually not expected, as it means that the risk is always acceptable. As in the case in question, the introduction of this level favors applying the methodology in companies that already have an EnMS, which has already drastically reduced various risk events. In this way, the company can understand how actions already implemented, thanks to the introduction of the EnMS, are essential to become aware of the risks and manage them.

5.Conclusion

In this paper, all the phases of a methodology to address risk and opportunities in EnMS, according to ISO 50001:2018 standard, have been presented. The proposed approach follows the principles defined by the international reference standard on risk management ISO 30001, contextualizing them in the energy scenario. The methodology is aimed at all organizations that intend to introduce an EnMS according to the ISO 50001 standard or adopt the new edition of the standard.

The proposed approach has been applied to a real case study of an industrial plant in the Italian manufacturing sector to test its effectiveness. The methodology's application has shown excellent results and was evaluated positively by the organization and expert auditors in the subsequent certification phases.

It should be noted that given the complexity of the organization examined, the risks and opportunities presented are only a part of what is the totality of risks available in the industrial plant. This analysis should be further extended.

One of the main results obtained through the application to the case study in which a certified EnMS was already present was to understand how positive can be the effects of the introduction of an EnMS on the management of the energy risks of an industrial site.

To test the versatility of the proposed methodology it would be interesting to apply it to a different type of organization, such as in the service sector, or to integrate the management of energy risks with those relating to other issues such as environment, quality, and safety.

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Appendix A. FIRST APPENDIX

Table A1: Case study - Defining the context

Context	Macro-group	Subgroup	Main Issue	Needs and Expectations	To Address through EnMS
External	Stakeholder	Authority	Incentive	Achievement of the energy savings planned for obtaining the incentives	++
Internal	Machinery and technologies	Compressed Air	Operational control	Contain the consumption of the compressors as they have a significant impact on total energy consumption	++

Table A2: Case study - Risk Assessment

Macro process	Type	Context element	Source	Event	Effect	Current measure	Proba bility	Impact	Rating scale
Supplying	Threat	Stakeholder	Energy Supplier	Low-quality palm oil fuel	Problems with the cogenerator	Checking the fuel upon entering the factory	Very low	High	Optional action
Self-production	Threat	Machinery and technologies	Cogene rator	Delays in the maintenance (external suppliers)	Downtime of the cogenerator	Scheduled maintenance	Very low	High	Optional action
Transformat ion	Opportu nity	Machinery and technologies	Compre ssed Air	More efficient use of compressors	Improvemen t of energy performance	A general model for monitoring the consumption of compressors	Mediu m	Medium	To monitor
Energy use	Threat	Organization of production	Product ion plans	Production plans not aligned with energy-saving needs	Overall inefficiency of the plant	Autonomous management	High	Medium	Not acceptabl e
Energy transfer	Threat	Social and economic context	Energy price	Reduction in energy price	Economic loss	Established cogenerator operation mode	Mediu m	Medium	To improve

Table A3: Case Study - Risk Treatment

Macro process	Type	Context element	Source	Event	Effect	Rating scale	Action to Address	Effectiveness
Supplying	Threat	Stakeholder	Energy Supplier	Low-quality palm oil fuel	Problems with the cogenerato r	Optional action	Evaluate the possibility of inserting automatic control on filters	Reduce the risk impact from high to medium
Self-production	Threat	Machinery and technologies	Cogener ator	Delays in the maintenance (external suppliers)	Downtime of the cogenerato r	Optional action	Provide training for internal operators to solve minor failures	Reduce the risk impact from high to medium
Transforma tion	Opport unity	Machinery and technologies	Compre ssed Air	More efficient use of compressors	Improvem ent of energy performan ce	To monitor	Implement monitoring systems to predict the performance of individual compressors	Realization of significant energy savings
Energy use	Threat	Organization of production	Producti on plans	Production plans not aligned with energy-saving needs	Overall inefficienc y of the plant	Not acceptable	Develop the production plan by integrating operation and energy efficiency by consulting the energy team	Reduce the risk level from "Not acceptable" to "Optional action"
Energy transfer	Threat	Social and economic context	Energy price	Reduction in energy price	Economic loss	To improve	Optimize cogenerator operation mode also concerning the price of energy	Reduce the risk level from "To improve" to "Optional action"