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Energy Management in Energy Intensive Industries – Recommended Technical & Managerial Actions and a Delphi Study

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HIGHLIGHTS

- Proposition of a set of technical and managerial actions for an energy management system.
- A Delphi study with Brazilian PhD specialist with academia and industry for referendum.
- Approaches based on ISO 50001 and ANSI/MSE 2000.

Abstract: This paper presents the proposition of a set of technical and managerial actions recommended for the management of energy in industry. Economic, environmental, political and social aspects have been putting pressure on the whole society for a more conscious and efficient use and consumption of energy in its diverse forms. Energy-intensive industries show a high energy consumption, they work with processes in severe temperature conditions, residual dissipation of heat and flux of not used residues, always being subject to great environment risks. These large-sized companies offer great opportunities for making energy more efficient, use of co-generation and various other possibilities for a better management and improvement of energetic performance. The research is characterized as quali-quantitative, exploratory and descriptive, presenting a statistical analysis for the questionnaire answers. The energy management practices refer to procedures used for dealing with energetic issues. In function of the interdisciplinary aspect of energy management in the industry, the management practices can be better understood with technical and managerial continuous or frequent actions. A Delphi study for verification of the validity of the proposed technical and managerial actions was carried out together with academia and industry specialists. The results show a favorable positioning, confirmed by a reliability rate among suitable evaluators (IRR – Inter Rater

Reliability). The set of technical and managerial actions is made up of reference elements for creation, organization and conduction of an energy management system in the industry.

Keywords: Energy Management System; Energy Intensive industries; Delphi study; Technical and Managerial Actions.

INTRODUCTION

Economic, environmental, political and social aspects have pressured society as a whole towards more conscious use and consumption and efficient use of energy in its most diverse forms. The energy intensive industries (cement, iron and steel, pulp and paper, petrochemical, chemical, aluminum and glass) (EII) have high energy consumption, operate with processes in severe temperature conditions, residual heat dissipation and flow of unused waste, which are always subject to major environmental risk.

The International Energy Agency (IEA) [1] forecasts in its reports that the industrial segment was and will continue to be, in forecast until 2030, the world's largest consumer of energy. According to the National Energy Balance (BEN) [2], published in 2018 and for the year 2017, Brazilian registered primary energy consumption of 260 million tons of oil equivalent (Mtoe), it is distributed in: i) 33.3% industrial sector; ii) 32.5% transport sector; iii) 14.4% of the buildings/services sector; and iv) 4% for agriculture sector, explaining the importance of the industrial sector for the national energy consumption.

Problems encountered for efficient energy management (EnM) industry, they appear in the form of barriers that can be of: (i) external origin (market, government/politics, suppliers, technology/services, designers, manufacturers, energy suppliers and financiers); (ii) intra-organizational origin (in the economic-behavioral and organizational perspective) [3-5].

Scientific literature reports a strong research trend focused on technological aspects and little attention to organizational issues [6-8]. With regard to organizational barriers, the understanding of which are the management practices and how they are used in companies is characterized as relevant. The weak connection between industry and academia makes it difficult to map the energy efficiency practices implemented [9]. In general, energy management practices (EnMPs) in the industry are implemented by the organization in actions aimed at acting on the use, consumption, energy efficiency (EE) and, therefore, on the organization's overall energy performance.

Due to the interdisciplinary aspect of EnM in the industry, it is difficult to characterize EnMPs practices, since they can be interpreted on different techniques (engineering, economics, finance, administration, environmental, etc.). Previous studies [10] found that EnMSs can be established in the form of continuous or frequent technical and managerial actions.

In 2008, the ANSI/MSE 2000 - A Management System for Energy [11] standard was launched in the United States. In 2009, the European community launched the standard EN 16001 Energy Management Systems in Practice [12] and, in 2011, the ABNT NBR ISO 50001 standard – Energy Management Systems: Requirements with guidelines for use was launched in Brazil [13].

The EnM standards incorporate the technique of continuous improvement established in the PDCA (Plan, Do, Check and Act) cycle, creating a new approach in relation to traditional and previous energy efficiency programs that, performed in a single opportunity, were later abandoned. In the case of the ISO 50001 standard, there is the inherent advantage of compatibility with the ISO 9000 and ISO 14000 series standards. In addition to these standards, there are reports in the scientific literature of successful EnM initiatives that need to be considered.

Thus, in this work, a set of technical and managerial actions recommended for EnM in the EII is identified and proposed, in order to complement the requirements defined in EnMS standards (ABNT NBR ISO 50001, ANSI/MSE 2000), a successful initiative in the industry in order to create, organize and conduct an EnMS.

With reference to the set of technical and managerial actions recommended and considering: (i) the complexity and the interdisciplinary aspect in which the field of energy management in the industry is characterized (involves several areas of the organization such as engineering, economics, finance, administration , etc.); (ii) contemporaneity and variety of factors influencing the theme such as environmental, commercial, legislation, etc.; (iii) the predominant qualitative aspect, a position of specialists with respect to the technical and managerial actions previously proposed is appropriate. It is also proposed to carry out a Delphi study to ratify EnMPs in the form of recommended technical and managerial actions.

The present research work is organized as follows: In section I, the relevance of energy management (EnM) in the industry, barriers, organizational aspects, standards, successful initiatives and identification of EnMPs practices used in the industry are briefly discussed. In section II, materials and methods, the methodology and objectives (general and specific) are described. Then, an overview of technical and

managerial actions for EnM in the industry, the Delphi method and the adopted reliability measure are presented. In section III, the set of technical and managerial actions recommended is presented in the form of a questionnaire, the Delphi method is applied, and the results of the application are presented and discussed. Finally, in section IV, conclusions, limitations and perspectives for future work are presented.

MATERIAL AND METHODS

The research is characterized as quali-quantitative, exploratory and descriptive, presenting a statistical analysis for the questionnaire answers.

The general objective of the article is to propose a set of technical and managerial actions recommended for an Energy management system (EnMS) in EII and to carry out a Delphi study for referendum, after consulting a group of specialists. The specific objectives established are: (i) Describe EnMPs in the industry; (ii) Propose a set of technical and managerial actions based on the ISO 50001 standard to conduct an EnMS in the EII; (iii) Carry out a Delphi study to endorse and obtain consensus on the proposed set of technical and managerial actions.

A. Rationale

(i)Technical and managerial actions recommended

In the literature, there is no single and cohesive definition for the term “Energy Management Practices” (EnMPs), since they can be seen from different perspectives: technological, financial, managerial, organizational, etc.

In a case study applied in the Swedish foundry industry, with the objective of identifying, classifying and characterizing EnMPs, [10] it was found that such practices can be better understood in the form of continuous or frequent technical and managerial actions. This interpretation is in accordance with the ANSI/MSE 2000 standard, which stipulates that EnMPs can be arranged in the form of technical and managerial actions and can also be arranged according to the phases of the PDCA cycle.

A list of EnM practices frequently mentioned in the scientific literature and established within the PDCA cycle is presented in tables 1, 2, 3 and 4.

Table 1. Technical And Managerial Actions Established In The Phase Plan (Pdca Cycle)

Phase: Plan	
Technical actions	**Managerial actions**
Long-term strategies for EnM [6] [8] [14]. Payoff criteria when investing in equipment replacement [6] [7] [14] [17]. Energy performance indicators (EnPIs) [7] [18] [19] [20]. Conduct detailed (initial) energy review [6] [7] [21] [22].	Designation of energy manager [6] [14] [15] [16] Creation of energy management team or internal commission for energy conservation [7] [14] [15]. Define energy policy [6] [8] [14].

Table 2. Technical And Managerial Actions Established In The Phase Do (Pdca Cycle)

Phase: Do	
Technical actions	**Managerial actions**
Submetering – It is related to the "Do" and "Check” phases [6] [7] [21] [22]. Energy measuring and monitoring systems – It is related to the “Do" and "Check" phases [6] [7] [22] [24]. Combined heat and electricity techniques- Cogeneration (CHP) [6] [26] [27].	Hiring of Energy Services Companies (ESCOs) [6] [7] [8] [23]. Training to prevent accidents and risks related to different types of energy [8] [14]. Energy education training [8] [13] [17] [25].

Table 3. Technical And Managerial Actions Established In The Phase Check (Pdca Cycle)

Phase: Check	
Technical actions	**Managerial actions**
Energy audits in diagnostics format. [7] [8] [14] [20].	EnMS internal audit [7] [8] [14] [20].
Benchmarking techniques (energy consumption, energy efficiency) [7] [13] [19] [22].	Corrective and preventive actions in EnMS [7] [8] [14] [20]

Table 4. Technical And Managerial Actions Established In The Phase Act (Pdca Cycle)

Phase: Act	
Technical actions	**Managerial actions**
Review of energy performance indicators EnPIs [7] [18] [19] [20].	Review energy policy [6] [8] [14]. Analyze audits result in the EnMS [7] [8] [14] [20].

It appears that due to the complexity inherent to EnM and the unfolding of actions, some of the management practices, whether technical or managerial, may require activities and be inserted in more than one phase of the PDCA cycle.

Thus, a set of recommended technical and managerial actions can be gathered to conduct EnMS activities, organizing the actions in order to consider the attributions recommended by the ISO 50001 standard for the top management, energy manager and Energy Management Team (EnMT).

The set of technical and managerial actions related to an EnMS is arranged in four parts: (i) Technical and managerial actions recommended for the EnMS - Energy manager; (ii) Technical and managerial actions recommended for the EnMS - Energy Management Team; (iii) Technical and managerial actions recommended for EnMS - Top management; (iv) Technical and managerial actions recommended for EnMS – Company. The term “company” refers to activities developed by any areas of the organization in order to meet the EnMS.

Although the energy manager is part of EnMT, the technical and managerial actions recommended in items 1, 2 and 3, relating to the energy manager, are highlighted in the EnMT questionnaire - in a separate provision to highlight the relevant human skills necessary for good performance of the EnMS as reported in ISO 50001 and in the scientific literature [14], [19], [25], [28].

Delphi Method

Delphi is a research method in which knowledge and assumptions about a particular issue or process under study are collected in an iterative process. This is an especially useful method when the phenomenon under study is complex, or when the subject is delicate and difficult to define, awkward to talk about, politically sensitive, etc. [29].

The Delphi method is structured in several rounds of communication without face-to-face interaction, that is, the study is conducted with a certain degree of anonymity. It is a method used especially in research to collect specialists opinion data on medium and long-term challenges, issues and/or problems [21].

The Delphi method is usually organized in rounds, where specialists participate. It starts with a questionnaire about the subject to be analyzed or problem to be discussed. Typically, there is an initial phase of inputting information about the problem, a second phase of discussing the views of the dissenting group members, and a final phase of evaluation.

The Figure 1 presents the phases of the Delphi method from the completion of the interview or the sending of the questionnaire to the specialists

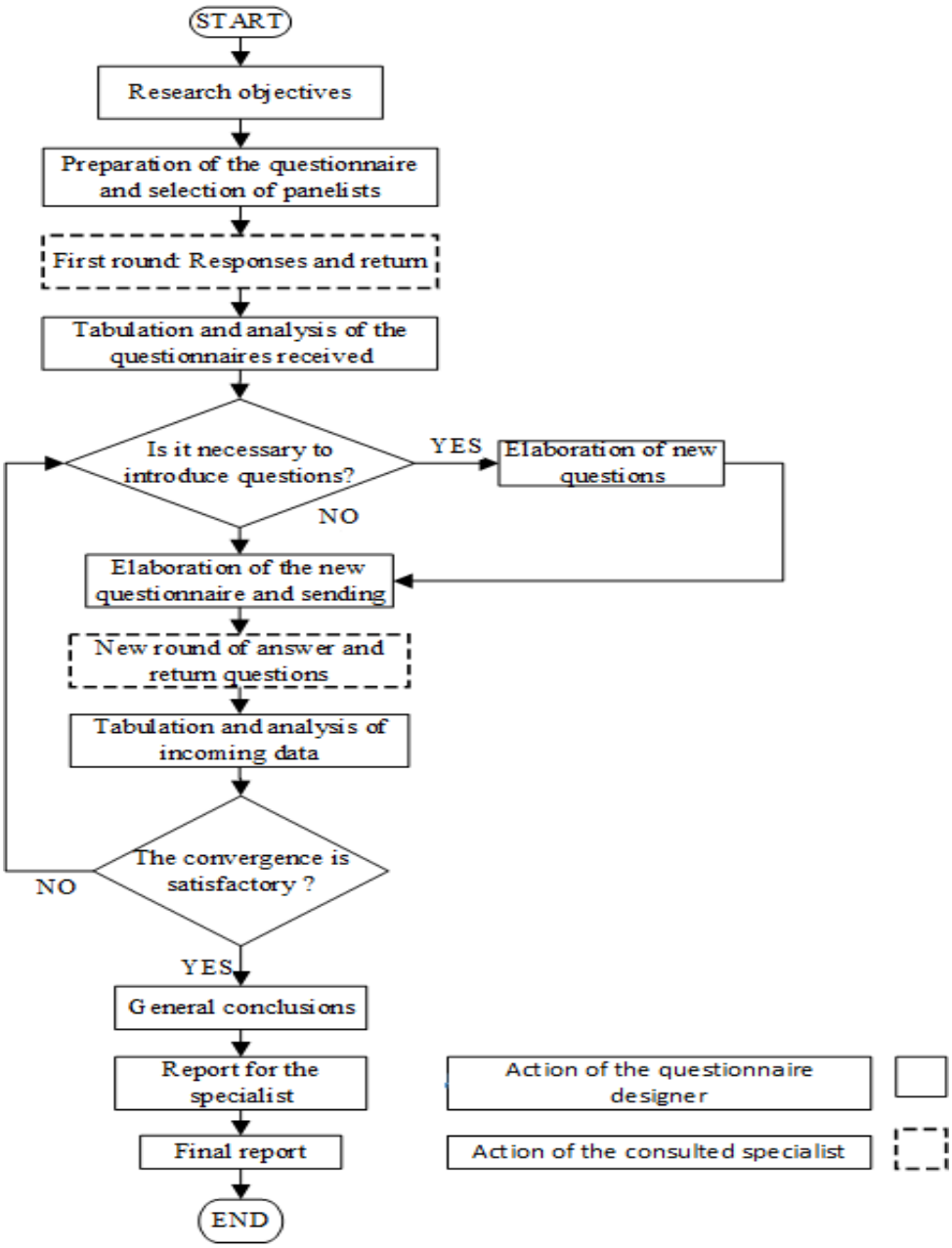

Figure 1. Execution Thread of a Delphi Query. Adapted from [31]

Following the flow shown in Figure 1, the questionnaire is initially prepared and the specialists who will participate in the study are selected. Then, the questionnaire is applied to the group of specialists and, provided that the expected consensus is reached in the first round, the process is terminated and the results are compiled into a final report.

If there is no consensus, the responses are evaluated and the information is returned to the group. Then, a new questionnaire is designed to conduct the second round of the study in order to reach consensus among specialists. If uncertainty persists, the third and final round begins to reach consensus, if convergence is not reached, a new questionnaire proposal must be prepared.

To achieve the objective of this research project, a questionnaire will be applied to evaluate the technical and managerial actions identified in the literature review regarding EnMPs.

The Delphi Study applied in this work can be classified as a modified Delphi Study, designated “e-Delphi” according to [32]. This is due to the fact that the first round had a format based on a set of pre-defined questions.

The number of rounds estimated for the application of this methodology is at least two, reaching a maximum of three, in order to obtain reasonable results. According to Laakso [33], a greater number than three rounds is not recommended due to time constraints and the fact that there are no significant changes in later rounds, as evidenced by previous experiments.

The Delphi method chosen for the purpose of this project is also configured in the one presented by [30], using, in particular, the elements presented in Table 5.

Table 5. Elements of The Delphi Method Adopted

Objective	Obtaining advice and reaching consensus.
Target panelists	Specialists selected based on research objectives (EnM in EII).
Administration	E-mail online survey via web.
Number of rounds	At most three.
First round (drawing)	The questionnaire with a set of instructions to guide its completion is made available as a preliminary model. Specialists are asked about their agreement when individually evaluating each of the proposed technical and managerial actions

B. Inter Rater Reliability

The Inter Rater Reliability (IRR), is defined as a measure that emphasizes the relative consistency or similarity of rater responses [34]. Therefore, the application of the IRR statistical method does not emphasize the equality of the absolute value of the evaluators' answers, but the relationship between these answers, thus expressing the reliability of the evaluated sample.

There are several statistical methods to estimate the IRR, and the choice of which method to use depends on the characteristics and the way in which the sample is collected. In this work, the sample to be evaluated are closed questions, containing a choice scale for the answers. Furthermore, each question was answered by multiple judges (evaluators). According to [35], when different judges evaluate a single question, using a scale for its answer, the IRR can be calculated using the equations mentioned below:

$$IRR = r_{WG(1)} = 1 - \left(\frac{S_{Xj}^2}{\sigma_{EU}^2}\right) \quad (1)$$

$$\sigma_{EU}^2 = (A^2 - 1)/12 \quad (2)$$

Where:

A =Number of possible answers alternatives for the questions.

σ_{EU}^2 =Variance of a rectangular or uniform distribution.

S_{Xj}^2 =Sample variance.

In the condition that the vast majority or all evaluators have the same position, which does not necessarily indicate that everyone has gauged the same answer to the question, the IRR can assume values between 0 and 1, and the closer or equal to 1 the value of the IRR is, the higher the level of reliability among the evaluators for the evaluated question. On the other hand, IRR values close to or equal to zero indicate a degree of low reliability among the evaluators.

RESULTS

In order to refine and obtain consensus on the recommended technical and managerial actions proposed for EnMS in the EII, the Delphi study was applied. The study was conducted among specialists with extensive experience in the industrial, teaching and research areas, all with the title of PhD. Two rounds of questionnaire were planned. In the first round, specialists were asked to inform their level of agreement with the recommended technical and managerial actions, presented in Section 3, according to a six-point Likert scale.

After the necessary adjustments to the content of the questionnaires, the specialists were submitted to a second round of questionnaires, whose results for each round are presented in Section 3.

Preparation of the Preliminary Questionnaire

The elaboration of the preliminary questionnaire was based on the technical and managerial actions presented in Tables 1, 2, 3 and 4, in order to obtain the position of the specialists regarding the pertinence and relevance of the set of technical and managerial actions proposed for EnMS in the EII.

The set of recommended technical and managerial actions, shown in Table 6, is divided into four parts: (i) Questions 1 to 3 are related to the Energy manager; (ii) questions 4 to 11 are related to EnMT; (iii) questions 12 to 19 are related to Top management and, finally, (iv) questions 13 to 40 are related to Company.

Table 6. Set Of Recommendated Technical (T) And Managerial (M) Actions

#		Technical and managerial actions recommended
1	M	The Energy Manager should be a leader, motivator, problem solver and able to deal with different goals.
2	M	The Energy Manager should have experience in energy issues and be available for training / certification.
3	M	The Energy Manager should have social skills and ability to interconnect activities between different work groups.
4	M	The Multifunctional EnMT should be motivated based in the Ad hoc structure (defined purpose).
5	M	The EnMT, along with the Top Management, should define roles, responsibilities, position and authority for the development of the EnMS activities.
6	M	The EnMT should prepare its work plan stating that, among other activities, it needs to monitor bills for electricity, gas and other relevant fuels
7	M	The EnMT should discipline and support the communication and documentation process (paper, electronic, or any other means) of the EnMS.
8	M	The EnMT should encourage and conduct measures to provide company employees with education, training, safety and occupational health (energy), so that there is awareness, competence and change in organizational culture, including that of EnMT itself.
9	T	The EnMT should conduct the energy review and its consequences in the fulfillment of the company's objectives, energy goals and action plans. The energy review may be under the responsibility of the functional area of engineering.
10	M	The EnMT should coordinate/support energy certification activities (including ISO 50001), greenhouse gas inventory control and energy benchmarking.
11	M	The EnMT should coordinate, in the verification stage, monitoring, measurement, analysis (preferably also using International Performance Measurement and Verification Protocol (IPMVP)) and assessment of compliance with legal requirements. Non-conformities must be addressed with corrective and preventive actions.
12	M	Top management should declare its commitment to continuous improvement of the EnMS and establish an energy policy.
13	M	Top management should incorporate a long-term energy strategy into other corporate strategies.
14	M	Top management should appoint a representative with the role of energy manager and approve EnMT declaring support for EnMS.
15	M	A Top management should reward EnMT with financial bonuses and prizes for performance in EnMS activities.
16	M	Top management should identify the scope (scope of activities, facilities and decisions) and boundaries (physical or local and/or organizational limits) of the EnMS.
17	M	Top management should support energy planning, guarantee EnPIs and provide various resources (including software, Information and Communication Technology (ICT) for integrating the EnMS with other systems, e.g. environmental, quality, etc.).
18	M	Top management should approve energy review, objectives, energy targets and action plans.
19	M	Top management should provide internal audit on EnMS and perform review of EnMS at specified times.
20	M	The Company, when adopting “Best Practice” practices such as Total Quality Management, world-class manufacturing, among others, should contemplate aspects of energy efficiency.
21	M	The Company should incorporate energy benchmarking into comparative information activities to be carried out internally and externally.
22	M	The Company should standardize energy management activities with process mapping to facilitate task automation, decision support, value chain analysis, detect strengths/weaknesses and integration failures.
23	M	The Company should adopt the use of ISO 50001energy standard on the condition of certification or self-declaration (initial stage).

Cont. Table 6

24	M	The Company should verify the need to hire an ESCO/specialist.
25	T	The Company should carry out the initial energy review, analyzing: (i) the supply of electricity, gas, etc. and distributed generation with a preference for renewable sources; (ii) use, significant consumption, opportunities for energy efficiency, Best Practices Technology (BPT) and cogeneration.
26	T	The Company should institute and control energy performance indicators (EnPIs)
27	T	The Company should establish an energy baseline using the information from the initial energy review.
28	M	The Company should establish at the implementation and operations stage the following requirements to meet the EnMS: (i) education, training, occupational safety and health (for energy awareness and competence); (ii) communication; (iii) documentation.
29	T	The Company should establish an operational control (maintenance and operation) and a project, both to address the facilities, equipment, systems and processes related to the EnMS.
30	T	The Company should institute procedures for purchasing energy efficient products/equipment and specifications for purchasing energy.
31	M	The Company should comply with legal provisions (country specific), with employee training in occupational safety and health for energy matters. In Brazil, regulatory standards (NR), NR10, NR12 and NR13, among others. Also, when convenient in international aspects, adopt OHSAS 18000.
32	M	The Company should identify and enable funding sources for energy efficiency activities and account for energy costs by products, processes or other needs.
33	M	The Company should analyze and adopt appropriate payback criteria in equipment replacement investments and in the analysis of energy efficiency opportunities.
34	M	The Company should analyze and integrate the EnMS with other compatible systems, such as: management of production processes, quality, environmental, greenhouse gases (GHG), risks, Product Life Cycle Assessment (LCA), assets, Corporate Social Responsibility (CSR), Health and Safety at Work (WHS).
35	T	The Company should identify and evaluate the best practices (Best Available Technology) in the aspects of energy efficiency, mainly in the productive sector.
36	T	The Company should make available ICT tools to support EnMS.
37	T	The Company should provide an electronic monitoring and measuring energy system in real time.
38	T	The Company should provide energy submetering.
39	T	The Company should provide appropriate maintenance instrumentation for energy aspects.
40	T	The Company should provide software (computer programs), simulators for diagnosis, modeling and statistical analysis of energy systems.

The technical and managerial actions can also be classified according to human, technological and organizational (HTO) aspects, allowing for further consideration and analysis of the influence on the performance of an EnMS. The technical and managerial actions from 1 to 4 can be graded on human aspects, from 5 to 34 on organizational aspects, and from 35 to 40 on technological aspects.

Characterization and Selection of Specialists Participating in the Delphi Study

The definition of specialists is carried out according to works published by Boyer [36], in which aspects related to research, applications and teaching are analyzed. In order to effectively characterize the participants of the Delphi study as specialists, fourteen professionals with knowledge in the energy area were selected, in which important characteristics were identified, such as years of experience, number of published articles and participation in projects, research, etc.

The Table 7 presents the characteristics of the specialists according to their experience in research, project implementation and/or consultancy and in teaching activities.

Table 7. Summary Of Expertise Experience

	Numbers of years		
	Research	**Project Implementation**	**Teaching**
Do not participate in this activity.	0	0	0
Less than 2 years.	0	0	0
From 2 to 5 years.	0	2 (14,29%)	4 (28,57%)
From 6 to 10 years.	5 (35,71%)	5 (31,71%)	4 (28,57%)
More than 10 years.	9 (64,29%)	7 (50,00%)	6 (42,86%)

The Table 8 contains the characteristics of specialists in the amount of work they have authored, projects and courses taught.

Table 8. Summary of the numbers of publications by specialists

Quantity of					
Scientific articles		**Projects' Implementation**		**Courses**	
< 10	5 (35,71%)	< 5	3 (21,43%)	< 2	0
From 10 to 19	4 (28, 57%)	From 5 to 9	5 (35, 71%)	From 2 to 4	10 (71, 43%)
From 20 to 50	3 (21,43%)	From 10 to 20	2 (14, 29%)	From 5 to 10	3 (21,43%)
> 50	2 (14,29%)	> 20	4 (28, 57%)	> 10	1 (7,14%)

A. Results and analysis of the First Round of Questions

Table 9 presents the results of the first round. With the specialists' answers, the inter-rater agreement index was applied, according to the model proposed in [35], where the degree of agreement of a question is statistically measured according to the answers of several people to the same question, indicating if there is a consensus among the interviewees. Their values can vary between 0 (zero) and 1 (one). The maximum value equal to 1 (one) means total agreement from all specialists, however, an IRR value ≥ 0.8 is acceptable to express a consensus.

This allows the technical and managerial actions recommended to be endorsed and there is a consensus among specialists for the practice of EnMPs in EII.

Table 9. Results of the first round of questions

IRR	Questions	Provisions
IRR ≥ 0,8	28 questions	No changes needed.
0,7 < IRR < 0,8	8 questions (8, 14 16, 23, 33, 34, 37, 40) 1 question (4)	No changes sent a note of clarification. Improvement was made.
0,5 ≤ IRR ≤ 0,7	3 questions (6, 15, 18)	Questions reformulated.

After the first submission (1st round), there was a high level of agreement among the evaluators, as the vast majority of questions had an IRR above 0.8, which is considered a reference value, with the exception of questions # 4, #6, #8, #14, #15, #16, #18, #23, #33, #34, #37 and #40, representing 30% of the total.

Questions with an IRR greater than or equal to 0.8, that is, 28 (twenty-eight) questions, do not need to be changed, as the evaluators present a strong tendency to agree on their content. As for the questions with IRR between 0.7 and 0.8, there is no need for changes, but there is a need to forward clarifications for a better judgment of the specialists. The only exception is question four, for which a better description was made, without, however, changing its initial understanding.

Below, we have the questions originally proposed, followed by clarifications for a better understanding of the specialists:

- Question 4 (IRR 0.73) reformulated: The multifunctional EnMT motivated in an ad hoc structure (defined purpose), as the initial proposition of establishing an EnMT.

Clarification: The proposition of an EnMT formalized in the company organizational chart and integrated into the company is presented as a better recommended solution, see propositions by [37] [38]. However, in reality, given several factors in which financial aspects prevail, only in some developed countries and in a limited number of companies (generally large corporations with intensive energy use) is this practice adopted. EnMS standards, such as ISO 50001, EN 16001, ANSI MSE 2000, and recommendations from international

bodies, such as the US Environmental Protection Agency (EPA) Guide Energy Management, explicitly state the need to compose an EnMT.

- Question 16 (IRR 0.73). Top management should identify the scope (coverage of activities, facilities and decisions) and boundaries (physical or local and/or organizational limits) of the EnMS.

Clarification: This issue is maintained because it complies with the requirements established in the NBR ISO 50001 standard. Top management must verify the scope and boundaries to be addressed by the EnMS [13].

- Question 34 (IRR 0.73). The Company should analyze and integrate the EnMS with other compatible systems, such as: management of production processes, quality, environmental, GHG, risks, LCA, assets, CSR, OSH.

Clarification: The scientific literature reports, in several research works [6], [7] and [14], the need to perform the integration of EnMS with other compatible systems. The integration of management systems enables cost reductions, standardization of procedures, greater control over the company's operation, improvement in the quality of information, among others

Question 23 (IRR 0.76). The Company should adopt the use of ISO 50001 energy standards on the condition of certification or self-declaration (initial stage).

Clarification: Question maintained for being in compliance with the requirements established in the ISO 50001 standard, which indicates that the standard is applicable to any organization that wishes to ensure that it complies with its established energy policy and demonstrates such conformity to third parties, which can be confirmed through a self-assessment and self-declaration [13].

- Question 37 (IRR 0.76). The company should provide the electronic system for monitoring and measuring energy in real time.

Clarification: This issue is maintained because it complies with the requirements established in the ISO 50001 standard, which indicates that an energy measurement plan appropriate to the size and complexity of the organization and its monitoring and measurement equipment must be defined and implemented, ranging from utility meters to complete monitoring and measurement systems, containing software for real-time monitoring and automatic analysis [13].

- Question 14 (IRR 0.77). Top management should appoint a representative for the role of energy manager and approve EnMT by declaring support for EnMS.

Clarification: Top management must demonstrate its commitment to support the EnMS and continually improve its effectiveness through activities such as designating a representative and approving the formation of an EnMT [13].

- Question 8 (IRR 0.78). EnMT should encourage and conduct measures to provide company employees with education, training, safety and occupational health (energy), so that there is awareness, competence and change in organizational culture, including that of EnMT itself.

Clarification: The organization shall identify training needs associated with controlling its significant energy uses and the operation of its EnMS [13].

- Question 40 (IRR 0.78). The company should provide software (computer programs), simulators for diagnosis, modeling and statistical analysis of energy systems.

Clarification: The scientific literature reports in several research papers [7]; [8]; [14]; [39], the importance of providing software and simulators for diagnosis, modeling and statistical analysis of energy systems. This software can be made available by public institutions such as the National Energy Conservation Program – PROCEL and the United States Department of Energy – DOE, universities and companies specialized in energy efficiency.

- Question 33 (IRR 0.79). The company should analyze and adopt appropriate payback criteria in equipment replacement investments and in the analysis of energy efficiency opportunities.

Clarification: The scientific literature reports in several research papers [16] [25] [32] the need to evaluate the payback criterion to enable energy efficiency projects.

Questions with IRR below or equal to 0.7, that is, questions #6, #15 and #18 were reformulated and forwarded to the specialists with additional clarifications. Below are the questions originally proposed, followed by justifications for their reformulation.

- Question 15 (IRR 0.55) reformulated: Top management could (in view of EnMT's volunteer work), recognize initiatives and good performance, rewarding the team with prizes and financial bonuses.

Rationale for Restatement: The United States Environmental Protection Agency (EPA) report “Energy Star: Guidelines for Energy Management” prescribes that an organization with a fully implemented EnMS stipulate rewards for successful EnM initiatives and performance. [22]

- Question 6 (IRR 0.66) reformulated: EnMT should prepare its work plan, stating that, among other activities, it needs to monitor bills for electricity, gas, relevant fuels, water consumption, etc.

Justification for reformulation: The Teaming Up to Save Energy report from the US environmental protection agency explains the need for EnMT to have a work plan where, among other activities, is the establishment of an action plan [40].

- Question 18 (IRR 0.70) reformulated: Top management should approve the energy review, objectives, energy targets and action plans. (Within its budgetary limits and eventually, hiring specialists for advice).

B. Results and analysis of the Second Round of Questions

After the results of the first round, questions #6, #15 and #18 were then reformulated and, together with clarifications, were then forwarded to the specialists to carry out and re-express their opinions on the recommended technical and managerial actions. After returning the completed questionnaires, it was found that there was a consensus among the specialists, as all questions had an IRR > 0.8, as shown in table 10.

Table 10. Results of the 2nd round of questions

#	Average	Standard deviation	IRR	#	Average	Standard deviation	IRR
1	1,36	0,48	0,92	21	1,64	0,48	0,92
2	1,43	0,49	0,92	22	1,50	0,50	0,91
3	1,14	0,35	0,96	23	1,57	0,62	0,87
4	1,64	0,61	0,87	24	2,07	0,59	0,88
5	1,43	0,49	0,92	25	1,36	0,48	0,92
6	1,43	0,62	0,87	26	1,50	0,63	0,87
7	1,57	0,62	0,87	27	1,57	0,62	0,87
8	1,71	0,70	0,83	28	1,57	0,49	0,92
9	1,43	0,62	0,87	29	1,71	0,70	0,83
10	1,50	0,63	0,87	30	1,43	0,62	0,87
11	1,29	0,45	0,93	31	1,50	0,50	0,91
12	1,14	0,52	0,91	32	1,50	0,63	0,87
13	1,29	0,45	0,93	33	1,57	0,73	0,82
14	1,50	0,63	0,87	34	1,50	0,63	0,87
15	1,93	0,80	0,78	35	1,64	0,61	0,87
16	1,86	0,83	0,76	36	1,43	0,49	0,92
17	1,29	0,45	0,93	37	1,64	0,61	0,87
18	1,43	0,49	0,92	38	1,64	0,48	0,92
19	1,57	0,49	0,92	39	1,71	0,59	0,88
20	1,43	0,49	0,92	40	2,00	0,65	0,85

DISCUSSION

A detailed analysis of the results obtained in the first and second rounds of the Delphi study is presented in the topic of results.

The research work showed that the set of technical and managerial actions recommended in the proposal obtained a favorable opinion from the specialists, attesting to the pertinence and relevance, with the possible applicability to contribute to the creation, organization and conduct of an energy management system.

CONCLUSION

The present study presented a description of EnMPs for EII in the form of recommended technical and managerial actions, which are based on successful initiatives in the industry. These actions are arranged within the PDCA cycle and also meet the requirements of EnMS ANSI/MSE 2000 and ISO 50001 standards. Thus, the first specific objective was achieved.

The identified technical and managerial actions were arranged in a manageable set to implement and conduct an EnMS in EII. The set of technical and managerial actions obtained was organized in such a way as to consider the attributions and responsibilities established by the ISO 50001 standard, which advocates the establishment of a directorate designated Top management (responsible for creating, organizing and conducting an EnMS), the indication of an energy manager and the composition of an EnMT. In this way, the second specific objective was achieved.

The set of technical and managerial actions recommended for EnM in the industry was endorsed by conducting a Delphi study, to obtain consensus among specialists with extensive experience in the industrial area, in teaching and in research, thus meeting the third specific objective established.

The availability of a set of recommended technical and managerial actions presents application perspectives in different situations, such as: (i) diagnosis; (ii) assessment of organizational potential; (iii) implementation of EnMS and energy efficiency programs; (iv) constitute a basis for improvements in implemented systems; (v) supply of elements to subsidize the creation, organization and conduction of an EnMS.

As a limitation of the method, it is highlighted that even a well-designed Delphi study may not understand the complete set of ideas and concepts regarding the subject of interest, since the specialists selected to participate in the study directly influence the results obtained. Still, the opinion of the specialists is of fundamental importance for the accomplishment of the Delphi study, however, it may not consider all aspects necessary for the practical application of the model developed.

In future works, case studies can be carried out in order to verify: (i) effectiveness of the applicability of the set of technical and managerial actions recommended for EnM in the EII; (ii) extract relationships between the technical and managerial actions recommended and classified in human, technological and organizational aspects.

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