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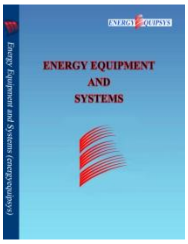

Proposing a quantitative approach to measure the success of energy management systems in accordance with ISO 50001: 2011 using an analytical hierarchy process (AHP)

Author

Abdorrahman Haeri [a*]

[a] School of Industrial Engineering, Iran University of Science & amp; Technology, Tehran, Iran

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ABSTRACT

ISO 50001: 2011 provides an integrated and systematic framework to plan, implement, operate, certify, and maintain energy management systems (EMSs). Evaluation of organizations in relation to meeting the standard requirements is performed by an auditing qualitative approach. In this research, a quantitative approach has been proposed and implemented to assess organizations and rank them based on the related capabilities of the EMS. Initially, ISO 50001 was accurately reviewed to extract requirements. Later, an analytical hierarchy process (AHP) was used to perform pair-wise comparison and to specify the importance factors of ISO 50001 requirements. A number of Iranian oil and gas plants were evaluated in accordance with the specified requirements of ISO 50001. The results of the evaluation were used to rank the considered plant in capabilities of the EMS. In addition, it was used to specify which areas of ISO 50001 need more attention in the considered plants. Finally, the improvement approaches were proposed to enable Iranian oil and gas plants to increase the effectiveness of the implemented EMS.

Keywords: Energy Management System (EMS), ISO 50001: 2011, Requirements of EMS, Analytical Hierarchy Process (AHP), Improvement Approaches.

1. Introduction

Energy managements systems (EMSs) help the organization to effectively manage energy-related issues through an integrated and systematic approach. The International Organization of Standardization (ISO) released ISO 50001, including a requirement of an EMS, on June 15, 2011. The requirements constituted a basis to evaluate the EMSs of organizations in different energy-related functions such as planning, documentation, record management, operation, monitoring, and auditing.

Qualitative approaches have usually been used to audit and certify EMSs. But such approaches are required to present an organizational situation with quantitative scores to provide a basis for the accurate evaluation and improvement of planning approaches. In addition, this provides the possibility to compare

* Corresponding author: Abdorrahman Haeri
Address: School of Industrial Engineering, Iran University of Science & amp; Technology, Tehran, Iran
E-mail address: ahaeri@iust.ac.ir

and rank the organization based on their capability, to meet the requirements of EMS.

A number of previous researches focused on EMS in accordance with ISO 50001. For example, Jovanović and Filipović (2016) proposed a maturity model based on ISO 50001 that presented the relationships between the business processes of ISO 50001 and the criteria of the capability maturity model. The PDCA cycle, which is known as a continuous improvement approach, and the criteria of the capability maturity model integration had a critical role in the proposed approach. The approach was applied successfully in practice to certified and non-certified organizations. Chiu and Lo (2015) used an integration energy practice (IEP) model to improve energy efficiency in EMSs (especially those EMSs that were based on ISO 50001). The results showed that the IEP model improved the energy use intensity (EUI) of the energy performance indicators (EnPIs). Rodriguez et al. (2015) presented a technical capability to monitor fuel consumption, including the appropriate tools for the fleet. In this regard, the obtained objective evidences provided a suitable collection of records for internal and third-party audits of EMSs based on ISO 50001. The results of applying the developed technical service indicated that it made a reduction in the fuel consumption by 20%. Zając (2015) proposed a new approach of auto-ID system evaluation by integrating automatic identification subsystem and logistics system functional components. In addition, he applied the proposed approach in a real case. Karcher and Jochem (2015) identified the critical success factors (CSFs) of planning, implementation, operation, and maintenance of an EMS based on ISO 50001. For this purpose, a survey was conducted among certified companies in Germany. The results showed that staff motivation, energy-related cost reduction and team-building capability were the most important success factors. Gopalakrishnan et al. (2014) used flow charts to present an analytical illustration of ISO 50001 to facilitate planning, implementation, certification, operation, and maintenance of EMS. The proposed framework could help consultants during EMS documentation and implementation. Brown et al. (2014) investigated major and inherent features of ISO management systems and discussed probable changes in ISO 50001 in the future, to improve their capability for its revision and aimed to convert it to a high-level structure in alignment with the International Organization of Standardization's (ISO) recent policies. Shushakov et al. (2013) considered implementation of EMS in the company Gazprom to provide a systematic and uniform approach for energy efficiency. The EMS included a number of elements such as energy policy, energy planning, implementation and operation, and checking based on the requirements of ISO 50001. Chiu et al. (2012) considered a number of case studies that implemented EMS based on ISO 50001 by applying an integration–energy–practice model to improve energy performance indicators. Martl (2012) investigated the features of an applied user-friendly energy monitoring application to provide the possibility to make informed decisions for energy cost-saving purposes. One of its main capabilities was recording energy consumption data during different time periods. The main purpose of applying the mentioned solution was to reduce environmental impacts and outcomes, and decrease the operational cost for companies.

The structure of this paper is as follows: After the introduction in Section 2, the main requirements of an EMS in accordance with ISO 50001 are identified and classified in two levels. Section 3 is dedicated to calculating the importance factors of requirements using the analytical hierarchy process (AHP). A case study of the Iranian oil and gas plants is explained in Section 4. Finally, the conclusions of this research are stated in Section 6.

2. Identifying and classifying the requirements of an EMS based on ISO 50001

In this section, the requirements of an EMS in accordance with ISO 50001 are identified and classified. For this purpose, the content of ISO 50001: 2011 is accurately studied and the requirements are classified in six main groups, including macro requirements, management responsibility-related requirements, energy planning-related requirements, implementation and operation requirements, checking requirements, and management review requirements, which are called the first-level requirements. Each of the main groups of requirements is classified into more detailed requirements named second-level requirements. The classification structure of the ISO 50001 requirements is shown in Table 1 in two levels.

Table 1. Classification of requirements of ISO 50001

First-level requirement title	First-level requirement code	Second-level requirement title	Second-level requirement code
Macro requirements	R1	General requirements	R11
		Energy policy-related requirements	R12
Management responsibility-related requirements	R2	Top management-related requirements	R21
		Management representative-related requirements	R22
Energy planning-related requirements	R3	Legal requirements	R31
		Other requirements	R32
		Requirements of energy review	R33
		Requirements of energy baseline	R34
		Requirements of energy performance indicators	R35
		Requirements of energy objectives	R36
		Requirements of energy targets	R37
		Requirements of energy management action plans	R38
Implementation and operation requirements	R4	Requirements of competency, training, and awareness	R41
		Communicational-related requirements	R42
		Documentation management requirements	R43
		Operational control requirements	R44
		Requirements of design	R45
		Requirements of energy-concern procurement	R46
Checking requirements	R5	Requirements of monitoring, measurement, and analysis	R51
		Requirements of compliance evaluation	R52
		Requirements of internal audit	R53
		Requirements of correction, corrective action, and preventive action	R54
		Requirements of control of records	R55
Management review requirements	R6	Requirements of input to management review	R61
		Requirements of output to management review	R62

3. Obtaining importance factors of requirements

The AHP is used to obtain the importance factor of each requirement. For this purpose, the viewpoints of 21 experts were received in a pair-wise manner. Initially, the first-level requirements were compared based on 15 questions to obtain the related importance factors. Then, for each group of requirements, a comparison was taken in the second level. For example, the fifth group of requirements (R5), which included five requirements in the second level, was considered based on 10 pair-wise questions. The related scale for each question is shown in Table 2.

Table 2. Linguistic term and the related numerical scale of the AHP questionnaire

Term	Numerical scale
Extremely less important	1/9
Very strongly less important	1/7
Strongly less important	1/5
Moderately less important	1/3
Equal importance	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9

For each question, the average of the answers was calculated and rounded off as shown for the first-level requirements in Table 3.

Table 3. Relative importance for first-level requirements

	R1	R2	R3	R4	R5	R6
R1	1	3	3	3	3	5
R2	1/3	1	1/3	1/3	1/3	1
R3	1/3	3	1	3	3	4
R4	1/3	3	1/3	1	3	2
R5	1/3	3	1/3	1/3	1	3
R6	1/5	1	1/4	1/2	1/3	1

Using AHP and the data of Table 3, the importance factors of first-level requirements were obtained. Then, second-level requirements were compared to obtain their importance factors in a similar manner. The obtained importance factors for the first- and second-level requirements are shown in Table 4.

Table 4. Importance factors of first- and second-level requirements

First-level requirement	Importance factor	Second-level requirement	Importance factor
R1	0.357	R11	0.5
		R12	0.5
R2	0.067	R21	0.67
		R22	0.33
R3	0.239	R31	0.046
		R32	0.055
		R33	0.067
		R34	0.106
		R35	0.180
		R36	0.180
		R37	0.167
		R38	0.200
R4	0.156	R41	0.091
		R42	0.031
		R43	0.086
		R44	0.369
		R45	0.211
		R46	0.211
R5	0.122	R51	0.106
		R52	0.116
		R53	0.136
		R54	0.542
		R55	0.099
R6	0.059	R61	0.5
		R62	0.5

4. Case study

In this section, 11 oil and gas plants in Iran were evaluated based on the identified requirements of ISO 50001. For this purpose, a group of competent auditors and lead auditors was employed to perform an internal audit process of EMSs. During the auditing process, objective evidence for each requirement was gathered. In addition, auditors and lead auditors assigned a score for each requirement indicating to what extent the considered plant met each requirement. The score was assigned a point based on a five-point Likert scale as follows:

- Point 5: Excellent
- Point 4: Above average
- Point 3: Average
- Point 2: Below average
- Point 1: Poor

Then, the obtained scores were multiplied with the importance factor of each requirement to present the final scores of each plant considered. The weighted scores of the plants are shown in Table 5.

Table 5. Weighted score of each plant (obtained from internal audit process)

Plant	Weighted Score
Plant05	4/40
Plant04	3/54
Plant07	2/85
Plant01	2/71
Plant06	2/71
Plant03	2/38
Plant08	2/16
Plant02	1/87
Plant09	0/48
Plant11	0/43
Plant10	0/33

Table 5 indicates that "Plant05" significantly had relatively more capability in comparison to the other plants. Then, "Plant07", "Plant01", and "Plant06" had similar scores from 2/71 to 2/85. "Plant03" and "Plant08" had similar scores (2/38 and 2/16). In addition, "Plant02" with a score of 1/87 was placed next in the order. Finally, three plants— "Plant09," "Plant10," and "Plant11"—were placed in the last ranks as their weighted scores ranged from 0/33 to 0/48.

The mean scores for each requirement in the 11 plants were calculated (Table 6) to show the overall condition of each first- and second-level requirement of ISO 50001 in all plants.

Table 6. Mean of scores for each requirement of ISO 50001

First-level requirement	Mean of scores	Second-level requirement	Mean of scores
R1	1/45	R11	3/00
		R12	2/82
R2	1/44	R21	2/82
		R22	3/00
R3	0/38	R31	2/64
		R32	3/18
		R33	3/27
		R34	3/73
		R35	3/36
		R36	2/27
		R37	3/09
		R38	2/91
R4	0/58	R41	3/27
		R42	3/09
		R43	3/18
		R44	3/91
		R45	3/09
		R46	3/36
R5	0/51	R51	2/36
		R52	2/27
		R53	3/73
		R54	2/09
		R55	4/18
R6	1/61	R61	3/45
		R62	3/00

The above table indicates that performance of the plants in accordance with R1, R2, and R6 was considerably better than R3, R4, and R5. Therefore, the plants needed to focus on requirements related to energy planning (R3), implementation and operation (R4), and checking (R5). In addition, in energy-planning-related requirements (R3), the plants needed to focus on meeting legal requirements (R31) and enhancing the plant's capability to meet the requirements of energy objectives (R36). In the requirements of implementation and operation (R4), the plants needed to pay more attention to communication-related requirements (R42) and design requirements (R45). For checking requirements (R5), the plants needed to plan and perform actions to provide more capability to meet the requirements of monitoring, measurement, and analysis (R51), the requirements of compliance evaluation (R52), and the requirements of correction, corrective action, and preventive action (R54).

To increase the organizational capability of plants to meet the above-mentioned requirements of an EMS based on ISO 50001, a number of improvement approaches are presented as follows:

- Identify and gather legal requirements in a database.
- Categorize legal requirements related to energy consumption and energy efficiency.
- Determine a specified period to review legal requirements.
- Specify and document smart energy objectives. Smart indicates that energy objectives should be specified (s), measurable (m), achievable (a), real (r) and time-bound (t).
- Categorize energy objectives related to processes and equipment of plants.
- Determine the relationships between each of the specified energy objectives with energy policy and legal requirements.
- Specify the relationships between energy objectives and energy conservation opportunities (ECOs).
- Identify the related business processes and activities in alignment of achieving the energy objectives.
- Determine the related departments, managers, and employees to perform actions in order to achieve energy objectives.
- Prove a control project process to monitor and evaluate energy action plans considering their time and budget.

- Evaluate action plan effectiveness to specify how many actions could help the plants to achieve their objectives.
- Set an internal communication plan including purpose, channels and of the communication messages in the plants, about EMS.
- Design and implement a suggestion system for EMSs.
- Provide motivation for managers and employees to present suggestions on energy conservation opportunities and improving energy efficiency in the plants.
- If needed, provide an external communication plan to the energy-related stakeholders and partners such as contractors, suppliers, customers, and mother companies (for plants in a holding structure).
- Design a "communication management" business process including sequential activities to plan, perform, monitor, evaluate, and improve communicational activities in the plants.
- Create an integrated database that includes energy-related requirements of new products, processes, equipment, and facilities.
- Create and regularly update a database that includes energy conservation opportunities (ECOs) related to current and new products, processes, equipment, and facilities.
- Maintain records of design activities in a systematic manner that can be easily retrieved in the future.
- Create a knowledge management system including valuable experiences of EMSs that can effectively be used in the future.
- Set and document a detailed work instruction to specify how monitoring and evaluation activities should be performed.
- Establish a comprehensive list of energy-related key performance indicators (KPIs) of processes, services, facilities, and major equipment.
- Specify which areas in the plants involve major energy consumption.
- Identify key factors affecting energy consumption.
- Measure the effectiveness of energy-related action plans to specify success in achieving objectives and targets of the EMSs.
- Set a specified template for energy annual reports of plants to compare actual versus planned energy consumption.
- Document and review a procedure for measuring energy efficiency.
- Use of business intelligence (BI) solutions to present automatic analytical reports.
- Set a plan of measurement system analysis (MSA) to check the accuracy of measurement equipment.
- Set a documented plan evaluating compliance with the requirements of EMSs.
- Provide a list of non-conformities and the related corrections and corrective actions.
- Define measures to monitor and control corrections, as well as corrective and preventive actions.
- Analyze causes of different non-conformities to specify major and common causes of current and potential non-conformities.
- Ensure the effectiveness of corrections, and corrective and preventive actions to prevent the occurrence of non-conformities.

5. Conclusion

Many organizations are being certified by international standards such as ISO 50001, but they do not effectively meet the requirements of EMSs. In this research, a step-by-step approach is proposed to evaluate the performance of implemented EMSs in oil and gas plants in accordance with the requirements of ISO 50001. For this purpose, an AHP is applied to obtain the importance factors of first- and second-level requirements of ISO 50001. Then, an internal auditing process is performed to assess the capability of 11 Iranian oil and gas plants in accordance with the identified requirements. The results show that plants should pay more attention to requirements related to energy planning, implementation and operation, and checking at the first level. In addition, the plants should implement improvement approaches to improve their capability with regard to some of the second-level requirements such as legal requirements, energy objectives, implementation and operation, communication-related requirements, design, checking, monitoring, measurement and analysis, compliance evaluation correction, corrective action, and preventive action.

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