

Original article

Specification of energy assessment methodologies to satisfy ISO 50001 energy management standard



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ARTICLE INFO

Keywords:

ISO 50001

Energy management

Energy assessment

Significant energy users

Energy efficiency

ABSTRACT

Energy management has become crucial for the industrial sector as a structured approach to lowering the cost of production and in reducing the carbon footprint. With the development of ISO 50001 standard, energy management has enticed the attention of upper level management in terms of continuous improvement. The ISO 50001 standard requires an intensive energy assessment process to identify SEUs and EnPI, based on which target energy reductions can be realized. Such an energy assessment approach can be easily developed based on the IAC energy assessment protocol and other approaches so as not to “re-invent” the wheel but instead focus and refine the process to generate knowledge and information that would assist manufacturers to initiate and determine the focus areas for energy reduction and develop the ensuing documentation. The aim of this work is to develop an energy assessment methodology and reporting format tailored to the needs of ISO 50001. The developed energy assessment methodology integrates the energy reduction aspect of an energy assessment with the requirements of Sections 4.4.3 (Energy Review) to 4.4.6 (Objectives, Targets and Action Plans) in ISO 50001, thus enabling facilities to reduce the time and other resources required for facilitating the implementation of ISO 50001.

Introduction

World energy consumption

The Industrial revolution (1760–1840) changed the nature of manufacturing processes by using mechanical energy. Machine tools started replacing hand production methods which increased the need for energy. The manufacturing sector became a dominant fuel for economic growth worldwide. This transition led to significant energy use in the world. According to the U.S. Energy Information Administration (EIA), total world energy usage for the year 2010 was 524 quadrillion British Thermal Unit (BTU) and is projected to increase to 630 quadrillion BTU by year 2020 and 820 quadrillion BTU by 2040 [1]. The industrial sector in particular uses more energy than any other

sector. According to Energy Information Administration (EIA), the industrial sector is primarily comprised of manufacturing (food, paper, chemicals, refining, iron and steel, nonferrous metals, metallic minerals and others) and nonmanufacturing (agriculture, mining and construction). In United States, the total energy use in the year 2014 was 98.3 quadrillion BTU [1]. The major energy sources consumed in the United States are petroleum (oil), natural gas, coal, nuclear and renewables.

Need for energy conservation

Energy conservation refers to reducing energy consumption through using less of an energy service whereas energy efficiency refers to using less energy for a constant service. It has been observed that there is a significant growth in energy consumption globally with respect to time.

Abbreviations: SEU, Significant Energy User; EnPI, Energy Performance Indicators; kW, kilowatt; kWh, kilowatt hour; Hp, horse power; BTU, British Thermal Unit; ISO, International Organization for Standardization; ANSI, American National Standards Institute; HVAC, Heating, Ventilation, and Air Conditioning; MSE, Management System for Energy; PDCA, Plan-Do-Check-Act; EIA, Energy Information Administration; GHG, Green House Gases; MMT, Million Metric Tons; ASME, American Society for Mechanical Engineers; EnPI, Energy Performance Indicator Tool; EN 16001:2009, Energy Management System Standard; AR, Assessment Recommendation; IAC, Industrial Assessment Center; EEAP, Enhanced Energy Assessment Process; ASHRAE, American Society of Heating, Refrigerating and Air-Conditioning Engineers; VSD, Variable Speed Drives; LBNL, Lawrence Berkeley National Laboratory; M & V, Measurement and Verification; EMS, Energy Management Systems; MMBTU, Million Btu

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<http://dx.doi.org/10.1016/j.seta.2017.09.003>

Received 28 August 2016; Received in revised form 2 June 2017; Accepted 1 September 2017

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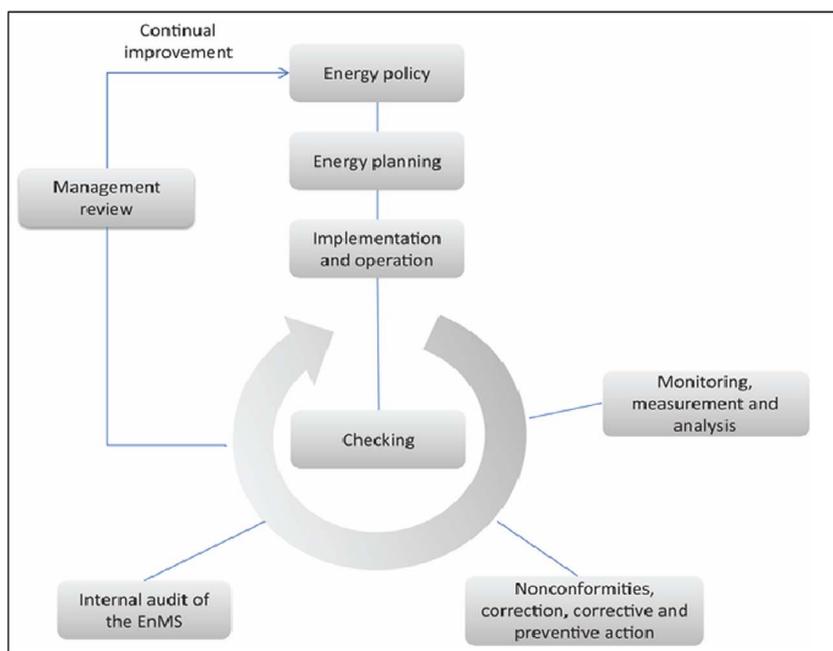


Fig. 1. Energy Management System Model for ISO 50001 [20].

Table 1
ISO 50001 requirements and information generated by different assessment methods [24,11,17].

ISO 50001 Energy Planning	Requirements	ASME Methodology	IAC Methodology	LBNL methodology
4.4.3 Energy Review	a) Identify Current Energy Source	Yes	Yes	Yes
	b) Evaluating Energy Consumption	Yes	Yes	Yes
	c) Identifying SEUs	No	No	No
	d) Variables effecting SEU	No	No	No
	e) Identifying EnPIs for facility	No	No	No
	f) Estimate future energy consumption	No	No	No
	g) Identifying Opportunities	Yes	Yes	Yes
4.4.4 Energy Baseline	a) Establishing Facility level Baseline	No	No	No
4.4.5 Identifying EnPIs	a) Identifying EnPIs for SEU's	No	No	No
4.4.6 Energy Objectives, Targets and Action Plans	a) Energy Objectives	No	No	No
	b) Energy Targets	No	No	No
	c) Action Plans for SEU's	No	No	No
	d) M & V Plans	No	No	No

The by-product of this growth in energy consumption is the increased emissions of Green House Gas (GHG) causing global warming. Many nations have started focusing on energy conservation and energy efficiency as a way to reduce greenhouse gases.

According to the manufacturing energy use and GHG emissions analysis in the United States [2], total manufacturing GHG combustion emissions were equal to 1261 Million Metric Tons (MMT) of carbon dioxide in 2006. Out of this, 619 MMT or 49% was from off-site generation of electricity and steam and remaining 643 MMT or 51% was from onsite combustion [2].

There are several reasons for reducing the energy intensity apart from environmental objectives. Due to increased globalization and outsourcing, manufacturing facilities need to be highly competitive. One way of being a market leader is to reduce the product costs thereby increasing their dollar productivity. Energy is one of the key factors in reducing operating costs. Energy conservation is also one of the pillars of sustainability and sustainable development. Over-dependence on non-renewable fossil fuels for various types of energy uses results in rapid decrease in their reserves. Studies show that if the world continues to consume fossil fuels at the 2006 rates, the reserves of oil, coal and gas will last a further 40, 200 and 70 years, respectively [3].

How to conserve energy?

Conserving energy can be done in several ways, ranging from simple no-cost behavioral changes to using sophisticated technologies. Behavioral change involves educating the people in the importance of conserving energy. It is based on creating awareness among the people and trying to develop simple habits to save energy.

Several technologies have been developed to address energy savings. The primary questions for the industry in using these technologies are whether the technologies available in the market are suitable and how much can they save in terms of energy and cost. Another barrier for implementing new technologies in the industrial sector is the investment and the rate of return. This has led to energy assessments whose primary objective is to evaluate the existing systems and arrive at recommendations for saving energy.

With increases in energy prices, industrial facilities are constantly undergoing changes in their systems in order to lower the overall cost of production. Similarly, energy management systems and application of ISO 50001 standard can significantly help to save energy. Manufacturing facilities are familiar with ISO 9001 and ISO 14000 standards and will be able to easily adopt the application of the energy assessment standards. However, the energy assessment procedures associated with energy management systems need to become more focused and streamlined in order to directly address the needs of the

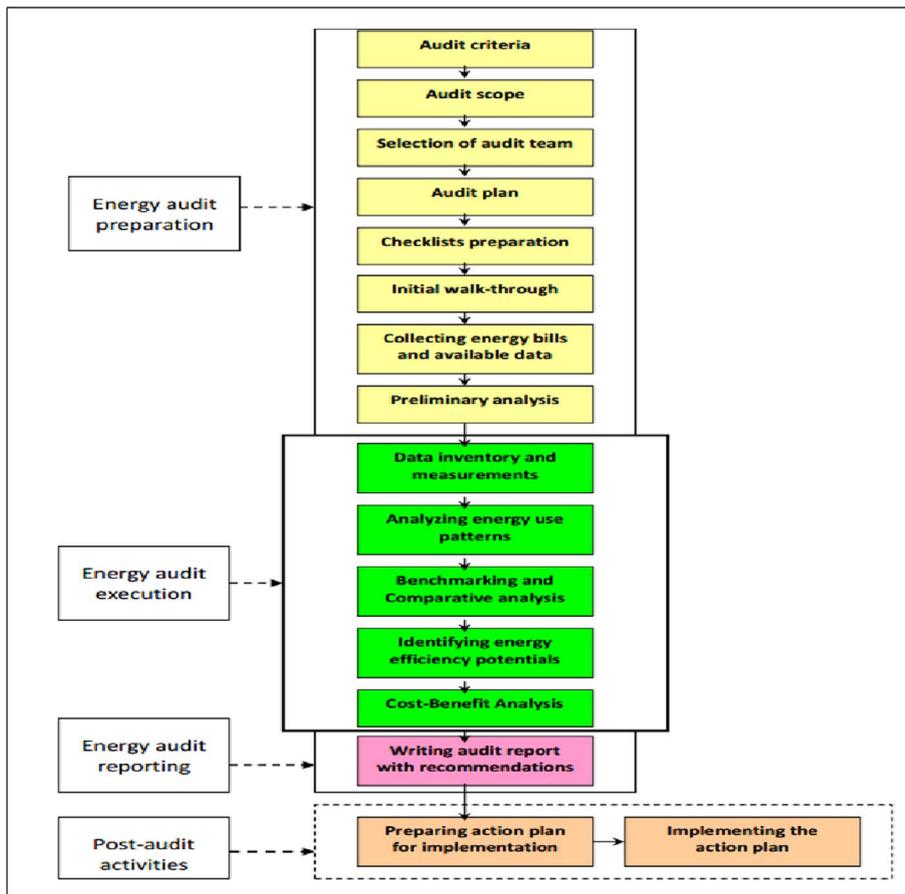


Fig. 2. Overview of Energy Assessment Process [17].

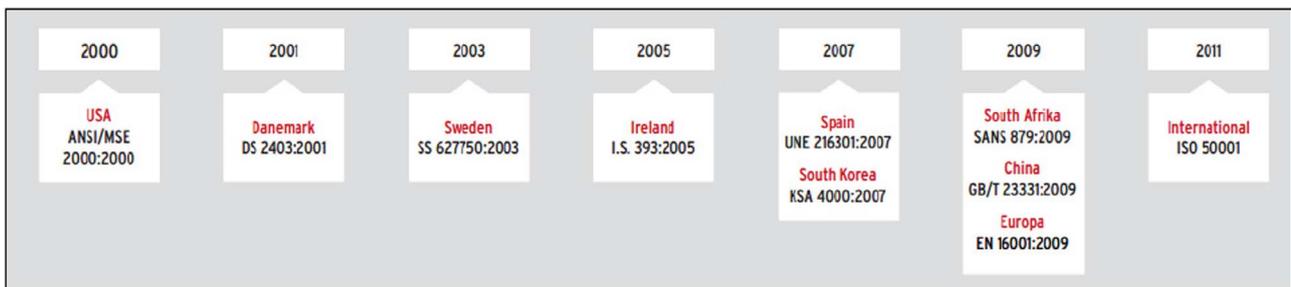


Fig. 3. Evolution of Energy Management Systems [18].

energy management standard.

Introduction to energy management

Energy Management focuses on planning and execution of energy related objectives such as resource conservation, carbon footprint reduction and cost savings. The VDI Guideline 4602 defines energy management as the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives [4]. Continuous improvement is a key requirement in any energy management system and it can be achieved using the Plan-Do-Check-Act (PDCA) cycle.

The PDCA cycle consists of four stages namely Plan, Do, Check and Act which can be used in systems to assist facilities to address processes to find solutions to problems. After the completion of the Act stage, the cycle moves back again to the Plan stage, giving the PDCA cycle the characteristics of continuous improvement [5].

Energy management standards

ANSI/MSE 2000:2008

American National Standards Institute (ANSI)/ Management System for Energy (MSE) 2000:2008 is an energy management standard developed by Georgia Institute of Technology. This standard specifies requirements for MSE that helps an organization to take a systematic approach towards continuous improvement in energy performance [6]. According to the standard, energy performance may include reduction in energy intensity, increasing use of renewable energy resources, and reduction in energy costs. This management system for energy covers the supply, demand, reliability, purchase, storage, use and disposal, as appropriate, of primary and secondary energy resources. According to this standard, organizations need to specify reasonable performance improvement goals based on their energy management planning process. ANSI/MSE 2000 was used as one of the resources for developing ISO 50001 energy management standard.

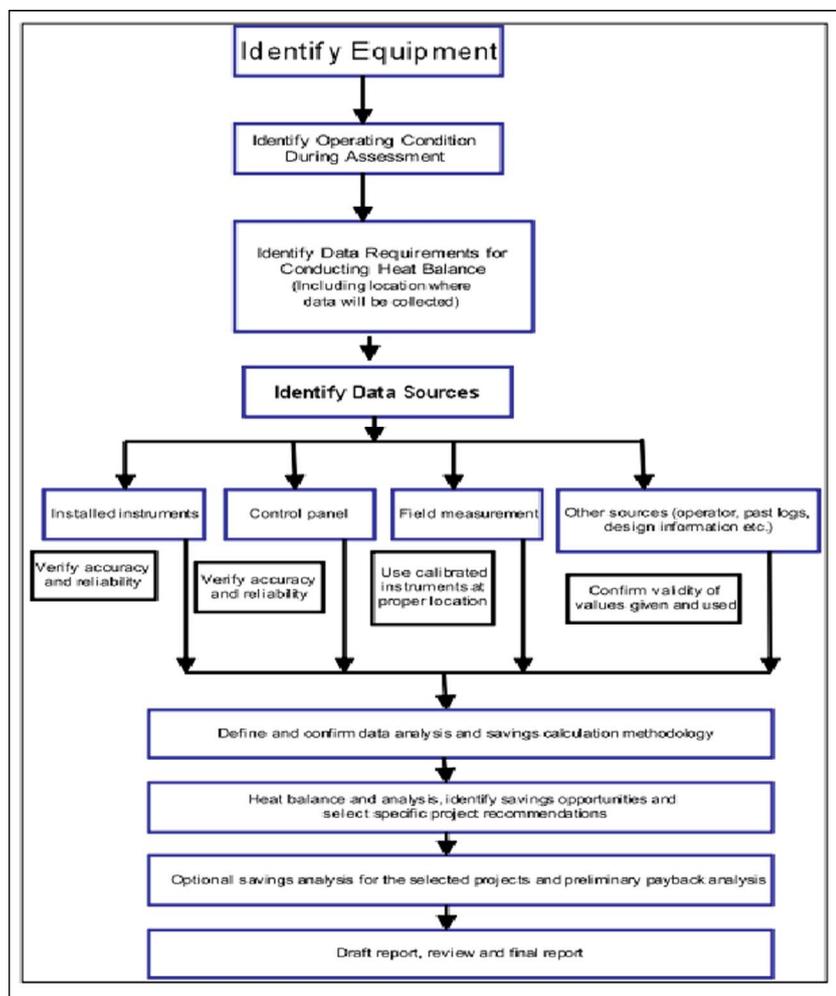


Fig. 4. ASME assessment methodology for process heating [27].

EN 16001:2009

EN 16001:2009 is the energy management standard developed by British Standards Institute. The standard ensures that energy management is integrated into the organizational business structure, so that organizations can save energy, costs and improve energy and business performance. The primary objective of this standard is continuous improvement in energy performance. EN 16001:2009 provides a range of possible methodologies that could be used in both satisfying the standard and ensuring the development and operation of an effective and documented Energy Management System. This standard will not establish any requirements for energy performance nor does it guarantee optimal energy outcomes [6].

ISO 50001 energy management standard

ISO 50001 is the latest energy management standard which is a successor of ANSI/MSE 2000 and EN 16001. The standard guides an organization to develop and implement a policy to identify significant areas of energy consumption and commit to energy reductions. The standard does not require any specific performance criteria similar to any other management system standards published by the ISO. ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management [8,21]. Energy assessment is an integral part of the process for complying with the standard.

ISO 50001 specifies requirements applicable to energy use and

consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance as shown in Fig. 1. It is applied to all the variables that affect energy performance [20]. This standard provides methodology for continual improvement in energy performance without explicitly specifying any performance criteria that has to be satisfied with respect to energy. This standard is based on Plan-Do-Check-Act (PDCA) continual improvement framework in the context of energy management. In Fig. 1, the activities under “Implementation and operation”, and “monitoring, measurement, and analysis” are being analyzed in this paper.

Literature review

Energy assessment procedures

Energy assessment is a detailed evaluation of how a facility uses energy, what the facility pays for energy, and finally, a recommended program for changes to operating practices or energy consuming equipment that will cost effectively reduce energy consumption adjusted for changes in production and weather [6,10,16].

Industrial Assessment Center (IAC) is a program funded by Department of Energy to conduct no-cost energy assessments for small and medium scale manufacturing facilities across the United States. The IAC program is a university based program and currently there are twenty-eight active industrial assessment centers located in various universities. The energy assessment process utilized by the IACs is detailed and specific to the development of energy efficiency

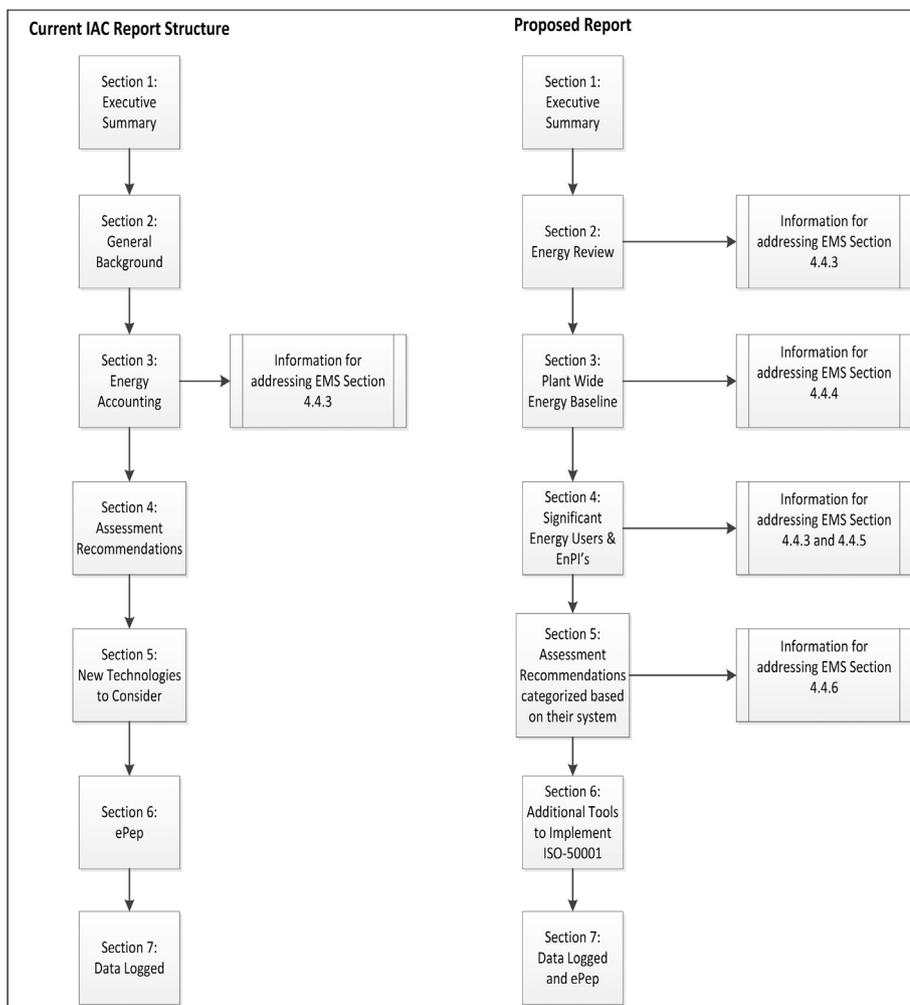


Fig. 5. Current and Proposed Report Structure.

recommendations and associated energy systems that provide the most energy savings at a desirable return on investment. Each Energy Assessment Recommendation (AR) has detailed formulae associated with its development, based on rigorous principles of energy systems operational characteristics [24].

The Enhanced Energy Assessment Process (EEAP) [9] was developed by West Virginia University Industrial Assessment Center Save Energy Now Project (now known as “Better buildings Better Plants”) program funded by the Department of Energy. The energy assessment process utilized by the IACs is similar to EEAP except for the detailed analysis leading to investment grade recommendations.

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) defines three levels of energy assessments. Each assessment level builds on the previous level. As assessment complexity increases, so does the thoroughness of the site assessment, the amount of data collected and details provided in the assessment report. One of the primary limitations of ASHRAE energy assessment procedure is that it mostly addresses the needs of residential and commercial building sectors [10].

The American Society for Mechanical Engineers (ASME) has developed standards for conducting energy assessments at industrial facilities and these standards are accredited by the American National Standards Institute (ANSI). ASME has separated the major energy consuming equipment in industries under four systems and developed their individual energy assessment procedures [11].

The effective implementation of ISO 50001 in the context of scarce resources in industry for sustainable development is addressed using a six sigma approach [25]. The application of ISO 50001 for

implementation of sustainable energy action plans combining the applicable energy indicators that are measurable using a well-developed methodology has been found to be beneficial [26]. The incorporation of the ISO 50001 standard in terms of application in sports management, particularly in sports stadia has been found to be challenging due to the variability of the inherent parameters that govern the operational characteristics of the system [27]. The implementation of ISO 50001 standard utilizing software attributes and procedures has been shown to successfully decrease the energy use and provide environmental benefits [28].

Importance of research

One of the primary objectives of implementing ISO 50001 is to enable continuous improvement in energy efficiency in any facility. In order to achieve continuous improvement, the support of the upper level management is critical. Often many energy efficiency improvements do not result in projected savings due to lack of management’s commitment towards energy efficiency. None of the energy assessment procedures can fully address the requirements of the ISO 50001 energy management standard [7]. Hence there is a real need for energy assessment processes that directly address the ISO 50001 standard. Table 1 provides the specific requirements of the energy planning section of ISO 50001 and the information generated by ASME energy assessment methodology, IAC energy assessment methodology, LBNL methodology, and the methodology developed and presented herein.

The Table 1 clearly shows a gap in existing energy assessment methodologies in terms of ISO 50001 and the necessity for developing a

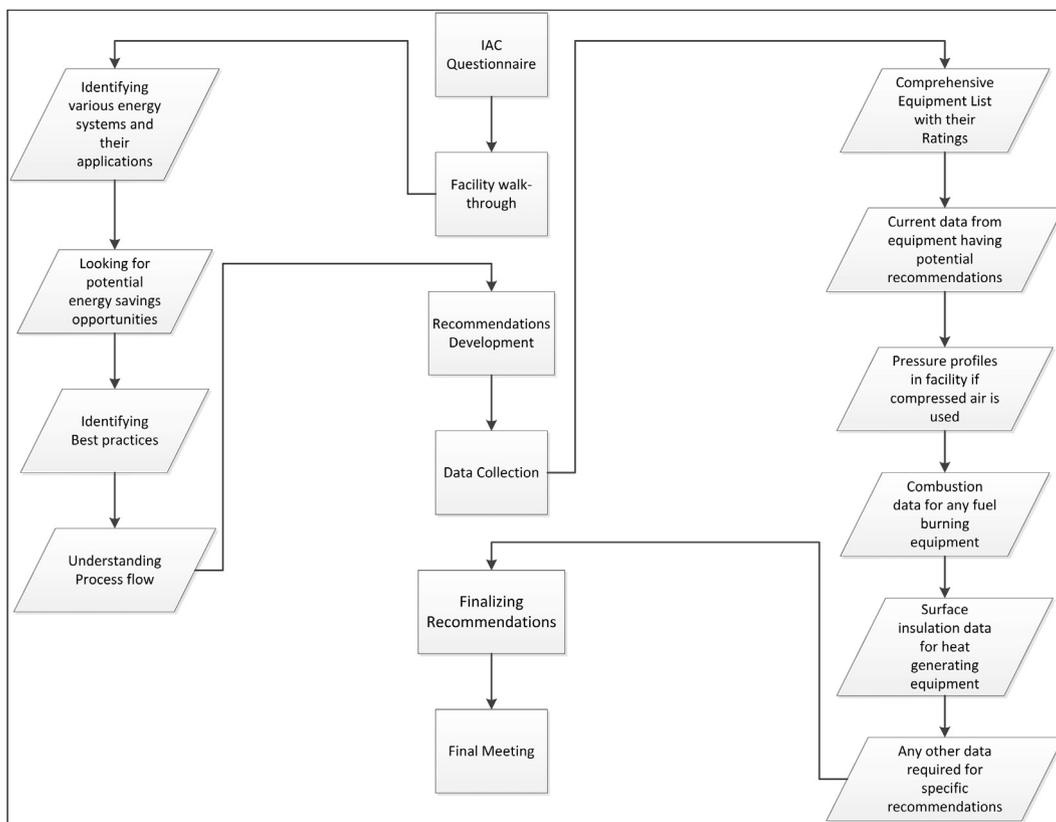


Fig. 6. IAC Energy Assessment Process.

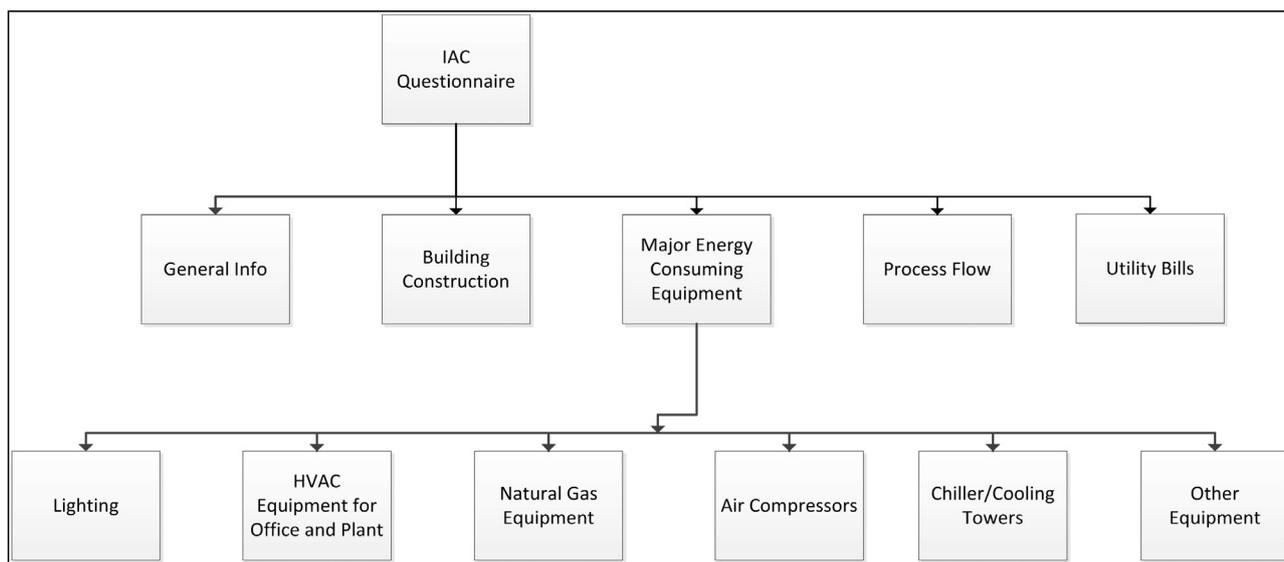


Fig. 7. Overview of Regular IAC Questionnaire.

focused energy assessment methodology. This gap will likely result in increased cost and time invested in energy assessment for manufacturers as they attempt ISO 50001 certification. The primary objective of the research reported in this paper is to develop an energy assessment methodology for integrating the energy planning section of ISO 50001 with standard assessment procedures and to develop a reporting format which acts as a supporting document for implementation of ISO 50001.

Energy assessment methodologies

The concept of energy assessment was born shortly after the oil energy crisis in 1970's [16]. It is one of the measures of efficiency in a manufacturing process, thus leading to interest in energy performance of machines and associated manufacturing systems [12]. The type of energy assessment conducted depends on the size of the facility and the level of accuracy needed in the energy efficiency recommendations. But in general, the energy assessments for industrial facilities are classified into two categories namely preliminary or walk-through assessment and a diagnostic assessment [13]. The primary objectives of a walk-

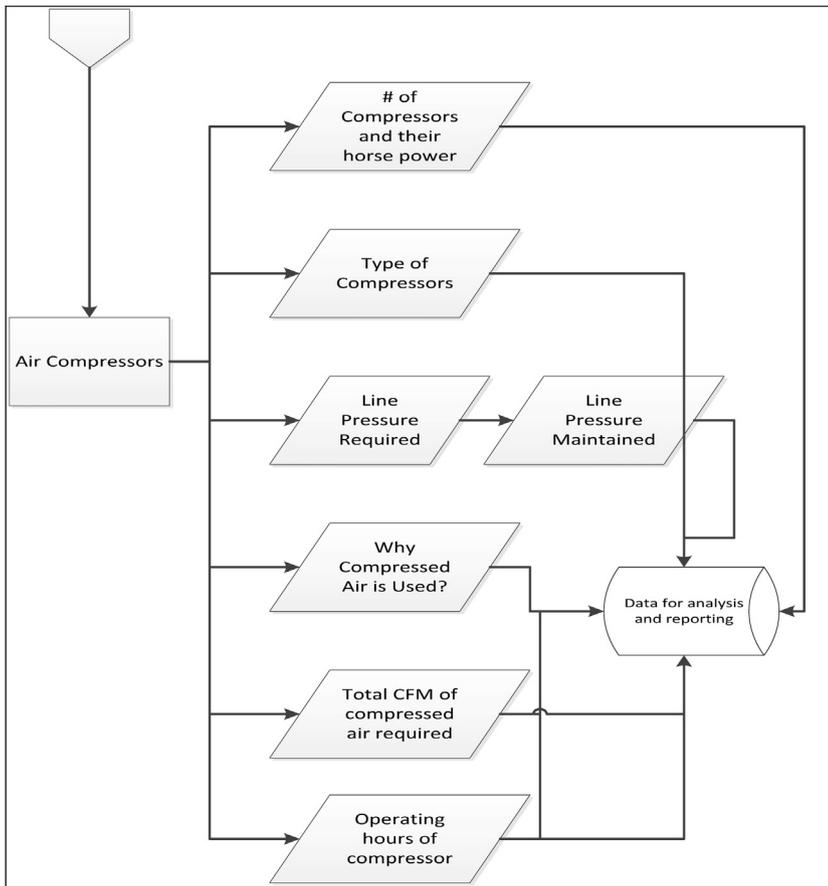


Fig. 9. Data Collected for Compressed Air System.

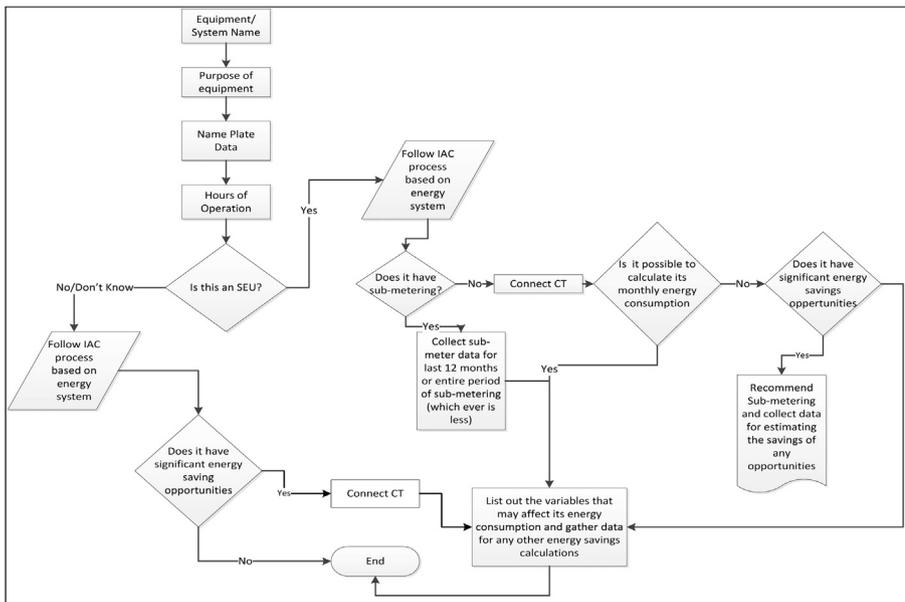


Fig. 10. Proposed data collection procedures for electrical equipment.

energy users and develop energy performance indicators. These requirements are not addressed adequately in any of the currently available energy assessment procedures. Fig. 4 shows the ASME energy assessment methodology for process heating.

Proposed energy assessment methodology

The energy assessment methodology that has been developed follows a reverse engineering approach. The requirements in ISO 50001

for Sections 4.4.3, 4.4.4, 4.4.5 and 4.4.6 (energy review to objectives, targets and action plans) are clearly mentioned in the standard. Based on the analysis of these requirements, a modified version of the energy assessment report has been developed. Based on the modified report format, the methodology for conducting an energy assessment is developed. A series of flow charts are designed to assist with the energy assessment and the reporting process for enhanced implementation of ISO 50001. The following aspects have been newly developed and incorporated into the utilization of the currently available IAC energy

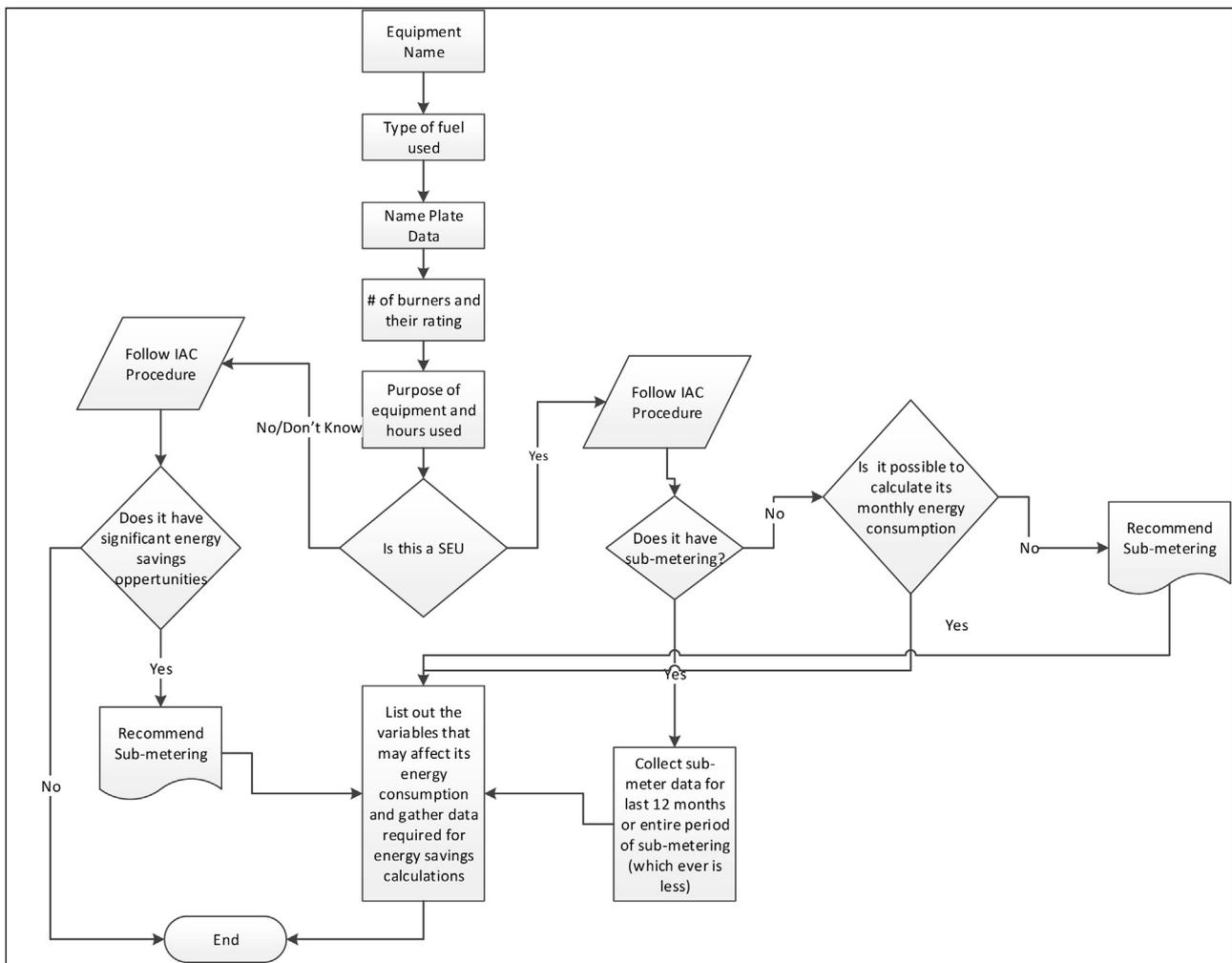


Fig. 11. Proposed data collection process for fuel burning equipment.

assessment and reporting methodology.

1. The questionnaire for obtaining general information from the plant has been modified significantly.
2. A section has been developed to depict significant energy users (SEU) and information to evaluate their performance using Energy Performance Indicators (EnPI).
3. The verification aspects related to sub metering have been incorporated.
4. In the reporting phase, the following have been included.
 - Energy review section
 - Energy baseline development at the facility level
 - The significant energy users (SEU) and EnPI
 - The verification methodology for validating the energy savings
 - Tools to help implement ISO 50001

The flow charts are designed for depicting the new assessment methodology that will integrate the energy assessment and reporting structure with ISO 50001 (Sections 4.4.3–4.4.6) requirements. These flow charts are divided into two basic categories:

- Flow charts for data collection process
- Flow charts for report development

Fig. 5 compares the existing procedure to generate an IAC energy assessment report, after a one day energy assessment is performed at the manufacturing facility, with respect to the proposed report catering

to the ISO 50001 standard. This involves a series of processes resulting in the final report which is shown in Fig. 6.

As shown in Fig. 6, the IAC energy assessment methodology starts with a meeting to discuss the contents of questionnaire. It gives the assessment team an understanding of the energy consumption in the facility. The questionnaire consists of facility information such as operating hours of the facility, energy consumption and various types of energy systems including motors, Heating, Ventilation, and Air Conditioning (HVAC), compressed air, boilers, chillers and cooling towers.

Fig. 7 shows the components of the IAC energy assessment questionnaire. The general information portion consists of elements such as facilities production schedule, annual production rate, raw material used, and utility bills (for all types of energy source used). The most important information gathered in this information section is utility bills of the facility for a minimum of twelve months. These bills are used for the energy accounting section of the current report format. The proposed methodology uses the existing IAC questionnaire as a base and builds up on it. It requires exhaustive modifications in the general information section of questionnaire and data collection process of the regular energy assessment. The recommended information that has to be collected for the proposed report is shown in Fig. 8.

There are two modifications done to the process of collecting general information. The first modification done to this section is the collection of all utility bills for baseline energy consumption development if the facility personnel determine that a particular twelve month period is a good indicator other than latest twelve month data. Usually in a regular IAC assessment, the recent twelve month utility bills is obtained

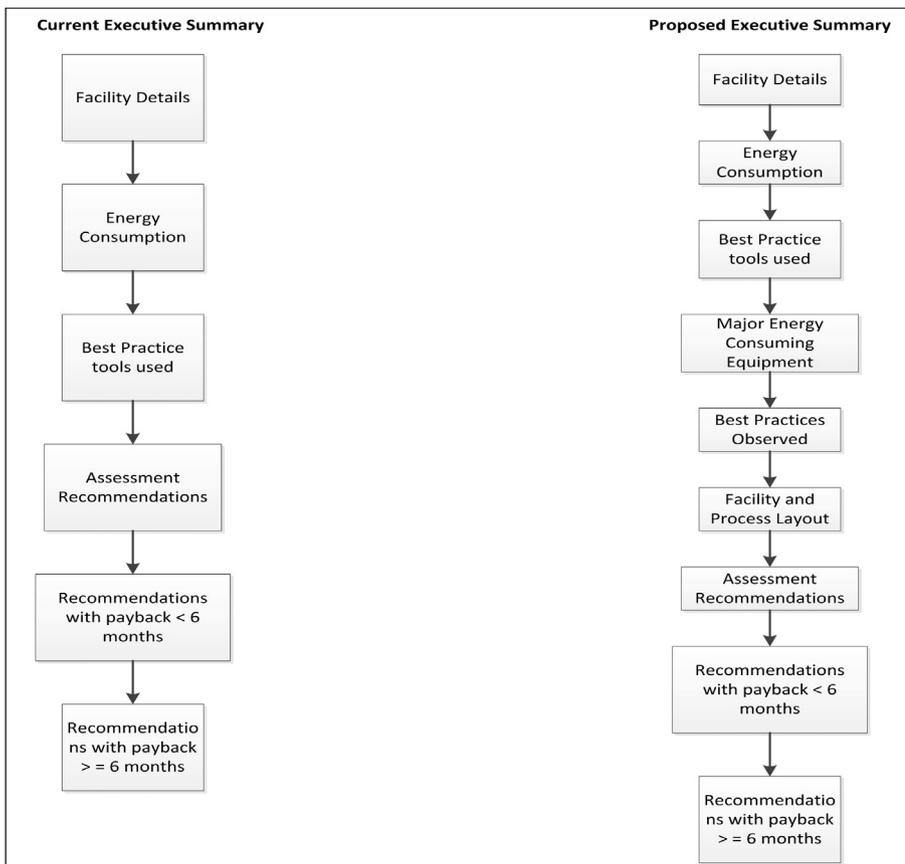


Fig. 12. Current and Proposed Executive Summaries.

and the primary objective for that is to calculate the cost of energy stream per unit. However, according to ISO 50001, it is not mandatory to use the latest twelve month data for developing facility wide baseline. The second modification done to this process is to add the variables that can affect the facility’s energy consumption. These variables can be production quantities, raw material used, scrap generated, heating degree days, cooling degree days or any other parameter that can significantly affect the facilities energy consumption. It is required to have the data for the period of the energy baseline.

Once the information is collected, the second phase of an assessment is a walk-through tour of the facility. There are no changes needed in this part of the assessment, as the information gathered will be similar to that needed to generate the proposed report. After the tour, the energy team will have a group discussion on the findings of the tour and possible energy efficiency improvement opportunities that should be evaluated further. This is called the assessment recommendations development phase, as shown in Fig. 6. Once the possible recommendations are finalized, the team breaks into groups to collect relevant data for further analysis of proposed recommendations. The data collection involves measuring a series of parameters and identifying the name plate data of the equipment on which the assessment recommendations are expected to be generated.

The next four flow charts show the current IAC methodology for data collection of various types of energy systems and later a data collection methodology for the proposed report is presented. The methodology calls for current methodology based on the requirements in the facility.

As an example, Fig. 9 shows the flow chart for the data which will be collected during the energy assessment for the compressed air system. The basic information in compressed air system is the number of compressors, type of compressors, size of each compressor in horse power (Hp) or Kilowatt (kW), type of control on these compressors (load/unload, inlet modulation, VSD etc.), pressure setting on the

compressors and the minimum pressure required to operate the equipment of the plant. Based on the information obtained, subsequent information is collected during the assessment to get an in-depth understanding of the compressed air system. During the walk-through session of the facility, any other observations related to potential energy savings opportunities are noted down for further examination.

Fig. 10 shows the data collection system used for electrical equipment as significant energy users and to evaluate their performance using Energy Performance Indicators (EnPIs). The initial phase is to know the primary purpose of the equipment and operating characteristics in terms of hours operated and nameplate information. The next step is to decide whether the equipment can be a significant energy user or not. If the equipment is a Significant Energy User (SEU) then the IAC protocol is used for data collection.

The next step is to verify if the system has any sub-metering or if it is possible to estimate the energy consumption of the equipment on a monthly basis. If there is sub-metering, then it is necessary to collect the sub-metered data for a period of minimum 1of 2 months or to the maximum available time period if the sub-metering system is less than 12 months old. If there is no sub-metering, it is advised to connect energy measurement transducers or fuel flow meters to the equipment to monitor its energy consumption. After the transducers or fuel flow meters are in place, the next step is to decide whether it is possible to estimate its monthly energy consumption with the available data. If the energy consumption can be estimated, then a list of the significant factors or variables that can affect the energy consumption of the equipment should be determined. This information can be obtained easily from the instruction manual of the equipment or a discussion with the operators of the equipment. If it is not possible to estimate the monthly energy consumption, then the next step is to check if it has any significant energy savings opportunities or not. If there are significant energy savings opportunities, then the installation of sub-metering would be recommended.

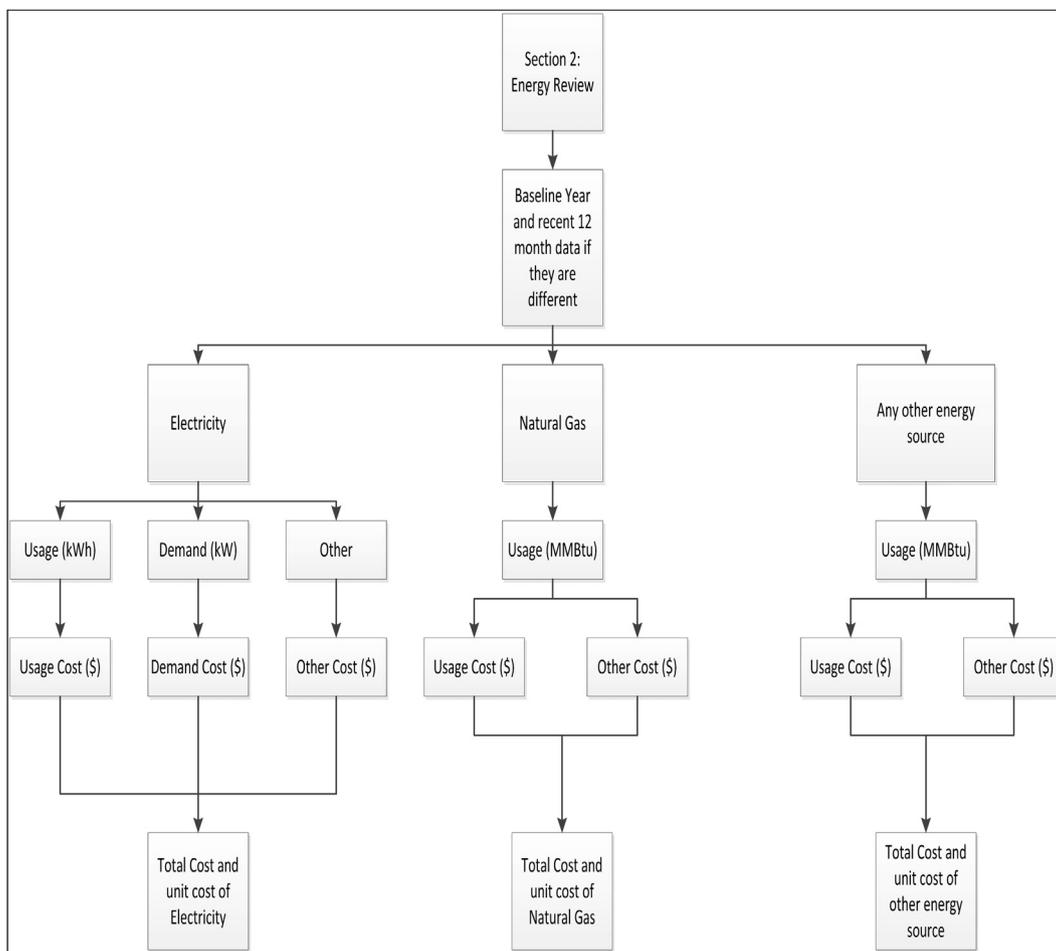


Fig. 13. Energy Review.

Fig. 11 shows the basic methodology for collecting necessary data in the case of fuel burning equipment. The approach followed here is similar to the one followed for collecting data for electrical equipment. Once data collection methodology mentioned herein is followed, all the required information to develop a new format of report as shown in Fig. 5 will be available.

As shown in Fig. 5, the first section of the report is the executive summary. There are no significant changes made in this section in the proposed report as compared to the existing report other than combining the background from the IAC report with executive summary creating only one section. The new executive summary is shown in Fig. 12.

Section “Literature review” of the proposed report includes the energy review section of ISO 50001. It consists of the energy consumption of the facility. ISO 50001 requires that all forms of energy entering into facilities to be accounted. Fig. 13 shows the energy review of the proposed section and this is similar to the existing format of reporting other than adding the energy consumption data for the baseline year.

Section “Proposed energy assessment methodology” is a new addition to the existing report format. It deals with the energy baseline development at the facility level. Energy Performance Indicator Tool (EnPI) [22] is used to develop the baseline for all the energy sources at the facility. Fig. 14 shows the inputs and outputs given to the tool for baseline development. All the inputs along with the regression models are presented. These regression models can be used to estimate the future energy consumption of the facility [23].

The ISO 50001 standard does not specify any criteria for model selection in terms of R-Square value or model “p” value. Any of the

variables shown above may be left out of the model if the variable would not affect consumption of the energy source. This same baseline for facility methodology is used to develop the baseline for all the identified significant energy users.

Section “Results and discussions” of the proposed report is “Significant Energy Users (SEU) and EnPIs”. Fig. 15 shows the documenting methodology for reporting SEU’s and EnPIs.

Identifying EnPIs can be a complicated task and requires extensive analysis. Most common EnPIs for various systems are given in Table 2. This list of EnPIs can be used in the initial phases. The process flow mentioned in the flow chart can also be used as a gap analysis tool during the initial phase of EnPI selection [22].

Section “Conclusion” is the assessment recommendations section. In the current format, all the recommendations are kept together and are sorted in the descending order of their cost savings. In the proposed approach, energy savings recommendations are grouped according to their corresponding energy systems. These sub-groups are arranged in the descending order of the cumulative savings of all the recommendations in that group. One major addition in this section is including the verification methodology for validating the savings, and the effect of particular recommendations on system level EnPIs and facility level EnPIs. Fig. 16 shows the assessment recommendations part of any system.

Section “Acknowledgment” of the proposed report deals with tools which can help in implementing ISO 50001 and Section “References” consists of all the data collected during the assessment process and an energy profile model for the entire plant developed using Plant Energy Profiler (PEP) software as shown in Fig. 17.

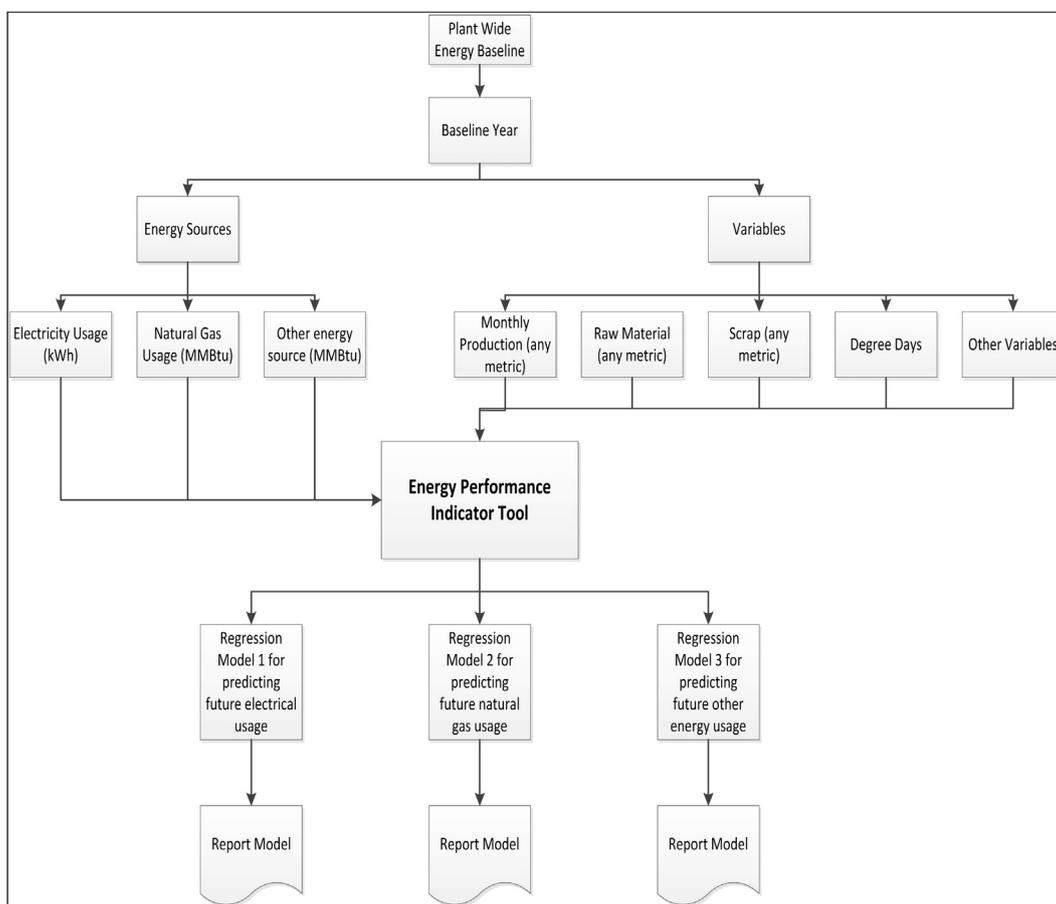


Fig. 14. Baseline Development at Facility Level.

Results and discussions

Based on the above mentioned energy assessment methodology, an assessment was conducted for a manufacturing facility which is in the process of implementing ISO 50001. By following the new assessment process designed in Fig. 11, the Heat Treat department was identified as the significant energy user at the facility and was considered for further analysis. All data on the natural gas equipment in the heat treat department was collected. The department is under un-interruptible natural gas supply line and has a dedicated gas meter. Hence the meter data was used for the analysis in the new report.

Table 3 shows the results obtained from the developed methodology.

Three spreadsheet based supporting files were also presented to the facility. Supporting files were provided to the facility so that any changes that might be required in future can be easily implemented by its personnel. The documents presented to the facility were:

1. Energy assessment report with modified format to address ISO 50001
2. Comprehensive spreadsheet file addressing Section “Results and discussions” of ISO 50001
3. Energy baseline file (EnPI tool)
4. SEU performance monitoring file (EnPI tool)

A new report was created for a manufacturing facility based on the new assessment methodology and three spreadsheet files were also submitted to the facility as supporting documents. The calculations for various parameters mentioned in the report are performed by using spreadsheets. The key features of the report are,

1. Energy Review: Addressing the section of ISO 50001
2. Energy Baseline: Addressing the section of ISO 50001
3. SEU’s and EnPI: Addressing the section of ISO 50001
4. Assessment Recommendations: Addressing the section of ISO 50001

The EnPI developed as a result of this process were found to be suitable for the facility and hence the same EnPI were used for the ISO 50001 certification assessment. Based on the new report, the facility selected the “Heat Treat” system as its significant energy user and the assessment recommendations in the report were documented as the opportunities for improvement. The variables used to develop regression models to predict future energy estimates were also accepted by the facility personnel and the models developed for various energy sources (electricity, natural gas and diesel) proved to be adequate for the estimation of future energy consumptions based on the ISO 50001 standard.

Apart from the assessment report, the spreadsheets presented to the facility includes several key templates that helped them to develop objectives and targets for SEUs, equipment calibration records and measurement and verification plans. The project tracking tool provided as a part of spreadsheet was used to keep track of on-going projects with respect to the PDCA cycle of ISO 50001.

Feasibility studies were being performed at the facility for the other assessment recommendations to improve their energy performance. Recommendations on the compressed air system are presently under the review of maintenance department for implementation.

Energy assessment report to cater to ISO 50001

The IAC energy assessment report has been modified in such a way that it addresses all aspects of the energy planning section of the ISO

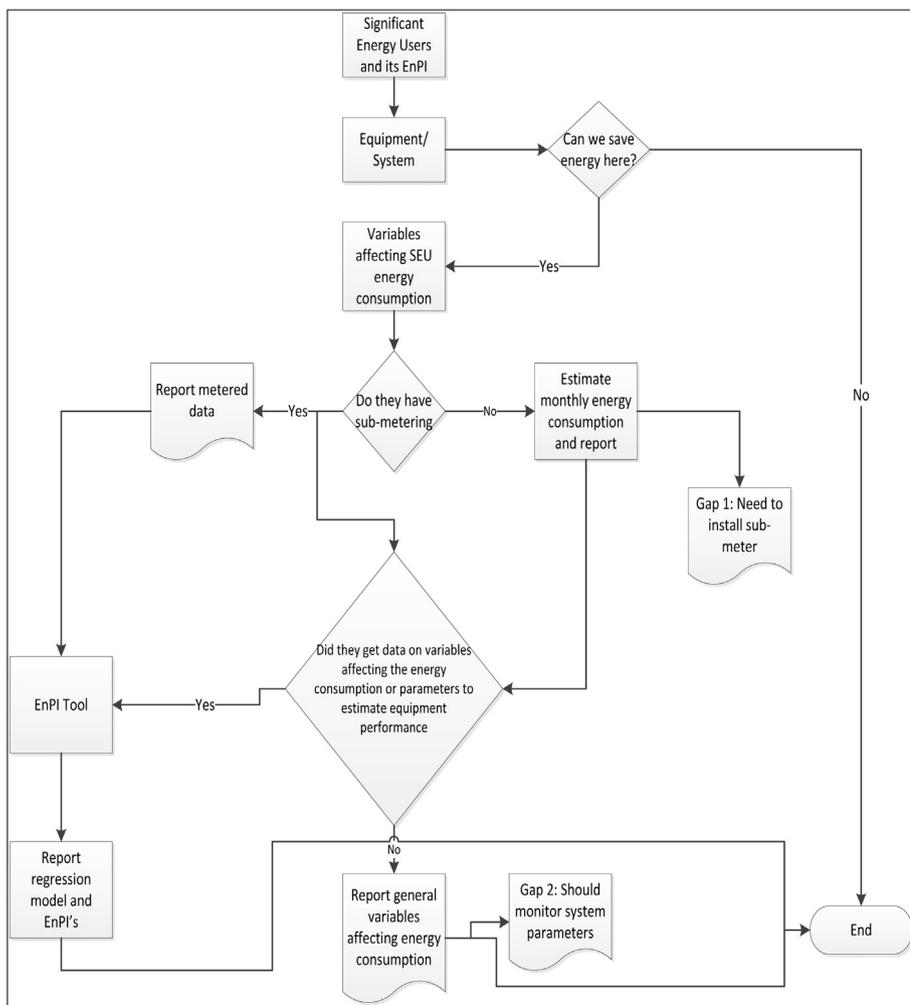


Fig. 15. Significant Energy Users and Energy Performance Indicators.

Table 2
Checklist for Various Types of EnPI's [22].

Type	Output, units	Energy Input, units	EnPI
Plant	Mass: lb., ton	Btu	Btu/lb, Btu/ton
	Units produced: autos, widgets	Btu	Btu/widget
	Clients served: customers	Btu	Btu/customer
	Mass: lb., ton	kWh	kWh/lb, kWh/ton
	Units produced: autos, widgets	kWh	kWh/widget
	Clients served: customers	kWh	kWh/customer
Production line	Mass: lb., ton from line	Btu input to line	Btu/lb, Btu/ton for line
	Units produced: autos, widgets on line	Btu input to line	Btu/widget for line
	Clients served: customers on line	Btu input to line	Btu/customer for line
	Mass: lb., ton from line	kWh input to line	kWh/lb, kWh/ton for line
	Units produced: autos, widgets on line	kWh input to line	kWh/widget for line
	Clients served: customers on line	kWh input to line	kWh/customer for line
Process	Mass: lb., ton through process	Btu input to process	Btu/lb, Btu/ton for process
	Units produced: autos, widgets in process	Btu input to process	Btu/widget for process
	Clients served: customers in process	Btu input to line	Btu/customer for process
	Mass: lb., ton through process	kWh input to line	kWh/lb, kWh/ton for process
	Units produced: autos, widgets in process	kWh input to line	kWh/widget for process
	Clients served: customers in process	kWh input to line	kWh/customer for process

50001. The modified table of contents is shown in Fig. 18.

As discussed in the methodology, the main modifications done to the report are including energy baseline information, significant energy users, energy performance indicators and segregation of assessment recommendations based on the energy system and their influence on significant energy users.

Conclusion

The proposed energy assessment and reporting methodology has significant benefits in terms of implementation of ISO 50001 in enterprises. The implementation of ISO 50001 requires commitment of personnel time and cost and this research paves the way for utilizing a

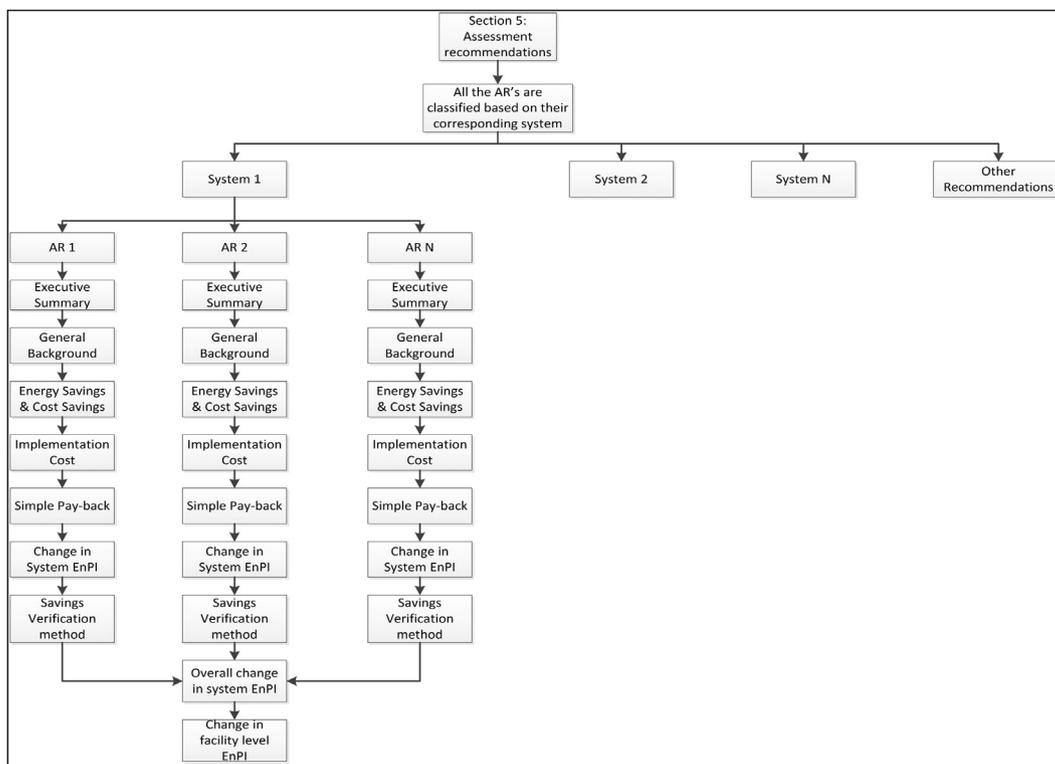


Fig. 16. Assessment Recommendations.

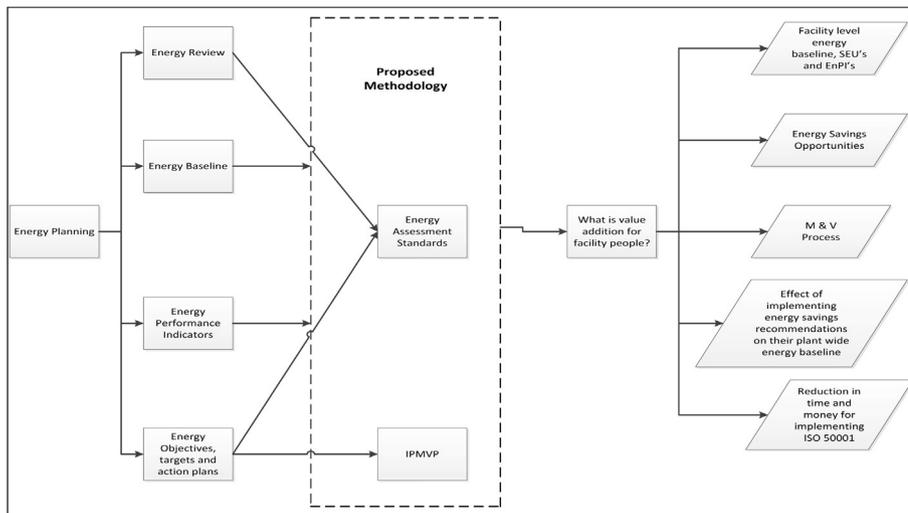


Fig. 17. Final results for proposed methodology.

Table 3
Results from the Various Procedures Developed in Methodology Section.

Requirement	Process Figure	Result	Usage of Data Obtained
General Information SEU – Electric	Fig. 8 Fig. 10	No system selected	In Reporting Analysis/ Reporting Analysis/ Reporting
SEU-Natural Gas	Fig. 11	Heat Treat	Analysis/ Reporting
Energy Review	Fig. 13	Utility Data	Analysis/ Reporting
Baseline Development	Fig. 14	Data collected for relevant variables	Analysis/ Reporting

streamlined approach to simplify the overall process, thus saving resources. The implementation of ISO 50001 in an enterprise is usually a lengthy process that requires checks and documentation at several levels and the proposed methodology will enable the incorporation of existing methodologies and improvements therein to render significant benefits for the plant personnel. The currently available energy assessment and reporting methodologies have value but they are not tailored for immediate use in the ISO 50001 implementation domain as they are not focused towards this objective. The proposed methodologies have no discernable disadvantages other than the attention to detail that they require in order to produce focused results that cater directly to the ISO 50001 implementation domain.

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Fig. 18. New Report Table of Contents.

Acknowledgment

The energy assessment inspired research was supported in part by the U.S. Department of Energy funding for the Industrial Assessment Center at West Virginia University.

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