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Implementing energy management system to increase energy efficiency in manufacturing companies

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Abstract

One of the main pillars of the modern industry is the uninterrupted supply of energy with a reasonable price. The energy production is based mostly on non-renewable energy resources that are getting more expensive progressively. This increase in energy cost consequently leads the companies to a more expensive production of goods. Therefore it has been established that energy efficiency is not only very important for the environment but also for the sustainable production in the manufacturing companies.

Effective energy management plays an important role in the necessary increase of energy efficiency in industry. Next to the expansion of regenerative energies, it establishes a further pillar at closing the energy supply gap resulting from the energy transition. This paper presents the current energy situation in Germany and its impact on the German industry. Furthermore this paper presents a methodology which can be used by organizations to systematically implement energy management system.

Eventually the paper provides a model that illustrates the realization of a PDCA cycle which is necessary for energy management in the organization.

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Keywords: Energy management; sustainability; organization structure; energy efficiency

1. Introduction

The energy costs in Germany are high in international comparison. For instance, already at an inner-European comparison, the electricity prices for German industry are around 14% higher than the other European countries [1]. The reason is especially a high tax component known as Renewable Energy Act (German: Erneuerbare-Energien-Gesetz, EEG). Through the planned expansion of regenerative energies, a further increase of energy costs is predicted [2]. This is straining the manufacturing companies enormously. Because of a share in energy imports of about 72%, the German national economy is additionally exposed to staggering prices at global market and a supply risk [2].

The competitive advantage and the strength of German industry are the products with high quality standards. As labor is very expensive in Germany, this competitive advantage is achieved through a high degree of automation in the German industry. Therefore an undisturbed supply of energy is absolutely necessary for the German industry in order to stay competitive in the world market [3].

Hence energy is seen as a critical factor for the economic competitiveness [4] with 33%, the industry has the highest share in the total energy consumption [1]. In terms of electric energy consumption this share lies at 44% [5]. Beside politics, which is responsible for the attractiveness of the market location Germany, consequently the industrial itself must become active to stay attractive in the market. Energy management provides the industry a possibility to overcome these challenges and become energy efficient.

1.1. Current situation

A wide range of different methods and measures are known in energy management but hardly systematized.

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However, the energy management in industrial companies is not purely a technical task, rather an interface function [6].

Usually the cross-sectional tasks in the areas of business administration, law and technology among others have to be processed alongside the steps of operational energy flow as shown in figure 1. Thereby, an increasing complexity is detectable. For example; even the concise energy law in Germany encompasses around 3000 paragraphs [7].

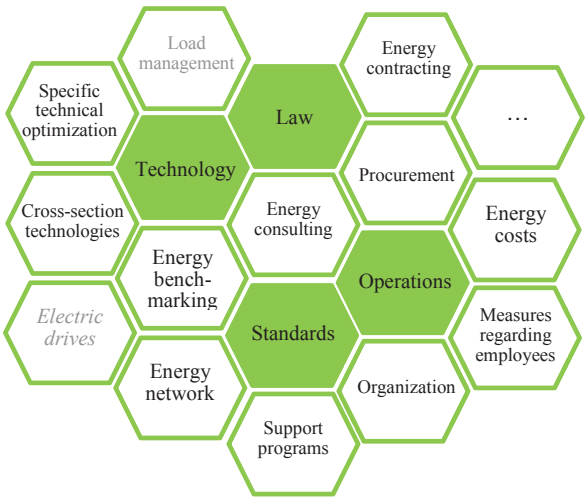

Fig. 1. Cluster of selected methods of energy management

An appropriate organizational orientation of the company is necessary to achieve the objectives of energy management. Here the state of the art norms and standards provide assistance and guidelines to tackle this complex challenge.

1.2. Definition

Altogether there exists a wide range of definitions in academic literature concerning the energy management system for companies [8]. That is why a structured and summarized definition is proposed as follows:

Energy management is the targeted deployment of methods and measures for energy –related tasks, thereby implementing a continual energy efficiency improvement approach in companies while keeping the costs and uninterrupted energy supply in consideration.

An Energy management system comprises of

- definition,
- implementation
- and controlling

of measures regarding energy-relevant issues. Here, the approach is

- transparent,
- systematic
- and continuous.

goal is to guarantee the energy supply under the following economic and ecologic aspects:

- adequate,
- efficient
- and sustainable.

2. Norms and standards

Energy management can be operated on the basis of standards and guidelines at different depths. It varies from individual, ad hoc implemented energy efficiency measures to certified energy management system. An energy management system is a systematic and continuous approach for sustainable energy improvements. However before implementing an energy management system in a company, a German Norm DIN EN 16247-1:2012 that provides guidelines to audit the company can be used to prepare for the internationally known energy management standard ISO 50001.

2.1. Energy audit

Energy audit is based on the norm DIN EN 16247-1:2012. It is considered as a fundamental step for companies that want to increase their energy efficiency and reduce energy consumption. It is a systematic approach for inspection and analysis of energy consumption of a plant, a building, a system or an organization with the goal of identifying energy flows and the potential for energy efficiency improvements. The energy audit process, i.e. the process of actual audits must meet essential criteria suggested in the norm. It includes the individual steps shown in figure. 2.

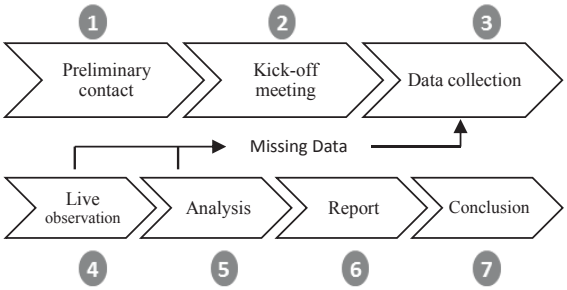

Fig. 2. The energy audit process in accordance with DIN EN 16247-1:2012

2.2. Energy management norm

DIN EN ISO 50001:2011 defines energy management system as the sum of totally integrated or interacting elements leading to the introduction of an energy policy and strategic energy goals, as well as processes and procedures to achieve these strategic objectives. It thus creates the conditions for the full application of methods and measures of energy management. Design and structure correspond to the previously introduced management systems ISO 9001 for quality management systems and ISO 14001 for environmental management systems. Thus, integration into existing management systems is possible. Here, the Deming cycle serves with the elements Plan, Do, Check and Act (PDCA) as a basis, which forces a continuous improvement program. Once the energy management system is fully implemented in a company, it is possible to get the company ISO 50001 certificate. This certificate brings next to the optimized energy efficiency additional benefits. Such as a

simple proof of being environmental friendly so an improved brand image. Furthermore companies can get tax reliefs in Germany if they are ISO 50001 certified.

The norm gives a list of criteria which a company must fulfill in order to get the certificate but the norm does not provide any guidelines or strategy to implement all these criteria in the company.

3. Barriers and obstacles

Regarding the concept design for the implementation of energy management system, an approach is selected, which considers the barriers and obstacles that hinder the companies in implementing energy efficiency measures and in the implementation of a systematic energy management system.

Overcoming these obstacles is the foundation for the implementation of a successful energy management system.

These barriers and obstacles have been already studied [9] and built upon these studies, a categorization is made, which illustrates a structured sequence shown in figure 3.

Fig. 3. Categorization and a sequence of barriers and obstacles

By using different methods for particular phases, the overcoming of the obstacles can be supported. These should be selected specifically for the respective company.

- Awareness for the need for energy management can be strengthened by an energy audit, including a measurement concept and energy performance indicators for comparisons with competitors, as well as an adequate information policy.
- A lack of motivation to change and to implement measures can be countered by incentive systems and the introduction of an energy-management organization, which promotes ideas and participation of the employees.
- A lack of knowledge can be compensated through training of the employees and occasional external support, for example through energy consultants or energy networks.
- Missing financial resources can be requested over funding programs or can be provided through loans at reduced rates of interest. Other funding opportunities can be availed by using the energy performance contracting.

4. Multi-Stage model

Since the approach should basically be suitability for various industrial enterprises, it is structured as a multi-stage model. The designed stage model, shown in figure 4, allows a gradual integration of energy management system in the companies. Depending on the company's initial position and goals, the multi-stage model allows the companies to start from a higher stage or stop at a stage which is appropriate for the company. This model consists of three stages. In addition to the basic package (Stage I), an enhanced package (Stage II) and a sustainability package (Stage III) are designed.

4.1. Basic package (Stage I)

The basic package includes two fundamentally successive phases. The first phase generally starts with an analysis of current situation. This can be performed using the energy audit in accordance with DIN EN 16247-1:2012. Identifying the relevant data and detecting it by means of an adequate measurement concept, before a transparent preparation and evaluation can take place is very important. On the basis of these data, measures can be evaluated, prioritized and decisions can be made.

The next phase of the basic package is based on the energy audit, and includes the implementation of quick wins which are identified during phase 1. These are the benefits that a company can achieve quickly with little effort and low investment.

These measures may differ significantly from company to company. It is crucial that visible results are generated quickly, which can then be presented to internal and external stakeholders of the company.

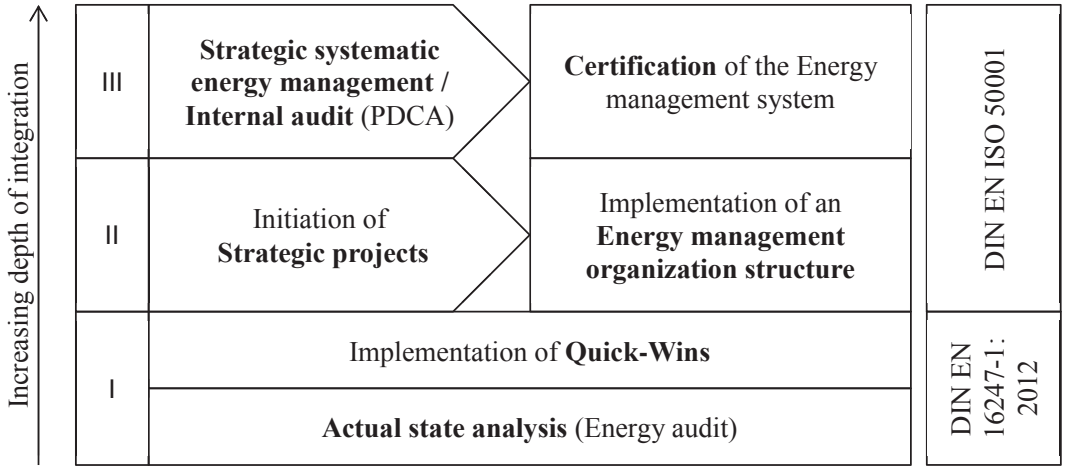

Fig. 4. Multi-Stage model for the implementation of the energy management system

4.2. Enhanced package (Stage II)

At the next stage the Enhanced package begins, which require the definition and implementation of an energy management organization. After the analysis of the current situation of a company regarding the energy aspects, a target is set and an energy manager is named by the Top management to carry out the strategic project. It may be necessary for some companies to redefine there current processes in order to comply with energy management standards. Companies that already have other management systems such as ISO 9001 based quality management system may find it easier to implement and integrate the new energy management system in their existing system. In phase 2 of this stage an energy management organization model (See Chapter 5) is implemented. In order to operate a sustainable energy management the application of the enhanced package is recommended. The definition of an appropriate structure and process organization is the central aspect here. Only when responsibilities, information and communication channels are clearly defined, an effective energy management can take place in which continuously coordinated and structured measures can be developed and implemented.

4.3. Sustainability package (Stage III)

The enhanced package creates the conditions for a sustainable and systematic optimization. However, only when the defined workflow and management processes are practiced, long term desired results can be achieved. In stage II an energy management process and work flow was developed and implemented. In stage III through an internal audit the workflow is then checked for its efficiency and effectiveness. The report of the internal audit is then presented to the top management. At this phase if required the process can then be optimised to fit the current situation. In this stage the systematic, continuous and strategic optimisation of energy consumption of the company using the Plan-Do-Check-Act cycle is initiated. In the phase 2 of stage III the company can then apply for the ISO 50001 certificate as at this point the company fulfils all of the requirements of an energy management system that is based on this international standard.

5. Organization Model

The organizational model, which is introduced at the second stage of the multi-stage-model, specifies and extends the elements of an energy-management system. These elements are defined in DIN EN ISO 50001:2011 in terms of the plan-do-check-act-cycle (PDCA). Figure 5 shows this possible energy management procedure for an industrial company in simplified terms.

In this model, roles are defined, which can coincide with a position but it is not a necessity. This way, a single employee can take several roles depending on the qualification. The energy manager is chosen by considering the individual requirements of the respective company.

Depending on the company size and goal, along with the energy manager, top management may decide to put together an energy management core team that continuously work on energy related tasks. It has continued responsibility for the adequate support of energy management. It must provide the necessary resources for Energy management. The top management defines the energy policy as well as short-, medium- and long-term goals. In addition, it is responsible for the periodic review of energy management of the company.

The energy report, addressed directly to the top management, deals with the energy related issues and

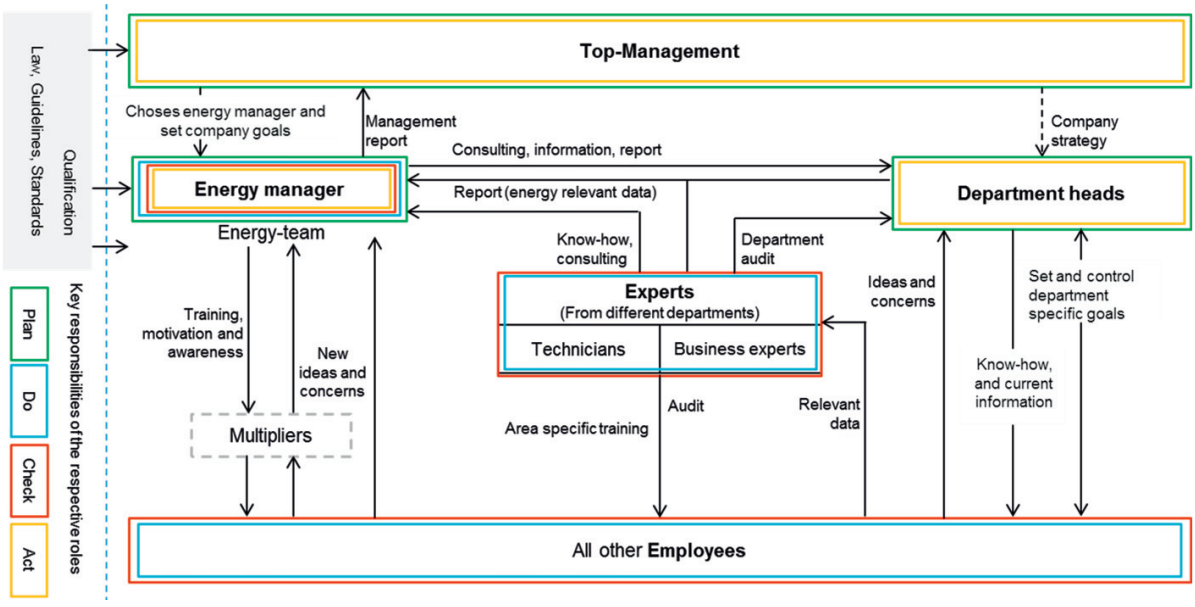

Fig. 5. Advanced organizational model based on ISO 50001

prepares basis for further decisions. One of the very important tasks of the energy manager is to define energy performance indicators (ENPIs) together with the energy team. The EnPIs may differ from company to company. These EnPIs can later be used for benchmarking and controlling of the company. Benchmarking plays a significant role in the annual report of internal audit which is substantial for energy management system. Therefore EnPIs must be defined very wisely. Table 1 show a list of some selected EnPIs which can be used for benchmarking.

Table 1. List of energy performance indicators (ENPIs)

EnPI	Calculation formula	Unit
Contribution of each energy carrier	$\frac{\text{Energy carrier}}{\text{Total energy}}$	%
Efficiency in internal energy conversion	$\frac{Output}{Input}$	%
CO_2 emission	$\frac{\text{Tons}}{Year}$	$\frac{\text{t}}{year}$
Share of energy costs in revenue	$\frac{Specific\ energy\ costs}{\text{Revenue (per product)}}$	%
Employees Specific energy consumption	$\frac{Total\ energy\ consumption}{\text{Number of Employees}}$	%
Area-specific energy consumption	$\frac{Total\ energy\ consumption}{\text{Heated area}}$	$\frac{\text{KWh}}{m^2}$
Production quantity specific energy consumption	$\frac{Total\ energy\ consumption}{\text{Input or Output}}$	$\frac{\text{KWh}}{t}$
Value-specific energy consumption	$\frac{Total\ energy\ consumption}{\text{Net revenue}}$	$\frac{J}{€}$
Production quantities-specific energy cost	$\frac{Total\ energy\ consumption}{\text{Produnction amount}}$	$\frac{€}{t}$
Energy intensity of a process / product	$\frac{\text{Energy consumption Process}}{\text{Total energy consumption}}$	%

Other tasks of energy manager/team include actively supporting all the departments of a company, planning and implementing energy efficiency measures.

However, in an extended energy team, task-specific and project-specific internal and/or external experts as well as decision makers may be consulted.

Multipliers should be deployed in order to distribute information on energy topics regularly to distinct employee circles and to report the ideas of the employees to the energy team. The tasks of each element in the organisation model are defined keeping the requirements of ISO 50001 in consideration.

6. Conclusion

Energy management is both for the companies and for society as a whole, of great and ever increasing importance. Its core objectives are supply security, economic efficiency and environmental protection.

For individual companies, there exist different reasons to apply energy management practices, to implement related measures and to establish an energy management system.

Nevertheless there are a lot of barriers such as employee awareness, behavior and motivation, know-how and financial resources that hinder companies from implementing an energy management system and execute measures to increase energy efficiency.

A variety of energy management methods are known in the literature. With the specific use of these methods existing barriers can generally be overcome. However, for a sustainable and continuous improvement a structured and systematic approach is required.

Although standards and guidelines provide an appropriate guidance for energy management, still these do not offer any structure or method to implement them in companies. It is shown in this paper that the multi-stage-model provides an approach for the gradual introduction of an energy management system where different starting and ending points can be considered.

Through the organization structure, proposed in this paper, a Plan-Do-Check-Act cycle for a sustainable and continuous improvement can be realized. The goal is to make optimal use of existing resources and existing expertise in the companies. Additionally through this the companies can qualify for the ISO 50001 certification.

The essential foundation required to implement energy management system is to analyses the current situation and to identify optimization potential regarding the energy efficiency. Here DIN EN 16247 standard provides a good support.

In Germany the application of standards in the companies not only provides a frame-work but also a possibility to avail other benefits, such as tax cuts and eligibility for government support programs.

Data on the energy situation for the implementation of energy management is of utmost importance. Properly collected and processed they create transparency and are the basis for business decisions.

With adequately defined EnPIs, analyses and comparisons can be carried out and controlling methods and measures can be derived. The list of EnPIs provided in table 1 offers a good starting point.

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References

[1] Bundesministerium für Wirtschaft und Technologie (BMWi), Energie in Deutschland. Trends und Hintergründe der Energiewende, Berlin, 2013.

[2] Bundesministerium für Wirtschaft und Technologie (BMWi); Bundesministerium für Umwelt,Naturschutz und Reaktorsicherheit (BMU), „Erster Monitoring-Bericht „Energie der Zukunft“,“ Berlin, 2012.

[3] Industrie- und Handelskammer, „Energiepreise und Unternehmensentwicklung in Baden-Württemberg,“ Karlsruhe, 2009.

[4] E. Abdelaziz, R. Saidur und S. Mekhilef, „A review on energy saving strategies in industrial sector,“ *Renewable and Sustainable Energy Reviews,* Nr. 15, pp. 150-168, 2011.

[5] S. Hirzel, B. Sontag und C. Rohde, Betriebliches Energiemanagement in der industriellen Produktion, Karlsruhe: Fraunhofer ISI, 2011.

[6] W. Posch, Ganzheitliches Energiemanagement für Industriebetriebe, Wiesbaden: Gabler Verlag, 2011.

[7] F. Wilhelm, „Ein mit Spezialwissen jonglierender Generalist,“ *Energie & Management,* p. 9, 1 Mai 2013.

[8] S. Backlund, P. Thollander, J. Palm und M. Ottosson, „Extending the energy efficiency gap,“ *Energy Policy,* Nr. 51 (2012), p. 392–396, 2012.

[9] E. Cagno, E. Worrell, A. Trianni und G. Pugliese, „A novel approach for barriers to industrial energy efficiency,“ *Renewable and Sustainable Energy Reviews,* Nr. 19 (2013), pp. 290-308, 2013.