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THE CHALLENGE OF ENERGY MANAGEMENT – STATUS- QUO AND PERSPECTIVES FOR REFERENCE MODELS

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Abstract

Energy management is one of the great challenges of the industry in the next years. Energy becomes more and more to a critical resource. Until now, enterprises need to implement energy management system with nearly no guidance. In the following paper we present the foundation of a reference model-based method that serves for setting up energy management systems in various industrial sectors. The goal is to support reduction emission and cost reduction as well as certification needs. In contrast to previous approaches, this approach enables a model-based certification and allows an automation of activities of the process of supervision of the consumption of energy and the appropriate reengineering of business processes.

Keywords: Reference Model, Energy Management, Model-Based Method, Model-Based Management

1 INTRODUCTION

With increasing scarcity of raw materials and the rising ecological consciousness in professional sector, energy becomes a more and more critical resource. Thus, energy is said to be the 6th Kondratjew cycle (Kondratieff and Stolper 1935). Although never empirically proven, economies believe in this phenomenon. Especially the demand for products belonging to this domain ascended so that opportunities for companies in terms of new products and markets evolved. Apart from being the next Kondratjew cycle or not, it is obvious that this task receives more and more attention from companies. Focus is set on issues like green IT, sustainability, energy efficiency and so on. There are multiple reasons for this development: enforcement by law, image benefits by showing corporate social responsibility and cost savings due to energy efficiency and according investment measures. As the product life cycles get shorter and market dynamics increase, the reaction time to these trends and developments decrease permanently. The main task is to make energy manageable by business experts. That includes energy planning, energy control, energy assurance and improvement of energy usage. An integral energy management system (EMS) is an instrument away from monitoring to a real management. ISO 50001 or DIN EN 16001 (Deutsches Institut für Normung e.V.) certification only forms one part of the system. The use of an energy management system can achieve sustainability in its ecological, economic, social dimensions (Boudreau et al. 2010).

In particular, small and medium-sized enterprises (SME) are challenged by the high number of requirements and regulations that are connected with EMS. On the one hand, SME often lack the necessary human and financial resources to cope with the tasks involved in an EMS. Current approaches are expensive because of the large consulting effort; the used methods neither support the implementation and monitoring of an EMS according to DIN EN 16001 nor do they assist the process of supervision of the consumption of energy or the appropriate reengineering of business processes. Against the background of a rising cost pressure, these approaches will no longer be able to meet the requirements of SME.

Our research transfers the idea of reference modelling to the field of energy management. So far, no reference model is published that enables an efficient DIN EN 16001 certification. We developed a reference model-based energy management system that consists of four integrated aspects: Reference models, algorithms, sensors and guidelines for the organizational embedment (figure 1).

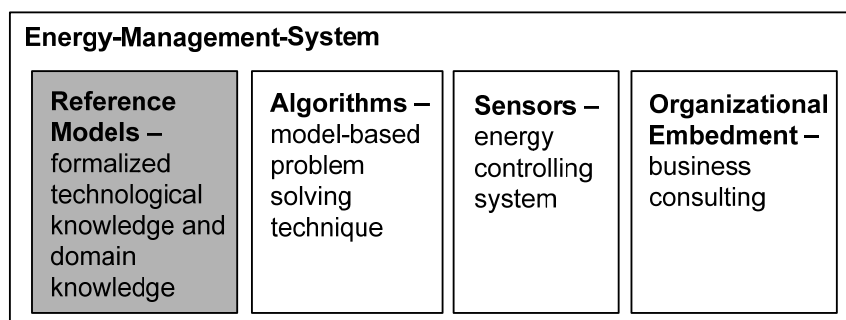


Figure 1. *Element of the model-based energy management system*

In this paper we concentrate on the reference models as the part of a model-based method. Model-based methods provide the possibility of a guided implementation, the inclusion of knowledge management and consistency checks. Hence, transaction costs for adaption and improvement can be reduced. Of particular interest, is the integration of energy consumption sensors with the management system. i. e. identifying energetically relevant products, processes and the development of adequate energy management objectives.

The paper is structured as follows: In the first section we give a detailed introduction to reference modelling. After explaining the theoretical background and the construction techniques of reference modelling we present a reference model for energy management. The paper ends with conclusions and suggestions for further research in this field.

2 FUNDAMENTALS OF REFERENCE MODELLING

2.1 Theoretical Background

In Information System (IS) research reference models are used to communicate best practice, common practice or normative rules (Becker 2004). They minimize the design risk and maximize the acceptance of model results. Reusing conceptual models or parts of models represent an integral area in research about effective and efficient software engineering and organizational design (Hammel 1999). Reference modelling targets both structures and processes (Schuette 1998). The purpose of reference models usage is a reduction of development costs and of development time (Schuette 1998) and furthermore the alignment of model construction to Common-Practice or Best-Practice-Solutions. A further goal is to specify rules and standards that guarantee the compliance to adaptability of a standardized application system or the compliance to organizational rules.

The idea of reference modelling goes back to the early 1970s, where – instead of reference models – the term “ideal model” was widely used. This term describes a model representing the target state of an information system and which may be used for its design. The first definitions of the term “reference model” emerged during the 1990s describing a model artifact with an intended recommendatory character (Thomas 2006). In the Anglo-American world, the term was first in the publication of the Open Systems Interconnection Reference Model (Zimmermann 1980).

Reference models are designed and intended for reuse. Considering this, reference models are to some extent generic models; their design emphasizes the adaptability to different scenarios (Schuette 1998). Vom Brocke (2003) argues that the degree of recommendations depends on a subjective perception. Similarly, the generality of reference models depend on the actual use of the reference model.

The definition of reference models is – considering standard conceptual modelling - confined to its notably deviant construction-process. A reference model is a model that is used to construct another model. Hence, the relation between the reference model and the derived specific model is the only constitutive characteristic. In accordance to that definition, each model, which is used for the construction of a specific model, is a reference model. The range of possible models applicable as reference is not limited to those who were intentionally designed as reference models. Three cases of development and use of reference models are discussed in the scientific community (Thomas 2006):

- A reference model is developed and declared as such, but not used in practice.
- A model is used to develop a specific model. But it is not explicitly developed or declared as a reference model.
- A reference model is developed and declared as such and also used to create specific model.

The first case is widely declined in the literature because an unused reference model misses the economic goals that are an essential aim for the reuse of information models. The development of the reference model is disproportionate to the benefit of it. In the second case, the impact of the reference model to the design performance can hardly be determined. The third case represents the ideal case. A defined reference model is used to create a specific model. However, to allow a methodologically reuse of models, the systematic preparation, i. e. defining appropriate rules for the derivation of consistent specific models, is required.

Two relations may be different depending on the formalization of derivation rules, which support the adaptation of reference models (Braun 2009): If rules are defined that declare, which constructions are allowed and which are not, it is referred as strict referencing. If the derivation of the specific model is not based on rules, then it is called loose referencing. In this case, the modeller can make any modification to the definition of the specific model.

To conclude, modelling knowledge and best practices can be described as models. Their content is reused to construct a specific model. Generality and recommendatory character are not constitutive characteristics, but they are intentional. The recommendatory character depends on how the description of the reference model reflects the problem adequately. In addition, a reference can only be described as general, when it was reused for a number of similar problems.

The demand for efficiency in the modelling process leads to the demand that model reuse is systematically supported. Thus, reference models need to implement mechanisms for reuse. Since the mechanisms should not obstruct the modeler in his freedom of modelling this results in a tense relationship between the level of methodological support and the modelers' degrees of freedom in the development of a problem adequate solution. This dilemma led to the development of various types of construction techniques to track each specific objective of different modelling situations.

2.2 Construction Techniques of Reference Modelling

Construction techniques of reference modelling contain the definition and integration of rules for derivation of specific models. They represent rule sets that define the way of reusing model content and their adaptation and extension (vom Brocke 2004). Scientific literature provides five main construction techniques for reference models: configuration, instantiation, specialization, aggregation and analogy construction. These techniques support different objectives and requirements of the modelling process (Becker 2004; Braun 2009; vom Brocke 2007; Delfmann, 2006).

Configuration is the most restrictive technique. It only allows the selection of pre-defined model variants. All these variants and configuration parameters pre-define the modelling process. Thus, the process of reference model development is very complicated. If the modelling situation requires freedom of design for the development of a specific model, generic forms of adaptation are preferred. E. g. the construction technique *instantiation* only requires that part of the model content, which is like a skeleton for all derived models. Placeholders are set up for model areas, which must be filled according to the domain context.

Using the construction technique *specialization*, general statements of the reference model need to be adopted and supplemented or modified by specific statements in the adopted model. The way of specialization is not specified in the reference model. The construction technique *aggregation* is based on the compositional principle providing a component library. The components can be combined according to their interface definitions. Together they form a consistent and coherent model.

The *analogy* construction represents the most flexible technique. It permits the free modification of the reference model during the adaptation process. The modeller conducts the activities for the adaptation of the reference model content for a new problem. The *analogy* construction is similar to the complete new construction of a conceptual model.

Usually the decision, which construction technique is used bases on the results of a cost-benefit analysis, i. e. evaluating the costs of reference model development and the construction of a specific model. The point of intersection between the development costs of implementing reference technique and the potential benefit, e. g. the probability of reuse, need to be estimated. A significant cost driver of reference model development is the complexity of the modelling context. The more options of adaptation are supported the more complex and cost intensive is the reference model development.

Hence, the challenge is to find a balance between the costs of preparing a model for its reuse on the one hand and the costs of constructing a specific one with re-use on the other hand. These costs correlate negatively (vom Brocke 2007). The practical use of reference models shows a variety of hybrid forms due to better cost-benefit ratio in comparison to the single technique approaches. Designated parts of a model are supported by configuration mechanisms. This is beneficially if the modelling results are quite stable for different situations or the freedom of design shall be limited due to administrative advice. Generic adaption mechanisms support the design of the other parts of a model that might vary more often.

2.3 Constraints in Reference Modelling

To support the reuse of model content by specific construction techniques adequate adaptation rules need to be integrated into the reference model. Appropriate language constructs are necessary which allow the explication of adaptation rules. The definition of these language concepts leads to its own reference modelling grammar, which supplements the actual modelling grammar for the description of the model (Braun 2009). Standardization efforts for a reference model language and thus the support

of an automated model exchange, however, do not exist. The reference model grammar should be more independent from the modelling grammar (vom Brocke 2004).

The use of a specific grammar in reference modelling limits their general applicability; i. e. model migrations are necessary if the end user prefers a model in a different notation. Model transformations imply additional effort und potentially information loss. Furthermore, adaptation mechanisms depend on the characteristics of the modelling language. The first step is the analysis of a generic reference model grammar for the definition of adaption rules. Otherwise, they might only be defined in dependence of the used modelling language.

In addition to that, the examination of the validity of reference models represents a challenging research task. The fit of the specific model with the reference model is evaluated individually and subjectively by the model creator. However, the acceptance and thus the validity of the solution is strongly depending whether the user of the reference model could understand the context of the original model and the design decision.

In existing research the focus is on the adaption of a specific model from a reference model. The interests are shifting increasingly towards the whole lifecycle of a reference model. Until now, the phases of evaluation and further development are missing methodically support. The evaluation can be initiated by changes of the development of specific model or by the change of normative rules.

If the specific model is not only created for one single application, but also for a long-term management of the information system, it is subject to a continuous change process. Thus, the reference model must be interpreted as a living artefact, which has an ongoing relationship to the derived models. The development of capable configuration management systems is necessary for management of relation.

3 A CASE STUDY ON ENERGY MANAGEMENT

3.1 Case Study Scenario

The case was performed in a plastics injection moulding company in Germany that meets the small and medium-sized enterprise (SME). The company employs more than 30 employees and is part of a company group. Energy consumption in 2009 for electricity added up to about 1,6 million kWh. Products vary in size between volumes of 10 cubic centimetres and up to one cubic meter. Different materials according to the requirements of the customers are used in terms of colour, quality and density. The company owns for production eleven injection-moulding machines of different size. Furthermore, different supporting processes are installed, liked compressed air, heating, cooling, air conditioning and electric lighting. These processes serve the value adding processes, i.e. the injection moulding machines use for example compressed air for valve control or cooling during the production cycle

The scope of the project was to analyse the implemented an EMS and its certification according to DIN EN 16001 (DIN 2009). Based on these findings, a reference model-based EMS should be developed as the starting point for setting up a complete company wide model-based management system. The first step was an As-Is analysis concerning the implemented EMS and the documentation for it. The DIN EN 16001 norm has not yet reached all of the companies so that until now guidelines and experience are missing.

Due to the upcoming focus on energy management this field is getting more and more attention, especially as tax benefits are in discussion for SME. The lately released norm on this topic has not yet reached all of the companies so that guidelines and experience are missing. The present process for documenting and implementing an EMS was mainly manual. For documentation purposes word processing software was used. Changes in a management system were made by a responsible person, unfortunately almost always with a time delay of one to 5 days. Two major processes were analysed in the project. On the one hand, the process for documentation of an EMS was analysed and on the other hand the process for measuring energy data. As measuring energy data is a significant part of an EMS, the interdependence between these two processes received a special focus.

3.2 As-Is Analysis

The As-Is analysis contained the evaluation of the existing process for documenting a management system. Here the EMS of the company did not exist before. The result delivered a manual process for documenting the EMS that followed 5 separate steps (figure 2). The steps were based on the approach the company took for documenting other norms, like ISO 9001 (quality management system) or ISO 14001 (environment management system).

At first the requirements of the norm were studied by checking the latest version of it. The interpretation of the norm is necessary because it is formulated in a quite general way. Later, the relevant and specific aspects for the company were extracted and set up to a functional specification. To fulfil the requirements of the norm workshops were held to analyse the As-Is-situation. These findings were checked against the norm. In case of discrepancies, processes were adjusted. Finally all processes that fitted to both the company processes and the norm requirements were documented in the new management documentation.

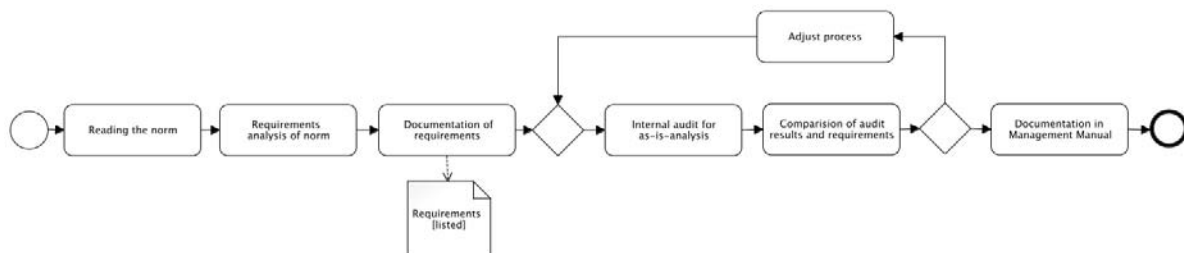


Figure 2. Process of creation of an EMS manual

The second process focused on measuring energy data, i.e. consumption of energy, mainly electricity (figure 3). The measurement was processed manually by writing down the meter values on a daily basis. Analyses were performed in a calculation program, generally due to the requirement of a monthly report on energy consumption. In terms of the measured details, the existing and pre-installed meters that existed since the opening of the site in 2007 were used. A previous analysis, e. g. with an ABC analysis, whether these meters represent the main energy consumers at this site was not performed. Therefore, the process of measuring energy data was rather arbitrary than planned.



Figure 3. Standard process of metering

The analysis revealed that on the one hand the two processes showed improvement potentials. On the other hand the integration of both processes, partly due to the requirement in the norm, showed potential for innovations and optimisation in this field. The process for documentation profited from other formerly installed management systems, as general processes could be re-used. As one of the main tasks for optimisation the stand-alone character of each document and the long time for the integration of changes can be quoted. An integral approach with these two processes – performed by two different employees – was missing.

3.3 Implementation of the Reference Model-Based Method

A reference model for an EMS delivers a reference framework for a company tackling this field. This framework gives normative guidelines and supports the specific modelling of an EMS with pre-defined components. The relevance of a reference model for energy management is based on the strong focus from various directions: society, law, costs to name only a few. Approaching this field all over the place will have negative consequences due to high costs in a dynamic and continuously changing environment.

Our reference model for an EMS is based on the approved norm of DIN from August 2009 (DIN 2009) and is also approved as European norm (EN). It is similar to ISO 50001 with which it shall soon be harmonized. The well-known standard of ISO 14001 for environmental management systems set the base for the development of this new norm. The certification for the presence and use of a management system, e. g. in terms of quality or environmental aspects plays an important role in different companies. The main structures of these managements systems follow the norms as they provide the boundaries for certification as well as approved processes.

The core process for energy management is structured in different aspects of DIN EN 16001. Following that specification we developed a new framework for reference model-based energy managment – the *Energy-E-Framework* (figure 4). It helps to systematically structure the model use in different aspects of the EMS and facilitates a communication between different partners.

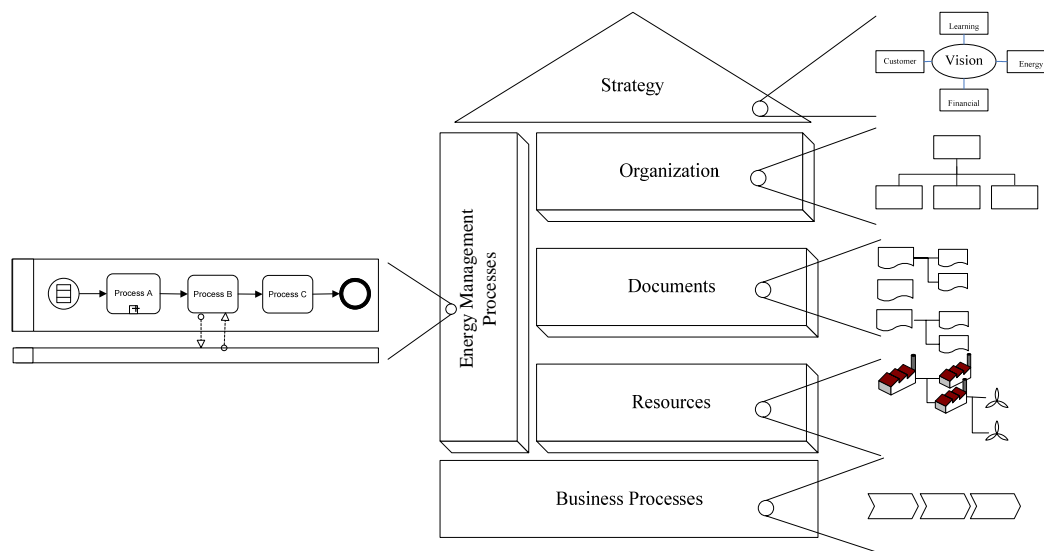


Figure 4. Framework for implementation of the energy management system

On the top of the *Energy-E-Framework* the strategy need to be defined. An EMS sets the commitment of the management towards the integration of the term and aspects of “energy” in its company. Once this decision is taken, the energy policy, energy targets und energy aspects are defined. The energy policy describes the alignment of the company towards all energy relevant issues. The energy targets deliver the desired level of energy usage determined by performance figures. The energy aspects show the different fields that are focused by the EMS, especially with regard towards the continuous improvement process (CIP) for increasing the energy efficiency.

The organizational aspects (company and process) contain roles and processes for a structured approach within the energy management system. The company organization shows the participating employees and key players of the energy management system. The energy management team contains all relevant roles, i.e. the general energy manager and subordinate energy managers. The process organization is the key part of this reference model. It contains three major processes that we describe in the following. All processes follow the PDCA (plan-do-check-act) cycle (Kanji 1996). Legal requirements that affect the requirements of the EMS itself as well as the behaviour of the company in terms of energy in general and specifically have to be checked regularly.

For implementation, support and application of the energy management system within the organization all employees have to be trained and occasionally retrained. Consequently, the standards are implemented and a sustainable change in behaviour in the long term is reached (process 2). The CIP is the most important process for the implementation. It provides the biggest possible impact in terms of required resources and emission and cost reductions. Due to current judicial propositions in Germany, i. e. the energy efficiency act, optimization measures must be evident und quantifiable in the future. Therefore, the CIP is the central element of the process landscape. All measures and their

outcome is documented here. The process can be further divided into sub steps to get more in detail and improve the energy consumption more efficiently.

This process is the core of the EMS reference model. As stated above, construction techniques support the adaptation of specific models. Therefore, we implemented modelling concepts in the model language to create a reference model grammar. Due to the high distribution and acceptance we decided to use the Business Process Modeling Notation (BPMN) for the process modelling. We use the meta-CASE tool cubetto® toolset for implementation (Cubetto 2009). Based on a meta-modeling language, it is possible to develop specific methods in the toolset. To use the BPMN we add elements to that modelling language. The concept of the group is used in the BPMN, to visualize elements in business processes, which belong together logically. As an element of our reference model grammar, the BPMN was extended by a specialization of group elements called “RM-group”. This group comprises all reference model elements. Therefore, we used similar representations of group elements, with a grey background. A special form of textual annotation (light blue box) was implemented to describe the construction technique for a section of the model or the single element. We call these annotations “RM-annotation”. The specification is defined by the following the syntax: It begins with the “RM-Technique” followed by “::” and the name of construction technique (section 2.2). After a further colon, application instructions in natural language describe, how the group or element can be adapted.

Figure 5 shows the reference process “base load reduction process” of the EMS. For this process a production free time is necessary. Therefore in the beginning two variants are depicted. According to the characteristics of the production, either a predefined production free time slot is chosen or a stop of the production is to be planned. In the further process, the base load is categorized by an ABC analysis. This activity is linked to an “RM-annotations”. It defines that for this activity a specialization should follow.

Our reference process models are developed for strategic processes of energy management and for operative processes. The operative part can be distinguished in cross-sectional processes and production processes. The distinction of these two processes is up to the handling of the resulting costs and the responsibility. For cross-sectional processes, responsibility is seldom taken. The assumption is that these processes, e.g. heating, cooling or compressed air, work the whole time as in general more than one production process requires the outcome. Therefore, cross-sectional processes lack attention in terms of energy consumption. Production processes have this attention because responsibility can be directed to employees. As major processes of energy management in production we identified base load reduction, top load optimization and efficiency improvement.

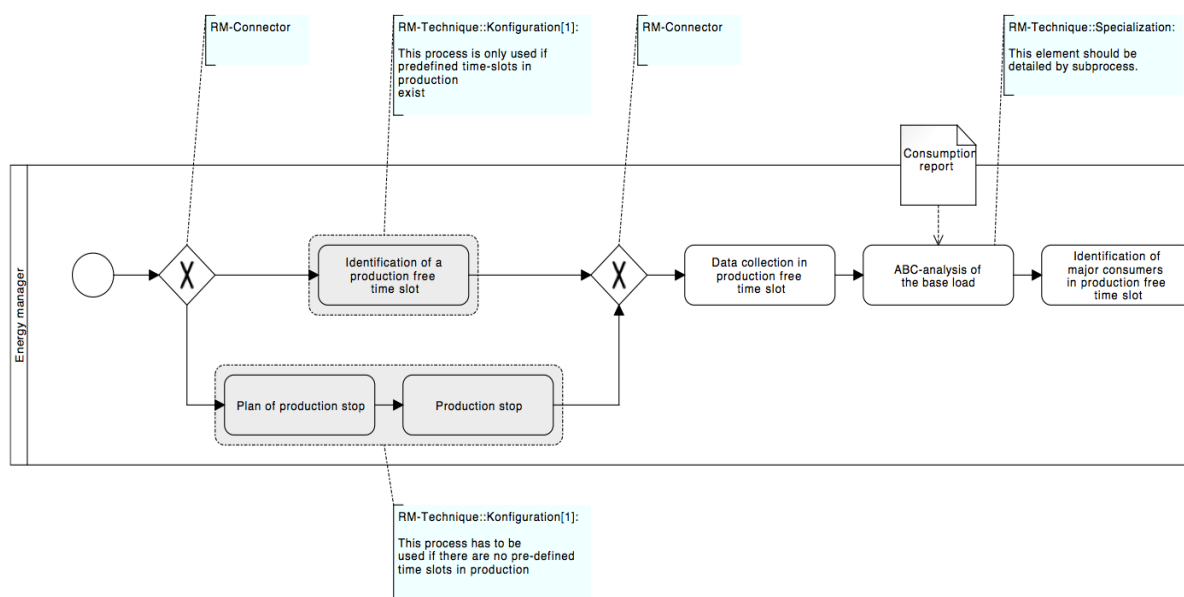


Figure 5. Reference model of base load reduction process (section)

Base load reduction tackles the problem of energy consumption although nothing is produced or used. Top load optimization concentrates on a homogeneous allocation of load peaks. This is especially relevant for energy utility companies, as they have to provide these peaks. The efficiency improvement process focuses on reengineering a technical process in terms of energy consumption.

We take the reference process for base load reduction to illustrate how the reference model (figure 5) can be adapted to a specific model. Figure 6 depicts the specific model for an EMS of our case scenario, which was build with the help of our reference model.

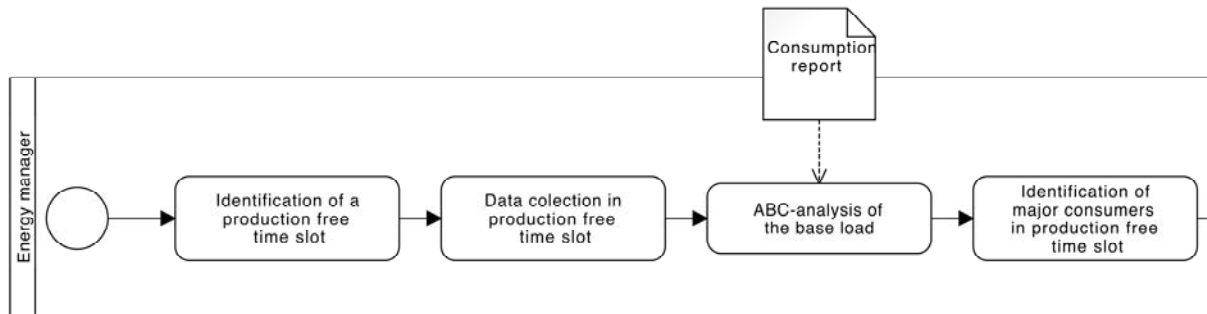


Figure 6. *Adapted model of base load reduction process (section)*

The model shows how to identify “A” energy consumers, to define measures and to monitor the effects of these. Identifying a production free time slot gives the chance to have a look at the base load itself. Normalization or reduction is not necessary so that influencing factors are minimized. Data of all relevant energy consumers have to be collected and brought to a format that can be displayed e.g. in charts or tables. The next step is an ABC-analysis to identify the consumers that should be focused on in the first place. Possible measures should then be described and valued against economic and ecological criteria. Based on a scoring-model or cost-benefit inspection the measure with the best fit can be discovered and implemented. The process ends after implementation of a measure. The quality of a measure can only be evaluated by comparing it with the status quo before the measure was taken. Therefore, a final review with comparison of old and new values are mandatory. The documentation of the measures and the following results provide the documentation of successful implementations and serve as a knowledge database for the future.

4 CONCLUSION

4.1 Results

An integral approach, i.e. an integration of the two separate processes described in the As-Is-analysis, was determined as the starting point for the model-based concept of an EMS. The designed reference model included the main tasks given by the norm as well as processes to tackle consumption and efficiency deficits. We defined process and documentation templates to guide users while setting up their energy management documentation. Relevant information and requirements for the documentation of the norm were included as well as process descriptions.

Apart from the documentation of the management system an energy measuring system was installed. This system was set up to continuously deliver consumption data. Therefore, the manual process was not necessary any more. The measuring results were integrated into the management system (see figure 7). So, the targets documented in the EMS can now be controlled and proven with the measured consumptions or costs. Scheduled and identified measures can also be checked in terms of their effectiveness.

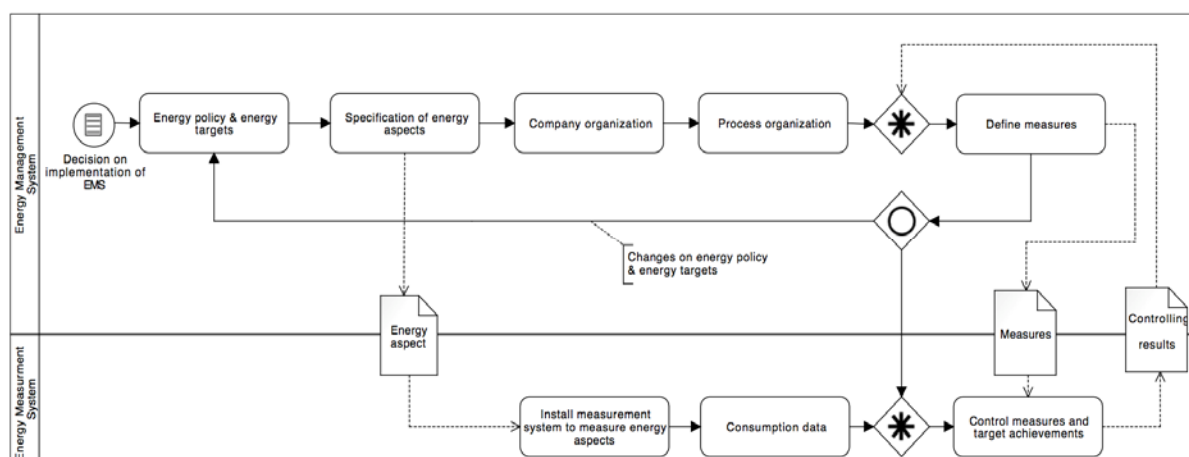


Figure 7. Integration between energy measurement and energy management system

One representative example was the identification of a wrong control program of the drying plant for plastic resin. The measuring system revealed that the drying process ran in the time-controlled and not in the more energy efficient dew-point controlled mode. Unfortunately, the switch between the two programs occurred during a service session 18 months before identifying this issue. The change of the control mode took five minutes with no investment necessary. The comparison of the consumption before and after the change revealed reductions from about 10% per day, i.e. 30 kWh. Figure 8 shows the different load profiles according to the control mode.

The longer an energy management system is consequently used in a company the more knowledge about efficiency measures is generated and systematically stored. For upcoming energy audits this knowledge can easily be extracted due to the standardized model. Consequently, the transaction costs for generating ideas about efficiency potentials are decreased.

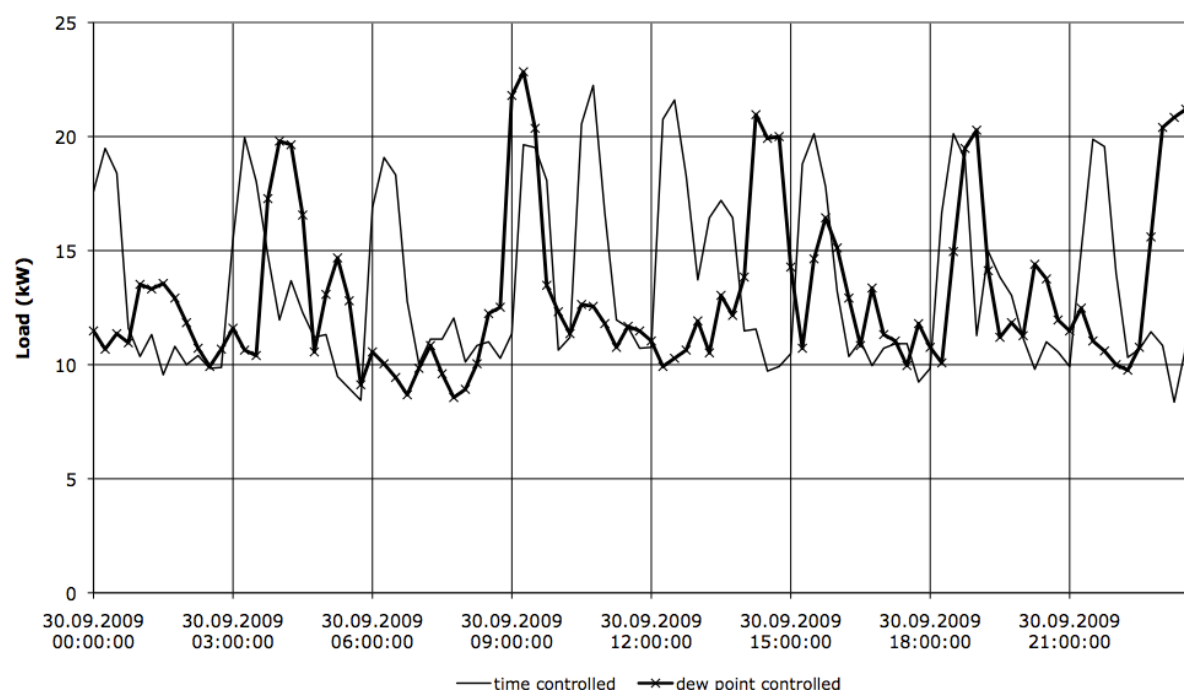


Figure 8. Load profile drying plan for plastic

4.2 Outlook

Energy management is receiving rising attention in companies due to the various reasons mentioned above. In this paper we developed the fundamentals of reference modelling. This set the basis for the design of a reference model for an energy management system. As this field is very new and young, empirical validity is not yet given. However, there are norms for energy management systems that already provide a useful scope. Based on the norms we chose to develop a reference model for energy management systems.

We will continuously advance this reference model due to empirical studies or adjustments to the norm. First steps will be the complete description of all processes. Industry specific processes and aspects may also be necessary due to particular circumstances. As soon as the implementation of energy management systems into companies based on this reference model take place empirical studies can be conducted. The benefits from the use of the system can be quantified as well as cost and emission savings.

Before using this reference model modelling techniques have to be integrated into the reference model. Therefore, an according method has to be defined. Furthermore, a way for integrating the developed model into existing management systems has to be developed. Acceptance and application will be the key factors for the reference model that can only be achieved with an integral approach and empirical validity. Once this status is achieved within the research community and among first users the communication and spread of the reference model will be upcoming tasks.

References

- Braun, R. (2009) Referenzmodellierung: Grundlegung und Evaluation der Technik des Modell-Konfigurationsmanagements, Reihe: Advances in Information Systems and Management Science, Logos Verlag, Berlin.
- Becker, J., Delfmann, P. and Knackstedt, R. (2004) Konstruktion von Referenzmodellierungssprachen: Ein Ordnungsrahmen zur Spezifikation von Adaptionsmechanismen für Informationsmodelle. *Wirtschaftsinformatik*, 46, 4, 251-264.
- Boudreau, MC., Chen, A. and Watson, R. (2010) Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community, *Management Information Systems Quarterly* 34, no. 1 (March 1, 2010): 23-38.
- Cubetto (2009) Cubetto toolset ®. <http://wise.wiwi.tu-dresden.de/cubetto>.
- Delfmann, P. (2006) Adaptive Referenzmodellierung: Methodische Konzepte zur Konstruktion und Anwendung wiederverwendungsorientierter Informationsmodelle. *Advances in Information Systems and Management Science*, 25, Logos Verlag, Berlin.
- DIN EN 16001, (2009)
- Evermann, J. and Wand, Y. (2005) Ontology based object-oriented domain modeling: fundamental concepts, in: *Requirements engineering* 10, 146–160
- Ferstl, OK., Sinz, EJ. (2001) *Grundlagen der Wirtschaftsinformatik*. Oldenbourg München.
- Frank, U. (1999) Conceptual modelling as the core of the information systems discipline - perspectives and epistemological challenges, *Proceedings of the AMCIS 1999*, 695-698.
- Fettke, P., Loos, P. (2004) Referenzmodellierungsforschung - Langfassung eines Aufsatzes. Johannes Gutenberg-Universität Mainz, Lehrstuhl für Wirtschaftsinformatik und BWL, Working papers of the research group information systems & management, Paper 16
- Hammel, C. (1999) Generische Spezifikation betrieblicher Anwendungssysteme. *Berichte aus der Wirtschaftsinformatik*, Aachen: Shaker.
- Kanji, GK. (1996) Implementation and pitfalls of total quality management. *Total Quality Management* 7, 3:331.
- Kondratieff, ND. and Stolper WF. (1935) The long waves in economic life. *The Review of Economic Statistics*, 56, 3, 1935; S. 573-609.
- Rosemann, M., Becker, J. and Kugeler M. (2005) Vorbereitung der Prozessmodellierung. *Prozessmanagement. Ein Leitfaden zur prozessorientierten Organisationsgestaltung*, Springer, Heidelberg

- Rosemann M., van der Aalst, A. (2007) configurable reference modelling language, *Information Systems*, 32,1, 1-23
- Scheer AW. (1994) *Business Process Engineering - Reference Models for Industrial Companies* Springer Verlag, Berlin.
- Schuette, R. (1998) Grundsätze ordnungsgemäßer Referenzmodellierung: Konstruktion konfigurations- und anpassungsorientierter Modelle. *Neue betriebswirtschaftliche Forschung*, Gabler, Wiesbaden.
- Schuette, R., Rotthowe, T. (1998) The Guidelines of Modeling - An Approach to Enhance the Quality in Information Models, *Conceptual Modeling ER 1998*, Springer, Berlin, 240-254
- Thomas Oliver (2006) Understanding the term reference model in information systems research: history, literature analysis and explanation, *Business Process Management Workshops*, Springer Heidelberg, 484-496
- vom Brocke, J. (2003) Referenzmodellierung Gestaltung und Verteilung von Konstruktionsprozessen. *Advances in Information Systems and Management Science*, Logos Verlag, Berlin.
- vom Brocke, J. and Buddendick, C.: (2004) Konstruktionstechniken für die Referenzmodellierung – Systematisierung, Sprachgestaltung und Werkzeugunterstützung, in: Becker, J.; Delfmann, P. (Ed.): *Referenzmodellierung: Grundlagen, Techniken und domänenbezogene Anwendung*. Physica-Verlag Heidelberg, 2004.
- vom Brocke, J. (2007) Design Principles for Reference Modeling: Reusing Information Models by Means of Aggregation, Specialisation, Instantiation, and Analogy. in: Fettke, P.; Loos, P. (Ed.): *Reference Modeling for Business Systems Analysis*. Idea Group Publishing, Hershey PA, 47-75.
- Zimmermann H. (1980) OSI reference model--The ISO model of architecture for open systems interconnection, *Proceedings of the IEEE*, 28,4, 425-432