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Providing energy data and information for sustainable manufacturing systems by Energy Cards

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ABSTRACT

Energy and resource efficiency, as main parts of sustainability strategies, have become important objectives for industrial companies. For designing sustainable, energy-efficient manufacturing systems and processes, new or improved tools and methods focusing on energy efficiency are necessary. Detailed but also manageable energy data, information and knowledge are required for energy efficiency improvements. This leads to the need to illustrate the issue "energy" in a tangible and visible form. Energy Management, as an organizational instrument, helps to consider energy efficiency in daily planning and operation activities. Energy Metering supports the continuous acquisition of energy data. Energy Labels are simple tools for benchmarking similar goods. However, they are not available for different industrial systems of a factory. The presented tool "Energy Cards" merges energy data of a system and enables the transfer of energy data, information and knowledge in a structured and clear manner and directly to the shop-floor. In this article, the core concept and the structure of the Energy Cards are described. In addition, possible implementations and an example for determining energy demands are also presented.

1. Introduction

In the context of sustainability, the impacts on the environment have become fundamentally important for the society. Energy and resource efficiency are establishing themselves as substantial targets in entrepreneurial activities, apart from their costs, time, and quality. This is primarily due to an increasing demand of raw materials on grounds of a growing world population and a depletion of natural resources. Secondly, this is due to climate political objectives which intensify the demands for ecologically sustainable corporate managements. Climate political objectives are, for instance, reducing global emissions and promoting renewable energy [1]. Energy efficiency is recognized as an essential tool for energy savings; however, this potential is not yet fully exploited [2]. Thus, companies are requested to integrate energy and resource efficiency as target values into their processes. The process of integration concerns staff, organization and technology. Manufacturing systems have to be energy and resource-efficient in order to remain competitive.

Therefore, energy efficient factories and manufacturing systems are becoming increasingly important because energy consumption of productive companies is greatly determined by production. Factory planning plays a significant role for the energy efficiency of a factory [3]. In early planning phases, the energy level of the entire system is set up. Afterwards in the operation phase, energy improvements are only possible within these borders. Thus, there is a demand for tools and methods to systematically integrate the objective energy efficiency in planning and operation processes.

In order to design energy-efficient factories or manufacturing systems, different data and information about the structures and functions of systems such as machines or facilities are important. The quantification and the visibility of energy consumption are necessary to improve energy efficiency [4]. Usually, data about functional parameters, design or quality characteristics, etc. of the systems are available. However, a major deficit represents the lack of knowledge and the lack of transparency about the energy-related interrelationships in the factory. In general, information about the required energy supply is delivered by equipment manufacturers. Nevertheless, these are mostly given in different ways and there is no information about the power level or the energy consumption in different operation states. Furthermore, the access to this data is difficult. In practice, the data of machines, buildings, building services, etc. is managed by different departments of the company or by external service providers with the help of specific information and communication systems. Therefore, this data cannot be viewed in combination with each other and the access to it is only available for defined groups of individuals.

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Thus, a comprehensive energy-oriented view on the entire factory or manufacturing system with its subsystems is not possible. As a result, for the provision of energy data and information, at least the following theses have to be considered:

- Which energy data and information are necessary?
- Where are these, how to get and to access these?
- How to use these?

To meet these requirements, instruments and a developed tool for energy data and information are presented in this article. The next chapters are organized as follows: the state-of-the-art is discussed in Section 2. The core concept and the structure of the tool are described in Section 3 and possibilities for implementation in Section 4. An example for a use case is shown in Section 5. Section 6 summarizes the main facts about the current and the further research work.

2. State-of-the-art – providing energy data and information

2.1. Energy Management

Energy Management is an organizational key instrument for systematically improving the energy performance of a company. Energy Management can be defined as "forward-looking, organized and systematic coordination of the procurement, conversion, distribution and utilization of energy in order to cover requirements and which takes ecological and economic objectives into consideration" whereby an Energy Management System includes the required organizational, informational and technical structures and resources [5]. Energy Management provides goals, policy, responsibilities, activities and tools to integrate the topic energy in the daily operations and focuses on a continuous improvement of energy performance including energy efficiency, energy use and energy consumption [6]. It raises the transparency on energy consumers, consumptions and costs and helps to detect waste of energy. This is why Energy Management is also an important tool for energy efficiency-oriented factory planning and operation [7]. Besides, implemented and certified Energy Management Systems are required for energy tax reliefs in some countries. Energy Management is based on, like other management systems [8,9], the plan–do–check–act cycle. In this way, the ISO 50001 [6] defines different actions (e.g. evaluation of energy, recording and updating of the energy basis, determination of energy performance indicators) which require energy data. Therefore, energy measurements or Energy Metering on different factory levels (e.g. buildings, areas or machines) are needed.

2.2. Energy Metering

Energy Monitoring [10] or Energy Metering [4] or also Power Metering [11] is seen as a main part of Energy Management especially for systematic and continuous energy measurements. A review of the state-of-the-art in electrical Power and Energy Metering is given by O'Driscoll and O'Donnell [4]. Energy Metering is mostly developed and implemented as a separate IT system or as a feature of a Manufacturing Execution System. It collects, saves and visualizes energy data of the factory operation with the help of hardware and software for measurements. These data can be used for planning and optimization tasks, too. In connection to a Manufacturing Execution System or an Enterprise Resource Planning System, the energy data can be connected with detailed process data (e.g. pieces from scheduling) whereby significant performance indicators in real-time are derivable. The metering is usually constructed for different levels of acquisition, e.g. for an entire factory (e.g. [12]) or a single machine, especially by condition monitoring (e.g. [13]). The analysis and visualization of measured data plays an important role [14]. Moreover, approaches towards smart metering enables active controlling of energy use in connection with continuous measurements [15].

However, for planning and operation of an Energy Metering System, experts for energy improvements, energy measurements and IT as well as financial investments for hard- and software are necessary. Furthermore, there are discussions in science and practice about the direct benefit for energy savings by the implementation of Energy Metering Systems. At least, the transparency of energy consumers and consumptions is strengthened whereby waste of energy and potential for improvement become visible.

2.3. Energy and Eco Labels

Due to environmental impacts, legal requirements and interests of consumers, selected products have to be developed towards eco-design [16]. According to this, the products are equipped with labels. With the help of Energy or Eco Labels, a standardized comparison of consumer products (e.g. refrigerators, washing machines, televisions) [17], buildings [18] or cars [19] should be achieved. Currently, the scope of these labels is about to be extended for benchmarking industrial goods such as machine tools [20]. The labels comprise at least data about the energy consumption for a standardized utilization. The labels divide the products of a same product group into ascending energy efficiency categories depending on a fixed benchmark. The comparability of systems based on the objective energy efficiency plays an important role for planning. Energy Labels support purchase decisions through a standardized comparison and classification of the product as well as the prediction of the energy demand. However, labelling is a complex process. The challenge for standardization lies in the diversity of the product group and its processes [21]. Furthermore, the Energy Labels can only be used within one product group. Besides, there is a large diversity of labels with different content, precision and reliability [22]. However, especially in industrial environments with a lot of different processes and facilities, there are more extensive demands to provide energy transparency in the whole factory.

2.4. Deficits and potentials

As a result, it was found out that there are different tools which can be used to provide energy data and information. Energy Management is an organizational instrument which coordinates systematically the energy-relevant activities in a company. Therefore, it is expected to have energy data through measurements. Energy Metering are able to measure energy continuously. It has to be considered that extensive efforts (energy experts, finance, hard- and software) are required to implement Energy Management structures or to run a comprehensive Energy Metering. In addition, these instruments are mainly used by experts such as energy or facility managers. Thus, the remaining personnel has no access to the energy information. Energy Labels are mainly available for consumer products.

As a result of the first two chapters, different energy data and information are needed to optimize the energy efficiency of a factory and of manufacturing systems. Several instruments provide and use energy data, but in different styles and precisions and for a restricted circle of people. Furthermore, the data is managed by different departments and information systems in a company. Thus, it was found that there is a deficit in systemizing, concentrating and visualizing energy data and information, especially in a simple way and available for all persons in a factory.