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An Approach for Reducing Energy Consumption in Factories by Providing Suitable Energy Efficiency Measures

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Abstract

Energy efficiency has developed into an important objective for industrial enterprises. However, there is still a need for systematic approaches to reduce energy consumption in factories. Existing methods focus on the optimization of manufacturing processes and lack upon considering the entire factory system. Additionally, they are based on a detailed quantitative analysis of processes and thus, they need a high effort during the phase of data acquisition. Therefore, an approach for reducing energy consumption by providing energy efficiency measures to factory planning participants was developed in order to overcome these barriers. The general approach is described in this paper and supported with a use case that demonstrates the required information and possible outcomes in terms of energy efficiency information. Main advantages of this approach are reducing the effort to acquire energy data and the possibility to consider the factory system holistically.

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1. Introduction

The importance of energy efficiency as an objective for industrial enterprises increases due to ecological, political and economic reasons. Considering the ecological perspective, the International Energy Agency identified energy efficiency as most important driver to reduce global greenhouse gas emissions [1]. Political conditions are fixed upon both international and national levels. For example, the European Union drafted a long-term strategy in the "Energy Roadmap 2050", which includes, among other things, an 80-95 % reduction of greenhouse gas emissions until 2050 [2]. From an economic point of view, industrial enterprises have an incentive to reduce their energy consumption because of increasing energy prices, such as the European average prices for gas in industry, which rose by approximately 34 % during the last four years [3].

Despite this situation, the implementation of energy efficiency measures has not met the expectations yet. The reasons for the deficits in realizing energy efficiency include lack of time, lacking transparency on energy consumption, lacking capital for investments and divided responsibilities within a company [4].

Different tools and methods have been developed in recent years to support the systematic analysis and optimization of industrial enterprises for reducing their energy consumption. However, the existing methods mainly focus on manufacturing processes and systems. Although these are important aspects of the energy-efficient factory, considering the interrelationships between products, processes and resources in the factory system is essential for a holistic integration of energy efficiency in the enterprise.

Another barrier in implementing methods is the high effort for data acquisition. Therefore, an approach to reduce energy consumption within factory systems was developed that

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provides energy efficiency measures to factory planning participants based on qualitative data [5].

The remainder of the paper is organized as follows: An overview of the state of the art of energy efficiency-oriented factory planning is described in section 2. The overall concept for the methodical approach is presented in section 3. A detailed use case describes the implementation of the approach in section 4. Section 5 summarizes the results and gives an outlook on future research work.

2. State-of-the-art

In general, existing tools for considering energy efficiency of manufacturing systems can be divided into assessment, monitoring and inventory tools on the one hand while engineering, design and improvement tools on the other [6]. The following discussion is focused on the second group, since the aim is to reduce energy consumption in factory systems.

The existing tools to support energy efficiency-oriented factory planning and management can be divided into energy efficiency guidelines, principles and methods [5]. Table 1 provides an overview on these tools, which are described in detail in the following.

Table 1. Overview on existing types of tools for energy-efficient production.

	Description	Example(s)
Energy efficiency guidelines	Collection of energy efficiency measures in specific sectors or fields	US Department of Energy – Energy Efficiency & Renewable Energy: Guide to Energy-Efficient Lighting [7]
Energy efficiency principles	Small number of general approaches for energy efficiency	• substitute energy sources • increase efficiency of equipment • energy recovery (selected according to [8])
Energy efficiency methods	Systematic approaches to identify and realize energy efficiency improvement opportunities	Energy metering and assessment of manufacturing processes

Guidelines provide an overview on energy efficiency measures within a specific industrial sector or a specific field of application (e.g. lighting). The guidelines are mainly published by independent institutions or governmental organizations (e.g. [7]). By providing information close to application and including examples of realization within enterprises, the guidelines are suitable for practitioners. However, finding the information that is relevant to a specific use case requires lots of effort and time.

Energy efficiency principles contain a collection of a small number of general approaches to increase energy efficiency. They are identified by generalizing energy efficiency measures and are mainly published by research institutions or consultancies. One example is distinguishing between substitution of energy sources, reduction of energy demand, increase efficiency of equipment, reduction of process losses, energy recovery and direct use of losses for heating [8]. Further examples can be found in [5].

Energy efficiency methods describe a systematic approach on the identification and realization of energy efficiency improvement opportunities. There are varieties of energy efficiency methods available in scientific literature, from which only a selection is presented in the following. The majority of energy efficiency methods focuses on manufacturing processes and identifies measures based on a detailed quantitative analysis of the underlying processes, whereof mainly manufacturing processes are considered (e.g. [9, 10]). Some contributions describe the implementation of analyses with regard to the requirements of a specific sector [11]. Other publications expand the approaches in terms of other objectives (e.g. resources, waste) and to a wider system definition (e.g. factory level) [12, 13]. There are also methods that do not require a quantitative analysis but lack to provide methodical support for the deduction of appropriate energy efficiency measures. The main focus of these methods is to create transparency within the process (e.g. [14]).

In general, the existing energy efficiency methods can be described by the general scheme to define a system, analyze the processes within the system by means of energy measurements, prioritize sub-systems and deduce energy efficiency measures. By using the measurement results, the expected savings of energy efficiency measures can be assessed quantitatively.

However, this state-of-the-art approach requires high efforts during the analyzing phase in order to acquire the relevant data. Another barrier lies in the necessity of expert knowledge for the deduction and description of energy efficiency measures since the existing methods do not describe this step detailed enough to enable practitioners to transfer it to another application on their own.

Thus, there is need for research for developing an approach to systematically identify suitable energy efficiency measures for a defined project task without the high effort of acquiring energy consumption data. The deduction of measures should be transparent in order to make the approach understandable and manageable.

3. Methodical Approach

The two most important requirements for the methodical approach are the systematic procedure and the reduction of effort for system analysis. The systematic procedure needs to ensure that information to factory planning participants is provided in a structured way (compared to energy efficiency guidelines, where there is no guidance for practitioners to find the information that is relevant for their specific situation). The reduction of effort for system analysis increases the applicability of the methodical approach since high effort for data acquisition without the possibility to forecast the results in energy savings is a high barrier for industrial application.

Based on these requirements, a general concept has been developed to systematically guide a factory planning participant from his or her project task to appropriate energy efficiency measures. The goal is to provide suitable energy efficiency approaches in order to increase the efficiency of