Abstract

Companies are forced by rising energy costs to seize control of their energy consumption to maintain contestability. Therefore, transparency over the companies’ energy flux along the production process is required. Energy data management software is helpful, but cost-intensive. Hence, especially small and medium sized enterprises (SME) spare this investment. In this paper, the requirements for an energy controlling infrastructure in SME are elaborated, followed by a deduced software-architecture which supports the respective controlling structure. Further, the prototypical realization of the corresponding tool “Green Cockpit” will be presented. The free of cost, open source and web-based tool is designed to help companies monitor, interpret, analyze, plan and report their energy consumption. The Green Cockpit tool outperforms other energy management software at management disciplines with its ability to not only analyze energy consumption, but plan and control it additionally.

Keywords: Energy controlling, energy management, operations management, open source data management

1. Introduction

Many, especially producing companies, are aware of the urge to save resources. Hence Thamling et al. [1] observed in their study in 2010, that 50 % of all polled enterprises in the segment of small and medium-sized enterprises (SME) consider energy efficiency as an important topic.

Due to a lack of tools and instruments for monitoring and controlling of resource consumptions, there is often times a missing of ability to identify and raise efficiency potentials. On a methodological level, energy management systems provide support. With the framework, which is suggested for instance in the ISO 50001, energy streams become transparent in order to reveal saving potential.

Even though there is given a basic method of how to proceed for the evaluation of a company’s energy consumptions hereby, a tool is missing which fulfills the ongoing need of analyzing, planning and controlling energy consumptions from an information technological perspective. Many suppliers of energy metering equipment provide energy data management software. However, this software does not address the problem in an ideal way for two reasons:

Usually, the software is cost intensive, which enlarges the restraint of companies (especially SME) to invest into an energy monitoring system. Further, the software modules support mainly the analysis of energy consumption with an emphasis on the technical aspect. There is yet no satisfying solution for the support of operative and strategic decision making as well as for the rolling planning process along with ongoing controlling.

The following paper compiles the reasons for, and the requirements of an energy controlling in SME and describes the structure of a prototypical energy controlling tool “Green Cockpit” which meets these requirements as described.
2. Energy Transparency

If the metering of energy consumption is being executed in a systematic, regular and repetitive way, one speaks of energy monitoring. If the gained data are being augmented with output values (e.g. consumption per unit produced) and used in a controlling circuit, one can speak of energy controlling, which represents a tool for generating transparency. [2]

As Hesselbach [3] notes, there are two fundamental ways of measuring energy consumptions in companies:

- Top-down: Measuring the overall energy consumption (i.e. for a production site by the energy supplier) along with subsequent derivation of information for the causative processes.
- Bottom-up: Measuring every single consumer (i.e. every machine of a site by using energy meters) along with the derivation of information for the overall consumption.

For the reason of an accurate, relatable and accurate metering with low time expenditures, permanently installed meters should be implemented according to the bottom-up approach, which measure the consumption according to defined parameters.

3. Energy controlling in enterprises

For organizational reasons, there is often times an institutional segmentation of strategic and operative controlling, whereby both departments contain the fields planning, controlling and reporting in the corporate practice.

3.1. Strategic and operative controlling

As Fischer et al. [4] clarify, the main difference between operative and strategic controlling lies in the goal of both alternatives. While the strategic controlling aims to ensure the sustainable and permanent existence of the company, the operative controlling strives year after year for the improvement of profitability and productivity. The operative controlling acts as supporting organ of the operative management level in order to meet these goals and sets its focus on the own undertaking under consideration of tactical and operational planning. The success of the operative controlling bases according to Vollmuth [5] substantially on the timely detection of variances from the defined goals.

With this classification, energy controlling can be assigned to the range of duty of the operative controlling. Particularities arise in the field of SME. Ihlau et al. [6] noticed in this context, that SME often maintain a simple, fiscal characterized accounting system, have restricted information sources, have only limited internal controls and the planning of business is not existent or not documented.

3.2. Incorporation of energy controlling in SMU

From the four solutions to organize controlling in SME, described by Peemöller [7], mainly two are deployed in corporate practice according to Reiß and Denison [8]: the implementation of a controlling position and the split-up of the controlling tasks. The extension of the regular controlling scope of duties with the field of energy involves, according to Gänfllein et al. [9], the following steps:

1. Provision or generation of energetic information as process input.
2. Processing or transformation of energy information via appropriate controlling instruments within the processes.
3. Provision of preprocessed energy information in a comprehensible form to the process customers.

Taking the management reporting as an example process, energy information needs to be gathered, analyzed, reported and discussed besides financial information, for instance.

3.3. Configuration of energy controlling

The foundation of energy controlling is the energy monitoring, hence the systematic and regular capture of all relevant energy data. According to Hesselbach [3], it requires the following components to realize an energy monitoring system:

- Measuring equipment (i.e. intelligent meters)
- Transmission equipment (i.e. bus cabling)
- Signal conversion
- Data logging (data base)

A data preparation and analysis is required for a sound evaluation of the energy consumption after the elicitation. In this context, data preparation primarily means the generation of comparability. Based on Schöhn [10], one can compare energy data for instance as follows:

- actual-vs.-actual: Comparison of the energy consumption of a single consumer; for instance comparing a present value with a historical value
- benchmark-vs.-actual: Comparison of the energy consumptions of two consumers (one of both being the benchmark)
- target-vs.-actual: Comparison of actual values with target values, which were planned in the past
- target-vs.-forecast: Comparison of target values with forecast values (values which are adjusted by actual values)

The expressiveness of measured values can be raised through the generation of appropriate key figures by associating the values with output dates. Exemplary performance indicators are listed in table 1.

| EnPI | Calculation formula | Unit |
|------|---------------------|------|
| Specific energy consumption | Energy consumption Output | kWh, pieces |
| Energy intensity | Energy consumption Total energy consumption | % |
| Specific energy costs | Energy consumption Costs of production | kWh, euro |
| Revenue based energy efficiency | Revenue (per product) Specific energy costs | % |
After the data preparation and formation of performance indicators, one can proceed with the energy analysis. The analysis contains the comprehensive contemplation of the monitored energy consumption.

Due to the enormous amount of data, instruments for visualization must be deployed in order to master the complexity. According to Grahl [11], energy saving potentials can be revealed with the help of these instruments by a macro analysis, followed by a micro analysis for further detailing.

After identifying energy saving potentials, it is important to work systematically and focused on the realization of the appropriate measures. The determination of realistic and achievable target values is therefore a suitable procedure. Subsequently, the ongoing comparison of actual key figures/energy performance indicators with the defined target values indicates whether the measures are expedient.

The process of determining target values is similarly arbitrary as the process of forming key figures. Depending on the goals and the processes which are to be optimized, each company has to define its own, realistic target values. According to Gleich et al. [12], several alternatives of setting target values from the corporate division “planning and budgeting” serve as aid for orientation:

- figures from previous years;
- benchmark values;
- calculated values (i.e. physical minima);
- top-down derived target values;
- negotiated target values.

The review and control process using target values can only be effective, if all process customers are being regularly and systematically provided with the latest, appropriate figures/EnPIs and target values. The control circuit is closed by the reporting system, subsequently.

According to Sicher et al. [4], the outcomes of reporting systems can be differentiated between standard reports, deviation reports and demand reports. With these reports, any process customer is able to initiate measures with the aim to achieve the defined goals and monitor their impact in the aftermath.

4. Prototypical realization of the Green Cockpit

The Green Cockpit prototype covers the fields as listed in table 2. The underlying processes are described in the following.

| Category     | Requirement                                      |
|--------------|--------------------------------------------------|
| Administration| Access control and user management               |
| Interfaces   | Optional export into Microsoft Excel             |
| Data processing| Generation and compression of characteristic values and EnPIs |
| Controlling  | Variance analysis (i.e. actual figure vs. target value) |
| Reporting    | Web based standard reports and ad hoc reports    |

4.1. Fundamentals of data warehousing architecture

According to Müller and Lenz [13], business intelligence (BI) deals with the gathering, preparation and analysis of internal (i.e. operational) and external data of all activities in a company, aiming for the creation of knowledge.

The data gains economic significance by transforming micro data (e.g. energy consumption in the seconds range) into analytical data (aggregated, sorted and grouped operational data). Analytical data can be derived from micro data via OLAP-operators (online analytical processing) and stored in data warehouses (DW) in the form of data cubes. Data cubes (as multidimensional data structures) allow for historic and statistical analyses as well as for the generation of key figures/EnPIs.

A comparison between the requirements of an energy controlling with the features of BI shows, that BI fits perfectly for the realization of an energy controlling process. The core of a BI-tool is the data warehousing process which contains the process of data acquisition from internal (operational) and external sources, the data transformation and data preparation, the process of loading the data into the data warehouse or data marts, respectively, and the OLAP-based data analysis.

4.2. Basic structure of the Green-based data analysis

The setup of Green Cockpit follows the basic structure as illustrated in figure 1. All relevant internal and external data are extracted via interfaces from the connected data sources and loaded into a staging area. In this temporary storage, the data are being revised, targeting the homogenization via transformation processes depending on their quality and eventual conflicts, and prepared for the generation of performance indicators.

![Fig. 1. Basic structure of the Green Cockpit](image-url)
After a successful transformation, the data are being saved in a core data warehouse and under certain circumstances outsourced into data marts for performance reasons. With OLAP-based analyses of data and OLAP-queries, these data are accessible for process customers, eventually.

4.3. Data source

Internal and external data are usually stored on the data servers/hosts in a company. The access to these data is executed via an interface between the BI-System and the server. Ideally, relevant data such as manufacturing data (e.g., output quantity) and energy data (e.g., energy consumption) are ready for instant recall on one or several data bases from which they can be called up at any time. For the purpose of the Green Cockpit these databases are being provided in the *.xls file format. There are five file categories: energy data, financial data, manufacturing data, target value data and core data (which are necessary for merging the categories).

4.4. Data processing (ETL) with “Talend Open Studio” (TOS)

The process of gathering, transformation and preparation of data is described by the ETL-process (extraction, transformation, loading). According to Schön [10], the respective process is responsible for the correct transmission of all data into the data warehouse:

- **Extraction**: Extraction of all relevant data from the data sources and deposition in a staging area.
- **Transformation**: Homogenization of all data formats and data structures which are stored in the staging area according to the scheme in the core data warehouse by transformation processes.
- **Loading**: Under consideration of the rules for extraction and transformation, the data are being loaded into the core data warehouse.

The implemented tool (Talend Open Studio) defines itself as a code generator and converts virtually modeled processes into source code, which can be executed subsequently. In a first step, all internal and external data are being extracted from the data sources and loaded into the staging area. As for the prototype, the source system consists of several *.xls files, the staging area of a *.csv file. In a second step, the data base, the data cubes and all required dimensions are being compiled along with their dimension elements and loaded eventually.

When data base, data cubes, dimensions and elements have successfully been compiled, the transformation process is ready to start. The transformation processes are preparing the buffered data of the staging area in a way, so that they can be loaded into the data cubes. This data preparation contains, besides the homogenization and merging of different data table, the formation of pre-aggregates.

The modeling of the ETL-processes terminates with the loading of all prepared data into the cubes and the generation of key figures according to the specified rules. These rules lead to the feature, that any user query (e.g., EnPIs) can be calculated in real time from the underlying data.

4.5. Data warehouse through “Palo Community Edition”

For being able to evaluate the data from the core data warehouse in a fast and flexible way via multidimensional-analyses, the OLAP-methodology can be used. According to Kemper et al. [14], OLAP is being described by five criteria:

- **Fast**: Regular queries need to be processed within 5 seconds, complex queries within a maximum of 5 seconds.
- **Analysis**: An intuitive analysis and the possibility of any calculation must be ensured.
- **Shared**: An effective access control and the possibility of a multiple user operation must be provided.
- **Multidimensional**: The possibility of a conceptual, multidimensional view must be existent independently of the underlying data base structure.
- **Information**: Due to the scalability, the response time of queries must remain stable even at large amount of data.

The specialty of multidimensional analyses is the fact, that they have a multidimensional data room underlying. Subsequently, OLAP-systems can provide data analysis operations such as pivoting, drill up/down or split and merge with a very quick response time.

The “Palo Community Edition” is a license free basic package, consisting of tools for the realization of typical BI-processes. The basic package provides all relevant components which are necessary for the Green Cockpit prototype. The Palo OLAP server is the core component. It is operated as a multidimensional in-memory-OLAP-server, in which the loading operations are being executed during the starting procedure of the OLAP-server application, which loads the complete data base from the ETL-process in cube structures into the internal memory. Modeling the data cubes with Palo-internal tools happens through the provided web module, which needs to be installed on a central server. This leads to the advantage, that the Green Cockpit can be operated from any computer with a common web browser. Depending on the access rights, the user has access to the contents of Green Cockpit interface via the user interface. “Palo Pivot” serves as a tool for the creation of ad-hoc reports.

4.6. Standard reports in Green Cockpit

Reports can be created on the user interface of Green Cockpit. After successful login, the user can administrate standard reports, which means create, delete, edit, and import or export reports. The four standard reports, provided in the Green Cockpit prototype, are described in table 3.

Figure 2 shows an exemplary screenshot of the standard report “energy planning”. Area (1) outlines a mask for planning the energy consumption of all production sites. In the columns of (2), the target factors (as described in table 3) can be set for each plant. The fields in (3) show a tabular comparison of actual and target (planned) values which are displayed graphically in (4). The fields in (5) serve the purpose to navigate between the different reports (see table 3).
5. Conclusions

With the development of the Green Cockpit prototype, a tool is being designed which meets the identified requirements for an energy controlling in SME. Hence, it helps managers to identify critical energy related figures. Discussions with energy data management software producers indicate, that the Green Cockpit prototype strikes a new path when it comes to energy controlling on a management level. However, first tests in companies showed that the implementation into the process data stream is a complex matter, since an energy metering infrastructure, which is installed in the aftermath, does not necessarily have an interface with the operating data system.

Figure 3 shows the draft of a data stream which can be implemented in a very easy way, since it uses features of existing software end equipment with minor additional adjustments only. The interpretation of the energy meter data (impulses) is being taken care of by a software which is usually provided by the meter fabricator. The energy data can then be exported to a *.xls file similar to the export of operation data by operating data systems. The data files can finally be loaded to a “Green Cockpit data base” for raw data which is then the point of contact for the Green Cockpit as it is described in this paper.

![Data stream for Green Cockpit 2.0](image)
Furthermore, testing the Green Cockpit gave the insight, that it can be of interest to evaluate electricity expenditures in the context of other expenditures, such as personnel or material. The next version of Green Cockpit will have an interface to accounting tools which will provide information that the operating data system cannot provide.

In the end, managers are designated as users of the Green Cockpit. However, some managers might not be able to work in a web-based environment. Subsequently, it is to be tested, if a Microsoft Excel based version of Green Cockpit can provide the same flexibility and functionality without losing the performance advantages of a web based tool.

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