Demand-side Energy Management Systems for Manufacturing

Michael Ameling, Markus Schief, Frank Nietzold, Christian Kuhn
SAP Research
[name.surename]@sap.com

Abstract: The awareness of energy consumption is an important factor for production. Energy consumption is related to costs. Regulations and laws have to be fulfilled. Furthermore, the ecological aspects have to be considered. Nevertheless, competitive goals prohibit an solely energy driven production control. In this paper, we describe the use case of demand-side energy management in the context of the project ADiWa and the Internet of things. Furthermore, the event-driven approach is being evaluated within a living lab. Current results are demonstrated with a first prototype.

1 Introduction

Sustainability is one of today's major trends that is heavily discussed on social, political, and economic perspectives. A particular focus in terms of sustainability is on energy management and carbon dioxide emissions. For organizations, both have a tremendous relevance. Firstly, associated expenses are an relevant factor, particularly in energy-intensive manufacturing. The price for energy supply and emission certificates, which are coming up with legal regulations, are important expenses. Secondly, a gradually increasing awareness of people in line with continuous presence in the media is forcing companies to consider emissions as an important image factor. Finally, reliability of energy supply is very important as energy is an integral part for manufacturing's business continuity.

Renewable energy supply is expected to cope with these challenges. Especially, local energy generation is a central element in today's strategies towards sustainable energy management. However, challenges such as natural fluctuation are associated with the acceptance of renewable energies. While some solution concepts address the supply side, e.g., by ensuring a broad mix of various energy sources, also the demand side offers potential to cope with this problem. The latter implies to adapt the power consumption to the availability of power. For a continuously-synchronized match of supply and demand, transparency is needed in terms of actual and planned power supply and consumption which can be provided by an highly-sophisticated energy information system based on smart meters. Along with agile business process management concepts, the goal of demand-side driven energy management can be realized. Certainly, the impact on business processes cannot be neglected, but needs to be an integral part of any potential solution. Boundary conditions in production such as capacity utilization and material consumption need to be reflected as well. In this paper, we propose a solution concept for green manufacturing based on demand-side energy management (DSEM). In addition to prognosis of demand and supply, an energy management system including intelligent load-balancing is introduced.

2 Related Work

DSEM is derived from the term demand-side management (DSM) [GC88]. DSM refers to utility activities only [Ene]. The influence on energy demand of end users with the objective of avoiding peak demands and flatten load-shapes is primarily focused. DSEM aims at providing a system at the consumer's side, which supports manufacturing in matching their energy demand to the availability of fossil and renewable energy. Currently there are a variety of ongoing research activities on the topic of energy efficiency. The German publicly funded research program E-Energy [een] is setting a "common ground between energy efficiency and information technology" with the objective of creating an "Internet of Energy", as networking is seen as an essential component on the way to increase energy efficiency and the use of renewable energy. One outcome of the E-Energy program is EE-Bus [eeb], a uniform communication standard between devices, realizing in combination with intelligent software a holistic energy management system.

Smart metering plays a crucial role for the establishment of energy management systems. As a prerequisite for realizing DSEM, recent laws [BD09] force utilities to install smart meters at the points of consumption. Metering infrastructures, as described in [KTK], provide the technical basis for gathering detailed energy consumption data. The Smart-House/SmartGrid project [KKN$^+$09] investigates, how ICT technology can be applied to the communication of Smart Houses with both customers and energy devices within intelligent electricity networks (Smart Grids). Their objective is to fulfill the requirements of decentralized power systems, which are becoming increasingly widespread. Smart metering in households is also investigated in [Str08], where consumption feedback is presented to householders through an in-home display, aimed at changing the householder's energy consumption habitus. However, little research has been done in the domain of manufacturing. Though energy aware production and the use of green energy, and hence energy management systems, become increasingly important for industries, since regulations, such as the Kyoto protocol [oCC97] or the "20-20-20 by 2020" aims by the European Commission [ECtCotR07] force companies to reduce their greenhouse gas emissions.

3 Scenario

To enable DSEM, transparency in terms of energy supply and consumption is a crucial prerequisite. For local energy generation, the energy supply strongly depends on the involved resources. In our scenario, we assume that based on the amount of resources, the mix of resources, and external factors of influence like weather forecasts the potential availability of energy can be predicted. Consequently, a company's target energy demand curve, which matches the supply forecast, can be defined.

In addition to energy supply, actual energy consumption needs to be as transparent as possible. For our scenario, we aim at tracking energy consumption on a single product item level. By that, energy transparency on various granularities such as equipment, machine, and process level can be achieved. Then, for future production plans, the statistics of energy consumption can provide an estimate for an energy demand curve. There is no denying the fact, that the accurateness of energy-demand planning depends on the production type. For instance, in make-to-stock scenarios the produced products are standardized and hence the forecast values are pretty good. Moreover, energy overheads that cannot be assigned to a specific product item instance need to be allocated as well via apportionment of indirect costs. If historical product-item-based energy consumption values are available, two main benefits can be reaped. Firstly, fluctuations over time, peak demands, and extensive energy consumption can be identified. So, respective measures such as an extraordinary maintenance can be triggered to avoid increasing energy consumption. Secondly, along with the order book and the production plan, future energy demand curves can be calculated for certain time intervals.

For any time interval, the target energy demand curves can be compared with the predicted energy demand curve. For our scenario we focus on the case that the planned demand curve exceeds the target demand curve (overall or in some areas). The production plan hence needs to be adapted. Basically, the energy target demand curve can be interpreted as an additional boundary condition within a production planning system. Thus, the system needs the following enhancements. Similar to other categories such as load factors, delivery dates, and throughput times, energy availability can be calculated as one optimization parameter. Depending on the particular purpose of an organization and the importance of concurrent goals such as delivery dates and capacity utilization, the priority and the severeness (must/can) of this additional parameter can be defined. Finally, the production plan should be updated and the target demand curve should not exceed the planned demand curve anymore. If production plans need to be constantly updated, a general change in energy supply should be considered. For instance, respective resources need to be increased to lift the target energy demand curve. All in all, two components can mainly contribute to the scenario: the identification, processing, and usage of real world events (i.e. energy consumption), as well as the agile adaptation of manufacturing processes.

4 Concept

The design of an energy management system, which supports production planners in optimizing the energy consumption in production, is driven by the requirements of the described scenario. Figure 1 shows the design for a layered architecture. In the bottom layer there are all devices and data sources, such as smart meters measuring the energy consumption on device level or services providing energy price and weather forecast information. Both energy price and availability define the target demand curve of energy.

In the next layer, the connectivity layer, all devices and data sources are connected via specific input output adapters to an event bus. Its task is to transform all the data from the bottom layer into uniform events, which can be processed by components in the layers

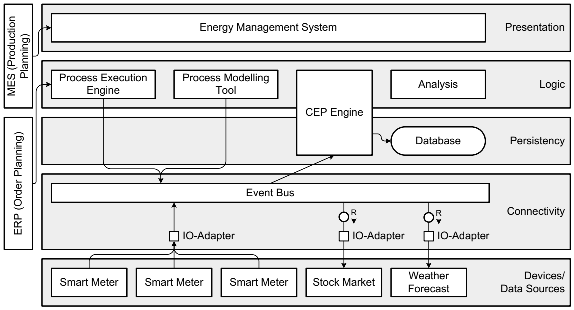

Figure 1: Architecture

above, after subscription. Smart meter data is pushed into the event bus, whereas stock market and weather forecast information are pulled by the bus. The event bus is also responsible for the communication between the components of higher layers and it is intended to perform a filtering, a content-based routing of events and a quality check of the event data. Filtering means that, for instance, if a smart meter sends unchanged energy consumption to the event bus every ten seconds, the event bus can filter these events unless no different value appears, and therefore forward only changes of the consumption, preventing unnecessary work load for components in a higher layer. Content-based routing means that it can recognize the receiver of the event based on data contained in the event.

A complex event processing (CEP) engine consumes the events from the bottom layer. Its task is to analyze, process and combine low level events and to generate new higher level (complex) events out of them, based on predefined rules. For example, a new event can be created if the energy consumption is above a certain threshold. The CEP engine is a cross-layer component, which is located in the persistence layer as well as in the logic layer. It is involved in the persistence layer, as events have to be stored in a database, since energy consumption data has to be kept over years in order to provide a basis for any statistics. But it is also involved in the logic layer as it does analysis of the data contained in the events such as historian data, the current consumption, and forecasting. The analysis component is responsible for data mining, i.e. the recognition of abnormalities within the data set. This enables to predict future events on the basis of previous events or to detect missing events. It can be used, for example, to recognize device malfunctions, overloads or the exceeding of consumption limits defined by a contract.

The top layer is the presentation layer, the user interface of the energy management system, which is mainly responsible for displaying the energy consumption on different levels, such as organization, process, device and product level, analysis results and complex events. It therefore provides an intelligent energy dashboard. In a later stage it can be connected to external systems, such as a process execution engine, a business process modeling tool, an enterprise resource planning system or a manufacturing execution system. This will allow the system to give optimization advices to production planners and will enable a semi-automatic production planning.

5 Prototype

The current prototype focuses the device connectivity and the visualization of smart meter information. DSEM requires a sufficient monitoring of consumed energy. In manufacturing a fine grained energy monitoring, done by energy meters, results in observing the power consumption of machines individually. The devices monitor the current used power (in watt) or the used power for a defined interval (in watt hours). Therefore, we are able to monitor and analyze the power consumption. Nevertheless, the integration into the aimed solution for the forecasting of power consumption and the dynamic process control will follow in upcoming prototypes. Finally, the collected data has to stored persistently after passing event bus and CEP engine in order to allow an detailed analysis. Furthermore, a proper visualization for energy monitoring has to be enabled. Within a vertical prototype we enabled the visualization of collected energy data by several smart meters. The *SAP Manufacturing Integration and Intelligence* (SAP MII) was used for the connectivity of the devices.

Since the first prototype was dedicated for energy monitoring a dashboard solution for visualization was chosen. Therefore, the SAP BusinesObjects Xcelsius was used for the user interface. The SAP MII provides the data via Web Services, respectively. Currently, we are connecting several energy meters observing several machines, e.g., a milling machine. The current used power of individual machines as well as the historian energy used can be seen in one dashboard (see Figure 2). The prototype is running at the *SAP Research Future Factory Dresden*, a living lab equipped with hardware and new technologies in the manufacturing environment. Several energy meters from different vendors are used for data acquisition. With future extensions it will become a complete energy monitoring of all equipments (machines) used for production within the *SAP Research Future Factory*.

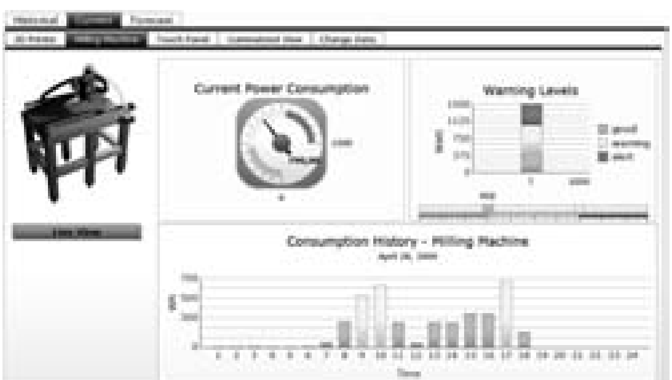

Figure 2: Energy Consumption Dashboard

6 Conclusion and Outlook

In the context of the future Internet we provided a concept for a generic solution following the event-driven approach. We are able to bring heterogeneous events from the real-life environment up to the next level. The approach offers a decision support reaching a green and lean production. In a decent prototype we proved the concept of device connectivity, event processing and visualization. Therefore, we are able to provide awareness of energy consumption in the manufacturing environment and a decision support as aimed.

7 Acknowledgments

This research is partly funded by the German Federal Ministry of Education and Research (BMBF) under contract 01IA08006, project ADiWa (www.adiwa.net), from January 2009 through December 2011.

References

[BD09] Bundesgesetz Bundesrepublik Deutschland. Energiewirtschaftsgesetz (EnWG) - Gesetz über die Elektrizitäts- und Gasversorgung, 08 2009. FNA: 752-6.

[ECtCotR07] The European Economic, Social Committee, and the Committee of the Regions. 20 20 20 by 2020 - Europe's climate change opportunity. Brüssel, 01 2007.

[eeb] EEBus: Inhome integration of energy consumers and energy management: http://www.kellendonk.de/eebus/. Last call: 20th April 2010.

[een] E-Energy Website: http://www.e-energy.de. Last call: 20th April 2010.

[Ene] Energy Information Administration Glossary: Demand-side management. Website: http://www.eia.doe.gov/glossary/. Last call: 20th April 2010.

[GC88] C.W. Gellings and J. Chamberlin. *Demand Side Management: Concepts and Methods*. The Fairmont Press. Lilburn, GA, 1988.

[KKN+09] Kok Koen, S. Karnouskos, D. Nestle, A. Dimeas, A. Weidlich, C. Warmer, P. Strauss, B. Buchholz, S. Drenkard, N. Hatziargyriou, et al. Smart Houses for a Smart Grid. In *20th International Conference on Electricity Distribution*, 8-11 June 2009.

[KTK] S. Karnouskos, O. Terzidis, and P. Karnouskos. An advanced metering infrastructure for future energy networks. *New Technologies, Mobility and Security*, pages 597–606.

[oCC97] UNFCCCC United Nations Framework Convention on Climate Change. Kyoto Protocol. http://unfccc.int/resource/docs/convkp/kpeng.pdf, 12 1997.

[Str08] Y. Strengers. Smart metering demand management programs: challenging the comfort and cleanliness habitus of households. In *Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat*, pages 9–16. ACM, 2008.