Energy management control systems: A quantitative and qualitative approach to the development of a holistic corporate energy strategy

Master thesis

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Kurzfassung

Entwicklungen der letzten Jahre deuten auf die Fortsetzung des Trends steigender Energiepreise hin. Diese sind von Produktionsunternehmen mit Ausnahme einer professionellen Einkaufspolitik nicht beeinflussbar. Um wettbewerbsfähig zu bleiben, sind Unternehmen angehalten, ihre Einflüsse auf Energieeffizienz auszuüben, um den Energieverbrauch im Unternehmen kontinuierlich zu senken. Die erfolgreiche Umsetzung kurz- als auch langfristiger Energieeffizienzmaßnahmen erfordern neben den notwendigen Ressourcen das Commitment der obersten Führungsebene.

Basierend auf den verschiedensten Feldern der Theorie (Benchmarking, Controlling, Datenanalyse, Organisation etc.) beabsichtigt die vorliegende Arbeit die praktische Umsetzung von Energieeffizienzmaßnahmen in der HIRSCH Servo AG mit ihren 20 Produktionsstandorten aufzuzeigen.

Das übergeordnete Ziel dieser Arbeit ist es, mittels quantitativen aber auch qualitativen Ansätzen die Grundlage für die Einbindung einer Energiestrategie in die Unternehmensstrategie zu schaffen. Diese umfasst neben einer konsequenten Zusammenarbeit bisher völlig unterschiedlich agierender Unternehmensbereiche auch Maßnahmen zur Bewusstseinsbildung. Das „Wie“ steht dabei im Vordergrund. Ein Energiemonitoring aufbauend auf technisch robusten Daten bildet die Ausgangssituation. Objektive Effizienzsteigerungen und Überleitungen in die entscheidungsorientiert aufgebaute Kostenrechnung können nur auf Messungen und validen Mengengerüsten beruhen. Das interne Benchmarking, basierend auf mehreren Produktionsstandorten, ist wegen der schwierigen Beschaffung vergleichbarer externer Unternehmensdaten eine bedeutende Vorgehensweise für Verbesserungen der Energieeffizienz. Energiekennzahlen für die Analyse und die Steuerung sind unternehmensbezogen aufzustellen.

Im Praxisteil erfolgt die Anwendung der theoretischen Ansätze auf den Produktionsstandort. Ein Messkonzept zur Erfassung der eingesetzten Querschnittstechnologien bildet die Grundlage einer verursachergerechten Zuordnung der Verbräuche und schafft damit die Voraussetzungen für das Aufzeigen von Effizienzpotenzialen. Mit einem Konzeptvorschlag von unternehmensspezifischen Energiekennzahlen soll neben der Entscheidungsgrundlage für die Einbettung bestimmter Kennzahlen in ein standardisiertes Berichtswesen auch der Grundstein für ein fundiertes Standortbenchmarking gelegt werden bzw. ein erster Schritt hin zu einer verursachungsgerechten Zuordnung von Energiekosten erfolgen.

Die Vielschichtigkeit und die Komplexität von Energieeffizienzmaßnahmen führen zur Entwicklung eines Erfassungsbogens. Es müssen neben den messbaren Daten auch qualitative Elemente bei der Umsetzung des Ziels berücksichtigt werden. Ein Erfassungsbogen ist das Ergebnis der Gespräche vor Ort und der Aspekte im Theorieteil. Das Sammeln und der Austausch von praktischem Wissen ist die Grundlage beim Aufbau eines standortübergreifenden Energiemanagementsystems.

Mit Verweisen zwischen dem Theorie- und Praxisteil wird vermittelt, dass es beim Thema Energieeffizienz Anknüpfungspunkte an viele Wissenschaften und Bereiche der Organisation gibt.

Abstract

Developments in recent years show that the energy prices keep rising constantly. This cannot be influenced by production companies with the exception of a professional purchasing policy. To remain competitive, companies are required to exert their influence on energy efficiency in order to reduce continuously energy consumption in the company. The successful implementation of short-term and long-term energy efficiency measures requires, in addition to the necessary resources, the commitment of top management.

Based on the various fields of theory (benchmarking, controlling, data analysis, organization, etc.), the present thesis intends to show the practical implementation of energy efficiency measures at HIRSCH Servo AG with its 20 production sites.

The overall objective of this thesis is to create the basis for integrating an energy strategy into the corporate strategy by means of quantitative as well as qualitative approaches. In addition to a consistent cooperation of previously completely different operating divisions, this also includes measures to raise a certain awareness.

The "how" is in the foreground. An energy monitoring based on technically robust data forms the starting point. Objective increases in efficiency and reconciliations in decision-oriented cost accounting can only be based on measurements and valid quantity structures. Internal benchmarking, based on multiple production sites, is an important way to improve energy efficiency because of the difficulty of sourcing comparable external enterprise data. Energy metrics for analysis and control are business related.

In the practical part the theoretical approaches are applied to the production site. A measuring concept for recording the cross-sectional technologies employed forms the basis of a source-related allocation of the consumptions and thus creates the conditions for the demonstration of efficiency potentials. In addition to the decision-making basis for embedding specific key figures in a standardized reporting system, a concept proposal for company-specific energy key figures should lay the foundation for well-founded location benchmarking or take a first step towards allocation of energy costs according to causation.

The complexity of energy efficiency measures leads to the development of an entry sheet. In addition to the measurable data, qualitative elements must also be considered when implementing the goal. An entry sheet is the result of the conversations on site and the aspects in the theoretical part. Collecting and sharing practical knowledge is the foundation for building a multi-site energy management system.

References between the theory and the practical part show that there are points of contact in many sciences and in many areas of the organization concerning energy efficiency.

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1 Introduction

Energy is a very important factor in manufacturing companies along with human labour, technology and materials. Apart from a professional purchasing policy, the energy prices cannot be influenced by the individual company. The causes of changes regarding energy prices are global political developments and the reaction of society concerning climate change. Businesses are therefore required to leverage their energy efficiency impact and continually reduce energy consumption to stay competitive. The Austrian Federal Government is also working with the EU to promote the efficient use of energy. The EU Energy Efficiency Directive postulates a binding energy saving target of 1.5% per annum and that for the 2014 to 2020 period. This objective will continue in the next program period (2021 - 2027).[1]

An energy management system (EnMS) is part of a modern and well-organized company. The aim of the EnMS is to guide the company to build systems and processes in such a way as to achieve an improvement in energy-related services and to promote energy-efficient use.

This demand already indicates that only lots of small measures affecting both the short-term (customer and supplier relationships) and the medium (replacement investment, procurement) and long-term areas (development, innovations, investments, locations) can lead to success. This is only possible with very high personnel expenditure which often leads to the fact that the projects are often not tackled. It is therefore very important that in addition to the usual measurable data, qualitative elements are also incorporated in the implementation of the energy efficiency target. Starting with the classification of the company in national and international competition in terms of its product and customer structure. It is also very important to confront the subject holistically, but to point to individual incentives and discussion status, such as the public incentive systems (subsidies) on the one hand, but also public pressure on the other. This requires measures that are conducive to raising employee awareness. Regarding the external view, the attitude and the technical and organizational pressure prevail over the competition. In addition to the quality requirements, image factors also play an important role in customer inquiries.

In terms of implementation, the usual factors for success are: time and costs, professionals, integration into standard reporting. In the course of reporting, the differences between the goals and the actual situation can be observed: benchmarking, new key figures, support for decisions. Above everything, as repeatedly will be stated in this thesis, is the absolute commitment of the highest management level.

Ultimately, the projects should pay off economically. The continuous improvements should also lead to product innovation and support the company on a development path.

With the help of suggestions from the most diverse fields of theory (measuring systems, controlling, benchmarking, organization) and politics, this work tries to point out links for the

[1] cf. EUR. (2012)

practical implementation of energy efficiency measures. Existing systems in the company are built in and in the outlook concrete suggestions for implementation are made.

Energy management as part of corporate strategy

In the present thesis, the term energy management follows the definition of the Austrian Federal Environment Agency, which assigns the tasks of energy management to point out weaknesses in the energy system and to elaborate proposals. The goal, of course, is to lower energy consumption and to keep this level in the long run. However, this approach not only considers the technical possibilities, but also has implications for the organization and motivation of the employees as its goal and requires a consistent cooperation of previously completely different operating divisions. In addition, the EnMS must be embedded in the existing management system in the best possible way, because it does not differ in principle from this. The Federal Environment Agency assumes that the savings can amount to several percent of the total energy consumption. The implementation of an EnMS is of course required at all sites.[2] Successful energy management requires enough robust data as a first step at the operational level.

Energy monitoring

The basis for energy monitoring (EM) is a measuring concept developed for this purpose with measuring meters that are used to record employed media. The aim is a cause-related allocation of consumption and the collection of detailed consumption data.

[2] cf. UB. (2005)

1.1 Initial situation

HIRSCH Servo AG is one of the leading companies in the production of expanded polystyrene (EPS) and expanded polypropylene (EPP) in Europe. In addition to the production of insulating materials and molded parts for a wide range of applications, the Group is developing systems and mould technology for the processing of EPS and EPP together with HIRSCH Maschinenbau GmbH.

HIRSCH Servo AG has made the turnaround in recent years and since then has grown to over 1250 employees through several acquisitions of production sites. The number of production sites increased to 20 in the following countries: Austria, Germany, Hungary, Poland, Slovakia, Romania and Ukraine.

During considerations of excellence, the Executive Board has recognized potential for optimization in many areas and would like to build these improvements continuously into the organization via controlling activities. Successful acquisitions have enabled the Group to grow rapidly. As a result, there are different starting points for energy efficiency in the Group. However, in the medium term, cross-site standards are to be established. The different starting situations in terms of customers, the market, the products, the procurement contracts for materials and energy, the nature of the equipment and the organization make this a complex undertaking. This can also be seen in the economic policy statements of the authorities and the EU.[3] The company has already taken several measures to address energy efficiency and energy management.

The theoretical part of the master thesis is based on sources that emerged from the research, which, more generally speaking, can be classified under the very wide range of topics of energy efficiency in production companies.

The practical part of the master thesis results from the observations and discussions at the location of HIRSCH Servo AG in Glanegg (AT), which also represents the headquarters and is to be further expanded in this function.

[3] cf. UB. (2019)

1.2 Goals

In the company itself, documents, processes and structures are built up in which this topic can be embedded. The present thesis is therefore intended as a basis for a later implementation. The first part comprises the quantitative part of the thesis, which covers topics in the area of controlling. The objectives mentioned in the second part can be seen as complementary to the quantitative part and consider the subject from a qualitative point of view. In general, the work should make a contribution to getting an overview of the topic of energy. Introductory proposals for standards are intended to support the continuous improvement process (CIP) and must therefore be based on reliable actual data. The prerequisite for an efficient EnMS is the long-term anchoring of energy-related goals in the corporate strategy.

1.2.1 Survey of the actual state and preparations for the implementation of an energy management system

An extensive actual state analysis is the first step towards reliable data.

1.2.1.1 Energy and process monitoring

The resilience of the data of an installed EM system forms the basis for subsequent investigations. Only then will the condition for further action be created.

- A reliable data base (verification)
- An advanced EM system
- A graphical and tabular presentation of the collected data in the EM system

1.2.1.2 Determination of company-specific energy key figures

The draft of an energy key figure system should serve as a basis for the decision to include certain key figures in the reporting system. The preparation of time series should enable long-term benchmarking of all Group locations.

- Design of an energy key figure system for the management of operational energy targets
- Processing of data series for a possible benchmarking of individual locations

1.2.2 Qualitative additions

Objective increases in efficiency can only be based on measurements. Nevertheless, it is particularly important at the start of complex in-house projects to catch up with the ideas for improvements from the affected employees and executives and to confront them with surveys.

1.2.2.1 Standardized entry form capture

It helps to create best practice and benchmark ideas that will capture sites in terms of sustainability, technical standard, effectiveness, organizational realities, and investment needs for further development, as many sites offer the opportunity to receive hands-on advice to a high standard in terms of energy efficiency. The exchange of know-how also contributes considerably to the development of a multi-site EnMS.

- A questionnaire as a guide for interviews with further investigations at other locations

1.3 Tasks

To achieve the above-mentioned goals, a whole series of investigations are needed. The following list is intended to provide an overview of the main tasks of the present work.

1.3.1 Survey of the actual state and preparations for the implementation of an energy management system

- Data comparison from EM with the installed measuring meters (plausibility check)
- An extensive analysis of various documents and records as an essential step for a reliable EM
- Detailed investigations using various product groups to determine further measures
- Anchoring of the EM system in running processes
- The development of an energy key figure system
- Preparatory work for a systematic data acquisition
- The development of an instrument for site benchmarking

1.3.2 Qualitative additions

- The development of a standardized entry sheet
- The testing at the Glanegg site and the conduct of interviews at at least one other location (site visit to Podolínec, SK)
- Further development of the detection sheet based on already conducted interviews

1.4 Study area

The present documents, measuring systems and evaluations were used for this thesis and integrated into the further considerations. The following points should be emphasized:

- Selected machines and systems as well as associated cross-sectional technologies
- Selected production locations of the HIRSCH Group (AT, SK)
- Accounting and corporate accounting departments and associated internal accounting
- EM software Janitza

2 Theoretical fundamentals

The theoretical fundamentals for the topic of energy efficiency concerns both technical and organizational issues. In addition, the measures are effective both in the short and in the long term. This means that the topic of energy efficiency must be reflected in the strategy (see section 2.1). The effects can be observed by monitoring (see section 2.2). The cost accounting (see section 2.3) supports the cost center managers, key figures (see section 2.4) support the management.

2.1 Energy strategy

Energy strategy is part of the overall strategy. An energy strategy can only emerge from the requirements of competitiveness in the core business and must, as far as possible, follow suit. External developments related to energy issues (national and EU energy policies) should be considered, as they apply to competitors as well. The sphere of influence of the enterprise concerns the investment policy, the energy procurement and the in-house processes according to the maturities.

2.1.1 Strategy in the company

A strategy can be defined as the basic orientation of a company to implement its goals. Along with this, a bundle of resources is needed for the transformation process, especially in production companies. "It must also address factors such as business strategy and results, core competencies, leadership, organization structure, process efficiency, technology, cultural attitudes, coordination systems, and employee development systems."[4] Production factors include materials, energy, machinery (time) and factory buildings. With the help of human labour, these goods are transformed into saleable products. The package of measures in the enterprise or in its procurement, production and organizational sections, under the principle of rationality, serves exclusively to achieve its objectives. This refers to the long-term success of a company. Strategic decisions ensure the best possible future success by determining the orientation of the company through the external view.[5]

2.1.2 The company and its surrounding systems (external view)

Every company is part of an overall system. And every company also interacts with environmental systems, such as society, nature, technology and the surrounding economy.[6]

[4] COD. (2015)
[5] cf. Hungenberg (2014), p. 3ff.
[6] cf. Spickers (2004), p. 11.

Strategic decisions determine the development of the company substantially. With strategic decisions, a company determines the plan for its future economic success and secures it through its implementation. This defines both internal and external alignment. They decide the position of the company in its environment, its market, and its resource base.[7]

This approach corresponds to the core competency ideas borrowed from the resource-based management approach. This idea formulates as a corporate goal the development of rare, difficult to imitate and substitute core competencies. They should contribute to building long-term competitive advantages in the company itself as well as among its customers. The core competencies defined in this way decide on the success or failure of a company. In the long term, however, the subject of energy will increasingly be attributed to the core competences of the production companies.[8]

2.1.3 Strategic energy considerations

With global warming, rising energy prices, and growing customer environmental awareness, energy-efficient manufacturing is high on the agenda. Companies are required to identify the most effective measures to increase energy efficiency in production processes.[9] Energy is one of the most important resources in the production-oriented industry and in industry. Nevertheless, the "majority of firms approach energy as a cost to be managed. This is a strategic mistake that overlooks opportunities to reduce risk, improve resilience, and create new value."[10] Achieving reductions in energy consumption, associated costs, and corporate regulation requires a long-term energy strategy.[11]

An energy strategy works like the overall strategy in both spheres, in the company itself and in the environments in which the company operates. These "environments" can be technical, environmental, political (Non-governmental organisations), legal (national laws, EU standards) and ultimately economic (competitor, product substitution). Therefore, the energy strategy cannot stand alone. It must fit into the overall strategy. And it is subject to traditional prioritization in decisions. Essentially, when establishing an energy controlling, the overall goals must be considered on the one hand; on the other hand, the energy controlling must be integrated into the controlling so that it can be considered and discussed during reporting and in-house reviews. Prior to this, decisions must be made at the management level, which objectives are pursued and with what accuracy. Dependent on this are profitability considerations and the corresponding resources (costs). Then a system of planning, incentives and efficient form of activities within the organization can be implemented. In Figure 1, the different interfaces of energy controlling in a manufacturing enterprise are shown.[12]

[7] cf. Hungenberg (2014), p. 4.
[8] cf. Rüegg-Stürm (2004), p. 86ff.
[9] cf. Bunse et al. (2011), p. 667.
[10] HBR. (2017)
[11] cf. COR. (2017)
[12] cf. Kovalev & Degtiareva (2017), p. 43.

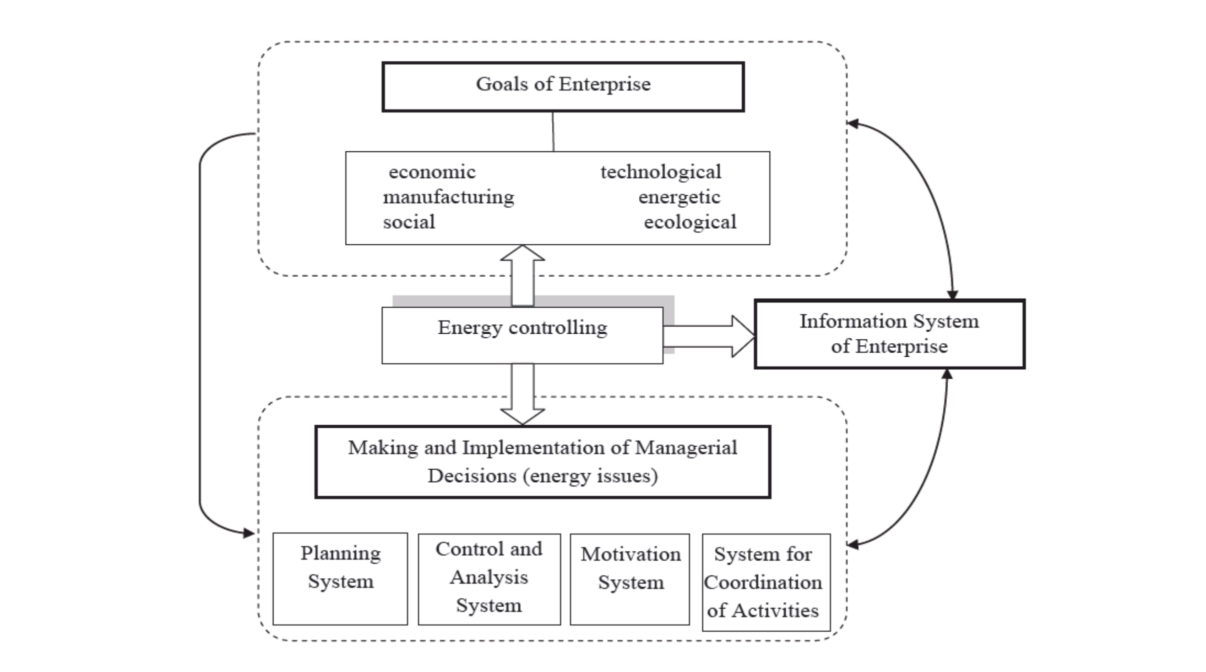

Figure 1: System frameworks of energy controlling in manufacturing enterprise[13]

2.1.4 Factors influencing the organization (inside view)

The existence of a company is based on several pillars, which must be in line with the financial room for maneuver. Management must give binding answers to the company's goals. If, with new specifications (or framework conditions) asked by the owners or the policy, a goal (e.g. energy efficiency) is given a higher significance, then asking (exemplary) the following questions could be helpful:

- What does the industrial companies want to do to the topic of energy management?
- Which goals should be pursued and achieved?
- Who is responsible for the measures and for the (interim) results?
- Where is the topic in the hierarchy?
- Are there ideas for a project organization?
- How can we implement energy management in our company?
- Which activities are planned?
- Can strategy help to increase success and save energy at the same time?
- What are the consequences for the most important stakeholders, the customers?
- What do employees have to learn and what are the financial consequences for the financiers and the owners?

Because of the fact that all these areas are affected by these or similar questions, the process can be set up well. But it also requires an order clarification by the top management.[14]

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[13] cf. Kovalev & Degtiareva (2017), p. 43.
[14] cf. Schuh & Kampker (2011), p. 10ff.

2.1.5 Governance

Governance means a conscious and defined definition of the process of an energy efficiency strategy. Without a clear governance structure and the associated commitment of higher management, an energy strategy cannot be successfully implemented in the company.[15] Successful implementation of energy efficiency measures requires motivated individuals who can also influence the necessary investment decisions.[16]

In the process of defining an energy strategy, the following issues also need to be integrated:

- the company's dependencies on technologies,
- its differentiated impact on competition in relation to the company's market position,
- and the dependence on national and international developments in product policy, here in relation to the position of the company in the value chain.

In short, it refers to a system of corporate internal and external decision-making, influence and control structures, including planning, objectives and relationships with key stakeholders.[17]

2.1.5.1 Measures assessment

At the operational level improvements with many individual measures are possible. This requires a comprehensive setting, from raising awareness through concrete training to performance-based bonuses. A major barrier of raising energy efficiency in manufacturing remains the mind-set towards sustainable product development in industry. Therefore, if an energy strategy is announced, considerations regarding its implementation are required at the same time. Otherwise the improvements will not happen.[18]

Before addressing the structural issues related to the design of the process, the dimension of the energy efficiency target is to be estimated. Since the subject of energy efficiency is, as already mentioned, a necessary subsystem in relation to the entire transformation process in a company, this topic must be subordinated to the general corporate policy and the corporate goals agreed with the partner (s). With regard to legal requirements.[19]

2.1.5.2 Contracting

Contracts of the company's energy supply can roughly be assigned to two spheres. On the one hand, these are the execution tasks along the entire production process or the value creation process. This efficiency must be organized and carried out by the managers at the operational level. The management, on the other hand, is responsible for the strategic tasks from the planning to the information policy and the control of the internal energy system.[20]

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[15] COR. (2017)
[16] cf. Thollander & Rohdin (2006), p. 1842.
[17] cf. Schuh & Kampker (2011), p. 14f.
[18] cf. O'Rielly & Jeswiet (2014), p. 330.
[19] cf. Schiwek (2002), p. 312f.
[20] cf. Posch (2011), p. 150.

2.1.5.3 Periods of observation (long, medium and short term)

The scope for design naturally changes with the term of the consideration. The more long-term the approach is, the more complex, and therefore more difficult to plan, are the possible intervention options.

In the long term, entire locations, technical and technological developments, investments, foreseeable changes in customer behavior, legal requirements must be incorporated into the energy strategy.[21]

If taking a medium-term view for the topic of energy efficiency, you are mostly confronted with completely different contracts. On the one hand, there is the service and maintenance of the operating facilities and the establishment of a targeted procurement strategy. On the other hand, there may be (framework) contracts with customers, which bind the company for a long time.[22]

At the operational level (short term), there are many small measures to improve energy use, starting with the basic behavior of employees in terms of saving energy. "In addition, the team should advise on how to integrate energy considerations with strategic processes and priorities. [...] Facilities and operations managers should consider energy in their resilience and business continuity planning. And the finance team needs to prioritize energy and carbon reduction in the capital allocation process."[23]

The topic of energy efficiency has, as the above statements make it clear, reached the level of top management in terms of responsibility. It can be assumed that legislators in the member states of the European Union are gradually implementing the European Energy Efficiency Directive 2012/27[24]. In Austria, the guidelines were just adopted in the form of draft laws (December 2018) (see section 3.7.3.2).

The empirical experience of production companies shows that energy efficiency can release considerable potential. Lowering energy costs leads to increased results even without major investment. In the long term, in addition to the measurable improvements in results, it can be assumed that new customers prefer to order from energy-efficient suppliers or develop new ones with them. Energy-efficient employer companies are more attractive, have a higher level of employee satisfaction, and can use their efficiency programs to set an example in terms of sustainability.[25]

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[21] cf. Schumacher & Würfel (2015), p. 11f.
[22] cf. Schumacher & Würfel (2015), p. 11.
[23] HBR. (2017)
[24] cf. EUR. (2012)
[25] cf. PP. (2014)

2.1.6 Embedding the energy strategy

The energy strategy must be built into its management and reporting systems for effectiveness. When considering this matter for the first time, organizational theorists recommend a process of awareness-raising, possibly in the form of a kick-off or an audit, which develops and describes the current situation. A "systematic approach for inspection and analysis of energy consumption of a plant, a building, a system or of organization with the goal of identifying energy flows and the potential for energy efficiency improvements"[26] is recommended. Furthermore, it is argued that an "approach is selected, which considers the barriers and obstacles that hinder the companies in implementing energy efficiency measures and in the implementation of a systematic energy management system (EnMS)."[27] Figure 2 gives an overview about the sequence of barriers and obstacles that come along with this process.

Figure 2: Categorization and a sequence of barriers and obstacles[28]

The authors argue that the awareness that energy efficiency is not only important for the environment can lead to long-term sustainable production in industrial companies. Behavioral patterns change and motivation arises. The motivation, as with other topics, develops the know-how for energy efficiency.[29]

2.1.6.1 Financing of energy management

Considerations for the financing and profitability of the savings must be made at the beginning, as with any project. A project organization is probably the most appropriate form for implementing an energy strategy. The company needs a communication structure with short routes and the necessary integration of all company divisions must be made possible. The energy (project) team is seen here as a steering committee, which also supports the project and project with power.[30]

For an energy audit it is essential to do preparatory work. As mentioned above, this preparatory work starts with checking the reliability of the data (see section 3.3.1). Energy efficiency can only be achieved credibly if reliable sources are available. This is significant because "many examples of energy efficiency initiatives are limited to "what" and not "how". A gap exists on how organizations translate energy efficiency objectives into strategy. [...] an energy efficiency initiative in one manufacturing plant; the launch of a central strategy across plants; inter-plant integration and coordination; completed improvement projects. [...] "[31] The definition of

[26] Javied et al., (2015), p. 157.
[27] Javied et. al (2015), p. 158.
[28] cf. Javied et. al (2015), p. 158.
[29] cf. Javied et. al (2015), p. 158.
[30] cf. EN. (1990)
[31] Lunt et al. (2015), p. 241.

interfaces requires a lot of effort. Information policy is essential for cooperation with organizational units.

Before starting with the collection of recent data, it is necessary to set up decision processes and desired results as an example and to determine the purpose of the collection of energy data. It may turn out that iterative processes are necessary because the data are not sufficient for the purpose, because smaller investments (meters, sensors) are necessary or because of lack of data security the purpose must be adapted (e.g. cost allocation according to the principle of causation (see section 2.3.5)). It may be useful to first model a more or less closed system (a production unit, a plant, a site), because these experiences show eventual weaknesses and – when rolling out the model similar problems can arise and must be eliminated. Moreover, the modeling of a system has the advantage that implementation decisions are taken at its base, so you can orientate yourself when rolling out.

2.1.7 Long-term positioning of the company as a sustainable production company

After the pilot phase, important issues must be defined with the management. These concern especially the medium and long-term energy policy. In the subsequent implementation of an EnMS, the following key question arises: How does the cooperation between the (energy) management managers and the daily routine work? A clear vision, defined in a top-level energy policy statement, provides the appropriate framework for successful energy management. The statement contains several targets, which must be implemented in the form of practical measures. Such a statement is not just a formality, but an effective tool to assess whether the targets can be met, and the energy strategy is geared to achieving the agreed goals. A statement on energy policy should include the following requirements:

- energy policy is driven by the highest management level,
- the company's energy policy states that the company will fulfil all relevant laws and regulations,
- energy policy sets continuous improvement processes as a key action and appeals to all stakeholders to avoid unnecessary energy consumption.

In the long term, the range of topics ranges from research and innovation projects, location issues to company acquisitions or acquisitions, the broad range of investments, building refurbishment and energy recovery. An important aspect of the medium-term energy policy is the procurement of important energy sources and the accompanying control of energy suppliers. [32]

[32] cf. BMNT. (2018)

2.1.7.1 Energy procurement

Unlike the materials used in the core production process, energy procurement markets are less clear. A comparison of the reported total costs in the electricity offers does not help. Because of the complexity and the subordinate importance in relation to the total manufacturing costs, energy controlling is often included only in terms of consumption in the ongoing controlling, often neglected in terms of procurement. The effects on the respective company are varied and very different. It doesn´t only depend on the amount of energy consumed in relation to the cost of production, there are a few more parameters added. While the very large companies train specialists or recruit them from the energy supply companies, it is difficult for mid-sized companies to gain an overview of the electricity market. In addition, the costs for this overview should not be underestimated, especially if several tenders are made and the company has not established a routine process. But in the long term, electricity procurement is a key factor in the company's success. [33]

The deregulation of the electricity market was fully implemented in Austria in 2001, and the gas market was followed up the following year.[34] This means that the electricity customers can freely choose which supplier they want to be supplied with. It puts the electricity and gas providers in competition with each other. The energy supply companies had to rethink radically. The digitization and decentralization of their home markets are attracting competitors but also allowing new business models. The energy supply companies have developed from a more monopolistic behavior to a more competitive approach. The models are also changing: for example, while network charges are rising, the variable costs are being lowered because of the energy transition. The industrial companies as large customers were and are required to build up know-how for electricity procurement. Prices were negotiable, an overview of how the different providers behave, could be achieved very difficult and with great effort.[35]

There is potential in the controlling of energy procurement due to the complexity of the contracts, changes in the business models of the utilities as well as long-held habits. Controlling must start with the stock contracts. This is the prerequisite for the (later) introduction of clear procurement processes (see section 3.7.3.3.2) The decision-making process for a suitable electricity procurement model is the core of the holistic electricity procurement strategy.[36]

Energy must be an integral part of production planning. For example, an extension of production could open scope for special contracts. On the other hand, reductions are the result of planned, predominantly technical energy-saving measures, which, however, act in the opposite direction in terms of negotiations. Or, as part of corporate social responsibility (CSR), the management wants to build up the image of a sustainable manufacturing company with alternative procurement (green electricity). But the essential work regarding new tenders comes to the purchase. The latter must communicate the invitation to tender to the market or

[33] cf. Schumacher & Würfel (2015), p. 135.
[34] cf. EC. (2018)
[35] cf. SPP. (2016)
[36] cf. Schumacher & Würfel (2015), p. 61.

several providers and sound out negotiating signals and notify the management before the complex procedure is started. It must also be decided whether an independent energy consultant should be called in, to ensure the four-eyes principle. Thus, the design of the overview of the procurement is one of the essential tasks of the energy controlling. Figure 3 provides clues for the relevant issues that need to be agreed with the management.[37]

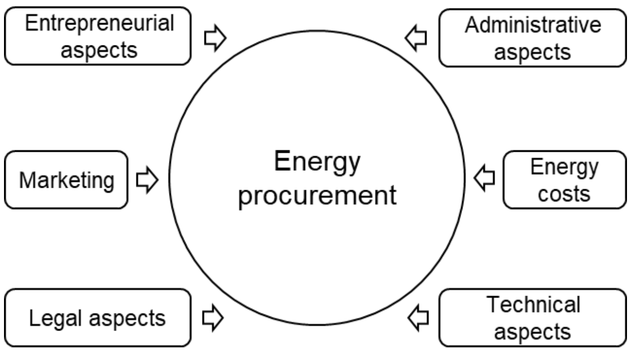

Figure 3: Factors influencing the electricity procurement[38]

As a first step, however, routines must be introduced. These are records which, in the form of graphics, make it possible to obtain an overview of the current situation (see section 3.7.3.3.1)

In practice, it makes sense to check the incoming invoices and compare them with the components of the contract. This is essential for preparing a tender. Later, this decision can be made routinely.

[37] cf. Schumacher & Würfel (2015), p. 6f
[38] cf. Schumacher & Würfel (2015), p. 6.

2.2 Energy monitoring

EM is the prerequisite for further activities to improve energy efficiency. It collects a timely consumption picture and enables the generation of time series for energy use.

2.2.1 Analysis of the actual state (energy analysis)

Actual state is the analysis of the current situation. The precise and – as far as possible – evaluation-free compilation of all business-relevant data forms the basis for the measurability of changes in the company. The determination of the actual state is carried out by document analysis or various other methods such as self-recording, surveys or observations. Employees and managers as well as documents, invoices, and the like are the sources for the analysis. The content depends on the organization and the reason for the investigation.[39]

The basis for the introduction of a high-performance energy management within the company is the recording of the current state of energy and the subsequent analysis and visualization and an associated transparent overview of the company's energy flows. By creating the broadest possible database of all energy-technically substantive information and its preparation in graphical form, the information base for assessing the existing, and the basis for decision-making for further activities is created. Based on the consideration of the actual state, the energy consumption can be determined and weak points in the energy demand coverage can be shown. Furthermore, measures for improving the energy supply can be derived from this and optimization measures for increasing efficiency can be discovered. A detailed analysis of the current situation (energy analysis) includes detailed information on the structure of the energy supply, the knowledge of the energy consumption and performance requirements of the company, as well as comprehensive knowledge of the local circumstances (and their environment), the technical equipment and the production process.[40]

The level of detail required depends on the individual requirements of the information needed to make energy policy decisions. Preferably, in-depth analyses are only made in the context of strategic or operational planning, once it has been clarified which priority areas of energy management are to be pursued. This avoids unnecessary expenditure on data collection - which in the detailed energy measurement and evaluation area is certainly associated with not inconsiderable time and cost expenditure - which in retrospect turns out to be superfluous (see section 2.2.2.2).[41]

[39] cf. Collin (2010), p. 1f.
[40] cf. Fink et al. (1997), p. 3f.
[41] cf. Posch (2011), p. 178f.

The following outline should give an overview of the possible procedure for the analysis of the actual state (energy analysis) (see section 3):

- General description of the location
- Factors influencing the production process
- Description of the utilities used (cross-sectional technologies) and of the internal energy flow
- List of energy consumers[42]

Essays on the actual situation are usually very individual. Below, the respective points will be explained in outline.

2.2.1.1 General description of the business location

The preliminary stage of a comprehensive analysis is the preparation of essential basic information about the company. Here, the operating structure, the manufacturing process used, and the resulting product groups should emerge (see section 3.1.3). This forms the basis for further considerations and is intended to enable a first assessment of improvement approaches and thus lay the foundation for the later identification of potential energy savings and efficiency improvements.

2.2.1.2 Factors influencing the production process

The use of energy as well as raw material in the production process is based on many process parameters, the slight adaptation of which may already have a significant impact on consumption. Only by a systematic recording of these an understanding of the process itself can be formed, but also approaches to increase the efficiency of production facilities. Figure 4 is intended to give an overview of possible "adjusting screws" for influencing energy efficiency.

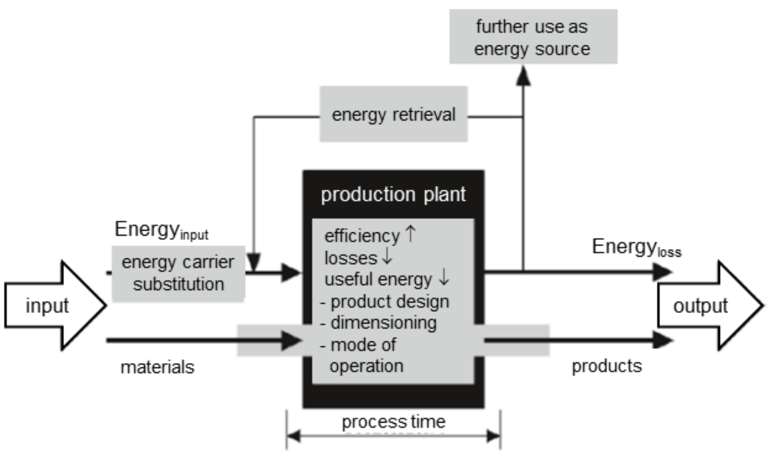

Figure 4: Approaches to increase energy efficiency in production plants[43]

[42] Note: Documents from the survey are available in the company.
[43] cf. Müller et al. (2009), p. 123.

Universal approaches to increase energy efficiency in production plants result from:

- Substitution of the energy sources used,
- reduction of the useful energy demand through energetically optimized product design, dimensioning or energy-saving operating modes,
- increase in efficiency,
- reduction and further use of the loss energy or
- energy recovery[44]

Investigations on the impact of energy quality on product quality are just another step.[45]

2.2.1.3 Establishment of cross-sectional technologies (utilities) and representation of the internal energy flow

In addition to the specific core technologies (production machines) of a company, many power, and fuel-based cross-sectional technologies are required for the manufacturing process. These are energy applications that are used across individual machines or process steps throughout the site (e.g. electric motors and drives, compressed air systems, pumps, etc.). These can either be energetically linked to the production process or they can be used outside the production process (e.g. space heating). Cross-sector technologies account for a not inconsiderable part of the energy consumption in the manufacturing process (in terms of total energy consumption) and thus also offer considerable potential for increasing energy efficiency in the company. It should be noted, however, that a continuous coverage of the process-essential media such as electricity, cold water, steam, compressed air, etc. must be ensured and approaches to reducing energy consumption always the ultimate goal - a continuous production process - are assumed. A complete list of the energy sources used (electricity, gas, etc.) and documents on installation and pipeline plans (cables, pipelines, etc.); Energy converters (boilers, transformers, etc.); existing storage (compressed air); installed measuring systems; etc. are indispensable. It must be ensured that the changes are always documented and that documents are kept up to date.[46]

2.2.1.4 List of energy consumers

In addition to device-specific information (e.g. year of construction), energy data such as nominal power (kW), average power data, operating hours and energy consumption must be considered when collecting energy consumers. The preparation of this information should initially take place in tabular form and, if appropriate, subsequently assigned to individual areas (e.g. supply levels, transformer outlets, production areas, etc.). Here, especially the energetic main consumers are to be detected with high energy consumption. Based on this list, a first estimate of the performance and, considering an estimated utilization period, the determination of the energy demand of the site can be carried out. In the determination of the above-mentioned characteristics, an awareness of the consumption of individual plants is already

[44] cf. Müller et al. (2009), p. 124ff.
[45] cf. Posch (2011), p. 179f.
[46] cf. Fink et al. (1997), p. 6.

created, thus creating the basis for the subsequent determination of energy-saving potentials.[47]

2.2.2 Acquisition and assignment of in-house power demand and energy consumption

As mentioned earlier, capturing in-house energy flows is a logical next step towards transparent allocation of energy consumption. A division of the total energy consumption can only be done by additional energy-related measurements.

2.2.2.1 Develop a measurement concept

Energy-related measurements affect a range of in-house areas. Among other things, they form

- the basis for energy procurement,
- assist in the identification of optimization measures,
- are necessary for correct allocation to cost centers and
- an essential component in the establishment of a certified EnMS.[48]

The design should be based on the physical energy flow and, on the other hand, on the hierarchical production structures, starting from the overall operation across individual production areas to individual plants (see section 2.4.3.2). Possible decision criteria for setting up a measuring concept are illustrated in Table 1.[49]

Table 1: Decision criteria for the creation of a measurement concept[50]

criteria	**structural level**	
	central (e.g. plant, hall)	**decentral** (e.g. line, machine)
costs	high investment, costs from lost production	high variable costs
local and temporal continuity	permanently installed measurement for permanent transmission of measured values	mobile measurement for temporary measurement
sampling rate	coarse resolution (daily to yearly) for energy billing	fine resolution (milliseconds to minutes)
knowlegde goal	energy management and energy controlling	load control, individual optimization
level of automation	automatic measurement	manual measurement
measurement accuracy	relevant for billing, calibrated	indicative

[47] cf. Fink et al. (1997), p. 12ff.
[48] Note: see also https://www.austrian-standards.at/infopedia-themencenter/specials/iso- 50001/ (ISO 50001)
[49] cf. Blesl & Kessler (2017), p. 47f.
[50] cf. Blesl & Kessler (2017), p. 47.

Highest attention when creating a measurement concept requires the selection of the necessary measurement continuity.
Continuous measuring points are used, among other things, for the

- collection and allocation of energy consumption,
- for the process engineering evaluation of the main consumers,
- or for the classification of slow process changes.

In contrast, temporary measurements are needed if

- analysing the load or standby behavior of equipment,
- when creating an energy consumption matrix,
- or to verify implemented energy efficiency measures.

While quarterly hourly billing has become established for billing-relevant measurements, a second-to-order resolution is necessary for a detailed understanding of the process. One of the most important goals of a measurement concept is the contribution to efficient energy controlling. The measured energy flows should support cost type, cost center and cost unit accounting (see section 2.3.6) and thus contribute to the transparency and conscious use of energy resources.[51]

2.2.2.2 Detail accuracy of the survey

Another important factor in the creation of a measurement concept is the detailed accuracy of the data acquisition of energy-related performance and consumption characteristics. In general, as with any other area of information provision, it can be said that as the available data becomes more accurate and more analytical, the chances of taking action to move away from the present state of affairs increase. In contrast, a high degree of detail accuracy represents a high metrological effort, which is associated with high costs and additional organizational and personnel use. When considering the degree of detail required, these considerations should be considered.[52]

2.2.3 Energy monitoring system

If the data recording is carried out in high resolution, the resulting data can also be used for a timely display of the consumptions. More generally, the term EM can thus be described as the continuous collection and processing of consumption data and the timely visualization of energy consumption. EM thus serves in general to show the cumulative energy consumption and gives further a timely overview of the place of consumption. Figure 5 gives an overview of the steps towards energy management.[53]

[51] cf. Blesl & Kessler (2017), p. 47f.
[52] cf. Schieferdecker (2006), p. 248.
[53] cf. ThEGA. (2018)

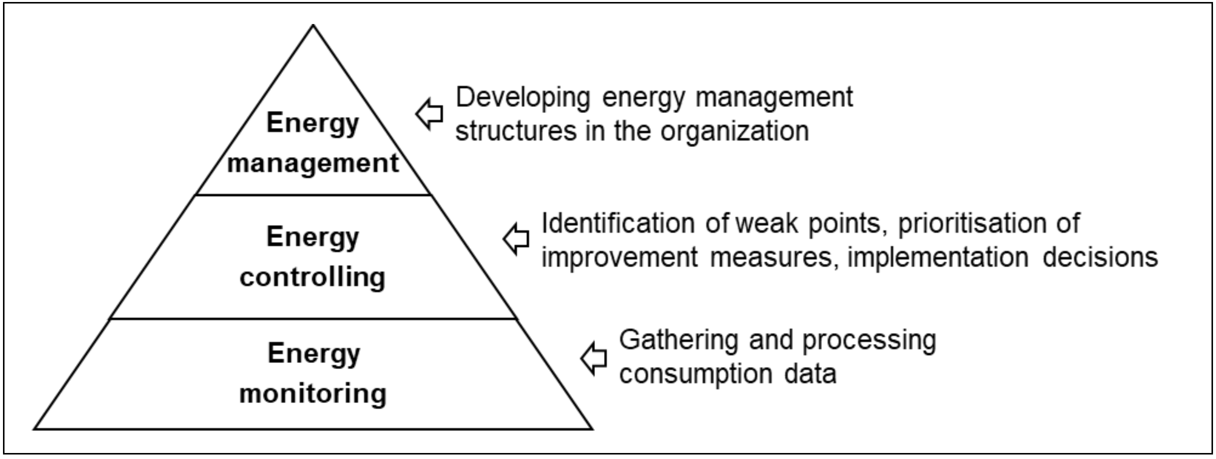

Figure 5: Energy monitoring as a starting point[54]

The monitoring of the internal energy flows can thus be given a significant role when it comes to creating a basis for energy controlling and, subsequently, the decision-making basis for the establishment of energy management structures. It forms the basis for the identification of organizational and low-investment optimization measures and thus supports the decision-making process for investments and projects to increase efficiency. The following list is intended to give an overview of the purpose of EM:

- Transparency over the distribution and development of energy consumption
- Identification of energetic hotspots
- Identification of abnormalities
- Improvement of energy saving measures
- Basis for the creation of energy reports
- Optimization of process plants and consumer behavior
- Awareness of the importance of the individual consumption points[55]

[54] cf. ThEGA. (2018)
[55] cf. ThEGA. (2018)

2.2.3.1 Energy monitoring system - structure

Figure 6 shows the elementary structure of an EM system.

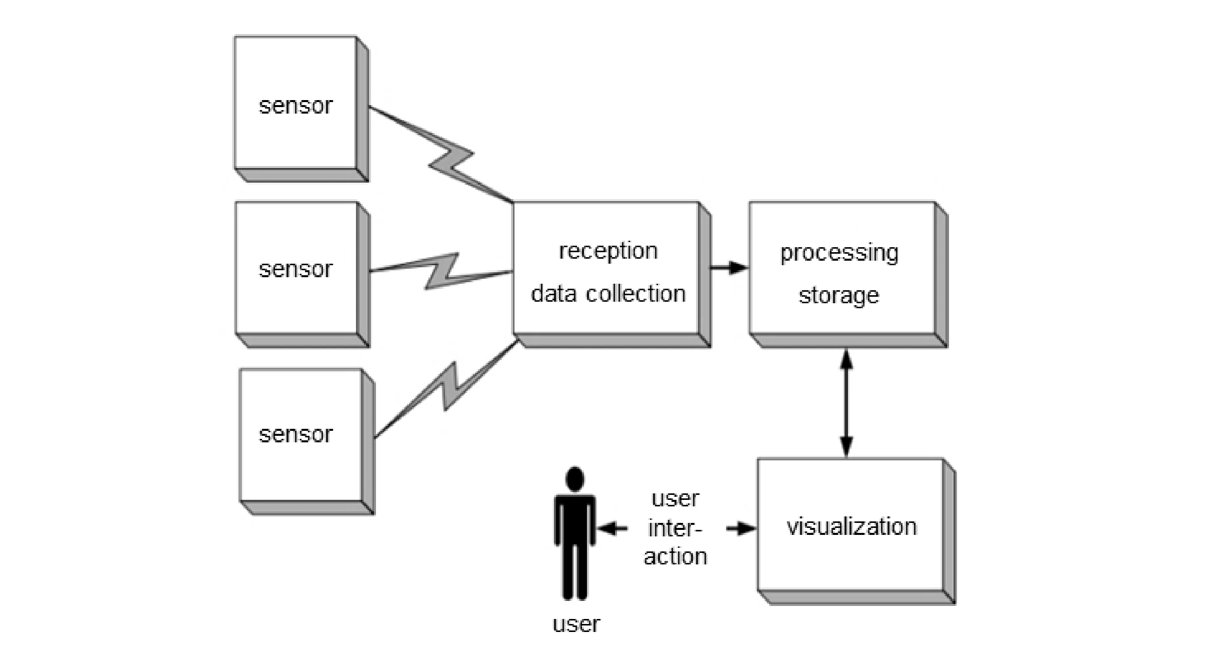

Figure 6: Structure of an energy monitoring system[56]

The basis for an EM system is formed by a series of electronic sensor systems that capture operating data, machine data and energy consumption data at the respective level. For this purpose, mostly measuring systems, which are provided with electronic interfaces, are used to transmit the determined energy consumption. The design or the measuring principle of the sensor depends on the respective medium. The detection of individual media such as water, oil, gas, electricity, steam, compressed air, as well as heat and cold thus takes place in different ways. Process values such as temperature, flow and pressure are recorded via the corresponding measuring devices and then transferred to the computer via a local data server. Subsequently, the collected readings are transmitted to a data collector, which concentrates the sensor data and feeds it to a unit for processing and storage. Another logical unit is the visualization, which represents the recorded and stored data and thus represents the interface to the user. In the visualization, different temporally or spatially related evaluations can often be selected (see section 3.3.2). A clear and well-structured presentation is the basic requirement for efficient EM.[57]

2.2.3.2 Requirements and considerations for realization

A system for EM comprises different and distributed devices that perform different tasks. Energy consumption must be recorded and, if necessary, pre-processed. The measurement is done at different locations, since the consumption points cannot be arranged centrally. The distributed data must finally be collected centrally. This can be done via a single-stage, multi-level, tree-like or star-shaped network of data concentrators. In the central collection point, the

[56] cf. Binternagel (2003), p. 13.
[57] cf. Binternagel (2003), p. 13.

transmitted measurement data must then be processed and processed. The following list is intended to provide an overview of the necessary requirements:

- Decentralized, electronic sensor technology with wireless data transmission
- Time resolution of the sensor in a small-time interval
- Unit for collecting and pre-processing the measured values
- Timely visualization of consumption
- Remote configuration options of the individual components

The development of a system for EM is performed by splitting in sub-areas, on the one hand to increase the significance, but a division also allows the expandability. The modularity of the components used is thus an essential prerequisite for enabling the flexibility of such a system. Quantity structures in the context of EM are the prerequisite for causal allocation and subsequently form the basis for evaluations in the context of cost accounting.[58]

[58] cf. Binternagel (2003), p. 33ff.

2.3 The cost and revenue accounting

For operational decisions in the production plant, a cost and revenue accounting is indispensable, because a functioning and accepted cost accounting not only provides the data, but also prepares it for the responsibility and decision-making system.

The time horizon for using the cost and revenue accounting is short-term. Almost always the individual months are considered. There are then quarterly and yearly comparisons, which are derived from it. The cost (and revenue) statement is primarily used to calculate the operational processes as well as the order result, the success per unit, the success per process section or the period result. Differentiated statements about the income statements are only possible if there are corresponding partial records.[59]

The cost and revenue calculation serve as the basis for calculations. Experience from the cost information is used in standard products and production processes for the objectives of the top management. From this, targeted action and short-term decisions regarding the taking of orders can be derived. If energy costs, as described elsewhere, are a relevant quantity, they must be derived transparently from the measured data and extra evaluated in cost accounting. Whether the types of energy are to be presented individually is a production process-oriented decision.[60]

In addition, however, the planning of long-term goals, such as investment decisions or the acquisition or sale of sites, also takes place in this context. The individual cost types and their development are also considered. The time frame of the planning then amounts to several years, corresponding to the investment cycles.[61] In these decisions, the foundation is composed of many positions. Energy costs, in relation to technological progress, play a decisive role in the sales policy of the energy supply companies and in the location. In recent years, the concept of cost management and cost controlling has increasingly come up. In contrast to the cost and revenue accounting, which is rather short-term (maximum time horizon of one year), cost management has a medium or long-term perspective.[62]

2.3.1 Tasks and objectives of cost and revenue accounting

The most important tasks of cost accounting are the quantity and value recording of the process, publicity and assignment of responsibilities, planning and control, management effectiveness control based on target / actual comparisons.[63]

The cost accounting documentation task captures costs that have already been incurred for very different purposes, from inventory valuation, to quantities and value inputs in the production process, to the cost items that are included in the purchase and sales. Precise

[59] cf. Götze (2004), p. 9ff.
[60] cf. Götze (2004), p. 9ff.
[61] cf. Schweitzer et al. (2015), p. 59ff.
[62] cf. Horsch (2018), p. 16f.
[63] cf. WL. (2018)

documentation, the most accurate derivations and the constant availability of recent data are essential prerequisites for many everyday tasks and for the usefulness and acceptance of cost accounting. Cost accounting also provides the basis for non-operational purposes such as industry comparisons (see section 2.3.8), annual reports, or litigation cases. The most important goal of cost accounting is the provision of decision-relevant basic data for information that serves the planning and control of the company. [64,65]

2.3.2 Cost functions - make or buy?

Cost functions describe the relationship between the production volume and the associated costs[66] and thus serve to identify influencing factors on the costs. With their help, questions about in-house or external manufacturing, procurement, production and sales issues are decided. Comparisons can be made in material and energy procurement, personnel costs and structural costs. The optimal procurement quantities, the best purchasing conditions, the optimal stock management are important preliminary decisions, which are supported by cost accounting. Does the company want to produce important precursors itself or to buy in full? The cost and revenue accounting provide information about the better choice. Start-up losses must also be planned or deliberately caused losses, because buying or cooperating would jeopardize the company's know-how. This question also arises in consulting or development projects. What opportunities and risks does the company incur if an energy efficiency project is developed in-house or should the procurement be outsourced to a specialized agency?[67]

2.3.3 Program selection in production and awareness of employees and executives

In the production area, cost accounting provides information for selecting the optimum production program. When production-related decisions have been made, employees and managers must implement them. Managers must be informed about the target specifications from the cost accounting, so that the decisions can be taken and implemented in the sense of the planning. The cost and revenue calculation support the management to monitor decisions and ultimately well-founded enforce. Profitability control is only possible together with planning and controlling. Through it, the values of the cost and revenue accounting are evaluated. This will subsequently determine, however, whether the original planning could be implemented. A comprehensive efficiency check enables time comparisons, target / actual comparisons, quality comparisons and key figure comparisons (benchmarking). Variance analyses are used to determine the extent and causes of deviations (overshoots or undershoots). The concept of cost accounting must be based on a transparent allocation of costs to cost centers and products or product groups.[68]

[64] cf. Horsch (2018), p. 17ff.
[65] cf. WL. (2018)
[66] cf. GAB. (2018)
[67] cf. IWW. (2014)
[68] cf. WL. (2018)

2.3.4 Concept overview of costs, cost elements, cost centers, cost units (payers)

Cost accounting terms refer to their task, thus many categories have emerged. The following examples should clarify this:

- Reference quantity: unit costs, total costs, unit costs, etc.
- Imputability: direct costs, overhead costs
- Type: material costs, personnel costs, energy costs
- Calculation model: calculated costs
- Functional: procurement costs, production costs, administration costs, distribution costs
- Origin: primary costs, secondary costs
- Production level or degree of finalization: material costs, production costs, production costs, cost price
- Time: actual costs, planned costs
- Dependency: fixed costs, variable costs[69]

Within the conception of cost accounting, costs are to be separated[70] from expenses, payments and disbursement. This results in the following for cost characteristics: There is an operational/performance-related consumption, which is priced. This consumption is best assigned and calculated automatically to the service provider. This calculation is a prerequisite for cost-effective calculations. The accounting principles are already a preliminary decision for the targets. The causation principle is rarely contradicted, but it is not easy to produce (measurement accuracy, purchasing, complex production processes, etc.). Nevertheless, costs are attributed to the departments (departments, plants, functions) or to the products or services where they were caused. But there are also other accounting principles, which are not further elaborated here.[71]

2.3.5 Terms relating to imputability

Imputabitlity is a more specific feature because, in addition to attempting the utmost in objectivity, it also leads to principles for the calculation of orders.
Direct costs can be directly attributed to a reference quantity, for example, a product (cost unit). They arise per unit of performance (e.g. per piece). A high proportion of direct costs has at the same time a high credibility regarding the cost-truth (causation principle).[72]

Overhead costs are always indirect costs. Real overhead costs can never be directly attributed, because they are not caused solely by the product unit alone. The salaries and associated

[69] cf. Joos (2014), p. 9ff.
[70] Note: Costs are the consumption of goods in the company performance process in one period. Costs have a set and a quantity component.
[71] cf. Joos (2014), p. 9ff.
[72] cf. Zunk et al. (2013), p. 33.

infrastructure for staff positions, management or rent for the administration are real overheads. Very often, energy is part of overhead costs. However, overhead costs can be differentiated according to their distribution to the cost centers. A distinction is made between

- cost center direct costs - overheads distributed directly to the cost centers and
- cost center overheads - only can be distributed to the cost centers by means of key assignment.

This thesis analyses the prerequisites for determining energy costs successively according to the causation principle and assigning them to the product groups (payers) (see section 3.6). Energy efficiency, as described elsewhere, is improved only by many small measures and is therefore very dependent on the basic records and the algorithms of cost accounting. Figure 7 gives an overview about the allocation of total costs to cost units and cost centers.[73]

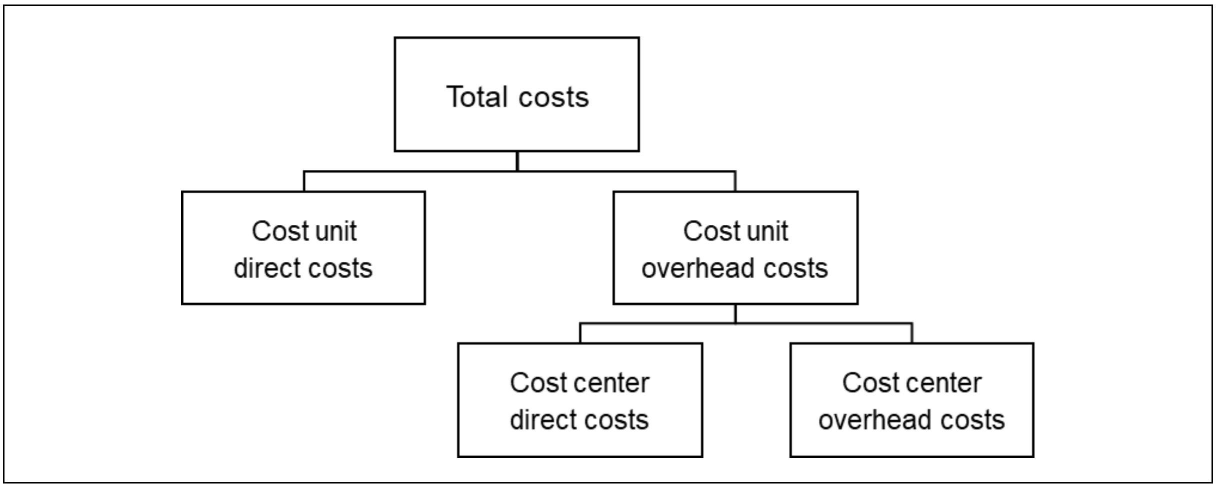

Figure 7: Allocation of costs to cost units and cost centers[74]

One of the most important cost differentials is the dependence on employment. Fixed costs are independent from employment - they are time dependent, such as salaries, rent. Variable costs depend on employment, use and / or utilization, such as the gas mileage of a car or the material and energy costs of production. The energy costs to be examined in more detail here have fixed and variable components. Acceptance contracts and infrastructure shares are usually fixed costs. Consumption in production is variable costs.[75]

2.3.6 Cost accounting systems (cost elements, cost centers, cost units)

Cost-type accounting should answer the question regarding the costs which have been incurred and in what amount. Cost elements correspond to the accrual expense accounts or the aggregated expense accounts. All costs incurred in a payroll period are categorized by

[73] cf. Zunk et al. (2013), p. 33.
[74] cf. Zunk et al. (2013), p. 33.
[75] cf. Zunk et al. (2013), p. 33.

cost type. The costs are recorded according to the type of goods and services consumed. Cost types are, for example, personnel, material and energy costs.[76]

The cost center accounting answers the question in which operational areas and in which amount overhead costs were incurred. The task of cost center accounting is the distribution of incurred overhead costs from cost element accounting to the cost centers.[77] Furthermore, the execution (further allocation) of the in-house activity allocation serves as preparation for the calculation as well as for the control of the economic efficiency through target-actual-comparisons. There must be accurate and transparent metrics for cost causation. Cost centers should be set up according to the individual functional areas: material locations (e.g. purchasing, material warehouses), production sites (e.g. production), administrative offices (e.g. management, accounting, quality assurance, legal, development department). The result of cost center accounting is the formation of calculation rates. They form the basis for the allocation of overhead costs to the payers. Thus, a connection is established between cost center and cost unit accounting.[78]

Cost object controlling answers the question of what the costs are for and is the basis of productivity and the competitiveness of a company's services. With the cost unit accounting, the company comes closest to the goal of a causal allocation of the individual and overhead costs to the individual payers. The cost object accounting differs in the production area according to the production methods, such as mass production, repetitive manufacturing or individual production. The causal distribution of overheads using key sizes or overhead rates is a very common practice in practice and much more accurate than simple overhead costing.[79]

Figure 8 shows a possible breakdown of energy costs into cost elements and the subsequent distribution via individual cost centers to the cost units.

[76] cf. Zunk et al. (2013), p. 81ff.

[77] Note: A cost center is part of a business, which is billed independently in cost accounting. Here arise costs and / or costs are added. Each cost center must have its own area of responsibility, which enables effective cost control.

[78] cf. Zunk et al. (2013), p. 105ff.

[79] cf. Zunk et al. (2013), p. 121ff.

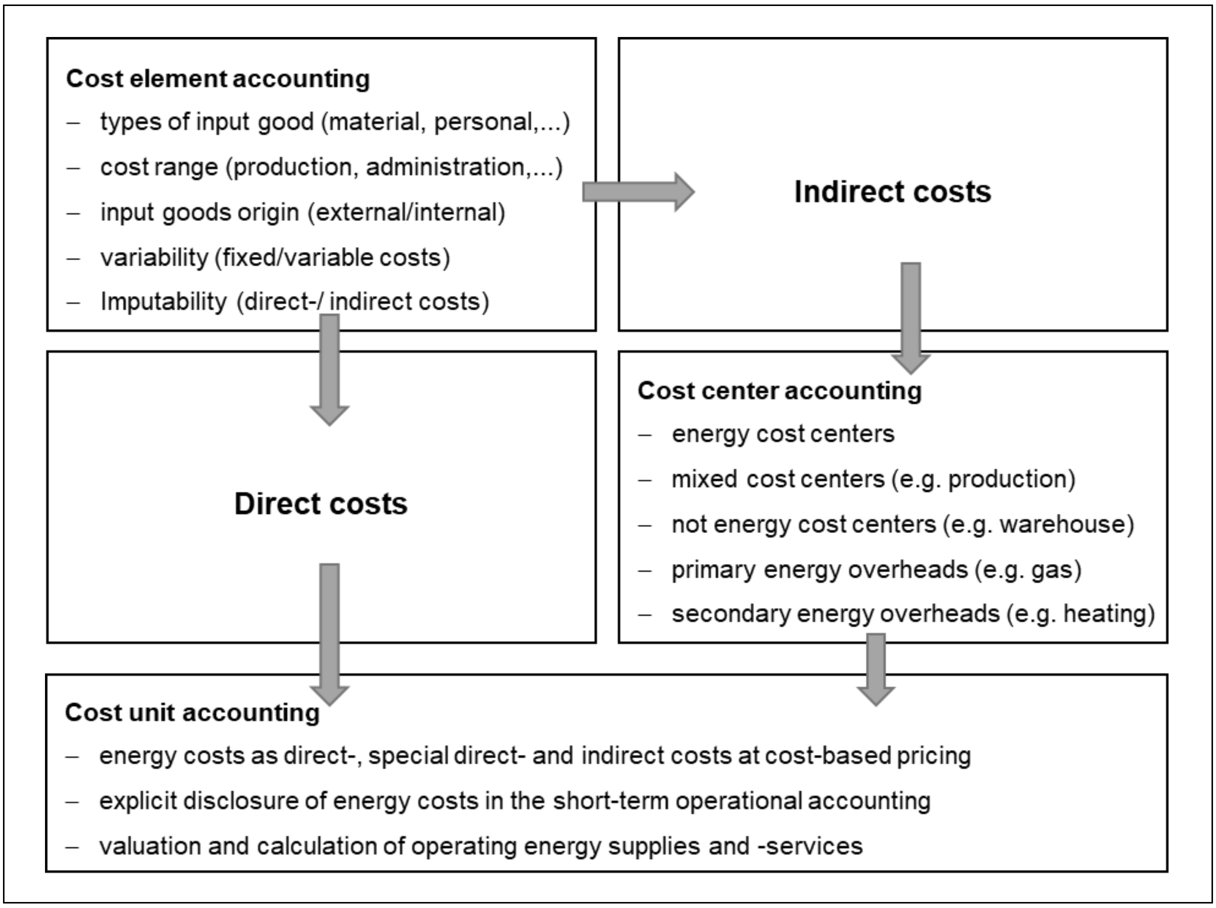

Figure 8: Energy costs in the individual stages of cost accounting[80]

If energy costs are not charged as a uniform surcharge rate, there are company-specific possibilities for differentiation. Their classification must be consistent with the goal of causation accuracy. For example, procurement costs for different energy sources can be reported separately if they are not produced on their own (make or buy). Further, investments that are owned by the company and are not included in the energy price are to be distributed over a business life to the cost center or vehicle. This particularly concerns costs for tanks, silos or storage media, heating plants, combined heat and power plants, own networks and recovery plants. If, in the context of the production process, waste and pollution from energy production are produced (ashes, exhaust gases, CO_2 certificates, insurance, maintenance), the above is valid. This can be handled as follows: Considering the corresponding direct costs, it is possible to calculate offsetting rates for the total costs of production cost centers, administrative offices and sales offices. In this way, the overhead rates for determining overhead costs per cost object can be determined within the cost object accounting. Despite these options for differentiation, the full cost accounting described here, especially for new customers and for new products in the phase of market introduction, is not very meaningful if these are to be won via introductory prices. The same applies to phases of underutilisation of individual factories if short-term relocation of production is to be decided (logistics costs, short-time work).[81]

[80] cf. Blesl & Kessler (2017), p. 24.
[81] cf. Blesl & Kessler (2017), p. 23f.

2.3.7 Proportional cost accounting

The full cost accounting procedures are not suitable for short-term decisions, in particular for the determination of short-term lower price limits due to under-utilization. Also, no support is offered by the full cost accounting for decisions "make or buy". In proportional cost accounting, only parts of the costs (variable costs) are offset against the cost objects. In some cases, overhead costs are also charged to the cost units. The most well-known is the single-stage contribution calculation (Direct Costing). It includes the offsetting of the variable costs on the payers and the fixed costs are included as a block in the current income statement.[82]

Cover amounts can not only be determined for individual products (unit contribution margin), but also for product groups, customers, sales areas, etc. The advantage is the simple procedure and no proportionalisation of the fixed costs. The disadvantage here is the imputed proportionality of the variable costs, which is rare in practice (e.g. volume discounts, routine effect). Cost splitting into fixed and variable costs is not always easy, as mentioned in energy costs. Contribution margin calculations provide further insights regarding the company's success structure. Areas of application of the contribution margin calculations are, for example, the determination of the optimal production program, price upper and lower limits and make or buy decisions. Figure 9 shows the calculation of the contribution margin.[83]

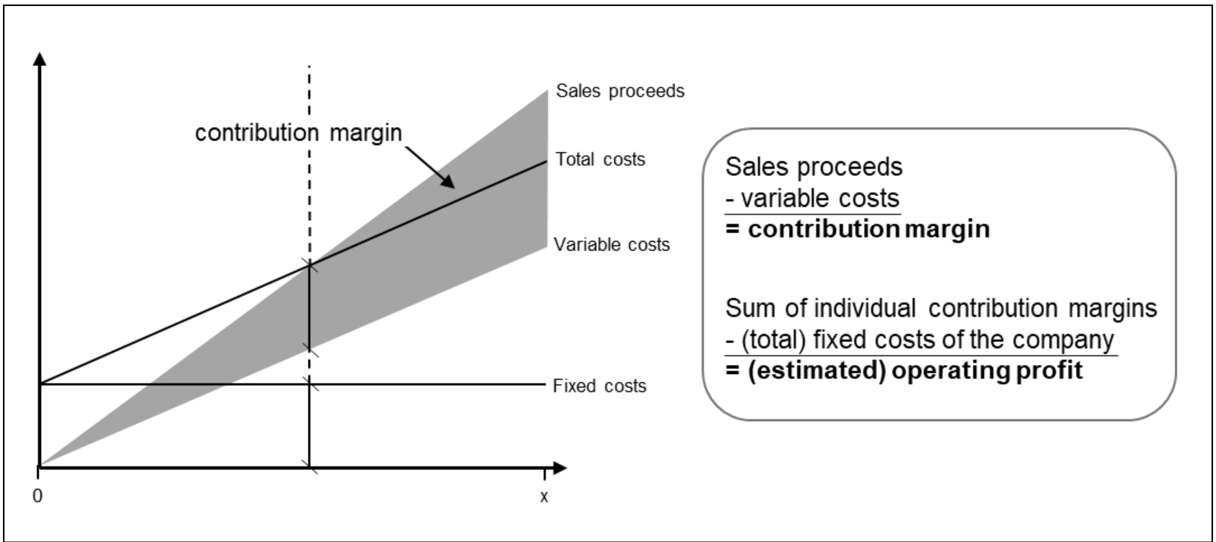

Figure 9: Contribution margin[84]

Cost accounting systems are an essential component for internal company decisions and are predominantly used for short-term analyses (e.g. new orders, short-term target / actual comparisons). For the management level, it is necessary for cost accounting to be implemented so that managers can work with it and prepare decisions. However, key figures are indispensable for controlling the entire company. When planning the production program, different decision situations are possible: no bottleneck (underemployment), one or more

[82] cf. Buchholz & Gerhards (2013), p. 104ff.
[83] cf. Buchholz & Gerhards (2013), p. 106f.
[84] cf. FW. (2018)

bottlenecks. The decision rule for a bottleneck is to accept the orders according to an order according to the relative contribution margins.[85]

Reasons for the acceptance of additional orders are that a positive contribution margin is generated and thus the operating result is increased. Free capacities can thus be optimally utilized. Avoiding short-time working and securing volume discounts can be justification. Maximum price limits apply to the use of goods (material, energy, additional staff). Price lower limits apply to the variable costs.[86]

Cost accounting systems are in practice called Enterprise resource planning (ERP) systems.[87]

All cost accounting systems listed here require the use of a uniform database for their acceptance. The technical infrastructure and a uniform software for data collection is required.[88]

2.3.8 Benchmarking

Benchmarking is a management tool for competitive analysis. The comparison is made either by competitors (competitive benchmarking), by functionally similar but non-competitive companies (functional benchmarking) or within a company (internal benchmarking). Benchmarking should, among other things, reveal the gaps in performance, the potential for improvement, or the optimization towards best practice examples. Benchmarking does not just mean a one-off competitive analysis, but a continuous comparative analysis using key figures. Figure 10 breaks down the different types of benchmarking into comparable partners and comparable objects.[89]

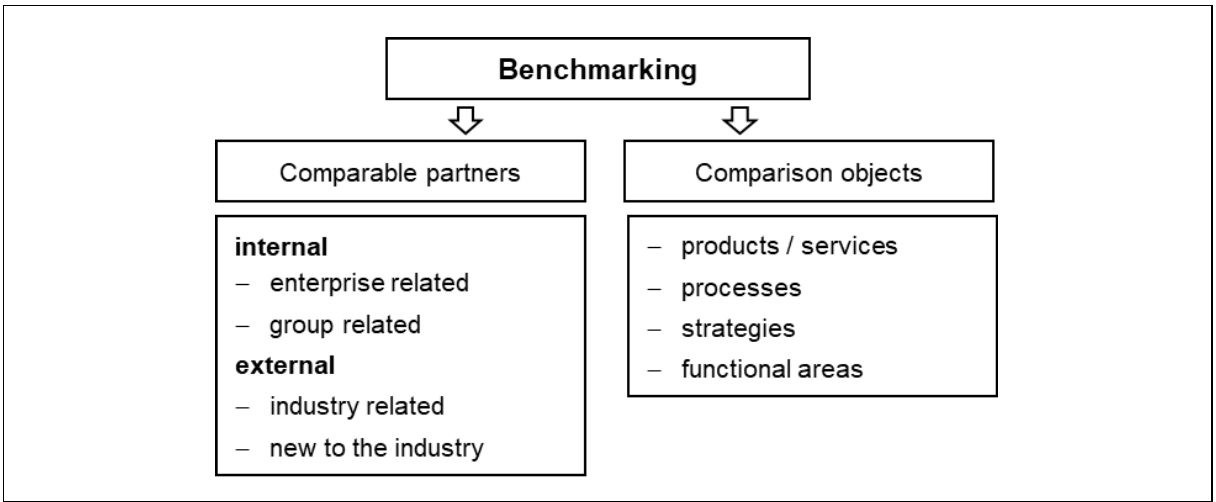

Figure 10: Types of benchmarking[90]

[85] cf. Gronau & Lindemann (2010), p. 202.
[86] cf. Buchholz & Gerhards (2013), p. 89ff.
[87] cf. GAB. (2018)
[88] cf. Buchholz & Gerhards (2013), p. 89ff.
[89] cf. CRM. (2018)
[90] cf. Joos (2014), p. 23.

The criterion "comparison partner" used in the figure leads to a distinction between benchmarking in internal and external benchmarking. It is difficult to benchmark comparable companies with comparable companies and does not know their derivations. For example, one does not know whether a consumption of energy is due to a lack of controlling in purchasing or inefficient production. The chamber of commerce and banks publish key figures from the most important sectors every now and then. As comparison objects, products as well as services, processes, strategies, functional areas or the like are suitable. Benchmarking therefore means analogously to compare standards.[91]

[91] cf. Joos (2014), p. 22f.

2.4 Energy key figures

In companies, energy key figures are not so well established yet, as key figures like for example the return on investment (ROI) or corporate earnings (DCF). In that sense, it is more important to develop metrics that can be used to make decisions related to a specific topic.

2.4.1 Key figures general

In organizations, metrics are one of the most important tools for collecting information about specific operations in an orderly way. Key figures serve to depict relevant relationships in an aggregated and quantitatively measurable form and thus play an essential role in understanding complex business contexts. Energy key figures are part of an overall performance measurement system.

2.4.1.1 Types of key figures

Figures combine existing data with each other and thus represent correlations in a compact form. Here, key figures can be fundamentally differentiated depending on the type of linking into absolute and relative key figures in different forms. Thus, the best-known and most-used absolute measure is the turnover of a company. Absolute key figures are taken directly from the balance sheet or the profit and loss statement for their comparability. More common are relative metrics. These have different characteristics. Thus, one describes the relations between sizes as outline key figures. For example, the equity ratio is a percentage that measures the balance sheet total with the equity interest in this balance sheet total. Furthermore, in the literature, but also in practice, there are relationship key figures (e.g. asset coverage) or change key figures (percentage reduction of personnel costs in relation to turnover). When using key figures, always pay attention to the reference value. For example, energy consumption is often quoted in relation to revenue, which can cause distortions for companies that trade and produce. For important decisions, therefore, the cost accounting and revenue statement and the short-term operational accounting (see section 2.3.7) must be used. Figure 11 illustrates the differentiation in absolute key figures and relative key figures.[92]

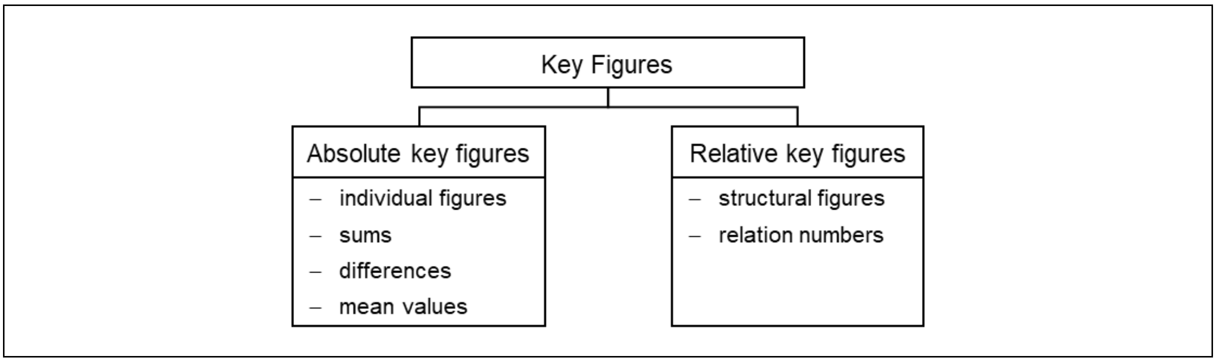

Figure 11: Types of key figures[93]

[92] cf. Nadvornik et al. (2009), p. 229.
[93] cf. Nadvornik et al. (2009), p. 229.

2.4.1.2 Functions and use of key figures

With the help of key figures and the condensed information contained therein, states and developments can be clearly displayed and analysed (see section 3.5.1). Key figures can be used to monitor processes and measure progress, for example in productivity or in this work, by lowering energy consumption. Key figures are used for planning and provide executives with the opportunity to quickly gain a comprehensive overview of operational relationships and processes. They also make a significant contribution to the governance of a business. Thus, it can be said that only this targeted concentration of individual information creates the basis for a rational tool for rapid decision-making. Figure 12 shows the various application functions of key figures.[94]

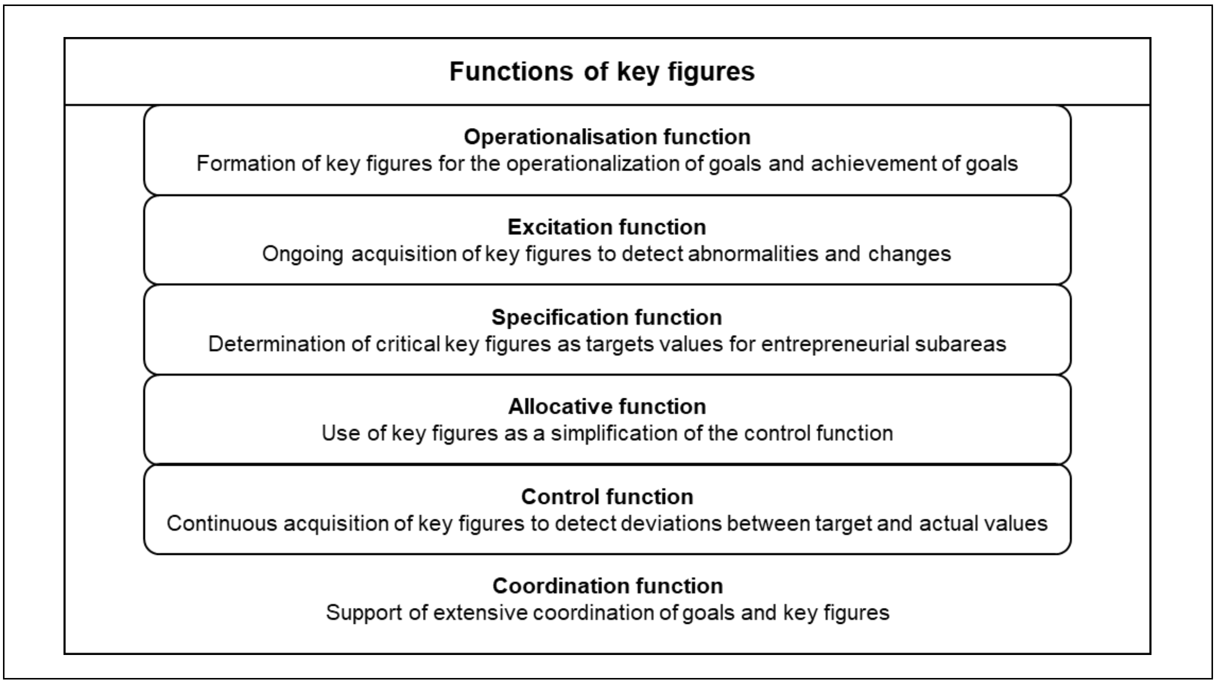

Figure 12: Functions of key figures[95]

Basic records in the company provide the basis for later evaluations. Their best possible accuracy is a prerequisite for reliable results. Errors in the basic records (quantity structures, prices, period accuracy, etc.) will otherwise continue in the evaluations derived from them using key figures and will no longer be recognizable as such. Analyses of the same size of an object can be performed in time comparisons (quarterly, annual, multi-year comparisons). Target / actual comparisons are comparisons of planned values with the actual values of a specific period. With the different comparisons of key figures, changes can be shown. Stability in the statements is obtained with ongoing analysis. Thus, conspicuous undesirable developments can be identified and potential for improvement identified.[96]

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[94] cf. Winkelmann & Becker (2014), p. 69.
[95] cf. Winkelmann & Becker (2014), p. 69.
[96] cf. Winkelmann & Becker (2014), p. 69.

2.4.1.3 Prerequisites for key figures

There are key figures that are used universally and everywhere, that are explained in the annual reports and form an important basis for external analysts (banks, investors). Examples include sales, equity ratio or employee numbers.

Furthermore, there are key figures that represent internal decision-making information. When creating them, important prerequisites must be observed regarding their later significance. The prerequisites are logical, but the requirements meet practical hurdles. Timely and accurate availability of the data from which the measure is derived is not always easy to achieve. At best, investments in hardware (measuring systems) and software (ERP systems) are required for them to be available or for their prerequisites to be created. Before these decisions are made, the determinations of the information goal and the intention of its procurement are essential. Based on these created conditions then the respective key figure is to be constructed. A clarification with those responsible is then necessary. If one wants to derive further information in addition to the internal goals, additions but also restrictions are likely.[97]

2.4.2 Key figure systems

A key figure system describes the interrelationships of quantitative parameters and thus enables the viewer to learn a lot about a certain situation. As already mentioned in the previous chapter, it is first tried by the formation of key figures to compress information while maintaining its validity. Viewed together, key figures thus provide the necessary information on the overall picture of the company or a subarea and thus provide the basis for comprehensively and systematically recording subjects. Therefore, a systematization of these key figures should be sought. As described above, the use of universal performance measurement systems is limited, depending on the field of application, due to the often very individual requirements. Individual key figures can be linked together in two ways. They can either be linked together by mathematical relationships (= computing system) or they are in a mere systematization relationship to one another (= ordering system). In contrast to computer systems, systems of order are thus much more unlimited in their intended use, since they must be related only in factually more meaningful and not mathematically.[98]

In the development of a performance measurement system a clear target concerning its use should be fixed right at the beginning. In this case, a distinction between analysis and control key figure systems can be made, which can be seen in Figure 13.

[97] cf. Botsis et al. (2015), p. 72.
[98] cf. Gladen (2011), p. 97.

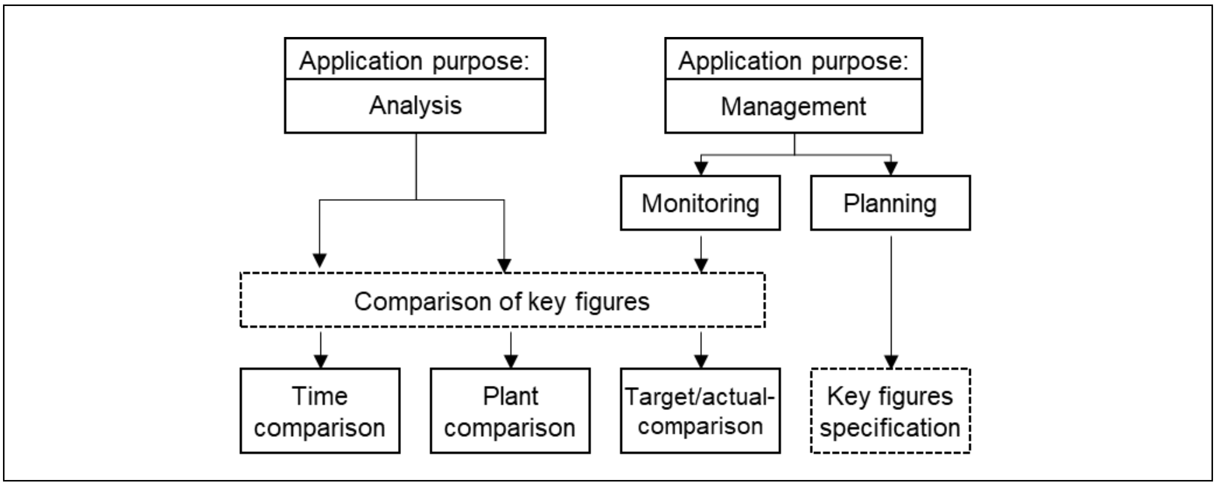

Figure 13: Comparison of key figures[99]

If key figures are used for the control, an appropriate order of the key figures and a small number of key figures is useful. The more transparent a system is, the more metrics it can include, without losing simplicity and clarity.

2.4.2.1 Development of key figure systems

The development of a generally accepted system of numbers can safely be described as a Herculean task. Behind the key figures are often conflicting goals concerning their field of application. For example, in business reports with "good" ratios, one wants to ensure the attractiveness of the company to financiers (owners, banks, suppliers and employees), but not without losing the deeper information content. In the internal consideration one connects with key figures responsibilities. For example, compliance with costs can be an objective - but incentives (premiums) can also be involved. Of course, from the practical experience of the behavior of those responsible, one knows that they are happy to allow themselves scope so as not to be called to account for even minor deviations. Thus, the contradiction between the acceptance of key figures and the definition of target values is often indissoluble. In practice, it is possible to approach this conflict by means of time series and revision of target values. When energy metrics are introduced for the first time, it is important, especially at the management level, to clarify the allocation of responsibilities so that, for example, someone responsible for the energy key figure does not lose sight of the bigger picture, the competitiveness of production, by taking on responsibility.

2.4.3 Energy key figures and energy key figure systems

After the general introduction to the key area of key figures, the key figures for energy input required for this work are explained. The terms, derivations and requirements for validity described above also apply to energy indices. Because the energy used for the production process, infrastructure and logistics is a key factor in the course of operational energy management. It can be influenced by such different factors that one can speak of it as a size involved by many small effects.[100]

[99] cf. Gladen (2011), p. 98f
[100] cf. Schieferdecker (2006), p. 40f.

What applies generally to key figures also applies to energy key figures. These form the basis for energy optimization measures. The increase in energy efficiency in production processes, however, often depends on the behavior of the topic of energy in the company. Energy key figures are therefore the prerequisite for a qualified assessment of measures and the basis for a continuous improvement process (CIP). Successful and accepted energy management requires a secure, high-quality, timely and appropriate database in every industrial enterprise (see section 2.2.3). The requirements for an active energy management are listed quickly but are not easy to implement. Particularly in naturally grown structures, there are various generations of plant facilities as well as measuring installations. If these are used in analyses without comment, not only their validity is questionable, it is also difficult to assign responsibility. Only if concrete relationships can be established between the contracts and the energy consumption and the corresponding costs, can a well-established energy management be set up and operated in the context of existing business information.[101]

The reduction of energy consumption represents a relationship that can be formulated in a simplified way: The goal is to "reduce the difference between energy introduced and emitted". The transformation of the precursor energy as part of the final product should be minimized. Conversion losses and their economic impact should be kept as low as possible. For the effects to be comprehensible, the actual energy key figures must be reliable. Only then the goal can be formulated. At this level, it is almost impossible to work with key figure comparisons because the underlying assumptions are not transparent. Measurements that are related to the use of energy must derive their basic records directly from the production processes in the enterprise. Infrastructures that also have an energy requirement but are only indirectly related to the production process must be recorded separately from it, but their energy input must also be measurable, analysable and influenceable.[102]

2.4.3.1 Use of energy key figures

When deciding on key figures in operational energy management, the purpose is always the focus. Only with this determination, an introduction can be successful. Not the number of key figures is relevant, but the acceptance, the influenceability and the discussion of measures based on the key figure. This means that those responsible must also know about the derivation of the key figure and continuously address the influence of the efficiency of energy use. The introduction of key figures for the effective use of energy can be manifold. One must deal with the following issues before they are introduced.

- Key figures form the basis for operational analysis. They serve the support of the operational energy management.
- Key figures must be set up so that they are suitable as base values for benchmarking. Very suitable for benchmarking is in-house information with the same or very similar products, production processes and technologies. If these are not available, you must be content with key figures of similar companies. If a company has several production sites, a comparison between the production sites with comparable basic records

[101] cf. Schieferdecker (2006), p. 40f.
[102] cf. Schieferdecker (2006), p. 40f.

represents an outstanding opportunity for the use, the continuous improvements and ultimately the resilience of the key figures.

- Of course, key figures can also form the basis for the decision on consumption information from manufacturers, the basis for maintenance work and Represent contracts and support investment decisions. Here, too, the above applies to the comparability of the production sites. The information provided by manufacturers on delivered and commissioned equipment must be verifiable by collecting actual data related to energy consumption. The same applies to the current operation. A time series of the energy consumption in relation to the utilization and the service life can be used for the maintenance and long term for the investment decision.
- Key figures also have the task of influencing the future product range and thus also influence the priorities in sales.
- Key figures are an instrument of management. All parties involved in decision-making processes can analyse their energy efficiency efforts and derive consequences from energy-related factors.[103]

2.4.3.2 Capture levels of energy key figures

Which energy key figures are relevant for a company depends on the target and the accuracy with which its achievement is to be measured. The following section deals with the level of the plant, the process, the individual machine or a machine group as well as the product and the product portfolio. Metrics capture means investments and running costs. Therefore, it must be decided on which level it must be operated and recorded. The recording should give an overall picture and support and complement each other. When it comes to benchmarking of the sites, it is advisable to specify higher-level key figures. Location-related decisions, in this context related to energy, can be done objectively. If several key figure systems exist, a general position determination can also be made of them. Site comparisons can also be used to estimate the potential for optimization. Because of the energy key data acquisition of the core processes and energy-intensive machines, targeted and objective-number-based decisions are possible. For this purpose, the selection of the key figures and the associated recording levels necessary for these measures must be implemented.[104]

Plant level: If no reliable quantity records are possible on the levels (machine, process), the plant level is a simple start. Measures at plant level enable comparisons of energy consumption between several plants with similar or identical production. A single key figure at plant level compares the total energy input (electricity, gas, etc.) with the quantity (kg, m^3, etc.) of the produced goods. This comparison is relatively simple, but the comparability, because of other factors is only very superficial. Ideally, this comparison only occurs between plants, with completely identical products. Because of the simplicity and the rapid availability, the potentials can then be used. [105]

[103] cf. Schieferdecker (2006), p. 41f.
[104] cf. Gleich & Klein (2014), p. 46ff.
[105] cf. Gleich & Klein (2014), p. 46ff.

Process level: The process level is already a more accurate form to show the comparability of the energy consumption. The process must be described exactly to capture everything that is needed for the manufacturing process. It's not just the manufacturing, it's also the internal logistics, and the infrastructure involved. Of course, if the measures rely on data collected at the process level, energy consumption can be assessed much more accurately than when comparing locations. Here, the potential for improvement is easier to control, and the comparisons have a much higher informative value. A recording at the process level must be supplemented with other energy consumptions in order to be able to be compared again at the plant level. To ensure that process energy is not only collected, but also optimized over the medium term, timely information must be provided, and meters installed in the individual process sections. In the case of all detailed surveys, a balance (control) with the energy billing of the respective energy supply company is necessary at the end of an observation period. The process level has many advantages. They range from suggestions for improvement in individual stages of the production process to less appropriate use of energy (especially if comparative figures are available) to decision support for repair, maintenance or new acquisitions (investment). The acquisition of new production plants can be carried out by means of specifications from the experience by means of key figures. Thus, there are guarantees of energy consumption, accurate production instructions and comparisons of learning effects between old and new installations.[106]

Machine level: Key figures at the machine level have many advantages. They help to measure not only energy, but also capacity utilization and downtime (and standstill energy. Increased energy consumption often indicates other vulnerabilities (wear). To prevent this from happening, deployment-oriented, predictive maintenance based on energy consumption is possible. A cross-comparison of many machines and systems makes it possible to monitor further energy efficiency. Individual energy-intensive and complex machines require individual monitoring. When measured accurately, the objectivity for comparisons increases. Meaningful key figures can result in the recording of all energy sources (in connection with other means of production) at the machine level.[107]

Product level: A calculation to complement the process level provides additional optimization options. Particularly in complex manufacturing processes, more precise conclusions about possible optimization processes can often be drawn here.[108]

2.4.3.3 Design process for key figures

Energy key figures require a planning process at the start. This should be defined as the beginning of a decision-making process. By describing a process for key figures, later comparisons can make it easier to discern the differences from the statements made in practice and to make visible the significance of the decision for a consistent system (in this case for key figures). An energy strategy needs strategic goals of the management. Especially in the case of the energy production factor, costs are a dominant topic in the short term; in the

[106] cf. Gleich & Klein (2014), p. 46ff.
[107] cf. Gleich & Klein (2014), p. 46ff.
[108] cf. Gleich & Klein (2014), p. 46ff.

long term, many factors that can be subsumed under the topic of the energy transition are significant.[109]

When energy conservation is defined as a strategic goal, the operational level must identify the data sources, their timely availability, and their reliability. According to the first statements, the availability of the sources must be compared with the strategic goal. It depends on these results whether the strategic goal with the existing data sources can be measured and subsequently reached. If there is a gap one important step is to take: identification of the equipment relevant to the measurement. The questions may be:

- What data do we need for measurement at the factory, machine, process and product level?
- What happens if measurements cannot be performed in isolation at all levels ?

At this point, the granularity[110] of how the achievement of the strategic goal is measured can be redefined, or the equipment needed to measure the achievement of the strategic goal must be purchased.[111]

The cost aspect may cause the detail accuracy of the measurement to be revised. (For example, is waived on measurements at the product level). The temporal aspect between the establishment of the equipment relevant to the strategic objective and the actual situation may lead to the implementation being lost of sight again. Therefore, bridging requires activities that enhance knowledge and awareness of energy goals (see section 3.7.3.2.3). The collection of data and the preparation of drafts of possible key figures are suitable for this. The cause-effect relationships are to be analysed and the measured variables determined (kWh, kg, etc.). For the comparability within an industry, an identical production process, a location, a bottom-up approach is suitable.[112] Separate data collection is required for comparability at the product or process level. If one of these units is equipped with the equipment required for the measurement, the data can be arranged accordingly. As a next step, the defined key figures are filled with data. After a short period (at least one year), the concrete target size can be defined, and the data concept adopted.[113]

[109] cf. Gleich & Klein (2014), p. 46ff.

[110] Note: In computer science, granularity refers to the fineness level of the outline that divides functions and activities in relation to the entire action. The granularity can refer to records from documents, texts or graphics, but also to memory, security measures, programs or the data transmission whose granularity is coarser or finer due to the length and number of data packets. cf. ITW. (2006)

[111] cf. Gleich & Klein (2014), p. 48ff.

[112] Note: Principle of an approach to problem solving. First, delimited, detailed sub-problems are solved, then with their help larger, overlying problems are solved. The individual partial solutions are assembled from "bottom" to "top" until the total problem is solved. cf. GAB. (2018)

[113] cf. Gleich & Klein (2014), p. 50ff.

With this approach, the basis is created to generate comparability (if possible at all levels). Figure 14 illustrates the above described design process.

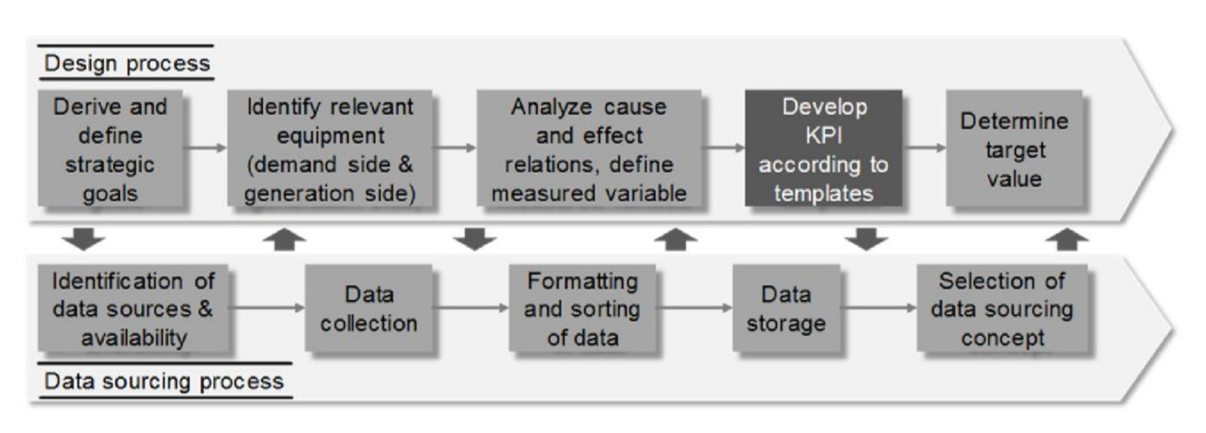

Figure 14: Design process of key figures[114]

2.4.3.4 Standardization of key figures as the task of controlling

A key task in the development of key figures is the standardization of the key figure. Key figure standardization is the definition and description of key figures. Especially for in-company comparisons, it is imperative that all units considered determine their key figures uniformly in terms of accrual, calculation method and time reference. Even for simple-looking key figures such as "employees", it must be clearly anchored who should be considered as an employee (e.g. interns, etc.), for which time the number of employees is calculated (e.g. first or last day of a month), and whether part-time and full-time employees are the same. Figure 15 gives an overview of a possible procedure for the description of key figures.[115]

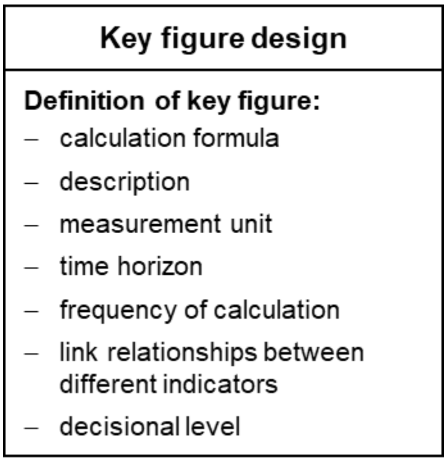

Figure 15: Standardization of key figures[116]

[114] cf. Schmidt et al. (2016), p. 760.
[115] cf. Joos (2014), p. 69.
[116] cf. May et al. (2015), p. 56.

2.4.4 Basic questions of internal reporting

The provision of information is an essential task of controlling. Internal reporting is responsible for the development and ongoing reporting. It serves to prepare and transmit planning and control information for the management.[117]

The energy report must be part of an ongoing reporting system and document the results of the energy data analysis. Continuous energy reports show the development of the EnMS in a company. The energy report also serves to keep employees up to date on the status of the company's EnMS. Proposals for the content of an energy report include up-to-date information on energy use and the identification of energy costs and consumption at a pre-determined level. Furthermore, an energy report should contain information on the achievement of the goals of the savings and the corresponding energy key figures. Optimization measures and possible corrective actions also complement an energy reporting system.[118]

[117] cf. Joos (2014), p. 54.
[118] cf. WEKA. (2018)

3 Practical problem-solving

The following chapter contains practical details of this work, which were carried out or implemented on site.

Section 3.1 is intended to provide an overview of the company itself and the production process, and subsequent chapters are to be read as an introduction to the topics mentioned in the theoretical part of this thesis, and deal with the analysis of the actual state (see section 3.2), the further development an implemented EM system (see section 3.3), the setting up of an energy key figure system (see section 3.4) and the development of a location benchmarking tool (see section 3.5).

Based on investigations carried out during the ongoing production operation, further fundamental considerations were made regarding a more cause-related surcharge rate calculation for product groups (see section 3.6) in the energy sector. In the concluding chapter (see section 3.7), considerations for a qualitative investigation of the subject area are cited and, in addition, a developed data entry form is presented (see Appendix).

3.1 General information about the location and production

In addition to the general presentation of the Glanegg business, the individual process stages of the manufacturing process are explained. Furthermore, the subdivision into the areas of insulating materials and packaging parts and fundamental differences in the production process as well as the resulting product groups shall be mentioned.

3.1.1 The company location Glanegg

The location Glanegg is the headquarters of HIRSCH Servo AG. Figure 16 provides an overview of the layout of the company location.

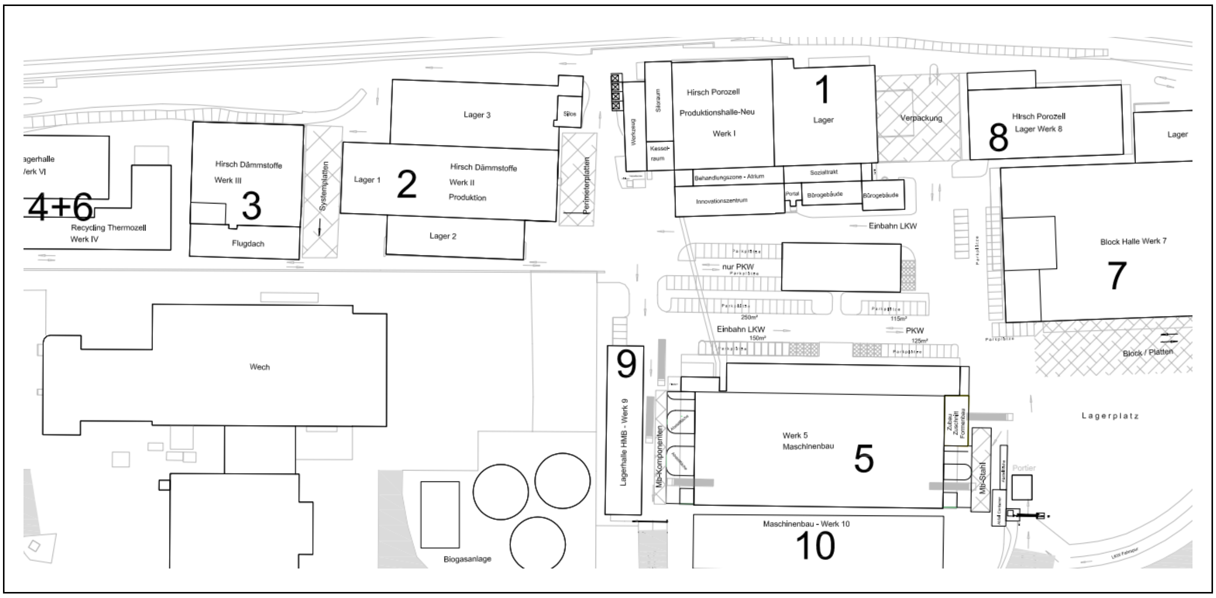

Figure 16: Company location HIRSCH Servo AG (Glanegg - AT)

Plants 1, 2 and 7 are production areas, Plant 5 is assigned to HIRSCH Maschinenbau GmbH, all other plants are designated as storage areas. Below is an overview of the individual production plants:

- Insulation boards (block material (BMM)) - Plant 7
- Floor system and perimeter plates (single plates production on molding machines (IMM)) - Plant 2
- Packaging (packaging parts of molding machines (IMM)) - Plant 1
- Thermozell (thermal and impact sound insulation (IMM)) - Plant 7

3.1.2 The production process of expanded polystyrene (EPS)[119]

Starting point for the production of EPS rigid foam (polystyrene) forms foamable polystyrene (EPS). The preparation of the pearl-shaped raw material is usually carried out by suspension polymerization of styrene, in which pentane is usually added as blowing agent. This process was developed by BASF in 1951 and remains the most significant to date.[120]

The original size of the granulate is between 1 and 3 mm and the raw material introduced into the production process has a density of 1030 kg / m^3 (or bulk density 650 kg / m^3)[121]. The proportion of propellant pentane is about 6% of the total weight and decreases during the manufacturing process. In general, the production of EPS rigid foam (styrofoam) takes place in a three-stage process. Figure 17 shows the schematic structure of a plant for the production of expanded polystyrene (EPS).

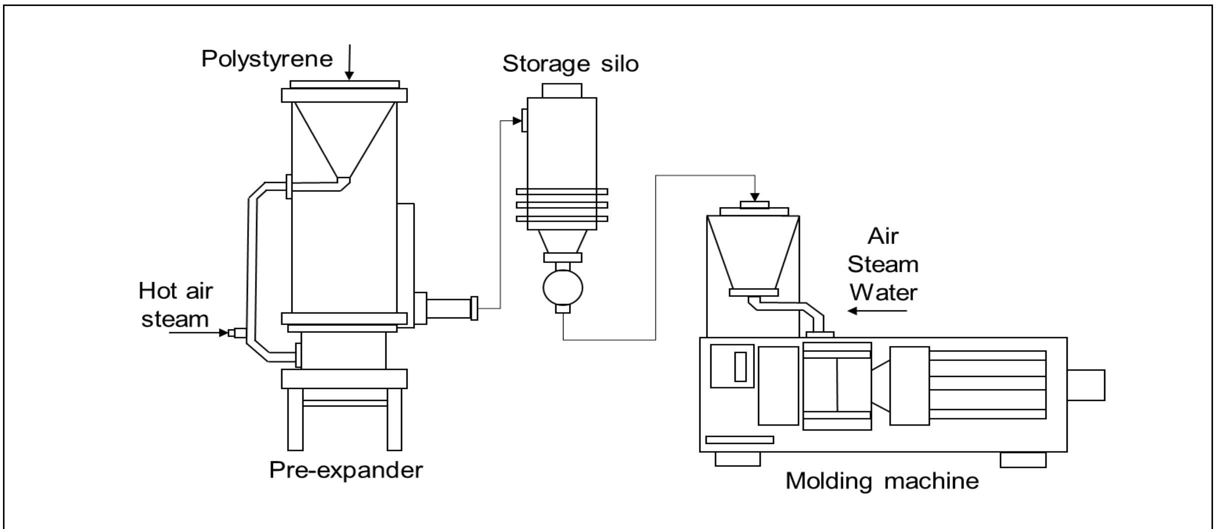

Figure 17: Production process of expanded polystyrene (EPS)[122]

In the first step, the fine-grained polystyrene granules are brought to the desired density by means of steam in so-called prefoamers at a temperature of about 90 ° C. In this process, the

[119] Note: The content in this section is partly based on on-site talk
[120] cf. Keim (2006), p. 121.
[121] cf. Schönell (2008), p. 350.
[122] cf. MH. (2018)

beads expand through the contained and evaporating pentane (about 2% of the total weight) as well as the penetrated water steam up to fifty times the original volume. (Significant influence on the degree of foaming (volume increase) is the duration of the heat effect.) "During pre-expansion, an agitator is used to keep the beads from fusing together. Since expanded beads are lighter than unexpanded beads, they are forced to the top of the vessel's cavity and discharged. This process lowers the density of the beads to three percent of their original value and yields a smooth-skinned, closed cell EPF that is excellent for detailed molding. "[123]

Subsequently, the prefoamed beads must be stored in ventilated silos for at least 48 hours During cooling, the remaining condenses in the cells, the remaining propellant and the steam, thus creating a negative pressure, which is slowly compensated by the diffusion of air. Only then do the prefoamed beads obtain the stability required for further processing.[124]

The third process stage is the foaming process. Here, the different products are brought into their final form. The production of packaging parts as well as the production of floor system and perimeter panels, which belong to the field of insulation (see section 3.1.3) are carried out on so-called automatic molding machines (IMM), whereas insulation panels are produced on so-called block mold machines (BMM). The prefoamed material is filled into the respective required shape (block, molding tool) and then expanded again under pressure (0.5 to 1.3 bar) through 110-120 ° C hot steam. The prefoamed beads weld together and a predominantly closed-cell foam with an air pore volume of approx. 98 volume percent is formed.[125] For better heat transfer tools are used, which help the water vapour to penetrate through perforated mould walls from all sides. Products from the production by means of IMM are ready for use after opening the molding tool and an short storage of at least 48 hours, however, the blocks produced must still be cut to size.

In Figure 18, the model pipe run based on a piping and instrumentation scheme (P/ID) of a block mold machine (BMM) is illustrated.

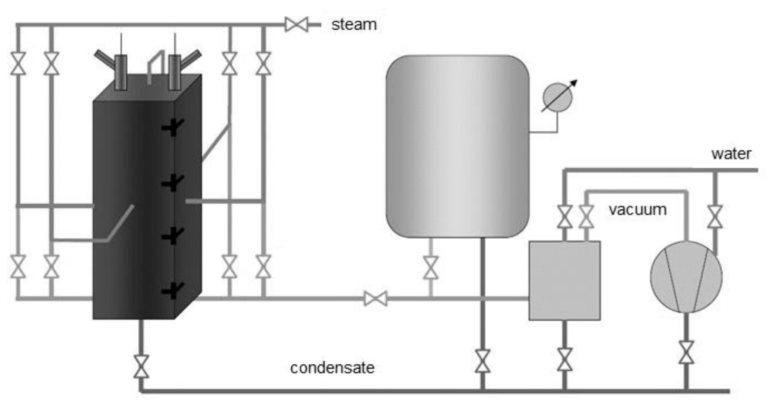

Figure 18: Basic structure of a block forming plant (Utilities)[126]

[123] MH. (2018)
[124] cf. Schönell (2008), p. 350f.
[125] cf. Willems & Schild (2017), p. 127.
[126] HIRSCH Servo AG – internal document

Figure 19 shows a steaming cycle of a block mold machine (BMM).

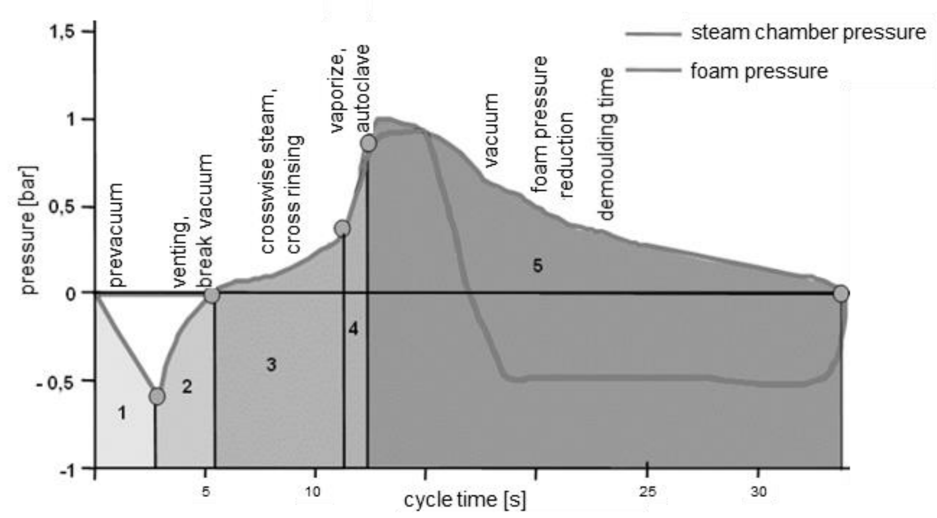

Figure 19: Steaming cycle[127]

3.1.3 Product groups

As already mentioned, the subdivision of the product portfolio takes place in the areas of insulating materials (block goods (BMM) and vending goods (IMM)) and packaging parts (IMM). The product portfolio offers a wide range of solutions for the construction, electrical, food, pharmaceutical and packaging industries.

The packaging area includes standard products for industry and wholesaling (boxes, containers), packaging for electrical and household appliances, load carriers, reusable packaging, thermal and insulating boxes and food packaging. Due to the development of special molded parts for industrial applications, new applications are increasingly possible. These include, for example, protective components for humans.[128]

The insulation division comprises products for the insulation of interior walls and facades, roofs and ceilings (BMM). System panels for floor system and perimeter insulation panels (IMM) as well as structural components with a high density of up to 200 g / dm^3 (e.g. shuttering elements) are also assigned to this category.[129]

Another product group can be found under the name of Thermozell, which summarizes products for the field of thermal and impact sound insulation.

[127] HIRSCH Servo AG – internal document
[128] cf. HIR. (2018)
[129] cf. HIR. (2018)

3.2 Analysis of the actual state (energy analysis)

A list of the applied cross-sectional technologies (utilities), a schematic representation of the energetic structure and the mapping of an energy flow scheme are presented. The following essay should serve the reader as a step-by-step guide to a comprehensive survey of energy flows and associated measurement systems. The tasks on site were not done in the following order, but the structure was deliberately chosen for a possible procedure.

3.2.1 Structure of used cross-sectional technologies (utilities) and internal energy flow

The manufacturing process requires a whole range of cross-sectional technologies. A stable supply of these is the basis for a continuous production process. In detail, a clear list of all occurring cross-sectional technologies is given. Figure 20 shows the energetic structure of all occurring media of the production site of HIRSCH Porozell GmbH, starting from the reference energy over all conversion stages up to the energy use. The transparent presentation should enable a targeted and continuous classification of later procedures. A fundamental subdivision is made into stream-based and fuel-based (gas) cross-sectional technologies.

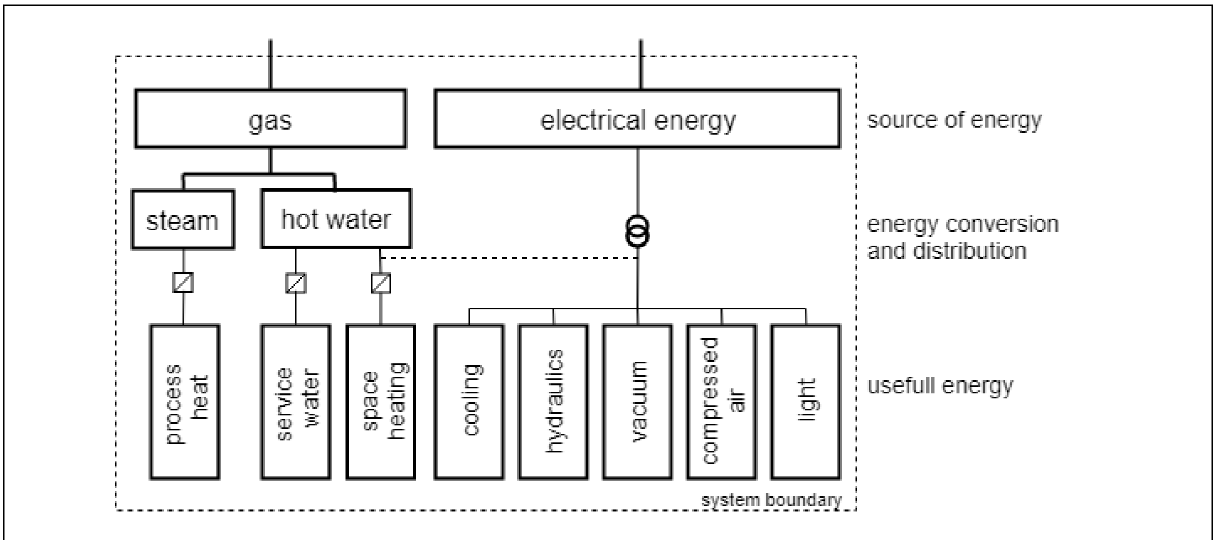

Figure 20: Energetic structure of the location[130]

The conversion of the reference energy gas to steam and hot water takes place by means of large boilers and serves on the one hand to provide the required process heat, on the other hand for hot water treatment and to cover the space heating requirement.

The electrical energy forms the second area. Here, the transformation or level conversion and the subsequent distribution of the required process variables in the manufacturing process: process refrigeration, hydraulic (mechanical drives), the generation of vacuum, the provision of compressed air and the lighting is shown. In some cases, the space heating requirement is also covered by electrical energy. The general site infrastructure (IT, administration) and the controller are not considered.

[130] cf. Fink et al. (1997), p. 8.

3.2.1.1 Energy flow and energy balance in operational energy management

The creation of a so-called energy flow scheme requires in-depth knowledge of the feed, any conversion points from the reference energy to the useful energy (e.g. steam boiler) and the distribution via the line scheme - here at plant level - and the plants (energy recovery should be disregarded in this part of the thesis). In general, creating an energy flow scheme is about "what goes where". It should not be said here, "how much where to go". However, here spatial arrangements and distances should be recognizable in principle.[131]

Figure 21 shows a possible energy flow scheme. As previously mentioned, the delineation of the operating system should be based on the implemented measurement concept, so only partial areas of this scheme are described in a more detailed way.

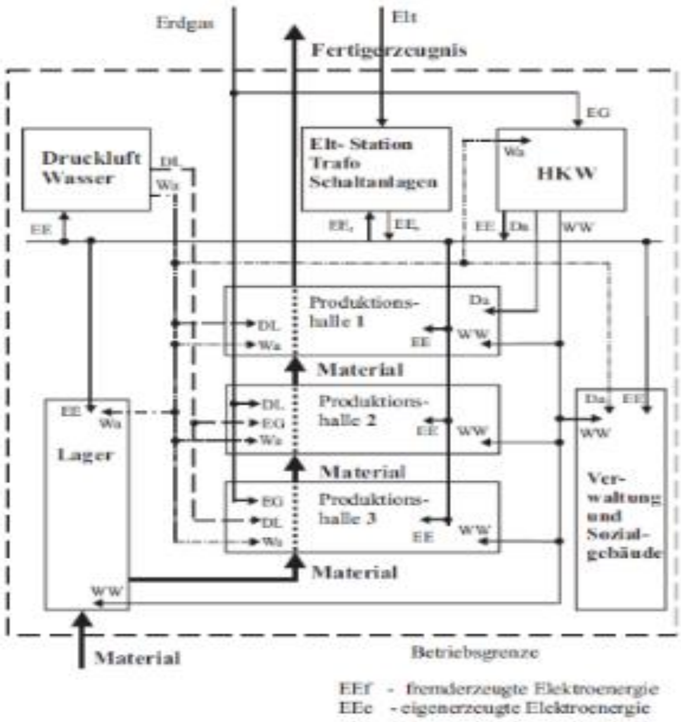

Figure 21: Energy flow diagram of an industrial enterprise[132]

This section outlines the energy flows of the Glanegg business location of the following media: electricity, gas and steam (in some cases water). Only those areas are considered that are important for the later presentation of the measurement concept.

In a first step, the areas essential for the investigation were limited. During the analysis, one could see that the existing internal company documents (P/ID scheme[133], pipe plans, etc.) were inconsistent with one another and that some changes in the course of the pipeline were not adequately documented. The gradual expansion of the site over the years and the consequent increase in the capacity requirements of all cross-sectional technologies led to continuous

[131] cf. Schieferdecker (2006), p. 62f.
[132] cf. Schieferdecker (2006), p. 63.
[133] Note: Piping and instrument flow diagram in the plant and process technology

changes in the distribution of useful energy. The relevant updated documents are available at the company.

It should also be noted that certain meters were not recorded electronically, which means a reduction of the survey effort, but also considered economic reasons. For reasons of completeness for the aggregate balance sheets, these were nevertheless considered.

3.2.1.2 Energy flow schemes of the media steam, water and electricity

Steam The distribution of steam at the Glanegg company location takes place from a centrally located boiler house via appropriate pipelines designed for the process-required pressure level of 6 to 8 bar. In the boiler house there is the steam boiler. Figure 22 shows the steam distribution network at the site.

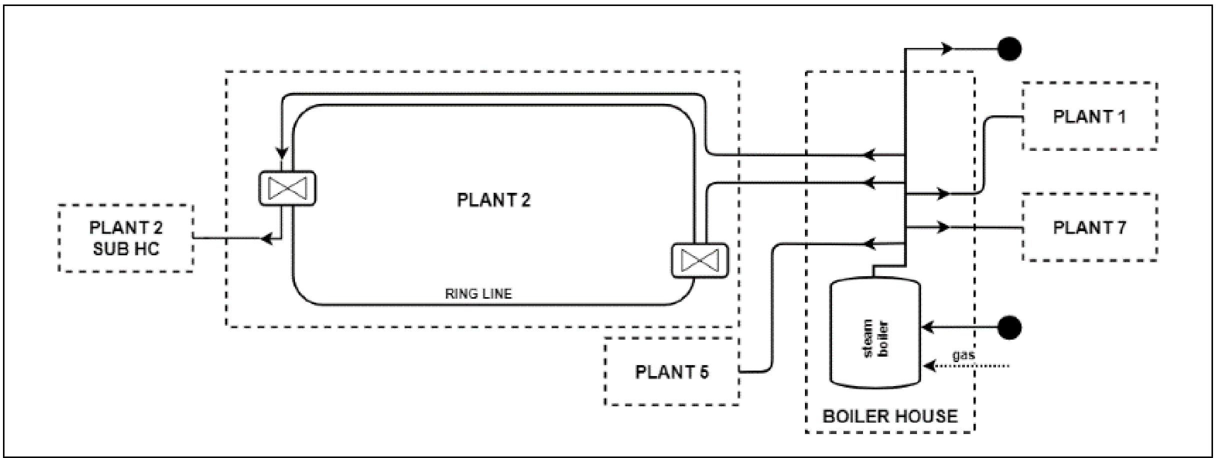

Figure 22: Steam distribution scheme at the Glanegg location (own illustration)

Steam is supplied to Plants 1, 5 and 7 via direct pipelines. The supply of the Plant 2 takes place by means of two pipes, which then supply a loop installed there. The transfer to a lower pressure level of about 5 bar takes place here by a distributor with pressure regulator. The plant in the side hall of Plant 2 (SUB HC) is fed directly from one of the two pipes for Plant 2 from the boiler house and thus does not come from the ring line.

Water Figure 23 gives an overview of the suspended pipe network and captures essential system components that come in steam generation used. This completes the steam production process and closes the steam generation cycle.

The provision of the boiler feed water required for steam generation takes place through a series of upstream system components, which are explained schematically below. The feedwater tank is supplied with the well water [4] and the condensate return [3]. This is then passed into the degasser, where it is degassed together with the not usable from the steam generation part - the degassing steam [2]. The boiler feed water is then fed via the appropriate piping [1] from the degasser to the steam boiler system. The boiler feed water is preheated by recovering the unusable process heat by means of numerous heat exchangers. The proportion of energy recovery is not recorded in the EM and is therefore not specified. This has a general impact on the efficiency of steam generation.

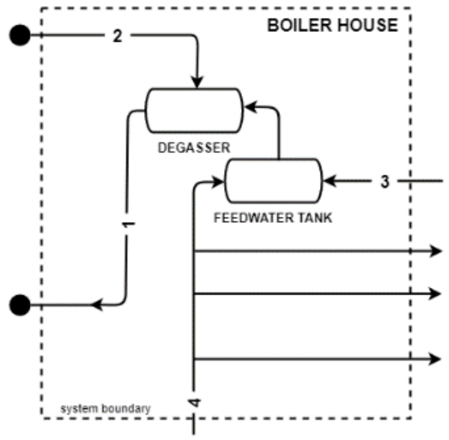

Figure 23: Scheme of steam boiler feed-in (own illustration)

The illustration of the steam distribution and the suspended pipe network updated here was based on numerous discussions and an on-site analysis of the pipe network. On a standardized representation was deliberately omitted for clarity. The goal of a quick understanding of the existing pipe network was in the foreground.

Electricity The records for electricity distribution were available and will be discussed in the following chapter.

The following section will now explain the positioning of the steam flow and water meters.

3.2.1.3 Meter positions and structure for a transparent allocation

A user-friendly allocation of the energy requirement - here at plant level - requires the transparency of the actual metering structure. Based on the flow diagrams created in the previous chapter, the determined meter positions were drawn correctly and, based on this, the measuring concept was explained. In addition, uninstalled meters and their impact on the energy balance must be considered. When reviewing the documents, the records were completed. The determination of the meter structure and the allocation of the meter positions was carried out by on-site analyses.

Steam In Figure 24, the steam flow scheme with accurate meter positions is illustrated. The sum of the steam used for the production process for Plants 1, 2, 5 and 7 is formed by the boiler feed water meter [1] minus the degassing steam [10] and assumes that all the water introduced into the boiler is converted into steam. The degassing steam [10] forms the unusable part and can thus be seen as self-consumption of the system. This is subsequently fed back to the degasser, as already explained in the previous chapter. The steam consumption measurements for Plant 5 and Plant 7 are made directly. The sum for Plant 2 is formed from the meters [5] and [6], meter [7] is a sub-meter and thus remains unconsidered in the summation for Plant 2. The steam flow meter in factory 1 [2] was subsequently removed due to technical problems, the consumption is thus determined by the difference between the total usable steam minus the steam consumption of Plants 5 and 7 and the sum of Plant 2.

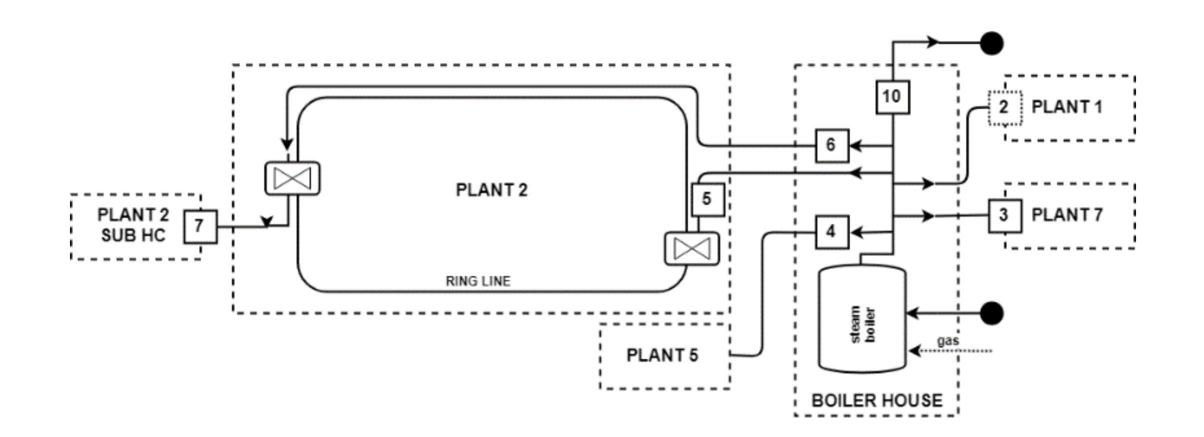

Figure 24: Steam flow scheme with meter positions (own illustration)

The following list shows the installed meters for the steam flow measurement at the location. A complete updated meter list is available at the company - Documentation Digital Meters HIRSCH Glanegg.

- [2*] Steam flow measurement: Plant 1 (*removed)
- [3] Steam flow measurement: Plant 7
- [4] Steam flow measurement: Plant 5
- [5] Steam flow measurement: Plant 2 (pedestal)
- [6] Steam flow measurement: Plant 2 (boiler house)
- [7] Steam flow measurement: Plant 2 sub-meter (Sub HC)
- [10] Steam flow measurement: degassing steam (unusable part)

Water Analogous Figure 25 shows the scheme of the steam boiler feed. The main supply of the water consumption recorded in the system is via the water meter well water [13] in factory 1. Starting from this, there is a meter for the process cooling. After the water meter before osmosis [8] there are two further outlets [9.1], [9.2] for the cooling water tanks at Plants 1 and 2, which are currently not recorded electronically, but because of the small quantities (filling up the cooling water tanks at the beginning of the week or after production shutdown – approx. 3-5 m^3) are deliberately neglected. This proportion is thus wrongly attributed to the condensate return [11], which is also not measured. The balance of the boiler feed water [1] for steam production can thus be calculated from the sum of the water before osmosis [8], the condensate return [11] and the degassing steam [10] [neglecting the consumption for the cooling water tanks works 1 and 2 [9.1], [9.2]].

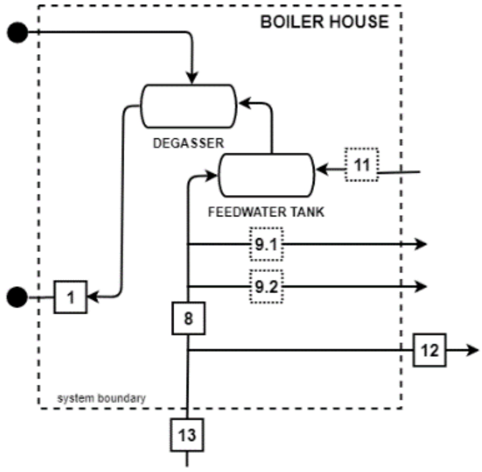

Figure 25:Scheme of steam boiler feed with meter positions (own illustration)

The following list shows the built-in meters for steam boiler feed. A complete updated meter list is available at the company -- Documentation Digital Meters HIRSCH Glanegg.

- [1] Water meter: boiler feed
- [13] Water meter: water consumption well water
- [12] Water meter: water consumption process cooling
- [8] Water meter: water before osmosis
- [9.1*] Water meter: osmosis water cooling water tank Plant 1 (*not recorded digitally)
- [9.2*] Water meter: osmosis water cooling water tank Plant 2 (*not recorded digitally)
- [11] No meter: condensate return (no measurement)

Electricity The transfer takes place at the factory site via five transformer stations. Consumption at Plant 1 is divided into the areas Plant 1 Office Building [1] and Plant 1 Production [6]. The total consumption for Plant 2 results from the main feed 1 [13] and 2 [14]. Works 3, 4 and 5 are attached to Plant 2 and form a common cost center. The total consumption for Plant 5 is recorded by the meters [23], [24]. The consumptions of plants 9 and 10 are added to this profit center. Further, in Plant 5, the outlets for Plant 7 are located (no measurement in Plant 5). The actual consumption for Plant 5 is therefore the sum of the two meters [23] [24] less the main meters for the production area Plant 7 [27] and the production area for the Thermozell production [29]. The feed for Plant 7 is thus via Plant 5 and must be subtracted in the records. Figure 26 shows the above described structure of the current distribution at the location.

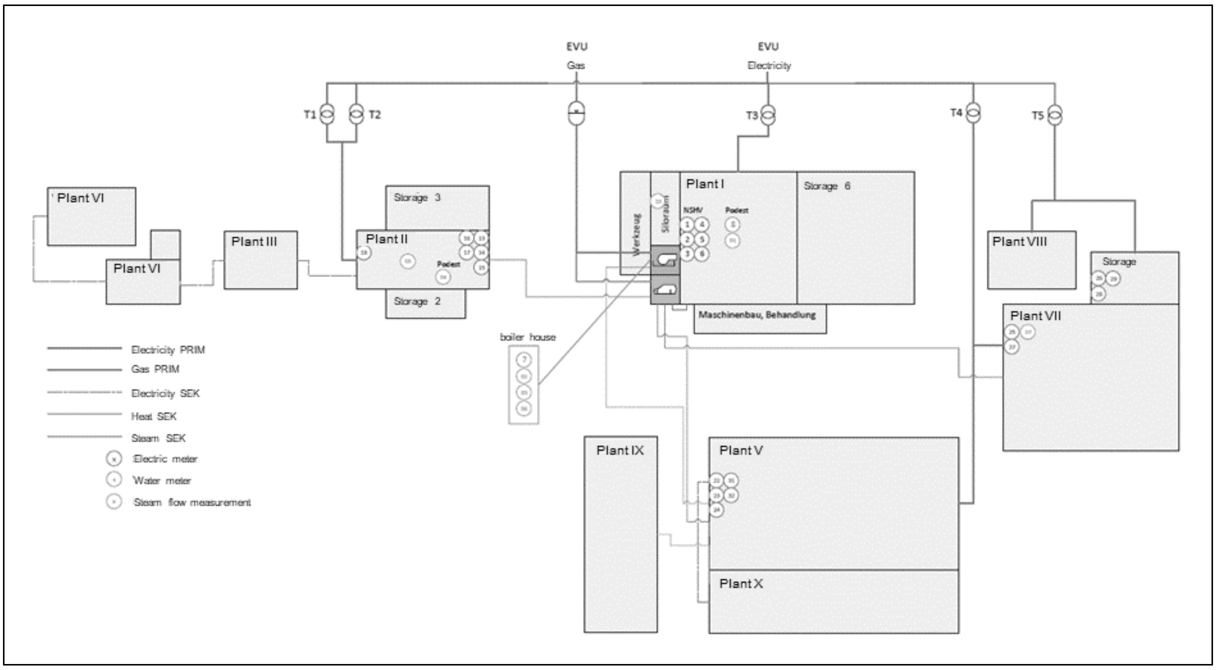

Figure 26: Scheme of current distribution with meter positions

The following list shows the built-in meters for current transfer. Only the main meters of the respective works are listed here. Updated documents about the sub-meters are available at the company - Documentation Digital Meters HIRSCH Glanegg.

- [1] Electric meter: Plant 1 Office building
- [6] Electric meter: Plant 1 Production
- [13] Electric meter: Plant 2 Main supply 1
- [14] Electric meter: Plant 2 Main supply 2
- [23] Electric meter: Plant 5 Metering AV
- [24] Electric meter: Plant 5 Metering UV
- [27] Electric meter: Plant 7 Production HV1
- [29] Electric meter: Plant 7 Thermozell HV 2

3.3 Energy monitoring system

In the spring of 2018, at the Glanegg company location the decision was taken to build up gradually an EM system. In co-operation with a power supply company, the installation of numerous measuring meters for recording the used media electricity, water, gas[134] and steam was carried out based on a measuring concept developed for this purpose. At the forefront of this decision was the goal of allocating the consumption of the individual plants at the site according to the polluter. In addition, a detailed database on consumption data should provide the opportunity to demonstrate efficiency potential, to optimize processes regarding energy efficiency, or to serve as a basis for future investment decisions. On the other hand, it was also the accumulation of experience in setting up such an EM system, which aimed at a fast and efficient implementation on other sites. After completion of the project and a comprehensive evaluation, the benefits of such a system are to be ascertained. Above all, however, it is intended to provide a basis for making decisions about possible implementations at other locations and the necessary levels of detail.

3.3.1 Plausibility check and data validity

Reliable data is the basis for sufficiently robust EM. A comprehensive plausibility check and verification by appropriate methods of the quantity structure (kWh, kg) collected are necessary for this. The continuous collection of measured values leads to a steadily growing database. This allows increasingly effective and efficient plausibility checks. The following list is intended to show a selection of the analyses carried out. Important factors contributing to valid data for EM are:

- Knowledge about the relationships between the individual meters (flow chart)[135]
- Knowledge about non-transferred measured values (see Table 4 and 5)
- Checking the transmission of measured values and associated transmission lines[136]
- Complete meter allocation[137]
- Checking the units used (m^3, kg)

[134] Note: Gas meters were not included in the EM system at the time of investigation. A quotation for the integration was obtained during the investigation and is available to the company.

[135] Note: Relationships of the individual meters were established. The EM system was then verified using appropriate flow diagrams from the backend. Corresponding adjustments were made.

[136] Note: Execution by external company, subsequent check of the measured value transmission took place. Error messages for non-transmitted measured values should be integrated into the EM system.

[137] Note: The relevant updated documents are available at the company.

Table 2 shows the comparison of electricity consumption figures for the monthly statement with the values shown in the monitoring. The analysis found that the difference found at the time of the investigation could be attributed to the lack of involvement of two control loops.[138] Furthermore, a deviation of <1% is possible for the measured value transmission.

Table 2: Comparison total consumption billing and energy monitoring

From	To	Total - billing	Total - monitoring	difference [kWh]	difference [€]
01.01.2018	31.01.2018	444.819,00 kWh	422.656,30 kWh	22.162,70 kWh	1.551,39 €
01.02.2018	28.02.2018	485.711,00 kWh	470.279,08 kWh	15.431,92 kWh	1.080,23 €
01.03.2018	31.03.2018	532.075,00 kWh	511.260,62 kWh	20.814,38 kWh	1.457,01 €
01.04.2018	30.04.2018	538.563,00 kWh	515.838,49 kWh	22.724,51 kWh	1.590,72 €
01.05.2018	31.05.2018	575.661,00 kWh	584.703,17 kWh	-9.042,17 kWh	-632,95 €
01.06.2018	30.06.2018	574.857,00 kWh	574.744,24 kWh	112,76 kWh	7,89 €
01.07.2018	31.07.2018	520.514,00 kWh	513.306,86 kWh	7.207,14 kWh	504,50 €
01.08.2018	31.08.2018	520.785,00 kWh	514.759,30 kWh	6.025,70 kWh	421,80 €
01.09.2018	30.09.2018	537.621,00 kWh	535.216,40 kWh	2.404,60 kWh	168,32 €
01.10.2018	31.10.2018	585.897,00 kWh	575.524,60 kWh	10.372,40 kWh	726,07 €
01.11.2018	30.11.2018	529.163,00 kWh	515.981,52 kWh	13.181,48 kWh	922,70 €

Based on the extract of data shown as an example in Table 3, the check for completeness of the transferred measured values was carried out.

Table 3: Data extraction of measured value transmission

	Bezogene Wirkarbeit	Bezogene Wirkart	Bezogene Wirkarbe	Bezogene Wirkarbe	Bezogene Wirkart	Bezogene Wirkarbı	Bezogene Wirkarbei	Bezogene Wirkarbei Be
30.08.2018 00:00	1851060992,00	8905587,00	199826448,00	330661760,00	14744407,00	121373912,00	1008983936,00	974853568,00
30.08.2018 01:00	1851085952,00	8907682,00	199826448,00	330661760,00	14744407,00	121373912,00	1009194176,00	975141568,00
30.08.2018 02:00	1851110016,00	8909850,00	199826448,00	330661760,00	14744407,00	121373912,00	1009395840,00	975433024,00
30.08.2018 03:00	1851133568,00	8912057,00	199826448,00	330661760,00	14744407,00	121373912,00	1009625024,00	975701632,00
30.08.2018 04:00	1851156096,00	8914125,00	199826448,00	330661760,00	14744407,00	121373912,00	1009883520,00	975969408,00
30.08.2018 05:00	1851181568,00	8916422,00	199826448,00	330661760,00	14744407,00	121373912,00	1010142528,00	976234688,00
30.08.2018 06:00	1851515648,00	8919515,00	199863328,00	330724128,00	14747012,00	121418040,00	1010364800,00	976500416,00

Table 4 shows the evaluation, which includes a list of the recorded quantities, the proportion of power consumption of the respective area in the total consumption as well as the number of untransferred measured values for the steam area.

Table 4: Data points – steam

		fuels		recording						Number of data values			
name measuring point	designation	electricity	steam	begin	end	Plant	recorded amount	unit	Share of electricity consumption	Target	Actual	missing data / measuring point	kWh / timestamp
HSP-W1-Dampf-VP	k.A.		Yes	23.02.2018	31.08.2018	W1	13 353 422	kg	61,55%	18195	12 186	33,03%	1 096
HSP-W2-Dampf-KessHaus	k.A.		Yes	23.02.2018	31.08.2018	W2	4 059 865	kg	18,71%	18194	17 639	3,05%	230
HSP-W7-Dampf-Pod	k.A.		Yes	23.02.2018	31.08.2018	W7	2 373 551	kg	10,94%	18190	17 595	3,27%	135
HSP-W2-Dampf-SubHC	k.A.		Yes	23.02.2018	31.08.2018	W2	1 082 701	kg	4,99%	18194	12 128	33,34%	89
HSP-W2-Dampf-Pod	k.A.		Yes	23.02.2018	31.08.2018	W2	610 112	kg	2,81%	18194	10 534	42,10%	58
HSP-W5-Dampf-KessHaus	k.A.		Yes	23.02.2018	31.08.2018	W5	111 408	kg	0,51%	18194	17 606	3,23%	6
HSP-W1-Dampf-SpW	k.A.		Yes	23.02.2018	31.08.2018	W1	104 305	kg	0,48%	18194	17 158	5,69%	6

Analogous to this Table 5 for the area of electricity:

[138] Note: Detailed documents have been deposited in the company. A quotation for the integration was obtained during the investigation and is available to the company.

Table 5: Data points – electricity

		fuels		recording						Number of data values			
name measuring point	designation	electricity	steam	begin	end	Plant	recorded amount	unit	Share of electricity consumption (%)	Target	Actual	missing data / measuring point	kWh / timestamp
HSP-W1-Prod	Vorsicherung Bürogebäud	Yes		01.01.2018	31.08.2018	W1	1 577 413	kWh	29,81%	23324	23324	0,00%	68
HSP-W2-EINSP1	HVT Feld 3	Yes		01.01.2018	31.08.2018	W2	844 898	kWh	15,96%	23324	22765	2,40%	37
HSP-W2-EINSP2	UMG 509	Yes		01.01.2018	31.08.2018	W2	834 077	kWh	15,76%	23324	23320	0,02%	36
HSP-W2-Komp3	HVT Feld 3	Yes		01.01.2018	31.08.2018	W2	366 590	kWh	6,93%	23324	22794	2,27%	16
HSP-W2-Komp4	HVT Feld 9	Yes		01.01.2018	31.08.2018	W2	325 919	kWh	6,16%	23324	23053	1,16%	14
HSP-W1-Komp2	VT Maschinen Feld2	Yes		01.01.2018	31.08.2018	W1	299 697	kWh	5,66%	23324	23324	0,00%	13
HSP-W5-UV	HVT Feld 1 Hauptverteiler	Yes		01.01.2018	31.08.2018	W5	204 077	kWh	3,86%	23324	23287	0,16%	9
HSP-W1-Komp1	VT Maschinen Feld2	Yes		01.01.2018	31.08.2018	W1	180 622	kWh	3,41%	23324	23324	0,00%	8
HSP-W2-Komp1	HVT Feld 3	Yes		01.01.2018	31.08.2018	W2	147 107	kWh	2,78%	23324	22872	1,94%	6
HSP-W1-Komp4	VT Maschinen Feld2	Yes		01.01.2018	31.08.2018	W1	111 385	kWh	2,10%	23324	23237	0,37%	5
HSP-W7-Prod	HV1 Zählernr 8	Yes		02.07.2018	31.08.2018	W7	83 924	kWh	1,59%	5777	5776	0,02%	15
HSP-W5-AV	HVT Feld 1 - Hauptverteile	Yes		04.06.2018	31.08.2018	W5	65 911	kWh	1,25%	8544	8501	0,50%	8
HSP-W7-Komp	HV2	Yes		01.01.2018	31.08.2018	W7	65 572	kWh	1,24%	23324	23324	0,00%	3
HSP-W5-Komp	HVT Feld 5	Yes		01.01.2018	31.08.2018	W5	57 545	kWh	1,09%	23324	23277	0,20%	2
HSP-W1-Komp3	VT Maschinen Feld2	Yes		01.01.2018	31.08.2018	W1	30 847	kWh	0,58%	23324	15976	31,50%	2
HSP-W7-Therm	HV2 Zählernr 9	Yes		02.07.2018	31.08.2018	W7	27 634	kWh	0,52%	5777	5777	0,00%	5
HSP-W1-Buer	UMG104 patz west	Yes		01.01.2018	31.08.2018	W1	23 633	kWh	0,45%	23324	19991	14,29%	1
HSP-W2-Masch.2	Maschine2	Yes		29.06.2018	31.08.2018	W2	21 145	kWh	0,40%	6144	6117	0,44%	3
HSP-W10-SUM	Abgang in Werk 5 / HVT F	Yes		01.01.2018	31.08.2018	W10	17 940	kWh	0,34%	23324	23276	0,21%	1
HSP-W7-SchnStr	HV2	Yes		01.01.2018	31.08.2018	W7	5 133	kWh	0,10%	23324	23324	0,00%	0
HSP-W7-E-Säulen P2	k.A.	Yes		13.06.2018	31.08.2018	W7	732	kWh	0,01%	7619	7619	0,00%	0
HSP-W7-E-Säulen P1	k.A.	Yes		13.06.2018	31.08.2018	W7	291	kWh	0,01%	7618	7618	0,00%	0
HSP-W9-SUM	Abgang in Werk 5 / HVT F	Yes		01.01.2018	31.08.2018	W9	251	kWh	0,00%	23324	23288	0,15%	0

Data validity can only be achieved if on the one hand continuous measurements take place, on the other hand someone gets a quick overview from the experience in dealing with them and recognizes errors immediately. The integration of alarms for non-transmission of measured values is recommended.

3.3.2 Preparation of the data

Based on the analysis, the verified data in the monitoring system were processed in a table and visually. The respective user must be provided with the information needed for the respective activity: a source-related allocation of the consumption to the respective profit center, a transparent overview of the consumption flows of the individual media or detailed information on individual areas (here plant level).

3.3.2.1 Tabular overview with profit centers

Efficient energy controlling presupposes a source-related allocation of consumptions of all occurring media. To create the monthly statement, the short-term profit and loss accounting (see section 2.3.6) and for planning, timely information on consumption data in controlling is needed.

At the time of the survey, the meter readings were entered manually at the end of each month. All the meter readings and consumptions were read out manually using the documents provided for this purpose and then transmitted to the controlling department. At the time of the examination, the measurement concept had already been revised several times, and the associated documents no longer corresponded to the current status. This meant that the correct allocation of consumption data was not given. It can be assumed that consumption data did not comply with the principle of causation. An allocation of the individual meters recorded in the EM to the respective profit centers and a clear presentation of the individual profit centers could be implemented (see section 3.3.1).

Steam Table 6 shows the overview of the steam consumption of the individual profit centers in tabular form. Reliable, valid data was made available retroactively as of August 2018 during this project.

Table 6: Consumption overview – profit center – steam

	Einheit	Januar 2018	Februar 2018	März 2018	April 2018	Mai 2018	Juni 2018	Juli 2018	August 2018	September 2018	Oktober 2018	November 2018	Dezember 2018	Gesamt
HP-Dampf-Summe-Produktion	l	20712000	22906000	26156000	27204000	19932700	2678200.75	2666100	2591599.75	2574400.5	2925200.25	2467699.25	1297300.75	134111201.
Gasverbrauch [l] Digitalein 1	EUR	20712000	22906000	26156000	27204000	19932700	2678200.75	2666100	2591599.75	2574400.5	2925200.25	2467699.25	1297300.75	134111201.
HP-W1-Dampf-Produktion (VP)	l	-	-	-	-	-	-	-	1304453.75	1214379.75	1474645.5	1220361.75	715384.75	5929225.5
Gasverbrauch [l] Digitalein 1	EUR	-	-	-	-	-	-	-	1304453.75	1214379.75	1474645.5	1220361.75	715384.75	5929225.5
HP-W2-Dampf-Produktion (FBH/PER)	l	-	-87809	189333	-	321614	823208	723843	735960	667441	686192	564844	295059	4919685
Gasverbrauch [l] Digitalein 1	EUR	-	-87809	189333	-	321614	823208	723843	735960	667441	686192	564844	295059	4919685
HP-W2-Dampf-SUB HC (Perimeter)	kg	-	150100	247147	-	549595	204746	178882	170717	217160	250655	227749	9251	2206002
Gesamtverbrauch Dampf	EUR	-	150100	247147	-	549595	204746	178882	170717	217160	250655	227749	9251	2206002
HM-W5-Dampf-Produktion	kg	-	-	-	-	-	-	-	12678	12217.45	13549.69	16259.8	9977	64681.94
Gesamtverbrauch Dampf	EUR	-	-	-	-	-	-	-	12678	12217.45	13549.69	16259.8	9977	64681.94
HP-W7-Dampf-Produktion (BLOCK)	kg	-	45034	376344	403304	371209	368661	0	312329	392790	423330	371520	248687	3313208
Gesamtverbrauch Dampf	EUR	-	45034	376344	403304	371209	368661	0	312329	392790	423330	371520	248687	3313208
HP-Dampf-Entgaser	kg	-	9516	3895	1673	5246	2626	27118	55462	70412.22	76828.13	66964.66	18942	338683.01
Gesamtverbrauch Dampf	EUR	-	9516	3895	1673	5246	2626	27118	55462	70412.22	76828.13	66964.66	18942	338683.01

Water Table 7 shows an overview of the monthly consumption of the collected water meters. At present (see section 3.2.1.3) not all meters are digitally recorded or at present no assignment to the individual cost centers is made. During the project, an offer for the integration of the remaining meters was requested. Valid dates are given here from July 2018.

Table 7: Consumption overview – water[139]

	Einheit	Januar 2018	Februar 2018	März 2018	April 2018	Mai 2018	Juni 2018	Juli 2018	August 2018	September 2018	Oktober 2018	November 2018	Dezember 2018	Gesamt
HP-W1-Prod	m^3	40575	45189	44194	55639	34349.4	4899.4	4459.1	5445.4	4011.9	4901.1	4056.8	2304.7	250024.8
Wasserverbrauch [m^3] Wasserverbrauch Brunnenwasser	EUR	40575	45189	44194	55639	34349.4	4899.4	4459.1	5445.4	4011.9	4901.1	4056.8	2304.7	250024.8
HP-W1-Prod	m^3	1	51	2	5391	261.5	81.6	96.4	3445.1	2274.3	681.4	981.1	163.7	13430.1
Wasserverbrauch [m^3] Wasserverbrauch Prozesskühlung	EUR	1	51	2	5391	261.5	81.6	96.4	3445.1	2274.3	681.4	981.1	163.7	13430.1
HSP-W1-Buero	m^3	20712	22906	26156	27204	19932.7	2678.2	2666.1	2591.6	2574.4	2925.2	2467.7	1297.3	134111.2
Wasserverbrauch [m^3] Wasserverbrauch Kessel Einspeisung	EUR	20712	22906	26156	27204	19932.7	2678.2	2666.1	2591.6	2574.4	2925.2	2467.7	1297.3	134111.2
HSP-W1-Buero	m^3	-	-	-	-	0	0	742.4	11335.5	11418.4	12945.2	5811.7	2004.4	44257.6
Wasserverbrauch [m^3] Wasserverbrauch Kessel vor Osmose	EUR	-	-	-	-	0	0	742.4	11335.5	11418.4	12945.2	5811.7	2004.4	44257.6
Gesamt	**m^3**	**61288**	**68146**	**70352**	**88234**	**54543.6**	**7659.2**	**7964**	**22817.6**	**20279**	**21452.9**	**13317.3**	**5770.1**	**441823.7**
	EUR	**61288**	**68146**	**70352**	**88234**	**54543.6**	**7659.2**	**7964**	**22817.6**	**20279**	**21452.9**	**13317.3**	**5770.1**	**441823.7**

139 Note: Costs can only be displayed in a newer version of the software used

Electricity Table 8 shows the overview of the electricity consumption in the respective profit center. The data were checked retrospectively, reliable data are given only from the calendar month of October 2018.[140]

Table 8: Consumption overview – profit center – electricity[141]

	Einheit	Januar 2018	Februar 2018	März 2018	April 2018	Mai 2018	Juni 2018	Juli 2018	August 2018	September 2018	Oktober 2018	November 2018	Dezember 2018	Gesamt
HP-W1-Produktion (VP)	kWh	191348.51	211905.17	237281.82	221497.65	310589.57	283121.73	213002.46	200233.31	219356.32	246332.19	223329.79	138521.34	2696519.86
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	15881.93	17588.13	19694.39	18384.3	25778.93	23499.1	17679.2	16619.36	18206.57	20445.57	18536.37	11497.27	223811.15
HSP-W1-Buero	kWh	-	536.79	3240.45	2612.49	2910.18	3147.77	4158.59	4284.7	3021.35	3220.55	3821.32	3376.07	34330.26
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	-	44.55	268.96	216.84	241.54	261.27	345.16	355.63	250.77	267.31	317.17	280.21	2849.41
HP-W2-Produktion (FBH/PER), inkl. W3/W4/W6	kWh	168764.22	194117.71	193599.42	212615.01	208951.3	234813.7	237885.12	252340.93	247193.09	239205.5	217524.86	100668.67	2507679.53
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	14007.43	16111.77	16068.75	17647.05	17342.96	19489.54	19744.46	20944.3	20517.03	19854.06	18054.56	8355.5	208137.4
HM-W5-Produktion/Büro, inkl. W9/W10	kWh	26077.95	22032.74	23425.16	20022.11	7783.58	2529.97	2914.1	-821.66	1864.3	6093.6	16382.43	13292.93	141597.21
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	2164.47	1828.72	1944.29	1661.84	646.04	209.99	241.87	-68.2	154.74	505.77	1359.74	1103.31	11752.57
HP-W7-Produktion/Büro (BLOCK), inkl. W8	kWh	30425.82	34338.04	43419.95	46624.56	42248.9	38973.76	41046.34	44647.52	47098.94	61061.54	42179.3	36214.27	508278.94
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	2525.34	2850.06	3603.86	3869.84	3506.66	3234.82	3406.85	3705.74	3909.21	5068.11	3500.88	3005.78	42187.15
HP-W7-Produktion (TZ)	kWh	6039.8	7348.63	10293.82	12466.67	12219.64	12157.31	14300.25	14074.5	16682.4	19611.22	12743.82	6730.59	144668.65
Bezogene Wirkarbeit Gesamttarif Summe L1..L3	EUR	501.3	609.94	854.39	1034.73	1014.23	1009.06	1186.92	1168.18	1384.64	1627.73	1057.74	558.64	12007.5
Gesamt	**kWh**	**422656.3**	**470279.08**	**511260.62**	**515838.49**	**584703.17**	**574744.24**	**513306.86**	**514759.3**	**535216.4**	**575524.6**	**515981.52**	**298803.87**	**6033074.45**
	EUR	**35080.47**	**39033.16**	**42434.63**	**42814.59**	**48530.36**	**47703.77**	**42604.47**	**42725.02**	**44422.96**	**47768.54**	**42826.47**	**24800.72**	**500745.18**

3.3.2.2 Sankey diagrams

A frequent display of the consumption flows takes place using Sankey diagrams. A Sankey chart is an exact representation of flow rates. The directional flow of the flows between two nodes (processes) not only provides information on quantities, but also an overview of the division and the structure of systems.[142] The following assumptions are considered:

- The quantities (steam, electricity) are extensive quantities and refer to a certain period of time.
- The flow quantities are represented by volume-proportional arrows, the width of the arrow showing the quantity of the represented medium to scale.
- No stock figures are considered, this means there is no stock formation.
- Energy or mass conservation is assumed, which can quickly reveal discrepancies in the balance sheet through any losses or inefficiencies.[143]

140 Note: Detailed documents on the relationships between the individual meters were stored in the company

141 Note: The reported costs are calculated using a fixed conversion factor

142 cf. IFU. (2018)

143 cf. Schmidt (2006), p. 25.

For this reason, Sankey diagrams represent an efficient way to represent energy flows and flow rates in production companies, thus making an important contribution to the introduction of an EM system in the company.

3.3.2.2.1 Steam flow at the Glanegg location

Figure 27 is a section of the monitoring system and shows the steam flow at the Glanegg production site. The implementation was based on the developed measurement structure shown in the previous section (see section 3.2.1.2). Time intervals can be selected as desired (hour, day, month).

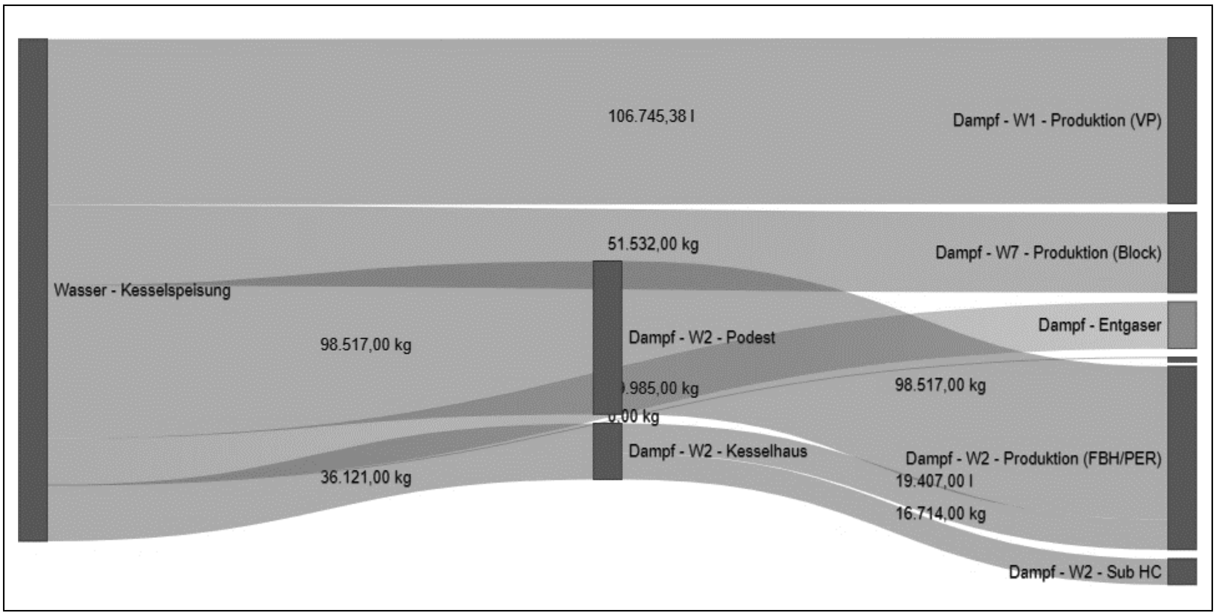

Figure 27: Sankey diagram – steam (February 2019)

3.3.2.2.2 Current flow at the Glanegg location

Figure 28 is a section of the monitoring system and shows the current flow of the Glanegg production site. Analogously, the implementation was carried out based on the developed measurement structure shown (see section 3.2.1.2).

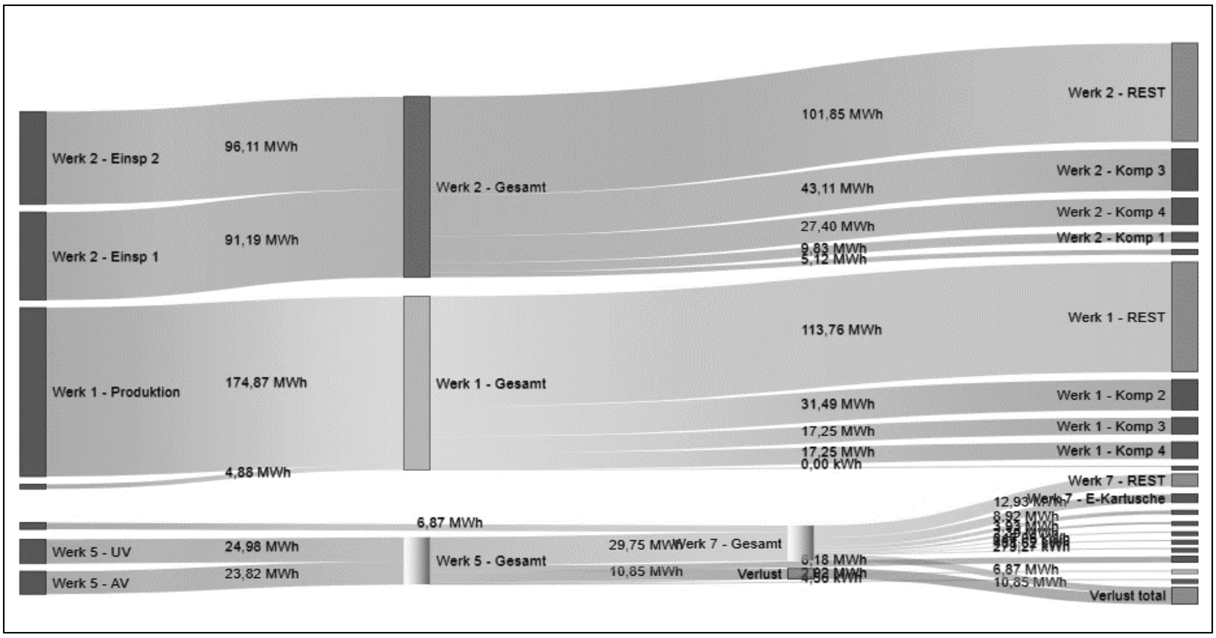

Figure 28: Sankey diagram – electricity (February 2019)

3.3.2.3 Detail view of individual areas (plant level) data

The recording and provision of energy consumption in a high frequency as well as their visualization forms the basis for a later determination of efficiency potentials. Timing is displayed using line, bar or dot diagrams. It is possible to collect data for further investigations in a much higher cycle time up to real time. Below are excerpts from the implemented EM system.

Figure 29 shows a diagram of the steam consumption of the location of a week. It shows the steam consumption in kg per hour. Different time intervals can be displayed.

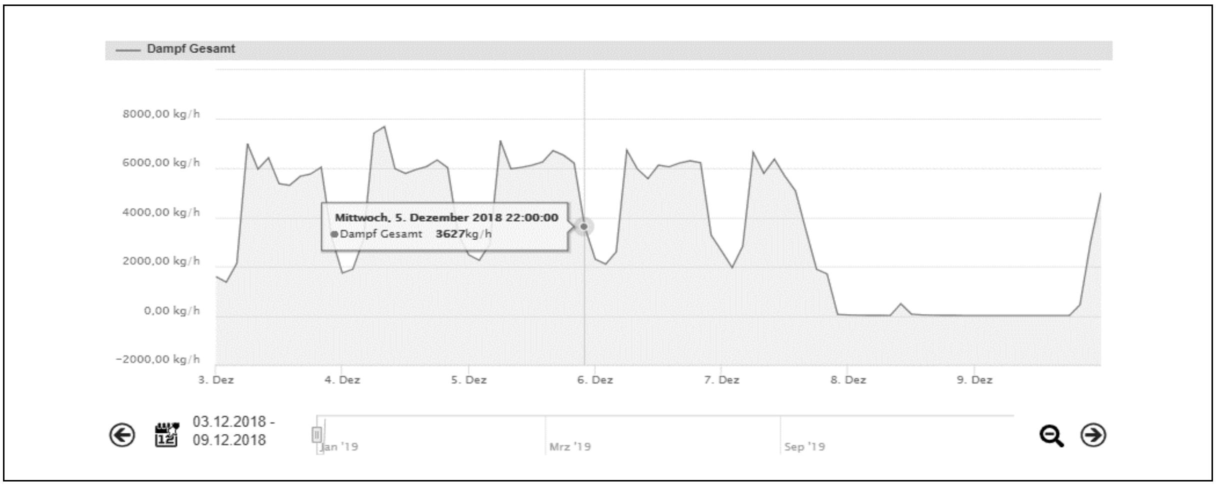

Figure 29: Detailed view – total steam consumption (calendar week 49, 2018)

Figure 30 shows the steam consumption of the individual plants in the location. Again, the installation can be done at any intervals.

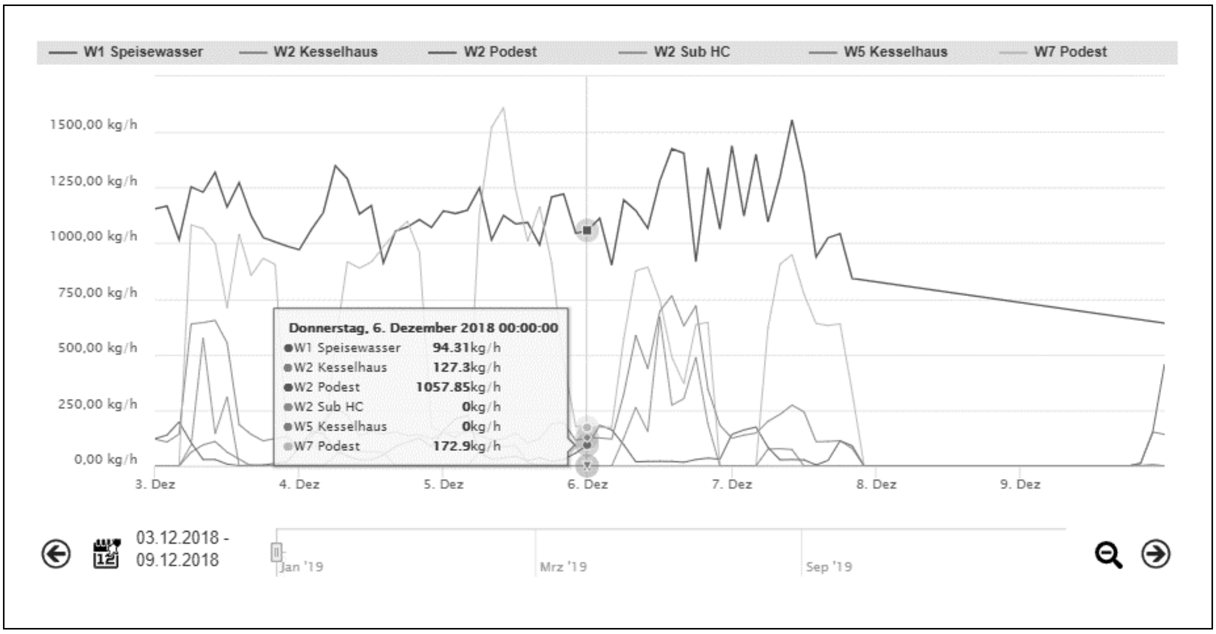

Figure 30: Detailed view – steam consumption of individual plants (calendar week 49, 2018)

The comparison of consumption values with values from comparison periods (daily, weekly, monthly, yearly) is illustrated in Figure 31.

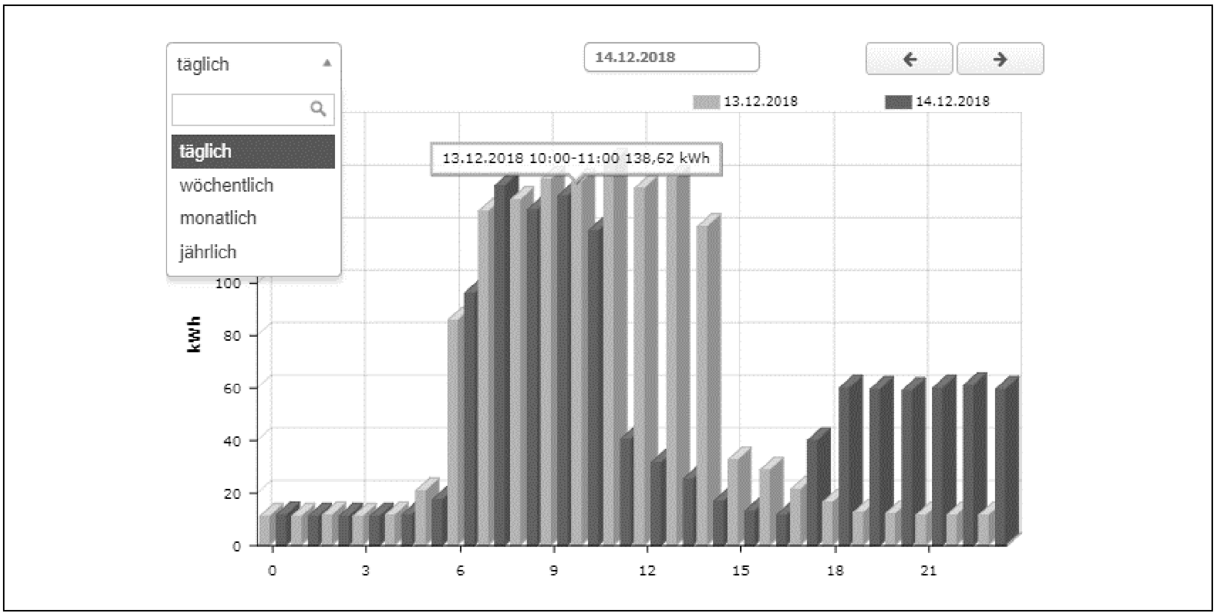

Figure 31: Detailed view – total steam consumption (calendar week 49, 2018)

The illustrations of energy consumption show a section on the possibilities of an EM system. For further projects to implement measures to increase energy efficiency, adjustments will be necessary based on the information required. These adjustments are preceded by decisions about the extent of directly attributable energy costs (see section 3.6).

3.4 Energy key figures

The following chapter describes the results of the development of an energy key figure system for the benchmarking comparison of the individual company locations of HIRSCH Servo AG and refers to the explained basics for the establishment of a suitable key figure system (see section 2.4).

In contrast to the structure of a performance measurement system presented in the theoretical part of this work, most of the key figure systems used in practice do not have a great deal of formal integrity. They usually consist of a selection of individual key figures without a precisely described hierarchy or order. Nevertheless, even in such "loose associates" there can be a "top key figure" that is dependent on the controlling culture and serves as a control parameter for the management. (e.g. energy costs in percent of sales).[144]

In the following, the development process and the result of the created concept will be described.

3.4.1 Energy key figure system

As already illustrated in the previous part of the theory, it is about setting up an energy key figure system. A long-term anchoring of the topic energy in the corporate strategy as well as the structure of a whole-time energy management in the enterprise presupposes a data basis from ascertained characteristics. The process as the iterative design process of an energy key figure system, which serves as the basis for a later decision-making process on the long-term embedding of specific parameters in the reporting system, forms the core. The collection and compilation of a complete database and existing time series of various parameters should enable the long-term benchmarking of the individual locations and thus play a decisive role in the decision of production orders.

The creation of a key figure system is an iterative process, and thus only after the existence of time series and detailed discussion of the actual benefit of individual ratios can be determined.

3.4.1.1 Key figures of the accounting system for setting up an energy key figure system

A first step is the consideration of the underlying data series in the company, which are already systematically recorded or which data are also reported at regular intervals from the other locations. According to an existing standardized reporting system of the company, a whole series of general figures are available in accounting, which are differentiated into absolute and relative key figures (as described in chapter 2.4). Data on company key figures such as sales, sales volume or raw material consumption are reported in accounting in the course of the short-term operational accounting monthly from all locations. Such parameters are subject to

[144] cf. Joos (2014), p. 74.

standardization but are also clearly defined internally across all locations and are reported according to existing criteria.

3.4.1.2 Collecting additional data

The structure of a key figure system is based on existing data series from accounting. In most cases, however, a mere combination of absolute values and relative variables is not sufficient. Although the data required for this are locally available mostly in the accounting department at the respective location, they are not part of the reporting system, as in the present case, or the transmission takes place in an interval that is too large for ongoing monitoring (e.g. once a year). Information about energy consumption and costs was obtained from all locations for setting up an energy key figure system.

As detailed in the theoretical part of this thesis, it is essential for in-company comparisons that all sites submit consistent data in terms of accrual, calculation method, and time reference. A standardized database is the basic requirement for a later benchmarking. In addition to standardization, however, it is also necessary to carry out plausibility checks of the transmitted data as part of a first-time query or to consult the responsible persons on site about the survey.

Table 9 shows a section of the survey.

Table 9: Request of energy data

HP, Dämmstoffe Rheda - DE

		February 2018	March 2018	April 2018	May 2018	June 2018	July 2018	August 2018	September 2018	October 2018	November 2018	December 2018	TOTAL
Electricity	kWh												0
	€												0

		February 2018	March 2018	April 2018	May 2018	June 2018	July 2018	August 2018	September 2018	October 2018	November 2018	December 2018	TOTAL
Gas	kWh												0
	€												0

In a first step data on the monthly consumption and the associated costs (total) per energy source (electricity, gas) were requested. Time series of the last two fiscal years were retroactively collected until April 2017.

3.4.1.3 Setting up an energy key figure system

The establishment of an energy key figure system pursues the goal of preparing information in concentrated form to the given facts for the management and responsibles. Time series comparisons and intercompany comparisons should be used for operational planning (short and medium term) (see section 2.1.7.1).

Information content of such a system must be co-ordinated with the information recipients. The present draft of an energy key figure system is intended as the basis for the decision-making process of later reporting routines. A focus on key parameters was in the foreground, on the one hand, an excess of information should be prevented, on the other hand, the survey effort should remain low or the necessary data at the time of examination were not available across the entire group. The present concept is divided into several stages and should be able to be extended step by step after evaluation.

Further, the list was made according to individual cost centers. Different product groups (insulating materials, packaging, floor system and perimeter plates, Thermozell) lead to the idea of sometimes defining different characteristics. In particular, the areas of insulating materials and packaging differ significantly in energy consumption, which means that a separation and thus independent characteristics are to be taken into consideration. The degree of detailing must be determined prior to incorporation into the reporting system. The cost types correspond to the basic accounting records. With different responsibility assignments (cost elements = purchasing, cost centers = production) condensed reports are necessary. These can be executed again according to cost elements (sum of all cost centers related to the respective cost element) and after cost centers (sum of all cost types of the respective area of responsibility or the cost center). Cost center managers need a report on the cost deviations with pre-formulated justifications in order to fulfil their responsibilities. Therefore, the breakdown by cost center is recommended.

When deciding on key figures, the degree of compaction must also be considered.

When cost element detailing, it is the case that the responsibility is assigned across departments. If there are different procurement contracts, it is advisable not to over-compact the individual types of costs. In any case, the individual reports must transparently display all costs incurred in a cost center. Of course, this also assumes that all costs assigned to the cost centers are assigned either directly (as direct costs) or via surcharge rates. The detailing of the cost elements no longer requires individual cost elements in the cost center reports but is to be shown in totals for cost element groups (for example, other personnel costs). An essential criterion for the level of detail is always the ability to influence costs by the cost center managers. Those that can be directly influenced by cost center managers must be reported separately in the reports, regardless of their quantitative significance. With their individual badges, control successes can be reproduced exactly, which increases the acceptance of controlling.[145]

3.4.1.4 Relative key figures

If absolute key figures are set in relation to each other, then those relative key figures are produced which are ultimately intended to provide the information content for the specific benefit reference. For the addressee of the report, the reference to the basic data should always be comprehensible.

[145] cf. Joos (2014), p. 60f.

As an example, in Table 10 a "profile" for a key figure is illustrated. These profiles should be visible and comprehensible for every responsible person. Changes in the calculation basis must be kept transparent and, for example, should only be used once, most meaningfully on the balance sheet date or as at 31 December respectively.

Table 10: Energy key figure profile

ENERGY KEY FIGURE - PROFILE

Key figure	Total energy cost per raw material consumption (IMM) (2)
Formula	Energy intensity = energy costs / sales revenue
Unit	kWh / €
Statement	The energy intensity is calculated by the amount of energy required in the comparative period divided by the sales revenues of this period.
Used energy sources	Electricity, Gas
Type of measurement	Energy monitoring
Frequency of measurement	monthly
Measurement accuracy	>99% (max 1% measurement inaccuracy with meters)
Priority for the company	A
Influencing factors	Self-generated electricity through PV system; infeed
Influencing factors taken into consideration	PV system
Data requirements	Monthly bill, revenue, basis of allocation based on cost centers using EM: HP–W1–Produktion (VP) + HP–W1–Büro; HP–W2–Produktion (FBH/PER), inkl. W3/W4/W6; HM–W5–Produktion/Büro, incl. W9/W10; HP–W7–Produktion/Büro (BLOCK), inkl. W8; HP–W7–Produktion (TZ)
Target value	Mean value from benchmark - HIRSCH Group - with defined bandwith
Measures to achieve the objectives	Benchmark
Measures for target deviation	Not specified
Change has an effect on	Profit and loss statement
Person in charge	Controlling
Is reported by	Controlling
Is reported to	Management
Frequency of reporting	Not specified
Complexity of the KPI	-
Benefit of the KPI	Control key figure
Use value of the KPI	-
Basis for (which) further calculations	Variance analysis, Benchmark, Forecasting

3.4.1.5 Concept proposal

Table 11 shows the design of an energy key figure system. As already stated above, a decision basis for the implementation into an existing reporting system should be created. The design was created using the cost center classification at the Glanegg site, making it possible to transfer it to other locations.

Table 11: Energy key figure system

ENERGY KEY FIGURE - CONCEPT

ABSOLUTE KEY DATA		RELATIVE ENERGY KEY FIGURES: PACKAGING (11)***, Plant 1, Packaging parts (111)		RELATIVE ENERGY KEY FIGURES: INSULATION (12), Plant 7, Block (121)	
Sales	€	Total energy costs / Sales (IMM)	%	Total energy costs / Sales (BLOCK)	%
Total energy costs	€	Total energy costs / Total raw material consumption (IMM)	€ / kg_{EPS}	Total energy costs / Sales volume (ρ) (BLOCK) (2)	€ / m^3
Energy costs per energy source	€	Total energy consumption / Total raw material consumption (IMM)	kWh / kg_{EPS}	Total energy consumption / Sales volume (ρ) (BLOCK)	kWh / m^3
Total energy consumption	kWh			Total raw material consumption / Sales volume (BLOCK)	Ø ρ
Energy consumption per energy source	kWh	Energy costs per energy source / Total raw material consumption (IMM)	€ / kg_{EPS}	Energy costs per energy source / Sales volume (ρ) (BLOCK)	€ / m^3
Total raw material consumption	kg_{EPS}	Energy consumption per energy source / Total raw material consumption (IMM)	kWh / kg_{EPS}	Energy consumption per energy source / Sales volume (ρ) (BLOCK)	kWh / m^3
Sales volume	m^3_{EPS}			Total steam consumption / Sales volume (ρ) (BLOCK)	kg_{steam} / m^3

The values in the left part of the illustration “Absolute key data” lead to the defined “Relative energy key figures”. The individual columns show the list based on the individual profit centers of the Glanegg business location (plant level). The subdivision is carried out fundamentally in the packaging area (11) (Plant 1) - with the profit center Packaging parts (111) and the insulation area (12), which in turn is divided into the profit centers Block (121) (Plant 7), Special insulation materials/perimeter (122) and FBH System plate (123) (factory 2). Sectors (122) and (123) (Plant 2) are not intended to be marketed at the time of the investigation due to the small number of sites that have this product category in the portfolio and are therefore not part of the figure. It should also be noted that most of the other sites in the Group produce products either in the packaging or insulation sectors and mostly block shape products here. Locations with both product categories have their own cost centers like the Glanegg location and can therefore also be used for the location comparison.

3.4.1.6 Necessary measures for additional key figures

For a gradual extension of relative energy, corresponding absolute values must be collected. An extension to the area of cross-sectional technologies requires, among other things, the installation of sub-meters at the individual locations. For the implementation, further possible key figures were summarized in the category "Others", which can be seen in Table 12.

Table 12: Energy key figure system (extended)

ENERGY KEY FIGURE - CONCEPT (extended)

ABSOLUTE KEY DATA	
Total steam consumption	kg_{steam}
Energy costs *(subcounter)	€
Energy consumption *(subcounter)	kWh
Production costs	€
Material costs	€
Base load (EnM)	kWh
** dependent	

CROSS-SECTIONAL TECHNOLOGIES	
Energy consumption *(subcounter) / Total steam consumption	€ / kg_{steam}
Energy consumption *(subcounter) / Total steam consumption	kWh / kg_{steam}
Energy consumption *(subcounter) / Cross-sectional technology	kWh / **

OTHERS	
Energy consumption *(subcounter) / Total energy consumption	%
Total energy costs / Sales	€
Total energy costs / Production costs	€
Total energy costs / Material costs	%
Total energy consumption / Base load (EnM)	%

3.4.1.7 Evaluation and integration in a standardized reporting (All locations)

The concept is understood as already described as a basis for decision for implementation in a later reporting. Prerequisite is a preliminary evaluation for the integration into the monthly reporting system.

3.5 Site benchmarking

In the following chapter contains excerpts for possible benchmarking. The aim here was the preparation of data series based on the described energy key figure system. Only internal company locations were compared. External comparisons (see section 2.3.8) are not part of this work.

3.5.1 Data series and their visualization

The graphic processing of data series is intended to enable comparisons across several locations. Suitable diagrams should help the user to get an overview of relevant information on trends and developments in energy consumption (see section 3.3.2). This should provide the basis for further reflection and action. In a first step, the processing was carried out based on the energy key figure system defined in the previous section (see section 3.4.1.5) with

- trend diagrams to actual costs and
- monthly comparisons of individual locations.

In addition to benchmark comparisons, time comparisons are also considered, which compare the current energy consumption and associated energy costs with the values of comparable prior periods as well as comparisons of planned and actual values with percentage deviations.

Figure 32 shows an example of the total energy costs in relation to the consumption of raw materials for the Insulation Division (€ / kg_{EPS}). The selection function makes it possible to select and compare individual locations. A trend line shows the evolution of the selected measure.

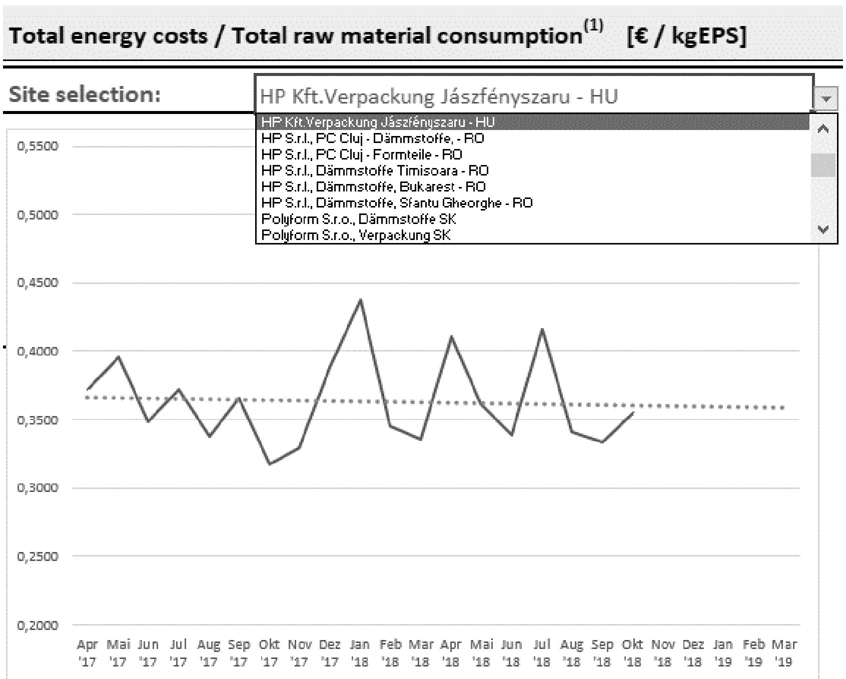

Figure 32: Energy key figure trend – location HU (BMM)

Figure 33 shows an example of the total energy costs in relation to the raw material used in the area of packaging - molded parts (€ / kg_{EPS}). The selection function allows location comparisons of single months to be displayed. The presentation of the mean should also give a better overview.

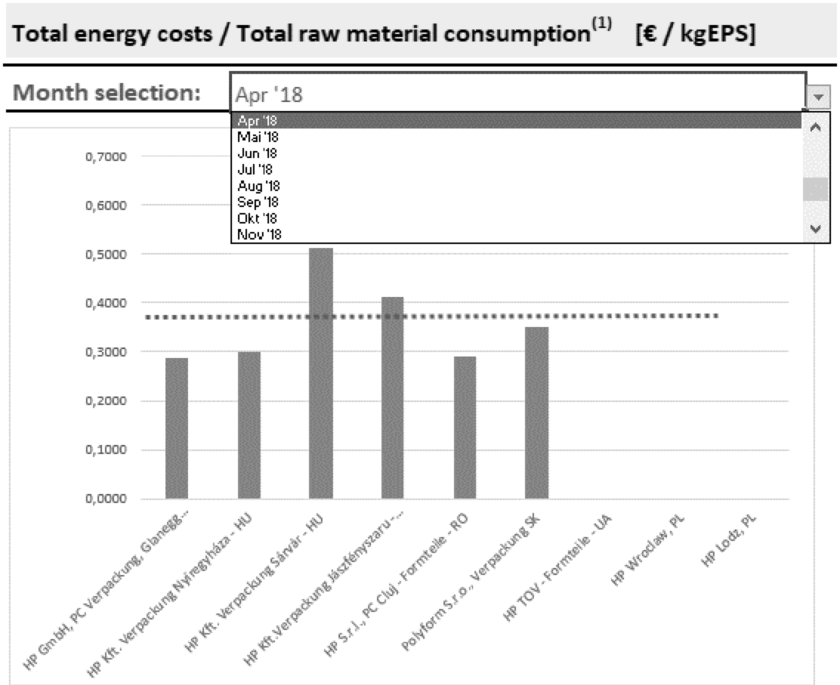

Figure 33: Location comparison of single months – April 2018 (IMM)

Figure 34 shows the development of total energy costs in relation to the raw material used for the insulating materials segment (€ / kg_{EPS}) of all locations (insulation materials).

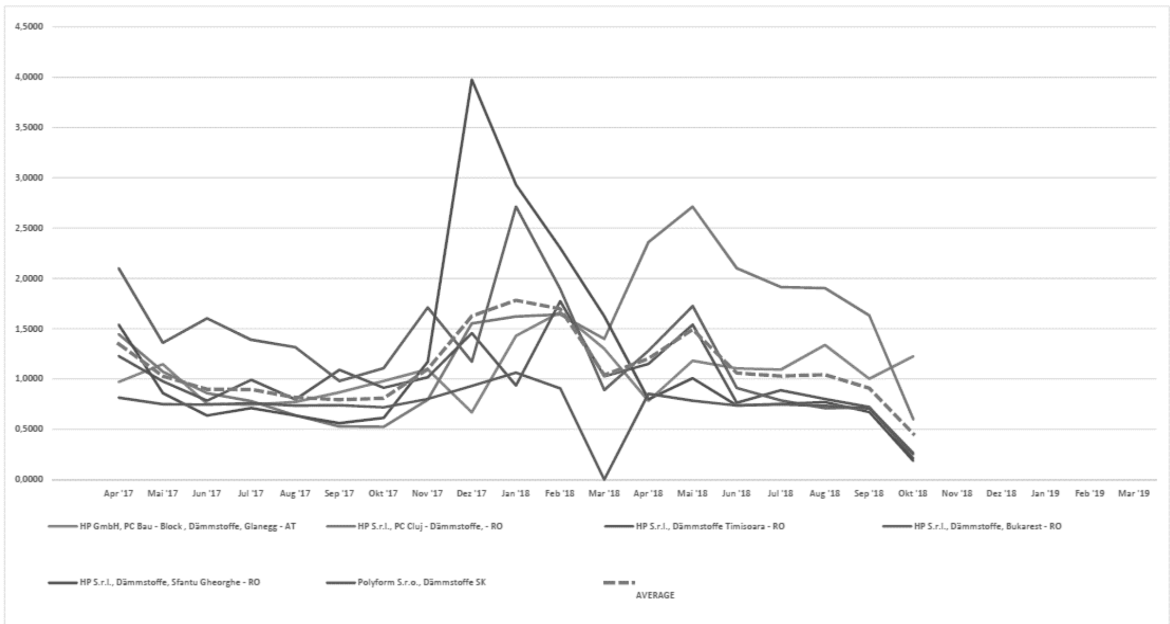

Figure 34: Overview – energy key figure trend (BMM)

Analogous to the locations (packaging), as can be seen in Figure 35.

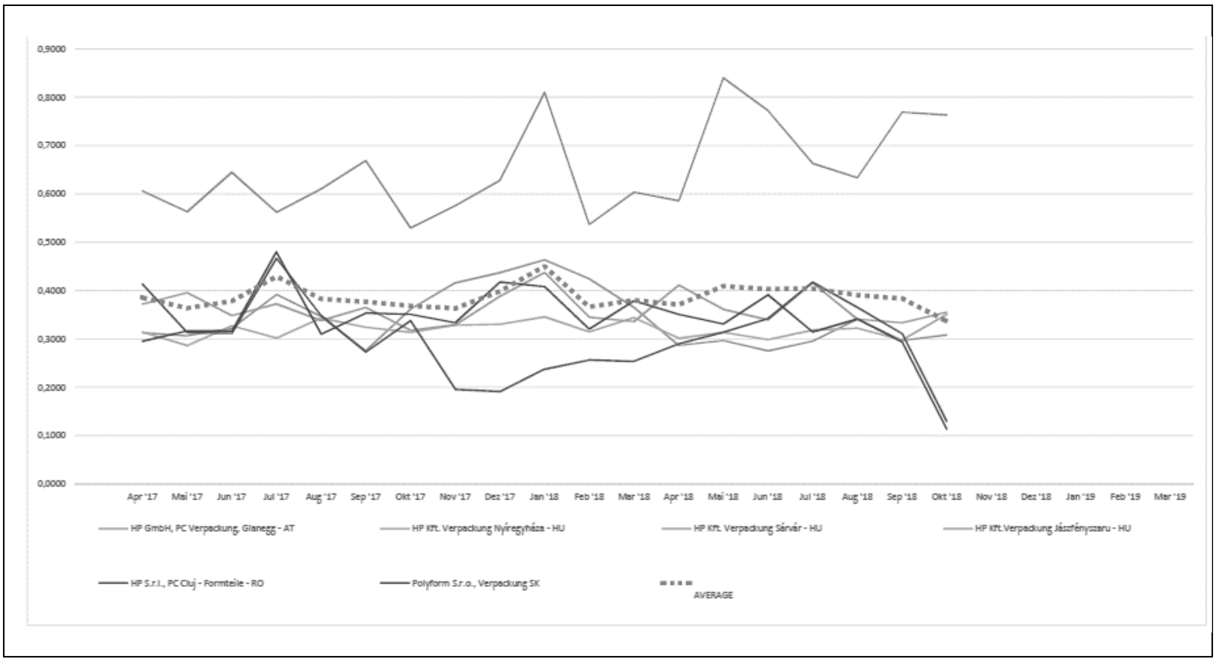

Figure 35: Overview – energy key figure trend (IMM)

3.5.1.1 Database for the location comparison (packaging)

The above diagrams are based on collected data series for the individual defined energy key figures. Table 13 shows a section (see section 3.4.1.2).

Table 13: Data base for energy key figure trend visualization

Total energy costs / Total raw material consumption(1) € / kg_{EPS}

LOCATIONS	Apr '17	Mai '17	Jun '17	Jul '17	Aug '17	Sep '17	Okt '17	Nov '17	Dez '17	Jan '18	Feb '18	Mar '18
HP GmbH, PC Verpackung, Glanegg - AT	0,3130	0,3066	0,3222	0,3915	0,3462	0,2759	0,3617	0,4158	0,4370	0,4635	0,4240	0,3649
HP Kft. Verpackung Nyíregyháza - HU	0,3139	0,2862	0,3270	0,3016	0,3430	0,3240	0,3136	0,3283	0,3303	0,3454	0,3147	0,3440
HP Kft. Verpackung Sárvár - HU	0,6058	0,5629	0,6445	0,5620	0,6101	0,6685	0,5293	0,5753	0,6280	0,8101	0,5367	0,6032
HP Kft.Verpackung Jászfényszaru - HU	0,3720	0,3955	0,3481	0,3724	0,3382	0,3654	0,3177	0,3292	0,3878	0,4375	0,3448	0,3359
HP S.r.l., PC Cluj - Formteile - RO	0,4133	0,3131	0,3115	0,4664	0,3481	0,2726	0,3377	0,1955	0,1911	0,2373	0,2562	0,2535
Polyform S.r.o., Verpackung SK	0,2951	0,3164	0,3162	0,4800	0,3095	0,3534	0,3508	0,3332	0,4178	0,4080	0,3201	0,3787
HP TOV - Formteile - UA												
HP Wroclaw, PL												
HP Lodz, PL												
AVERAGE	0,3855	0,3634	0,3783	0,4290	0,3825	0,3766	0,3685	0,3629	0,3987	0,4503	0,3661	0,3800

LOCATIONS	Apr '18	Mai '18	Jun '18	Jul '18	Aug '18	Sep '18	Okt '18	Nov '18	Dez '18	Jan '19	Feb '19	Mar '19	AVERAGE
HP GmbH, PC Verpackung, Glanegg - AT	0,2865	0,2967	0,2751	0,2951	0,3406	0,2965	0,3081						0,3432
HP Kft. Verpackung Nyíregyháza - HU	0,3014	0,3134	0,2985	0,3181	0,3222	0,2978	0,3506						0,3197
HP Kft. Verpackung Sárvár - HU	0,5857	0,8400	0,7723	0,6630	0,6334	0,7691	0,7633						0,6507
HP Kft.Verpackung Jászfényszaru - HU	0,4110	0,3611	0,3392	0,4155	0,3408	0,3332	0,3551						0,3632
HP S.r.l., PC Cluj - Formteile - RO	0,2898	0,3136	0,3421	0,4176	0,3651	0,3107	0,1291						0,3034
Polyform S.r.o., Verpackung SK	0,3507	0,3309	0,3912	0,3144	0,3412	0,2934	0,1133						0,3376
HP TOV - Formteile - UA													
HP Wroclaw, PL													
HP Lodz, PL													
AVERAGE	0,3709	0,4093	0,4031	0,4040	0,3906	0,3835	0,3366						

3.5.1.2 Overview

Figure 36 gives a quick overview of the evolution of consumptive information and enables rapid intervention in operational decision-making processes.

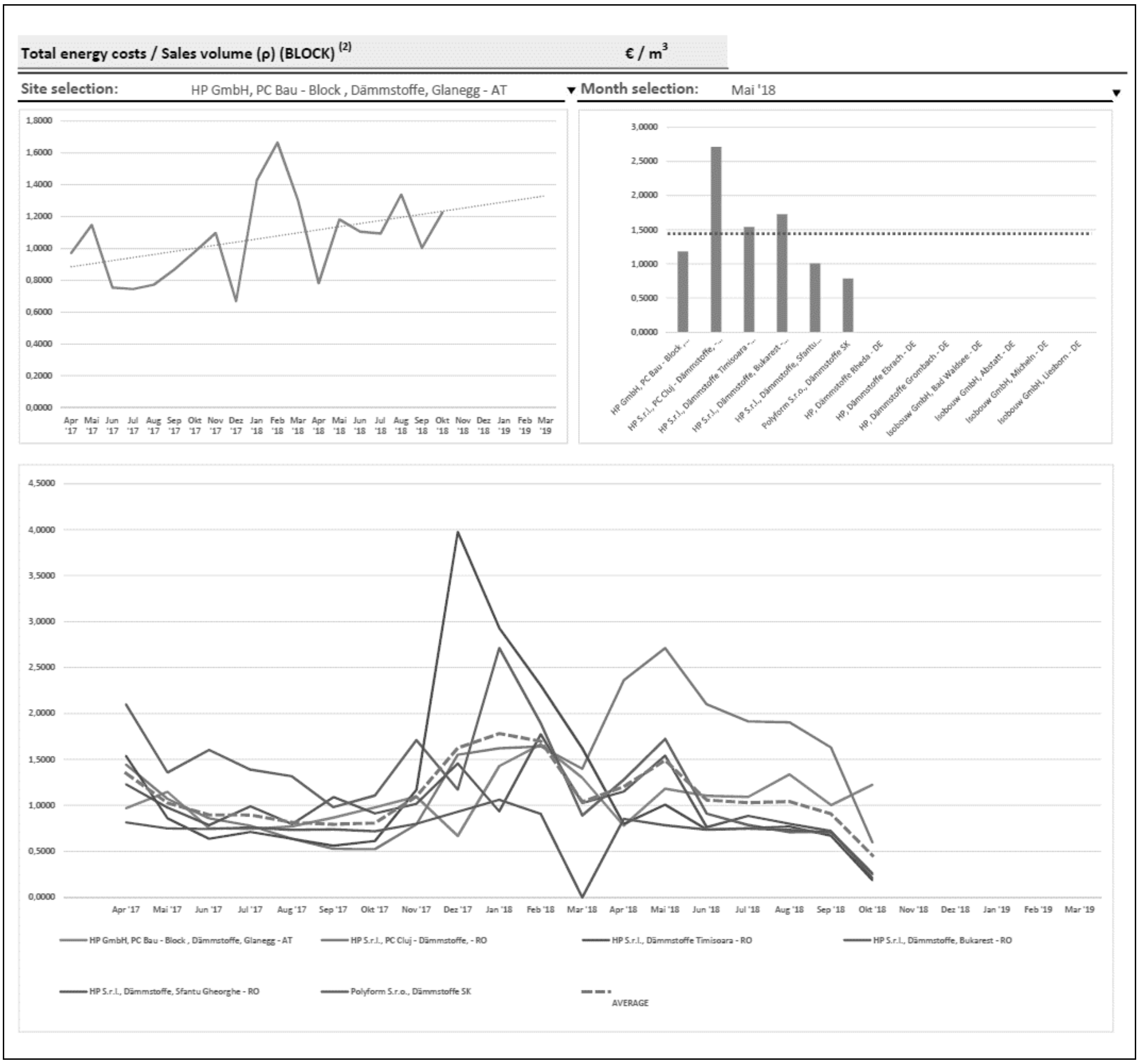

Figure 36: Overview

3.6 Surcharge rate calculation by product groups

The increases in energy prices in recent years will continue in the near future. Energy costs are taken from accounting in many companies and added as a surcharge to the direct costs (material, personnel) together with other types of costs or separately. This, however, violates the principle of causation. If in production plants the production process consists of material transformation by means of energy, machine use and personnel, it would be very expedient if these cost types could be directly attributed to the products. The evolution of energy costs makes it appropriate to identify them separately as one or more (see section 2.3.6). Because consumption (value inserts) do not behave (always) in proportion to the quantities used.

The distribution of energy costs as existing primary cost center[146] overheads (see section 2.3.5) can only be assigned to the individual cost centers by using envelope keys (cost rates). In the present case, the weight is the appropriate reference quantity for further allocation to the cost center.[147]

3.6.1 Determination of overhead cost surcharge rates and reference size choice

After performing the activity allocation, incurred overhead costs are allocated to the cost centers. This allows you to determine (overhead costs) surcharge rates that prorates overheads to the payers (products) as part of the (overhead) costing calculation. To get closer to the principle of causation, differentiated benchmarks must be considered, as the payers claim the cost centers in varying degrees of intensity. The choice of these benchmarks is the main problem in the determination of surcharge rates. [148]

3.6.2 Investigation of divergence in energy consumption

For the above implementation, examples of related steam volumes have been collected for various products during ongoing production. As already mentioned, the energy consumption is not always in relation to the material consumption. The exemplary comparison of the amount of steam used to wet or dry weight led to the assumption that products with low weight disproportionately consume more energy (steam) than products with higher weight. The present study was limited to the amount of steam used. Other forms of energy were not included in the study, but correlative behavior can be assumed.

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[146] Note: Primary cost center overheads are those overhead costs incurred through production factors procured from "outside" (e.g. material, auxiliary wages)
cf. Zunk et al. (2013), p. 110.

[147] cf. Zunk et al. (2013), p. 111ff.

[148] cf. Zunk et al. (2013), p. 111ff.

3.6.3 The formation of product groups as a possibility of an usage-based accounting

An attribution of the respective energy consumption to the individual products proves to be impracticable due to the large number of different products as well as several other influencing factors (e.g. material, machine setting, etc.). However, an approximation method whereby the product is divided into product groups by weight should be considered as an alternative, in order to be closer to the principle of causation and more accurate in calculations. It is assumed that within a product group of similar average weight, energy consumption is approximately proportional. With this, surcharge rates can be defined according to "weight classes". The following example should clarify this.

Table 14 shows the collection of steam consumption using products from different weight classes. Data on steam consumption in relation to dry weight were collected. Averages were made by taking three samples each of a product. Weight classifications were based on the goods produced at the time of the investigation.

Table 14: Weight classes

date	machine	product (item number)	Sample no.	Time (machine)	cycle time	weight moist [g]	steam [kg]	average steam [kg]	date	weight dry [g]	average weight dry [kg]	steam [kg] / weight dry [kg]	average	weight category
19.09.2018	HEW 14 (#6)	ISOSPAN 1250x550	101/4	14:28	119,0	3004,5	5,69		25.09.2018	2626,2		2,2		
20.09.2018	HEW 14 (#6)	ISOSPAN 1250x550	101/5	08:38	119,0	3092,6	5,46	5,6	26.09.2018	2658,3	2646,7	2,1	2,1	> 2500g
21.09.2018	HEW 14 (#6)	ISOSPAN 1250x550	101/6	08:15	121,7	3060,7	5,71		26.09.2018	2655,7		2,2		
24.09.2018	HEW 14 (#6)	3080541	101/7	08:52	120,9	2589,8	6,63		28.09.2018	2194,0		3,0		
25.09.2018	HEW 14 (#6)	3080541	101/8	10:20	145,4	2644,0	6,62	6,3	28.09.2018	2230,2	2255,8	3,0	2,8	> 2250g
27.09.2018	HEW 14 (#6)	3080541	101/9	10:20	109,7	2694,2	5,62		03.10.2018	2343,1		2,4		
13.09.2018	HEW 14 (#6)	3080543	101/1	09:10	147,0	2169,0	6,85		19.09.2018	1892,4		3,6		
14.09.2018	HEW 14 (#6)	3080543	101/2	09:06	150,3	2178,0	6,83	6,8	19.09.2018	1848,5	2059,9	3,7	3,4	> 2000g
18.09.2018	HEW 14 (#6)	3080543	101/3	10:22	143,2	2989,8	6,83		21.09.2018	2438,7		2,8		
17.09.2018	HEW 1300 (#44)	3000229	201/3	10:05	179,1	992,1	11,1785		19.09.2018	931,0		12,0		
18.09.2018	HEW 1300 (#44)	3000229	201/4	10:37	178,3	1002,8	11,2995	11,2	21.09.2018	904,3	897,9	12,5	12,5	> 800g
19.09.2018	HEW 1300 (#44)	3000229	201/5	14:38	175,5	961,6	11,0425		25.09.2018	858,3		12,9		
13.09.2018	HES 800 (#45)	2304501	301/1	08:34	70,0	145,0	2,423		18.09.2018	136,4		17,8		
14.09.2018	HES 800 (#45)	2304501	301/2	08:18	68,1	146,0	2,465	2,4	19.09.2018	138,5	135,1	17,8	17,7	> 100g
17.09.2018	HES 800 (#45)	2304501	301/3	08:46	62,5	136,8	2,303		19.09.2018	130,5		17,6		
14.09.2018	HES 800 (#46)	2305363f	401/2	08:22	54,6	135,0	2,224		18.09.2018	122,9		18,1		
17.09.2018	HES 800 (#46)	2305363f	401/3	09:30	57,9	135,0	2,507	2,3	19.09.2018	123,7	122,7	20,3	18,6	> 100g
18.09.2018	HES 800 (#46)	2305363f	401/4	09:15	53,0	133,1	2,111		24.09.2018	121,6		17,4		

The basic assumption that the weight is suitable as a reference for the division into different weight classes is corroborated by the above investigation. However, a finding on a linear relationship could not be determined during this investigation and requires explicit in-depth investigations. An approximation to a usage-based accounting of energy costs by weight classes, however, makes sense according to the above findings. Increasing the weight classes (corresponding to a reduction in weight differences per class) could be a subsequent next step to benchmarks for a more causal overhead costing of energy consumption.

3.7 Entry sheet - energy management (qualitative)

The investigation has two main strands as mentioned at the beginning. The quantitative part is worked on and explained in detail in the previous sections. This section follows qualitative requirements and, in essence, an explanatory and well-founded entry sheet has been prepared. The preparation was based on the experiences and discussions at the Glanegg location and the literature cited in the theoretical section. The topics listed there were transferred to questions and additional questions.[149] As already mentioned, the questionnaire should primarily serve as a guide for interviews and further investigations at other locations of the Group. Awareness raising, the exchange of know-how and best practice considerations were in the foreground.

3.7.1 Introduction to the qualitative examination

Energy costs are dominated by cost savings, which are the catalyst for concrete measures. Efforts in industry as well as in science are considerable in terms of measures to reduce energy consumption in production (core processes). But it is also important to develop these in the supporting business units. Because energy is not the main cost category, the measures can only have a measurable impact on the aggregate.

A company, such as the HIRSCH Group, which on the one hand can look back at difficult times, on the other hand has achieved a dominant market position in German-speaking countries and Central Europe after achieving turnarounds with many individual acquisitions, must, in addition to the quantifiable parameters, continue its energy goals through qualitative methods approach. But it is suitable for many reasons for the qualitative approach to energy efficiency. Due to the high number of small sites, the differences suggest a bundle of improvements, which makes the introduction of standards a worthwhile goal.

It can be assumed that the decisions to acquire several small sites were made because of the profitability of the investment and its proximity to the market, and thus the contribution margins (see section 2.3.7) due to low transport costs. Energy efficiency has played a very minor role in these decisions due to the standardized production process. In the quantitative part of this work it was found out that the energy consumption in the company for the individual factories was not yet fully integrated into the existing target system. Thus, the associated key figures cannot yet be integrated into the ongoing optimization processes in the company.

Approaches in the optimization of energy consumption have been limited in the quantitative part of this work to the analysis of the actual situation. Time series based on graphics subsequently form a basis for monitoring the key figures. In contrast, qualitative energy efficiency optimization should enable a first stage of continuous improvement of business processes. This should also make small effects visible. A rough overview of several plants and locations should identify potentials.

[149] Note: Methodological approaches (standardized questionnaire, interview techniques) were not used.

3.7.2 Procedure for creation[150]

The procedure for creating a data entry form has its origin at the main location. It was assumed that the complexity of the product portfolio and the basic records were apt to use this location as a reference. However, this does not mean that this location serves as a benchmark for the other locations. The first result of the study is the structure of a collection sheet following the chapters in the theoretical part of this thesis. Questions and additional questions should enable an expert to identify the small (operational) and possibly larger effects.

3.7.3 Subsections of the entry sheet

The entry sheet is divided into the areas of [I] Strategic anchoring and efficiency objectives, [II] Anchoring energy management in the organizational structure, [III] Energy procurement and [IV] Technical systems and measurement principles. The following explanations are intended to give an understanding of the individual subject areas and to serve as a preparation for discussions on the respective subareas. A corresponding form with the questions collected is attached (see Appendix).

[150] Note: The further development of the registration form took place after a visit of another location of the Group.

3.7.3.1 Strategic anchoring and efficiency goals [I]

The first subarea forms the anchoring of energy management in the strategic level in order to emphasize the importance of energy efficiency in the discussion partner. This is not just about the short-term small measures, but also investment projects and their follow-up costs or savings as well as any consulting projects should be inquired qualitatively. Of course, appreciation should be given to the existing system of energy management measures. Thus, the topic of energy culture can be touched. Figure 37 shows a procedure model for the gradual implementation of energy management in the corporate structure and can be used as a support for starting the conversation. Only by analysing the current status and implementing fast effects [1] a long-term strategic anchoring in the organization can succeed [2] and prepare for certification[151] [3].

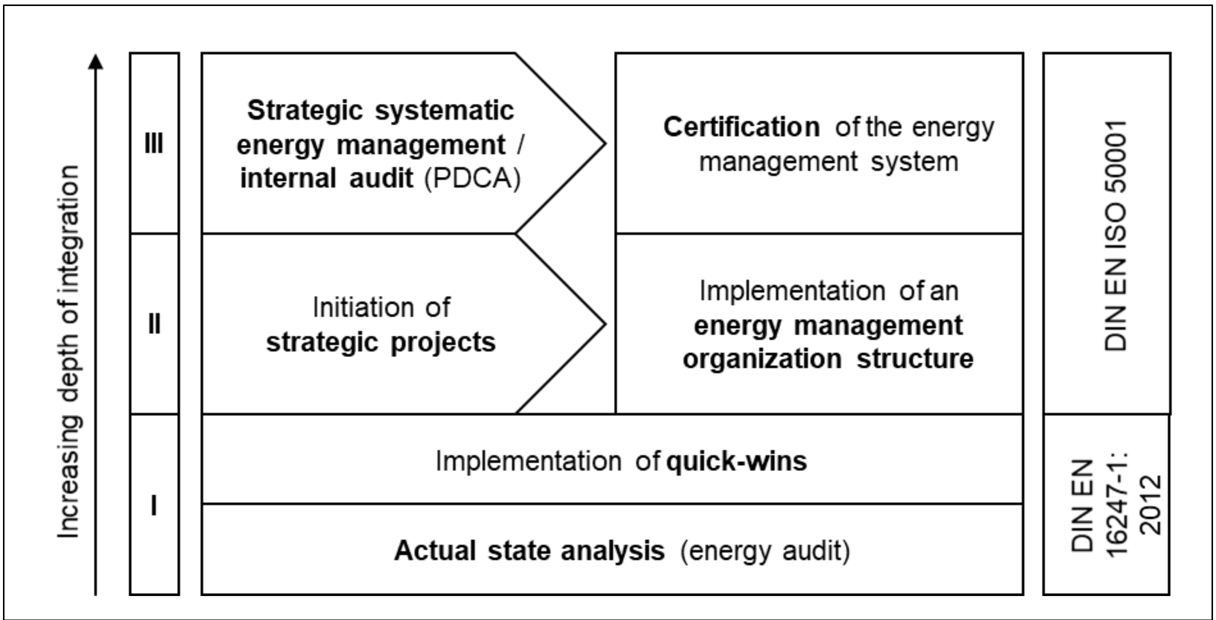

Figure 37: Multi-stage model for the implementation of the EnMS[152]

3.7.3.1.1 Energy efficiency and energy consumption

Targets in energy consumption are to be anchored in the strategy, because only in this way the long-term change in the behavior of the company in relation to the low energy consumption is guaranteed. The definition of objectives must therefore be made at the highest level, and measures considered in the long-term planning. (1)

The strategic definition must be broken down into measurable and traceable sizes in the plans. (2)

Energy improvement goes hand in hand with major changes in many divisions. An organization cannot do all its activities at once. In addition to energy cost planning, investment and continuous improvement are also important. (3)

[151] Note: see also https://www.austrian-standards.at/infopedia-themencenter/specials/iso-50001/ (ISO 50001)

[152] cf. Javied et al. (2015), p. 158.

3.7.3.1.2 Investment

The investment policy in terms of energy consumption is based on the standards of investment accounting. However, it is intended to set up an EnMS for investment decisions and their implementation. This applies to every location of the Group. (Deviating from the production process investments in the chapter Infrastructure treated (see. Section 3.7.3.4.2) Energy efficiency should play a crucial role in investment decisions. (4)

3.7.3.1.3 Consulting activities on energy efficiency

In the run-up to energy-saving measures, external expertise is often obtained. Consulting projects can be supportive for the first time dealing with the topic of energy management. (5)

3.7.3.2 Anchoring energy management in the organizational structure [II]

Organizational integration of energy efficiency as a business objective in the business processes of the company is of central importance for the implementation. For in addition to the causal energy billing, as proposed in the quantitative part of this work, the impact-oriented inclusion of energy consumption in the target system is only considered useful if responsibilities and procedural instructions have been established and the responsible parties are involved in the improvements. (6)

The objective of the introduction of an EnMS is the continuous improvement of the performance in terms of energy consumption. The measures for optimizing productivity, which are common and established in production, are to be transferred to the control of energy consumption (continuous improvement process (CIP), key figures, variance analysis). To make improvements measurable, the introduction of EnMS by the management or the site management must specify the starting point for the energy consumption. (7)

Legal framework conditions exist at the individual locations, which are decisive for the implementation of energy efficiency measures. Reference is made here to the Directive: 2012/27 / EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125 / EC and 2010/30 / EU and repealing Directives 2004/8 / EC and 2006/32 / EC Text with EEA relevance[153]. (8)

3.7.3.2.1 Energy key figures

Efficient energy planning requires recent data on energy consumption and development. This is the basis for planning and is indispensable for setting target / actual comparisons. Energy key figures are a suitable tool for monitoring key energy use areas. (9) (10)

3.7.3.2.2 Reporting on energy consumption and on-site internal communication

Energy consumption information must be timely to identify and respond to deviations from planning. The embedding of information on short-, medium- and long-term effects in the field of energy should be part of a standardized reporting system on the company situation. (11)

The transmission of key data on energy consumption and processes to headquarters is necessary in the long-term achievement of common standards and policy proposals. (12)

3.7.3.2.3 Cultural anchoring

The establishment of an energy controlling becomes possible only if awareness (awareness) is created in advance. However, more and more indirect factors such as image and Corporate social responsibility (CSR) are crucial for the integration of energy efficiency as a target. Of course, this happens with investment decisions, but less often in daily business.

Awareness raising is a significant concomitant of interviews[154] using the registration form. (13)

[153] cf. EUR. (2012)
[154] cf. VDI. (2018)

3.7.3.3 Energy procurement [III]

Due to the long-term nature of contracts, energy procurement has enormous potential if a clear procurement process is defined (see section 2.1.7.1). "The decision-making process for a suitable electricity procurement model is the core of the integrated electricity procurement strategy."[155]

Monopolies in the energy sector belong to the past. Electric utilities are very creative in keeping their position with the customer. As network fees increase, variable costs are reduced. The industrial companies must build up know-how for energy procurement.

3.7.3.3.1 Ongoing controlling - operational level

The procurement principles are integrated in the ongoing reporting system. For contract changes, the plan values are adjusted. (14)

3.7.3.3.2 Contract control - procurement contracts

Unlike procurement of, for example materials, energy procurement markets are less clear. Due to the lack of clarity and subordinate importance, energy controlling is often neglected in terms of procurement. (15)

[155] Schumacher & Würfel (2015), p. 158.

3.7.3.4 Technical systems and measurement principles [IV]

Large space is given to technical ideas and possible measures. The detection of actual conditions is illustrated based on existing documents, records and practical applications on site. The following outline should give a comprehensive list of all areas to be covered.

3.7.3.4.1 Data collection and measuring systems

The acquisition of measured data for energy consumption must be carried out at specified levels (factory, machine, process level). The creation of energy flow schemes based on a defined standard is only made possible by this. (16)

Uniform documents and clear standards on the reported consumption data for office space, production areas and storage areas are a necessary step towards the creation of comparable data. (17)

3.7.3.4.2 Technical energy efficiency in the building and infrastructure sector

Future investment decisions also require an overview of the existing infrastructure. A detailed status report on the current situation (18) provides the essential justification for planned energy efficiency measures. (19)

3.7.3.4.3 Technical energy efficiency measures in production including cross-sectional processes[156]

Cross-sector technologies cause for a not insignificant part of the energy consumption in the manufacturing process (in terms of total energy consumption) and thus also offer considerable potential for increasing energy efficiency. The investigation is intended to raise the state of the art of the used electrical (20) and fuel-based (21) base and cross-sectional technologies. Heat recovery is a key factor in determining savings potential. (22)

3.7.3.4.4 General measures - maintenance

The handling of unused installations represents a not insignificant contribution to energy consumption. (23)
Predictive maintenance[157] of machinery and equipment on the one hand contributes significantly to production and quality assurance, on the other hand also helps to comply with the energy goals. (27)

[156] Note: The structure of the following chapter is partly based on the work (Blesl & Kessler, 2017).

[157] Note: Predictive Maintenance takes a proactive approach and proactively maintains machinery and equipment to keep downtime to a minimum. The method uses measured values and data recorded by sensors
cf. BDI. (2017)

3.7.4 Procedure of an investigation of the locations

The procedure should be explained to the interview partners and it should be conveyed that the best ideas are incorporated and thus also a competitive situation between the locations is desired, because thereby the overall competitiveness of the Group is improved. The results should be included in a catalogue. Checklists with successful measures that can be transferred to several (all) locations and that contain comprehensible and qualified components can be created and subsequently implemented based on approved standards.

The catalogue of prioritized measures identified as being effective will subsequently represent the first result of the surveys. As part of an iterative process, these measures can be implemented and, after evaluation, transferred to selected locations as reference processes. For this form of energy analysis as an in-house business process, the motivation of employees to participate is a success factor for continuous improvement.

During the survey, a qualitative assessment will assess strategic, investment, organizational and technical potentials for energy efficiency.

4 Summary and Outlook

HIRSCH Servo AG is one of the leading companies in the production of EPS and EPP in Europe. A company of this size must also deal with the economic and energy policy framework conditions. On the one hand, the competitiveness of the company may deteriorate in the medium and long term due to location-related factors such as energy transition measures or changed customer preferences, while on the other hand, investment incentives and renewable energy subsidies may make other locations more attractive. The selection of the right "innovation location" (headquarters) in co-operation with the production is decisive for the preservation and improvement of the competitiveness.

Technological as well as organizational developments become standardized elements that can be transferred to the production plants through defined processes. For the time being, the concepts are not changing the existing business model. However, the results can be observed in the quantitative monitoring.

A company with several locations must define the topic of energy efficiency as a general corporate objective across all locations, in particular in order to use economies of scale in costs and to make use of the benefits for the entire Group through location comparisons.

In the HIRSCH Group, energy efficiency measures were launched. At the beginning of this thesis, on the one hand, selected production facilities, including their associated cross-sector technologies, as well as relevant areas in accounting and controlling, including internal accounting, were examined. A comprehensive examination of the existing energy flows and the comparison of the data from the energy monitoring with the corresponding meters formed the basis for further activities and led to reliable energy data at the site.

Before starting to collect recent data, it is necessary to set up an example of decision-making processes and the desired results, as well as to determine the purpose of collecting energy data. Energy-related measurements are required throughout the company and are the basis for energy procurement, optimization and cost-effectiveness and the long-term positioning of the company as a sustainable production company.

The robust basis was the starting point for the design of an energy key figure system, which should serve as an attempt to provide a basis for deciding on the application of relevant key figures in standard reporting.

On the one hand, a high level of detail represents a high level of metrological effort, which is associated with high costs and additional organizational and personal commitment, on the other hand results are better and more easily comprehensible. The right balance can only be decided by the management.

It soon became apparent that due to the diverse approaches to the subject, qualitative elements were needed for a comprehensive picture. A registration form was created and adapted to practicality after testing. Many individual measures may lead to a significant reduction in energy costs and, in relation to the above, an accompanying qualitative approach should be used to capture their potential effects for the time being.

Long-term measures are more complex, and therefore more difficult to plan. Their implementation requires a comprehensive awareness-raising, concrete training, and performance-based bonuses.

The efficiency of an energy monitoring presupposes the assignment of responsibility, whereby the internal quality management would offer for it. Concrete training measures are indispensable for the success and continuous engagement with this topic.

Operational energy key figures must be determined on a company-specific basis. Metering must be seen as an "investment" and results in ongoing costs through monitoring. It is therefore necessary to decide how to record and aggregate. Comparisons can only be made if all units considered use the same basis for the key figures.

As part of the preparation of data series for a possible benchmarking of individual locations, it should be noted that in addition to the efficiency gains, which is based on measurements, it is essential for the success of this complex in-house project to receive ideas and commitment from the executives.

However, these very complex questions can only be dealt with by experts in the field of benchmarking, because in-depth information on the qualitative assessment of locations in the broadest sense is not available in many companies. An indispensable complement to be worked on within the company, is details on the development of the company's competitors or on the long-term plans of key customers. This is contrasted by the internal benchmarks cited in this thesis with regard to individual types of costs and locations.

Quantity structures are often neglected but are a prerequisite for the allocation according to a usage-based accounting of energy. An EnMS should include a multi-year consideration of quantity structures. The thesis contains suggestions on how to set up a process that enables energy to be successively recorded according to the principle of causation and assigned to cost centers. This can only be done if energy costs are not charged as a single surcharge. The formation of product groups as a possibility of a usage-based calculation of energy consumption could be the beginning.

The work has shown that an all-embracing planning and control function for company-wide energy management would mean a central information hub. A decision-making system of energy parameters must be based on information from production (sensor and measuring systems) as well as information from the accounting department. Based on this, there is an overlap of previously isolated areas and a new leadership function to be considered. This could ensure that an economic energy management system develops in the company, which has a significant impact on energy costs. The question arises whether this should be covered by a staff department or whether the area of responsibility within the management must be established.

Future research may focus on more in-depth analysis of production systems that focus on increasing efficiency in terms of energy consumption, key metrics and characteristics in the production process, and production controlling to improve organizational and logistical targets. This leads to how incentive systems (tax relief, research funding, consulting and investment) must be designed so that production companies and research institutions are more involved in the issue of energy efficiency.

A final point to be made here is, that the references between theoretical and practical part are intended to refer to aspects in both parts in further considerations and projects, because in the field of energy efficiency, points of contact can be found in many sciences but also in many areas of the organization.

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List of Abbreviations

BMM	Block mold machine
CIP	Continuous improvement process
CSR	Corporate social responsibility
DCF	Discounted cash flow
EM	Energy monitoring
EnMS	Energy management control system
EPP	Expanded polypropylene
EPS	Expanded polystyrene
ERP	Enterprise resource planning
IMM	Injection molding machine
P/ID	Piping and instrument flow diagram
P/L	Profit and loss statement
ROI	Return on invest

APPENDIX

Entry sheet - energy management

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The entry sheet is divided into four subchapters [I] - [IV] and contains the questions and sub-question for the investigation. Explanations can be found in the related section of the thesis (see section 3.7).

[I]	Strategic anchoring and efficiency goals	Comments
	Energy efficiency and energy consumption	
1	Is energy consumption anchored in the strategic considerations of the location?	
	Is the energy-related performance (measurable result in terms of energy efficiency, energy use and energy consumption) considered in the long-term planning?	
	How is this done?	
2	Are there any specific targets for the reduction of energy consumption?	
	If yes, which are these?	
	How is the achievement of these goals measured?	
	Are there any current recordings?	
3	How do you assess the possibilities for improving energy efficiency at the location?	
	Investments	
4	What role does energy efficiency play in investment decisions? (e.g. in the procurement of new equipment or machinery.)	
	Can you show me an investment proposal?	
	Consulting activities on energy efficiency	
5	Are external consultants assigned to your company?)	
	Have consulting projects on the topic of energy been carried out?	
	In which areas were projects carried out?	
	If so, what was the outcome?	

[II]	Anchoring energy management in the organizational structure	Comments
6	Has your company set tasks and responsibilities for energy management?	
	Are these anchored in the organizational structure and documented? (e.g. organization chart, task-competence-authority matrix)?	
	Are there procedural instructions and responsibilities defined?	
	Are there any records?	
7	How are improvements in energy consumption recorded?	
8	Are there country-specific legal bases in the context of energy management?	
	What are the requirements (country-specific)?	
	Energy key figures	
9	Are energy key figures defined in your company?	
	Are the key figures precisely defined in a "profile"?	
	If, who receives this information?	
	Are there any measures for deviations?	
10	Does your company monitor the main energy use areas?	
	Are there any process instructions?	
	Reporting on energy consumption and on-site internal communication	
11	Are information on energy consumption and energy flows reported at fixed intervals in your company?	
	How is information reported?	
	Is there feedback in case of deviations?	
12	Are data on energy consumption and processes transmitted to the headquarters?	
	If so, in what form? (Monthly reports, trends, etc.)	
	Are these compared with other locations?	
	Cultural anchoring	
13	Is the economical use of energy culturally anchored?	

[III]	Energy procurement	Comments
	Ongoing controlling - operational level	
14	Which procurement principles are based on the electricity price contracts at the location?	
	Contract control - procurement contracts	
15	How are contracts recorded so that a quick overview for negotiations is possible?	
	Is there a key account manager at the energy supply company?	
	Is there an annual conversation?	

[IV]	Technical systems and measurement principles	Comments
	Data collection and measuring systems	
16	Do energy consumption measurements take place in your company?	
	At what level is data collected? (factory-, machine-, process level) (e.g. office space, production areas, storage areas)	
	Are there any documents? (e.g. meter statement, flow charts, etc.)	
	Which basic and cross-sectional processes are covered?	
17	Is the availability of information on energy consumption ensured at fixed intervals?	
	Is there a data base of all energy consumptions (e.g. energy flow diagram, establishment of processes)?	
	Technical energy efficiency in the building and infrastructure sector	
18	Have energy efficiency measures been implemented in recent years in the following areas?	
	Space heating & hot water treatment (e.g. use of heat pumps, heating control)	
	Thermally improved building shell (e.g. through thermal insulation, elimination of thermal bridges)	
	Lighting	
	Cooling & air conditioning	
	Photovoltaic systems	
	Stand-by consumption reduction	
19	Are energy efficiency measures planned in the above areas in the future?)	

	Technical energy efficiency measures in production including cross-sectional processes	
20	Has your company implemented energy efficiency measures in electrical-based basic and cross-sectional technologies?	
	Electric motors	
	Pumps	
	Vacuum technology	
	Compressed air (e.g. load-dependent speed control of the compressors, correct dimensioning, prevention of leaks, maintenance and repair)	
21	Has your company implemented energy efficiency measures in fuel-based basic and cross-sectional technologies?	
	Heat generation by combustion processes (e.g. optimization by more efficient burner types)	
	Heat exchangers for the recovery of waste heat (e.g. use as heat, conversion to other form of energy	
	Boiler for steam generation (e.g. high efficient steam generators with economiser, burner control, etc)	
	Thermal insulation (e.g. thermal insulation of installations to prevent heat or cold losses)	
22	What is the proportion of heat recovery?	
	General measures - maintenance	
23	Are measures been taken to reduce standby consumption? (e.g. by switching off unused equipment, switching off compressed air, etc.)	
24	Is the condition of the systems checked at specified intervals?	
	Are there any scheduled maintenance intervals?)	
	Are the cross-sectional technologies checked for their capacity limits?	
	Are new technologies for increasing energy efficiency considered?	