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Measured and managed - Energy Monitoring Systems within IKEA Industry.

Mapping of the current situation and recommendations regarding energy management

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Examensarbete på Civilingenjörsnivå
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Lunds Tekniska Högskola | Lunds Universitet

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Föreliggande examensarbete på civilingenjörsnivå har genomförts vid Avd. för Energi-hushållning, Inst. för Energivetenskaper, Lunds Universitet - LTH samt vid företaget IKEA Industry i Malmö. Handledare på företaget IKEA Industry: Glenn Karlsson, projektingenjör; handledare på LU-LTH: biträdande universitetslektor Kerstin Sernhed och universitetslektor Per-Olof Johansson Kallioniemi; examinator på LU-LTH: universitetslektor Marcus Thern.

Projektet har genomförts i samarbete med IKEA Industry.

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Lunds Universitet - Lunds Tekniska Högskola

Box 118, 221 00 Lund

www.energy.lth.se

Abstract

IKEA Industry has ambitious goals for increasing energy efficiency at the production sites. Energy monitoring systems are therefore an important tool towards fulfilling those goals. The purpose of this master thesis is to get an overview and map the current situation at the production sites. Furthermore, the aim is to give recommendations and produce methods that can help organise the energy work. By using research methods such as questionnaires, personal interviews, visiting the production sites and having a supporting reference group the following results have been obtained: The questionnaire showed a large variation regarding the types of software installed at the sites and the way the energy work is structured. It also showed a need for formulation of a standard document that can help with organising the work with the energy monitoring system at the sites. Additionally, there is a desire for clarification regarding what should be included in the reports and which energy performance indicators should be the output of the energy monitoring system.

Results that are presented include solutions concerning how the visualisation of the energy monitoring system should be presented, what kind of users the system should be designed for, together with how features such as alarms and reports should be organised. These solutions have been partially based on the results of four case studies. A list with specific energy performance indicators is also included in the result section of the master thesis. Last but not least, energy measuring methodology in the form of a pyramid structure was produced as a guideline for the sites when deciding on how to structure the energy measurements. In conclusion, there is a need for the production of a standardised way of working with energy monitoring systems.

Keywords: Energy monitoring system, energy efficiency, energy performance indicators, energy management, industry, IKEA Industry

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Last but not least, we would like to thank our families and friends for their support and love from the very start to the end of our thesis.

Abbreviations

AI Artificial Intelligence.

DIP Device Integration Platform.

EED Energy Efficiency Directive.
EnMS Energy Monitoring System.
EnPI Energy Performance Indicator.
ERP Enterprise Resource Planning.

HMI Human Machine Interface.

IIoT Industrial Internet of Things.
IoT Internet of Things.

KPI Key Performance Indicator.

PLC Programmable Logic Controller.

SCADA Supervisory Control And Data Acquisition.

Contents

1 Introduction

Turning raw material into goods is often a very energy consuming process. The industry as a sector accounts for 28% of the total energy use in the world, and the greenhouse gas emissions of the sector stood for around 30% of the global emissions in 2010. Energy efficiency together with innovation and further actions could lead to energy savings of around 25% in the industry sector (Fischedick et al., 2014). Energy efficiency is an relatively untapped global resource, consisting of many small saving opportunities that add up to make a big difference. In this thesis, we address energy efficiency as a means of minimizing the energy consumption in the production process within IKEA Industry.

IKEA is a well-known Swedish furniture retail company with stores worldwide. IKEA Industry is a part of the corporate group and the in-house producer of many of IKEA's best-sellers when it comes to wooden furniture. IKEA Industry has ambitious goals for reducing their ecological footprint with regard to greenhouse gas emissions. The proposed goal for 2025 is to reduce the emissions in absolute numbers by 80% (Carlsson, 2018). Improving energy efficiency in the production process is one way of achieving this goal. Industrial companies always strive towards increasing energy efficiency as it both saves money and decreases environmental impact, but the matter often ends in a battle between the advantages of available technology and the investment costs. Since all processes are limited by the laws of thermodynamics, there is a need for creating what Fischedick et al. (2014) calls a "best practice technology" by identifying and targeting "best available technologies". Performance optimization of processes is possible through use of both software and hardware solutions.

In this thesis, focus will be put on Energy Monitoring Systems (EnMS), which is a tool for the industry for monitoring energy. According to the IKEA Industry Energy Savings Handbook (Karlsson et al., 2015), an EnMS is "a combination of hardware and software components for the measurement, analysis and visualization of energy-related data". Necessary components include meters and an energy monitoring software. The meters measure parameters such as current, voltage and temperature. In the software, the data from the meters is visualised in charts and tables to give an overview of the energy consumption and the energy flows at the production site. The implementation of an EnMS is an important first step in the energy efficiency work, as it can help identifying large energy consumers and it is also a necessary tool for the follow-up of improvement actions.

There is a need within IKEA Industry to investigate the current situation at the different sites and also to find guidelines for the future. By investigating the current situation regarding implementation of EnMS at the factories, a gap analysis can be made. The analysis conducted in this thesis aims to describe the gap between where IKEA Industry is today and where they want to be in the future, regarding implementation of EnMS. Describing the current situation is a necessary first step towards a more structured way of working with energy monitoring, and it also serves other purposes, such as identifying differences between the sites. Large differences can cause problems when it comes to benchmarking, comparison and follow-up on energy work. Furthermore, lack of knowledge of how the other sites work with energy monitoring can halter efficient solutions being spread between the sites.

In this thesis, we also study energy management from a structural perspective, by identifying users of the EnMS and defining levels of detail of the measuring. As opposed to the gap analysis, this latter part of the thesis aims to suggest guidelines for the future work with EnMS within IKEA Industry.

1.1 Purpose

The overall aim of this thesis is to contribute to energy efficiency improvements within IKEA Industry, in order to decrease both the environmental impact and the financial costs. One purpose is to map the way the different sites within IKEA Industry work with energy monitoring today. In addition, we aim to contribute to the strive towards energy efficiency by giving recommendations regarding methodology and ways of working with energy data.

1.2 Research questions

The research questions are divided into three categories: Current situation, Methodology and mapping and lastly, System features.

Current situation

- What is the current situation at the IKEA Industry sites, as of energy monitoring and ways of working? Is there a gap between the present and the desirable position?

Methodology and mapping

- In what way should the sites within IKEA Industry measure, monitor and analyse energy data? What kind of energy performance indicators should be used to map energy performance/consumption?
- Are there practices at the IKEA Industry sites that should be highlighted and spread? Aspects that should be taken into consideration are energy monitoring methodology, mapping and software.

System features

- What features should be included in an energy monitoring software regarding visualisation, reporting and other functions?
- Are off-the-shelf solutions desirable?

1.3 Limitations

- The energy consumption can be divided into three sectors: Production, Transport and Building. The division of energy consumption is further discussed in section 4.6 *Level of detail of measurements*. In this thesis, it is assumed that the Transport part is of negligible interest when it comes to digital energy monitoring systems. It is thus out of scope.
- Time constrains have limited study visits to six sites. Ideally, all existing sites should have been visited.

2 IKEA Industry

This chapter is intended to give an overview of the company organizational structure and how IKEA Industry works with monitoring coupled to energy efficiency. In the first section, IKEA Industry and its divisions are presented briefly. Then, the energy work within the company is explained by going through energy management, the role of energy managers and relevant standards. The next section is about key performance indicators and their appliance within IKEA Industry. The chapter is wrapped up with a section about energy efficiency.

2.1 IKEA Industry in short

IKEA Industry is one of the three core businesses of Inter IKEA Group. The structure can be seen in Figure 1. A somewhat simplified explanation of Inter IKEA is that it is the part of IKEA that designs, purchases and/or produces the goods, as opposed to the retail side that sells and delivers the goods to the customer.

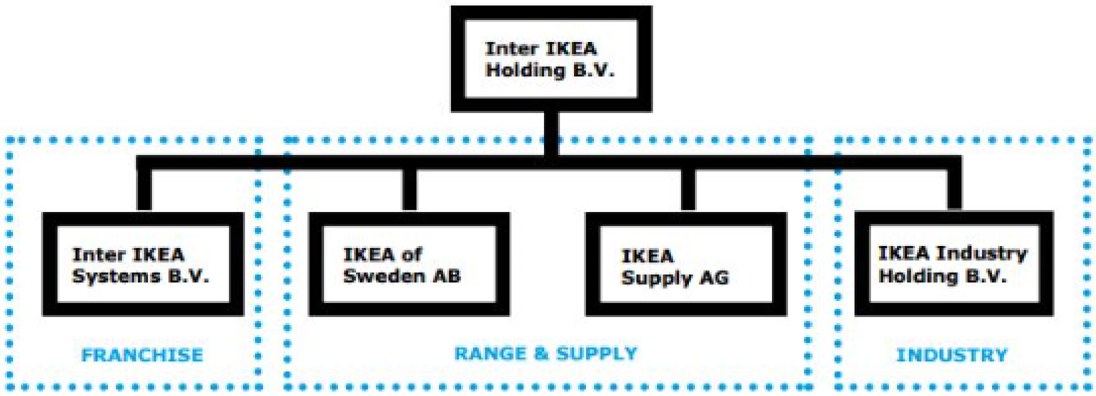

Figure 1: Schematic presentation of the IKEA Inter Group. Source: Inter IKEA Systems B.V. (2016).

The basis of IKEA Industry activities is the production of wooden furniture (largest producer in the world) and wood-based furniture. IKEA Industry is the in-house producer of many of IKEA's best seller furniture. The factories that produce these furniture are spread in ten countries all around the world and together they employ 19 000 co-workers. Depending on the kind of furniture produced, IKEA Industry is further divided into divisions: Boards, Flatline and Solid Wood (Inter IKEA Systems B.V., 2018). The Boards division produce chip boards that are turned into furniture in the Flatline factories. At some places, a Boards and a Flatline site are placed next to each other to minimise transports. As suggested by the name, division Solid Wood produces furniture out of solid wood as opposed to chip boards.

See Figure 2 for a map over the sites, where Boards sites are dark blue, Flatline sites are light blue, sites that have both Boards and Flatline production are green and Solid Wood are red.

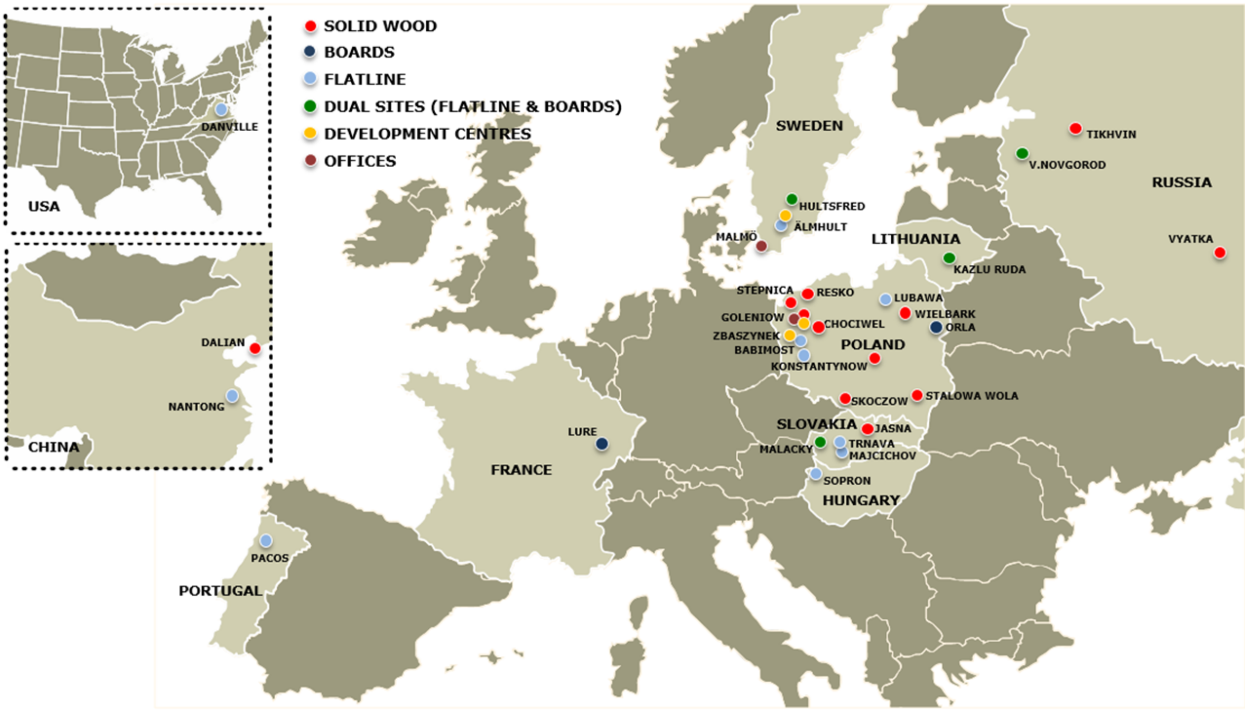

*Figure 2: IKEA Industry locations around the world. Source: IKEA Home. (2018*a*).*

Division Purchase is also a part of IKEA Industry, however, since the department is not a part of the industrial process it is outside the scope of this thesis and will not be mentioned further. Neither will the Development Centres (marked in yellow on the map in Figure 2) be included. Therefore, in this report, when the term "divisions" is used, it only includes divisions Boards, Flatline and Solid Wood. The information in chapters 2.1.1 *Division Boards*, 2.1.2 *Division Flatline* and 2.1.3 *Division Solid Wood* below is taken from Inter IKEA Systems B.V. (2016).

2.1.1 Division Boards

The sites that are part of the Boards division (see Table 1) produce the chip or fibre boards that later on are sent to the Flatline sites to be further processed to end product furniture. Processes such as drying and pressing of the chip- or fibre boards are large energy consumers. Other processes that take place in Boards sites are timber sorting, sawing, re-cutting, chipping etc. One of Boards patented product that is worth naming is the low-density BOBOARD, which has normal density only on the parts where for example screws and plugs are to be fitted.

Table 1: Boards factories and their location. Source: Inter IKEA Systems B.V. (2016).

Boards factories	Country
Lure	France
Kazlu Ruda	Lithuania
Orla	Poland
Novgorod	Russia
Malacky	Slovakia
Hultsfred	Sweden

2.1.2 Division Flatline

Sites that produce lightweight furniture belong to Flatline division. The chip or fiber boards that are produced by division Boards are further processed here where they go through lacquering, precision cutting and packaging. Some of the most known products are PAX, LACK, KALLAX, BESTÅ and MALM. As seen in Table 2 below, there are 14 production units in 9 countries.

Table 2: Flatline factories and their location. Source: Inter IKEA Systems B.V. (2016).

Flatline factories	Country
Nantong	China
Sopron	Hungary
Kazlu Ruda	Lithuania
Zbaszynek	Poland
Lubawa	Poland
Pacos de Ferreira	Portugal
Novgorod	Russia
Trnava	Slovakia
Malacky	Slovakia
Älmhult	Sweden
Hultsfred	Sweden
Danville	U.S.

2.1.3 Division Solid Wood

Furniture made of solid wood are the main product of the sites (see Table 3) that belong to the Solid Wood division. A Solid Wood factory can be a cluster of a sawmill factory, a glue board factory and lastly a furniture factory similar to the Flatline division. Each Solid Wood site does not necessarily have all three of the factories named above. In chapter 7.3 *Wielbark*, a Solid Wood site that includes the whole production chain is described. Top products produced by division Solid Wood are HEMNES, HURDAL and IVAR.

Table 3: Solid Wood factories and their location. Source: Inter IKEA Systems B.V. (2016).

Solid Wood factories	Country
Dalian	China
Chociwel	Poland
Goleniow	Poland
Konstantynow	Poland
Resko	Poland
Stalowa Wola	Poland
Stepnica (Ivar)	Poland
Stepnica (Pine SM)	Poland
Wielbark	Poland
Vyatka	Russia
Tikhvin	Russia
Jasna	Slovakia

2.2 Energy work within IKEA Industry

2.2.1 Energy management

An EnMS is an element of energy management in general. Within IKEA Industry, guidelines and requirements are given in the Energy Management Manual by Boström (2017). The manual states that the work should be structured in a classic Plan-Do-Check-Act cycle. When it comes to energy performance, the first step is Plan - planning energy efficiency actions. The next step is Do - performing the planned actions and improvements. The Check part is where energy monitoring comes in, as measurements often are needed to be able to follow up the result of the actions. A good EnMS displays historical data so that it can be easily compared to new data, and thereby the progress can be monitored. The last step in the cycle is Act, where the cycle is reviewed and decisions on a new cycle are made. The EnMS output can also well be used in the Plan phase, as analysis of the energy data can indicate where unnecessary consumption takes place.

Another document that is used within IKEA Industry is the Energy Savings Handbook by Karlsson et al. (2015). There, one can find suggestions and guidelines regarding energy efficiency actions. It has a more technical approach than the Energy Savings Manual and includes both organisational (such as night walks to detect unnecessary consumption) and cost analysis information (such as investment costs and pay-back time). Moreover, it includes a chapter that is dedicated to energy monitoring systems and the benefits of using them for detecting and treating energy issues.

In other words, energy management is a larger concept in which energy monitoring is a key part. Monitoring is necessary in order to evaluate implemented actions within the management cycle and to see to which extent they have contributed towards the energy conservation goals. By monitoring the energy consumption, the energy management work is given a structure. In addition, valuable lessons can be learned so that the successful actions can be repeated and repeating the mistakes can be avoided.

2.2.2 The role of energy managers

According to the Energy Management Manual by Boström (2017), an energy manager is an employee that is appointed by the top management of the site. This is a way for the top management to ensure that energy actions are implemented, energy policies are followed and that the EnPIs (Energy Performance Indicators, see chapter 2.3.1 *Energy Performance Indicators*) are established. The manual recommends that the technical manager should be appointed the task of energy manager. It is clearly stated that an energy manager has to be appointed on every site, at least as a part time employment, and that his/hers authority should be clearly stated. The energy manager should:

1. Work with energy data analysis.

   Energy data should be collected and analysed on a regular basis. Here, the three parts measuring, visualisation and analysing/reporting are the main focus of this thesis.

2. Direct the work with the energy efficiency program of the site.

   Energy efficiency programs consist of among other things, action plans and budgeting, together with the evaluation of the data from point 1 above.

3. Follow up the progress of the energy management and analyse the results of the implementations of energy actions.

   The energy manager should actively follow the process of the different implementations and reflect upon the resulting situation.

4. Communicate between different actors and coordinate by appointing responsibilities at the site.

   Since the energy manager should have a clear mandate, he/she should function as the communicator between the departments of the site and organise the work.

5. Produce energy reports for the site and send it to the site/division management.
6. Share the knowledge with other sites within IKEA Industry.
7. Book training sessions and meetings for the employees.
8. Fill in and upload the "Evaluation Tool Energy Management Implementation" (a reporting tool that is used within IKEA Industry).
9. Appoint an energy team and organise regular meetings with them, at least four times per year.

Energy team

As stated by Boström (2017), the size of the energy team should depend on the site size. The members of the team should come from different areas, such as production, technical department, sustainability and maintenance. Depending on the agenda of the meeting taking place, persons with relevant competence should be added to the team.

As mentioned above, the energy team together with the energy manager should meet at least four times per year. The meetings must be documented and topics of discussion such as energy savings plan, EnPI follow-up, investments etc. should be discussed with the team. Additionally, the energy team should have a clear picture of the energy consumption of the site (energy mapping), support and actively be a part of the implementation of energy efficiency. They should also motivate all factory employees and conduct control walks, which are walks through the factory during the time that there is no production. Moreover, the energy team is responsible for providing technical basis for decision making regarding investments and lastly, sharing the knowledge with other sites.

2.2.3 Standards used within IKEA Industry

Within IKEA Industry, there is a large number of documents and informatory material that is used to help organise and guide the work at the sites. The ones that are relevant for this study are presented briefly here. The four standards below are all called technical standards. Some of them were referred to in the questionnaire, see Appendix A. Further explanation about the terms below are found in chapter 3.2 *Industrial system architecture*.

Device Integration standard

The Device Integration standard includes criteria that should be followed concerning communication signals that are sent from machines, lines and equipment to the Device Integration Platform. Written by Hesselgård (2015*a*).

Electrical standard

The Electrical standard includes criteria about electrical connections and all the steps that should be followed when connecting to an energy supplier. This standard can be used on both new factories and during renovation of old ones. Written by Hesselgård (2014).

MES Integration standard

The MES (Manufacturing Execution System) Integration standard is a support document for the integration of new machine installations. It also includes a list of signal tags that shall be used for the data exchange between the PLCs (Programmable Logic Controllers) and the MES. Written by Hesselgård (2015*b*).

PLC, PC and SCADA standard

The PLC, PC and SCADA standard includes criteria about how a control system should be built and structured. SCADA stands for Supervisory Control And Data Acquisition. Written by Hesselgård (2015*c*).

2.3 Key Performance Indicators

According to Investopedia (2018), Key Performance Indicators (KPI) are a tool of measuring performance in a quantitative way. KPIs indicate how well a company performs in comparison to its predetermined goals and can also be used to make comparisons between different companies within the same industry. The indicators can also help with continuously aligning the direction of the different activities so that they comply with the goals of the company.

Common KPIs are based on financial metrics, although the metric can be adjusted depending on the type of information one is seeking. For example some non-financial KPIs that are qualitative are employee turnover and costumer relationships (CGMA, 2013).

Some do’s and don’ts according to CGMA (2013):

- Use easily understood and clearly predetermined KPIs throughout the company.
- Focus not only on quantitative measures, but on qualitative aspects as well.
- Too much data and too many KPIs do not necessarily provide a better picture. Find the core of the area in interest and limit the KPIs so that they show relevant information.
- Focus on how the KPIs can help influence the process. A number does not show the whole picture and does not by itself provide a solution.

2.3.1 Energy Performance Indicators

In this thesis, the term Energy Performance Indicator (EnPI) is going to be used instead of KPI. This is due to the fact that the report focuses on energy rather than financial aspects and because it is the term that is used internally when working with energy.

EnPIs that are used at IKEA Industry are kWh/m^2 or kWh/m^3. Since division Flatline and Solid Wood products produce individual pieces with a known area (m^2), the specific energy consumed is therefore divided by the area of furniture produced (kWh/m^2). On the other hand, division Boards products are boards with different thickness (m^3) and composition, and the thickness rather than the area is used for the calculation of the EnPI (kWh/m^3). To summarize, divisions Flatline and Solid Wood use kWh/m^2 as EnPI, whereas division Boards uses kWh/m^3 (Boström, 2017).

2.4 Energy efficiency within IKEA Industry

Improving the energy efficiency is often a win-win situation for manufacturing companies. It is hard to see any disadvantages with accomplishing more economic activity with less energy inserted into the process. The benefits are intuitive to understand. The business values include lower energy costs, lower vulnerability to volatile electricity prices, decreased ecological footprint, strengthening of the company brand and proactive legal compliance (Energimyndigheten, 2017*b*). However, for the environment, improved energy efficiency does not always have positive effects per se. A relative improvement is not always an absolute improvement. In other words, an increase in production can outweigh an improved energy efficiency so that the net emissions increases. Even if more usable goods are produced per energy unit, the environment still only “sees” the increased emissions. It is therefore important to look at other measures as well to ensure that the desired environmental effect is reached.

IKEA Industry has ambitious goals for reducing their ecological footprint with regard to greenhouse gas emissions. The proposed goal for 2025 is to reduce the emissions in absolute numbers by 80%. The information about the 2025 goals is taken (with permission) from a not yet released internal document by Carlsson (2018).

There are three identified ways to reach the proposed goal.

- Implement renewable energy sources on site (i.e. solar panels on the roof, biomass boilers)
- Purchase electricity from renewable sources
- Improve the energy efficiency

The latter is connected to energy monitoring, as having a good EnMS often is the first step towards a higher energy efficiency.

“What gets measured, gets managed”

The above quote or some variation on the theme, is an often used quote attributed to management guru Peter Drucker (Zak, 2013). In this case, energy monitoring is needed to follow up on the energy efficiency actions that are carried out at the sites. It also enables a systematic and structured approach to energy management.

The proposed IKEA Industry 2025 goal is an increase in energy efficiency between 1-5 % yearly, depending on time period and division. Division Boards has somewhat lower goals than the other two divisions.[1]

2.4.1 Legislative context: EU directive

In December 2012, the EU Energy Efficiency Directive (EED) came into force. The directive requires all countries to use energy more efficiently in both production, distribution and consumption of energy, in order for the EU to reach its goal of 20% increased energy efficiency until 2020 (in 2016 updated to 30% until 2030) (European Commission, 2017). As almost all of IKEA Industry's sites are situated within the EU, the internal IKEA Industry goals are a way of complying with the directive.

2.4.2 Energy audits and savings estimations

In Sweden, the EED is implemented through a law regarding energy audits in companies of a certain size (In Swedish: Energikartläggning i stora företag). The law requires energy audits by a qualified auditor every fourth year (Energimyndigheten, 2017*a*). IKEA Industry have adapted similar energy audits in the factories outside of Sweden as well. An energy audit is part of a structured work towards improved energy efficiency and aims to identify potential energy saving actions. The report that follows an energy audit typically consists of a summary of energy data, and a list of identified improvements that is completed with a financial analysis of the monetary savings of the improvements. The energy consumption data is divided into three sources; process, building and transport. In this thesis, the energy data from the process is deemed the most relevant for the energy monitoring system. Energy data concerning the building (i.e. ventilation, comfort heating and lighting) is also interesting and is therefore a separate part of the questionnaire and the analysis. However, the energy data from the transport sector is mostly out of scope for the EnMS and this thesis. A detailed review of the division of energy data can be found in chapter 6.2 *Energy measuring methodology: the Pyramid*.

If an EnMS is not already in place, the implementation of one could be part of the listed potential improvements in the energy audit report. Another improvement could be expansion or modification of an existing system. The financial analysis of the investment is based on estimations. The estimations of how much energy that can be saved by implementing an energy monitoring system are based on praxis in the industry, which in turn stem from empirical observations. The standard numbers that are used as a basis for calculation within IKEA Industry are as follows:

1. Initial savings of 2-4% of the power bill by basic analysis and subsequent actions.
2. Additional 2-5 % in savings by optimising utilization of equipment.
3. Additional ∼10 % in savings by reducing downtime and increasing power system reliability.

The numbers are taken from the energy audit report from the Flatline site in Hultsfred in 2017 (Karlsson and Nojman, 2017*a*). Hultsfred flatline factory currently has no EnMS in place and there is therefore a potential for energy savings. In the energy audit report, the savings are estimated to be 3 % of the annual bill. 3 % is the average of the standard initial

[1] Carlsson, A, Sustainability Manager IKEA Industry. (25th May 2018)

savings of 2-4% in the list above. Notwithstanding the additional savings, the yearly savings are estimated to amount to 266 977 kWh and 10 144 € (Karlsson and Nojman, 2017*a*). However, it should be noted that no savings occur by themselves - the data from the EnMS always has to be analysed and acted upon. One way of illustrating the process can be seen in Figure 3 below.

Figure 3: Process from capturing of data to energy saving actions. Design changed by the authors. Source: Powerpoint from Michael Ober (2018)

Even if we assume that implementing/improving an EnMS leads to savings of energy, there are also limitations to consider. For example, before a meter is placed permanently on a machine, the savings potential of the machine should be analysed (Karlsson et al., 2015). If the savings potential is very low, it could be more meaningful to place the meter some place else. Low savings potential can be found in machines that are used seldomly, or in machines with low power. Also, if installing the meters require an effort, in cost or in working time, that may outweigh the benefit, the installation should be carefully considered beforehand. It is crucial that the installation of a EnMS creates business value in some way. The most obvious value is decreasing the cost of energy. As aforementioned, there could be other benefits as well, such as decreasing the environmental impact and thereby also creating good will in the eye of the public.

3 Energy Monitoring Systems

This chapter provides the reader with the background knowledge that is needed to interpret the results later in the thesis. It starts with an outlook on the forecast changes in the manufacturing industry (Industry 4.0). In the subsequent section, industrial information system architecture as it looks today is explained. After that, we move into the main focus of this thesis - Energy Monitoring Systems (EnMS).

3.1 Industry 4.0 and the Internet of Things

The term Industry 4.0 stands for the ongoing and future transition into manufacturing systems characterized by automation and connectivity of devices. It is seen as the fourth industrial revolution, the first three being mechanisation, mass production and computerisation. The term is originally German (Industrie 4.0) and was coined in 2011 as the name of an initiative supported by the government, aiming to prepare the German industry for the wireless future. A key feature of Industry 4.0 is the integration of Internet of things (IoT). (Hermann et al., 2016)

IoT is a concept that is expected to become a big part of manufacturing and society as a whole. Theoretically, anything with a power switch can be connected to a network, and thereby send and receive information in order to improve and rationalize the use of the connected device (Morgan, 2014). In a manufacturing context, this creates enormous amounts of data that have to be managed in a cloud-based storage solution. There is even a term for IoT applied to the industrial sector - Industrial Internet of Things (IIoT). The major difference between the two terms, besides IIoT being more specific, is that IIoT refers to larger systems with higher stakes. When it works, it is expected to lead to huge increases in productivity and efficiency (Gold, 2018). Energy efficiency is one of the areas where connected devices can play a major part, as it gives a detailed view of the energy consumption - given that a good energy monitoring system is implemented.

When it comes to analysis of the energy data, Artificial Intelligence (AI) is an interesting alternative in the future. Especially when there is large amount of data to examine, it can be very time-consuming to manually try to find patterns and anomalies. Algorithms can possibly be more effective than humans, and also save time and money for the manufacturing company. Already now, alternatives exists for energy optimisation of commercial buildings (Sennaar, 2017).

3.2 Industrial system architecture

According to a definition by Jaakkola and Thalheim (2010), system architecture is a conceptual model of a system that express relationships between the different components. It also presents paths and values that can be carried from one part of the system to other parts. In this case, the conceptual model that is presented in Figure 4 consist of physical as well as immaterial parts for example screens (physical objects) and software (immaterial).

The architecture described in Figure 4 is specific to IKEA Industry, however, the set-up is similar to a more general industrial system architecture.

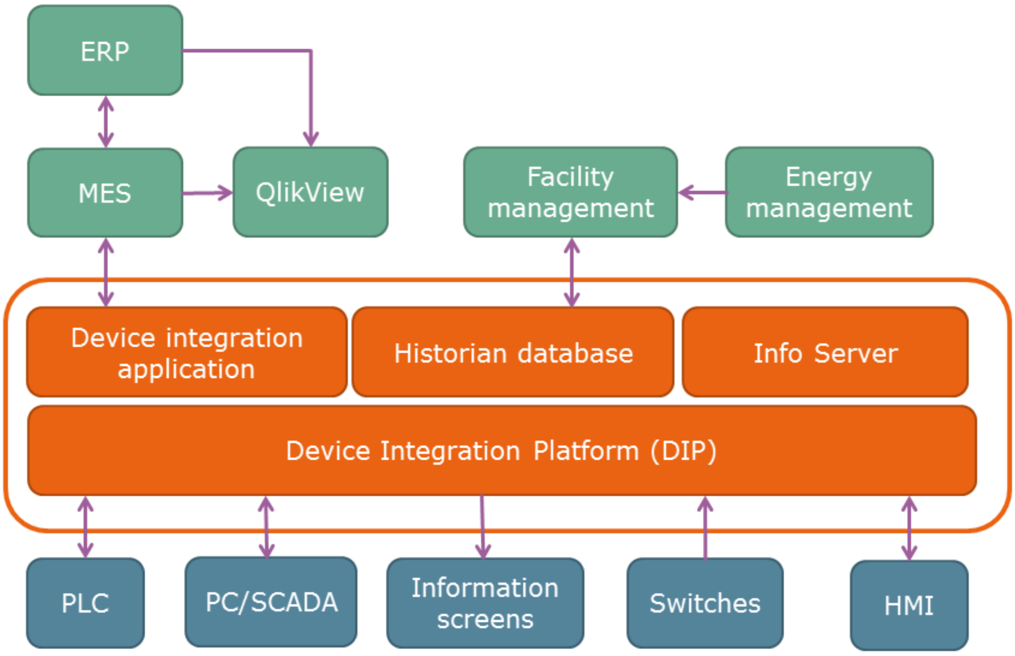

Figure 4: The architectural structure of industrial systems and the relationships between the different parts. The orange line includes the parts of an Energy Monitoring System. The figure is adapted by the authors by only including the parts that are relevant for this thesis. Original source: Hesselgård (2015a).

The green parts in the system architecture presented in Figure 4 are assumed to be situated in office environments and the blue ones at the factory floor. The orange parts (also encircled in orange) represent an EnMS and can be assumed to exist in between.

ERP
ERP stands for Enterprise Resource Planning which is a term for the integrating programs and systems that are used by a company to execute various tasks between different departments such as sales, purchase, manufacturing etcetera (Beal, 2018).

MES
The Manufacturing Execution System is a way of closing the gap between the ERP and the factory floor users. Through this system one can schedule production, handle orders, gather data and get an overall view of the situation involving production (Choi and Kim, 2002).

QlikView
QlikView is an example of a software that is able to visualise data in an adaptable and user-friendly way. It displays key performance indicators as graphs or tables and is used for keeping track of performance and long-term trends (Visual Intelligence, 2018).

DIP
The abbreviation DIP which stands for Device Integration Platform, is a terminology that is used within IKEA Industry and was introduced by Tommy Hesselgård (Project Engineer) and Michael Ober (Project Manager)[2]. It is a broad term that is used to encapsulate a

[2] Hesselgård, T, Project Engineer IKEA Industry. (3rd May 2018)

system that can be used as "a communication platform based on real-time information". It solves the problem of heterogeneity between the different input signals, controls and functions within an organisation (Bangemann et al., 2006). It consists of an application called Device Integration Application (again a term within IKEA Industry) which is a target specific application. For example, there is a need for a special application for the connection of the MES to the DIP.

Servers called Device Integration Servers function as the conductor of a large orchestra: they contribute with data acquisition, sending the signals to the right address, archiving data and distributing data to the MES (Hesselgård, 2015*a*). Data archive servers store relevant information under a predefined period of time. This data can then be accessed by other parts of the DIP.

Historian database
A historian database, also called process historian or operational historian, is a logger of time series data. Each data is "tagged" with a time-stamp and stored in a structured way. The information that can be stored here varies; it can be analogue or digital readings, product, quality and alarm information as well as aggregated data such as averages, sums and standard deviations (Automated Results, 2018). This kind of database is a vital part of the energy monitoring system, since the information that has been stored here can be analysed and the output can be used for decision making processes. All of the components are connected via Ethernet.

PLC
The Programmable Logic Controller is used for the controlling of electromechanical processes. According to Unitronics (2018), information that is received by sensors and meters via input modules is processed by the PLC processor and then the result of the process, which can be a change in flow, drive etc., is sent to the machines by an output module. The I/O (Input/Output) modules can handle both analogue and digital signals. The PLCs are built to withstand the harsh conditions that can occur on the factory floor.

SCADA
The Supervisor Control And Data Acquisition (SCADA) is a control system technology that allows a user to collect data from a part of the system and control a process from a distance. Therefore, the user doesn't need to be in the same place/area as the process that she/he wants to control. The operator can control some processes such as opening and closing valves and monitoring alarms (Boyer, 1999).

Information screens
Screens are usually placed in strategic parts of the factory for providing relevant information to the operators. The information can include status of the most important KPIs.

Switches
A DIP switch is a set of electrical switches on printed circuit boards that hold certain configurations. In other words, during specific conditions it regulates how a component should react. DIP switches have two options: they are either on (1 stands for on) or off (0 stands for off)(Future Electronics, 2018).

HMI
For real-time interaction between the PLC and the user, a Human Machine Interface (HMI) is used. The HMI consists of a display with a mouse, keypad or just a touchscreen. In industrial environments, the data that flows through the PLC can be exported to SCADA. Note that SCADA can connect multiple PLCs at the same time thus gaining a central overview of the factory's process (Unitronics, 2018).

3.3 What is an Energy Monitoring System?

As mentioned before, implementing an Energy monitoring system (EnMS) is an important step in the energy efficiency work in manufacturing. In this chapter, the concept will be explained to clarify what is included in the term, at least in this thesis. The different components that are included in an EnMS are encircled with an orange line in Figure 4 in the previous section. Remember that the figure is a conceptual way of presenting an EnMS and that the actual set-ups can vary.

An EnMS measures (step one) and visualises (step two) data related to energy consumption in the factory. The third step after measuring and visualisation is analysis of the result. The different steps are described in more detail below.

Measuring
The first step is to capture the energy data, and in order to do so, hardware in the form of meters and sensors are needed. Common parameters that can be measured include current, voltage, power, reactive power and flow of compressed air. The captured data is then stored in a database.

Visualisation
For the visualisation part, a software accesses the database, collects energy data and visualises it in predefined tables, graphs and charts. In this thesis, we call this software the Energy monitoring software. The software can include alarms when a value is outside a given threshold and creation of reports. One characteristic of the energy monitoring software is that it handles historical data as opposed to only real-time data.

Analysis
It is possible to have the analysis as a feature of the system, especially in the future with new possibilities with Artificial Intelligence (AI), though as it is today, the analysing part is mostly done by a person investigating the output from the visualisation. The analysis can include detecting abnormalities, identifying inefficient processes, deciding focus areas and following up energy efficiency actions.

3.3.1 Software solutions

Different software can be used for the visualisation of the energy data. This fact is also part of the background for the objective of mapping the current situation at the factories - the different sites do not use the same software, and their visualisation output therefore looks very different from each other. However, there are some software that are more interesting than the others since they are currently in use as a DIP and therefore are worth mentioning.

Wonderware system platform/InTouch
Wonderware is a well-known provider of industrial software, including HMI, SCADA and MES systems (Wonderware, 2018). Wonderware provides a platform that can be tweaked to handle large amounts of data of almost any kind, including energy data. About ten years ago, installing Wonderware was a recommendation to the sites from top management.[3]

Siemens Simatic/WinCC
Siemens is one of the largest manufacturing companies in Europe, and industrial automation is one of the company's main activities (Siemens, 2018). They have their own process visualisation software called Siemens Simatic WinCC. If many other components in the manufacturing chain are made by Siemens, it can be seen as a advantage to have Siemens software too, as they communicate easily.

3.3.2 Users of the EnMS

When it comes to software, it is important to analyse the different users and their respective needs. The users can have entirely different requirements and background knowledge. Therefore, different levels of access to the data might be necessary in order to facilitate reporting and avoid information overload. Information overload refers to the phenomenon when decision making is flawed or delayed due to difficulties with separating relevant information from irrelevant (Rogers et al., 2013). Not everyone needs to have access to all energy data, and the data that is actually needed should be displayed in a way so that it is useful for the user. In order to investigate this aspect, so called User stories were created to clarify what the different users want from the EnMS. They can be found in chapter 9.1 *User stories*.

[3] Hesselgård, T, Project Engineer IKEA Industry. (28th March 2018)

4 Method

This chapter describes how the thesis work has been structured, and how we have obtained the information that is the basis for the results. First, the study visits are described. The methodology concerning interviews and having meetings with a reference group is treated in the two following sections. After that comes a section about the literature study. Conducting a questionnaire that was sent to the energy managers at the sites has been a valuable source of information, and how it was created can be found in section 4.5. One part of the questionnaire was to map how detailed the different sites are measuring energy. The last section concerns the different levels of detail of measurements that were used in the questionnaire.

This thesis is based on the combination of different methods used for building a base that can be used to answer the questions stated in chapter 1.2 *Research questions*. Since IKEA Industry can be perceived as being a large and complex company for a person that has just started to read about it, there is a need to choose a variety of approaches.

The lack of written literature concerning organisational, structural and technical issues has driven us to conduct many interviews with people that are experts in these areas. A reference group has been our panel when trying to test our material and find how the theory can be used in practice. Study visits have from the beginning been a good way of understanding the current situation, identifying interesting practices and trying to find solutions. The use of two questionnaires aimed to aid us with understanding the current situation, gathering data and finding an appropriate course of action. It was an easy way of gathering information when there was no time to visit all sites in all corners of the world.

4.1 Study visits

Study visits in both Sweden and Poland were a way of obtaining an understanding of the manufacturing processes and coming in contact with the people working at the factories. The reason why there was of need for study visits is that we had no previous knowledge of the site organisation, the processes and the end products.

The factories that were visited in Sweden were Älmhult and Hultsfred. In Poland, a whole week was dedicated to visits in Lubawa, Orla and Wielbark. In each place visited, a meeting with the technical manager, engineering manager and energy manager was booked. The factory tours were a hands-on way of following the different processes and understanding the difference between the three divisions within IKEA Industry. Moreover, the large energy consumers were identified and hot-spots were pointed out by the managers. By far the most fruitful part of the visits was seeing the plethora of energy monitoring systems and comprehending how they are utilised by the managers.

4.2 Interviews

When one initiates a study within a large company, written information and literature cannot cover the vast and complex structure built over decades. The knowledge capital within IKEA Industry exists in the people, therefore interviews have been the fastest and most accurate way of obtaining information. During the time of the master thesis, numerous meetings were booked, either via Skype, telephone or physical meetings and information was surged from people with deep specialisation in their sector. The meetings were semi-structured with prepared questions that were adjusted depending on the person and the subject.

The interviews were used as a source of information about how IKEA Industry operates and what kind of processes the sites include. Chapter 7 *Case studies* is based on both Skype interviews (Paços de Ferreira, Sopron) and physical meetings (Wielbark, Älmhult).

Table 4: Some of the reoccurring personal interviews that took place during the thesis are named below.

Name	**Title**	**Division**
Conny Jakobsson	MOM Advisor and IT Architect	ÅF, Central
Janusz Nojman	Electricity Purchase and Energy Efficiency Specialist	Central
Zsolt Ferenzcy	Benchmark Specialist	Boards, Malacky
Michael Ober	Project Manager	Flatline, Central
Tommy Hesselgård	Project Engineer, Central Engineering	Central

4.3 Reference group

A reference group was set up by Glenn Karlsson (supervisor). The reference group has been to our disposal throughout our time at IKEA Industry and was informed beforehand about the scope of our thesis. The participants of the reference group belonged to different departments, among others representatives from all three divisions and people from the central office (see Table 5). During the analysis of KPI (Key Performance Indicators) and pyramid development the group had an important role, where discussion about our suggestions and their applicability lead to choosing the final pyramid suggestion. The purpose of the reference group meetings was to test our suggested material and receive their input based on their experience at the sites.

An agenda with the main points of the meeting was sent out a couple of days before the meeting. During the meeting the points were discussed one by one and everything was noted. Lastly, after each meeting, we went through the notes, analysed them and sent a summary of the meeting to the group.

Table 5: The list of the people that were part of the reference group are presented according to name, title, division and location.

Name	Title	Division	Location
Tommy Hesselgård	Project Engineer	Central	Malmö
Glenn Karlsson	Project Engineer	Central	Malmö
Janusz Nojman	Electricity Purchase Specialist and Energy Efficiency	Central	Lubawa
Michael Ober	Project Manager	Central	Malmö
Zsolt Ferenzcy	Benchmark Specialist	Boards	Malacky
Marcin Wejdelek	Automation specialist	Flatline	Zbaszynek
Waine Franzen	Energy Manager and Infrastructure Manager	Flatline	Älmhult
Camilla Kunstelj	EHS-manager	Flatline	Älmhult
Antonio Silva	Equipment Development Engineer	Flatline	Paços de Ferreira
Jason Hang	Sustainability coordinator	Flatline	Nantong
Robert Tomczak	Project Leader	Flatline	Zbaszynek
Andrzej Domanski	Maintenance Manager	Solid Wood	Wielbark
Dusan Kozica	Energy Manager	Solid Wood	Jasna
Tomasz Frontczak	Technical Manager	Solid Wood	Konstantynow

4.4 Literature study

The main source of written information that was used for this thesis were internal documents and reports, such as the standards (see chapter 2.2.3 *Standards used within IKEA Industry*), the Energy Management Manual and the Energy Savings Handbook (see chapter 2.2.1 *Energy management*). These documents provided us with the necessary background information about IKEA Industry and structure of the energy work. The Energy Savings Handbook was the base regarding which processes should be included in the questionnaire and the Energy Management Manual was used for understanding the organisational processes when structuring the energy work.

Books, articles, on-line sources and previous master thesis were also used for building a base for conducting this research and learning more about technical terms, such as the terms in chapter 3.2 *Industrial system architecture*. Background information about key performance indicators and user stories was found from on-line sources.

4.5 Questionnaire design

The questionnaire has been a large part of the thesis, connected to the research question about mapping the current situation regarding energy monitoring at the sites. In order to do so, a questionnaire was compiled after meeting with experts within IKEA Industry and conducting a short literature study. Apart from learning the workings of IKEA Industry, we also carried out a short literature study on how to write a good questionnaire. The questionnaire was aimed towards and sent to the energy manager of each site.

The questionnaire was created in Excel, which was a decision taken for convenience. Since IKEA Industry regularly uses Excel for similar purposes, the recipients of the questionnaire were familiar with the format. Furthermore, in some cases more then one person was required to answer the questionnaire in order to cover all questions. Excel enables saving the partly answered questionnaire between sessions which also is an advantage if the respondent does not have a lot of time and is unable to answer all questions at once. The questionnaire took approximately 40 minutes to fill in. All the questions are listed in Appendix A.

The questionnaire was divided into four main categories:

- General

  This part aimed to provide us with information about which division and which position the respondents belonged to.

- Measuring

  Here the intention was to get an understanding of how they measure energy, what kind of processes they measure and how detailed these measurements were.

- Monitoring

  The aim of this category was to collect information about what kind of energy monitoring system was used, how satisfied the respondents were with the system in place, get an overview of the features of their system, and in the end obtain the respondents views regarding EnMS.

- Analysing/reporting

  The last category was focused on the output of the EnMS, such as the energy reports, what kind of EnPIs that were used and how satisfied the respondents were with these indicators.

The main categories were complemented with three additional sheets; one called "What why how", another called "Read me first" and lastly "Your ideas". The fist two additional sheets were of informative nature about the purpose of the questionnaire, how the recipients should answer, the deadline date etc. The last sheet was a place where the recipients freely can express points about energy monitoring that they find worth mentioning.

A question in the "Measuring" category from the first questionnaire was deemed unclear, therefore a second questionnaire was sent using Google forms in which the question was made more clear.

4.5.1 Analysis approach of the questionnaire answers

The questionnaires were analysed by focusing on specific questions, to which the answers were sorted per division. All the answers that we received via e-mail were imported in Excel by using a query and the four main categories (General, Measuring, Monitoring, Analysing/reporting) were used as a structure for this query. Using the statistical tool COUNTIF the answers were separated and categorised depending on their content. The result is presented in diagrams and tables. Six matrices have also been used for presenting the results from the Measuring category, see chapter D *Matrices regarding level of detail.*

By using the qualitative and quantitative information of the answers given in the questionnaire, the carrying out of a gap analysis was made possible. Also, the answers provided us with a basis that could later on be used to book interviews and meetings with among others the reference group. For example, the questionnaire answers from the measuring category were a starting point of the discussion that lead to the formulation of the pyramid structure that is presented in chapter 6.2 *Energy measuring methodology: the Pyramid.* The answers about the Key Performance Indicators lead to the discussion about which Energy Performance Indicators that should be used for reporting and visualisation. The two questionnaires have been the foundation of which we have started and progressed this master thesis.

4.5.2 Response rate

Of the initial 30 sites that the first questionnaire was sent to, 24 answered. As seen in Table 6, all Boards sites answered to the first questionnaire, 83% answered from division Flatline and 67% from division Solid Wood.

The second questionnaire was sent only to the sites that answered to the first questionnaire. Of the 24 sites, 20 of them sent their answers. The response frequency was 67% for Boards division, 100% for Flatline and 75% for Solid Wood.

Table 6: Response rate of the two questionnaires, presented per division.

Division	Questionnaire 1	Questionnaire 2
Boards	100%	67%
Flatline	83%	100%
Solid Wood	67%	75%

Overall, the answer frequency from both questionnaires (80% for the first questionnaire and 83% for the second) were deemed satisfactory and therefore the results that are presented in the following chapters are assumed to be representative of the situation at the sites today.

4.6 Level of detail of measurements

This section explains the alternatives in the questionnaire regarding level of detail of measurements. As mentioned before, measuring is the first step in an EnMS as it is necessary in order to capture data. The measuring is done by placing meters or sensors at strategic points. The more measuring points a site has, the more detailed a picture of the energy flows can be obtained. This of course requires that the meters are placed in a structured and logical way. IKEA Industry's Electrical Standard states that "Each separate load $\geq$75 kW shall have measuring equipment" (Hesselgård, 2014). Instead of asking the sites whether they follow this or not, we decided on a different approach, based on a pyramid structure.

The pyramid structure as a conceptual model originates from Janusz Nojman (Electricity Purchase and Energy Efficiency Specialist). The figure below was used as a starting point for the development of the methodology regarding energy measurements and their level of detail. It started at the lowest level of detail, called the main counter, where the energy invoice is the only information about the energy use. Then it moves on and divides the measurements to three categories: buildings, transport and process. At the last and most detailed level, there are some examples of the three categories. In other words, the pyramid as a structure was chosen to show that more detail can be added in the measurements by starting at the top of the pyramid and continuing to the base.

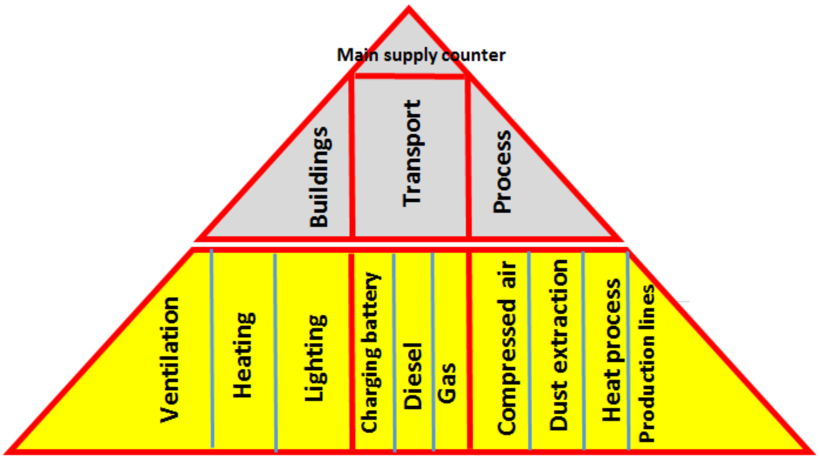

Figure 5: The original concept of a pyramid structure, produced by Janusz Nojman, for the expressing of the different levels of measuring detail.

This pyramid was later on changed and adapted after the analysis of the results of the answers we got from the questionnaire and from the meetings with the reference group. The final pyramid that we have produced based on the results, is presented in chapter 6.2 *Energy measuring methodology: the Pyramid*.

In this thesis, different levels of detail were defined in the questionnaire that was sent out to the IKEA Industry sites. Asking how detailed they are measuring their energy flows within different processes enabled a gap analysis regarding where IKEA Industry are today and where they want to be in the future. See Appendix D for the analysis of the questionnaire answers. The levels of detail that were used in the questionnaires are described below.

4.6.1 Level of detail in the production

This section explains the different levels of detail that were used to map maturity at the sites when it comes to measuring energy data in the production. In the questionnaire, the respondents were asked to choose one of the four levels for all the processes that were relevant for their site. To improve the quality of the answers, a short description of the level and an example were included in the questionnaire that was sent out.

Factory level
Factory level is the least detailed level of measuring - or rather, it indicates a lack of measuring. At this level, the source of energy data is for example the electricity invoice for the whole factory. It requires little work to compile this small piece of information, and the total energy consumption can be compared between sites or between years. However, it is very hard to investigate reasons for increases or decreases in the consumption. Note that after the questionnaire was sent out, it came to our attention that the word *factory* was a bit ambiguous. It can be use to describe different parts of the production (e.g. frame factory, pigment factory), while we mean the site as a whole. *Site* is therefore a better word. When the results from the questionnaire are displayed, *factory* is used as that was the alternative that the respondents had.

Process level
A somewhat more detailed level of measuring is what we call process level. It means that the sites are able to allocate energy consumption to different parts of the production. In the

questionnaire, a number of processes were named. However, the respondents were able to add processes that they missed on the list. The list can be found in Appendix A.

Line level
This level of detail means that the energy consumption can be traced to specific machine lines within the factory. A line is a series of interconnected machines that performs a part of a process. It can also be the case that one process is performed by several similar or identical lines. In other words, a line is a subset of a process. Measuring on this level enables benchmarking between lines and it also facilitates troubleshooting.

Machine level
Measuring down to machine level indicates that it is possible to see how much energy a specific machine consumes. This is the highest level of detail. Implemented site-wide, it requires a substantial number of meters, but it also enables a complete and detailed view of the energy consumption.

4.6.2 Level of detail in the building

The energy consumption connected to the building (as opposed to production and transport) includes the necessary processes that ensure a comfortable working environment. The building processes that were listed in the second questionnaire were:

- Ventilation
- Lighting
- Heating
- Water

As aforementioned, the first questionnaire was completed with an additional, smaller questionnaire to clarify one part. The clarification that was done was regarding the levels of detail in the building. In the first questionnaire, the same levels of detail as in production were used (factory level, process level, line level, machine level). However, it was later deemed that it induced a risk of getting results that were hard to interpret. For example, what does it mean to measure lighting on machine level? For the building part, other more suitable levels of detail were created, and a small second questionnaire was sent out. All the questions in the smaller questionnaire can be seen in Appendix B. Below, the levels of detail are described briefly, and a visual presentation can be found in Figure 6.

Site level
At this level of detail, it is only possible to obtain energy data for the site as a whole, e.g. by looking at the invoice. Large overhead trends can be found but the lack of detail restricts the analysis. Note that this level is equal to Factory level on the production side, but the more clear word *site* is used here to avoid the ambiguity from the first questionnaire.

Building level
This level indicates that the energy consumption can be traced to a specific building. It enables for example comparison between different buildings.

Sector level
When it comes to energy consumed in the building, this is the highest level of detail. In our definition, a sector is a smaller part of a building, e.g. a room. For the Heating process, sector was specified to correspond to a boiler room, since it is more relevant.

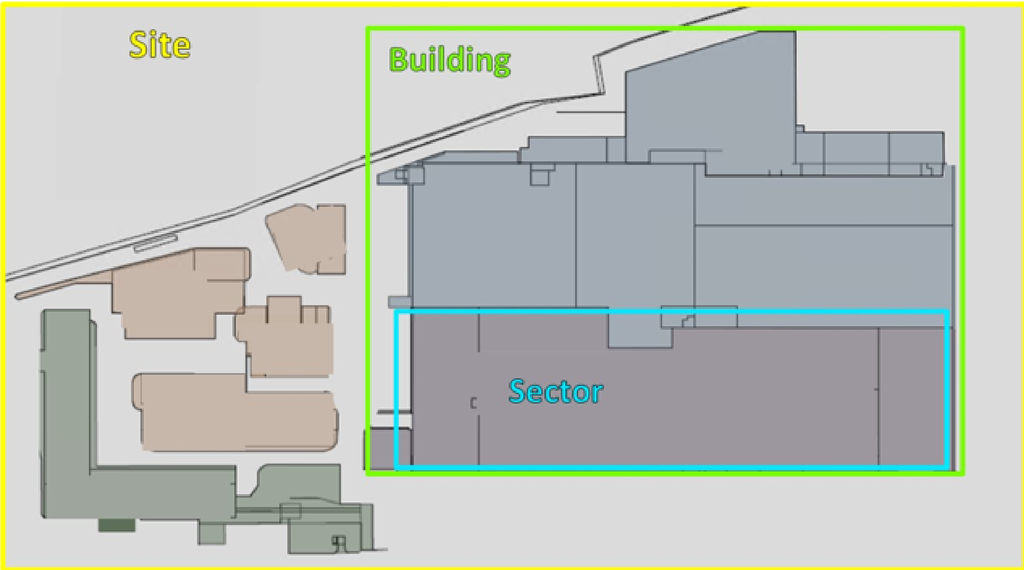

Figure 6: Schematic presentation of the division for the level of detail on the building side. Adapted by the authors.

5 Gap analysis

*Mainly, this chapter aims to give an answer to the research question about overview of the **current situation**. It begins with the results from the questionnaire, which is the basis for the gap analysis. Firstly, the different software that were used at the factories are studied. The subsequent sections concerns the level of satisfaction with the different software, missing features from the software, how the reporting is carried out and the extent of work for the energy mangers at the different sites. The next question that was investigated was whether the respondents prefer an off-the-shelf software solution, which corresponds to the research question under **system features**, "Are off-the shelf solutions desirable?". After that, there is a section about energy performance indicators, where the findings are the result of both the questionnaire and the meetings with the reference group. This section aims to answer the research question concerning **methodology and mapping**, "What kind of energy performance indicators should be used to map energy performance/consumption?".*

This part of the thesis aims to answer to the following research question: *What is the current situation at the IKEA Industry sites, as of energy monitoring and ways of working? Is there a gap between the present and the desirable position?.* The results presented in this section are based on the first questionnaire.

5.1 Energy monitoring software

One of the main purposes with the questionnaire was to map which different software that were used at the sites. From our initial interviews with knowledgeable IKEA Industry employees, it became clear that platforms from Wonderware and Siemens should be represented as alternatives to the question "*What kind of energy monitoring software do you use?*". As can be seen in Figure 7, the other alternatives were "Other" and "None" . If the respondent chose the latter category, they were asked to specify which software that was (see Table 7).

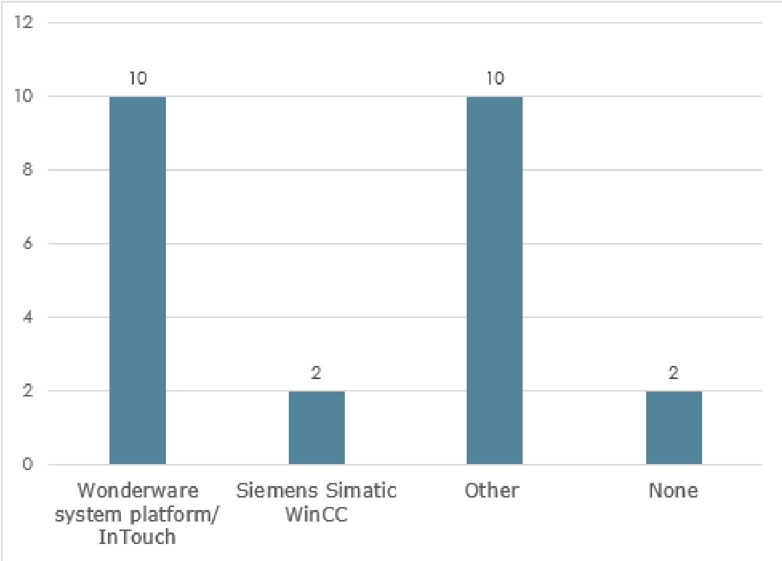

Figure 7: Names and amounts of energy monitoring systems installed at the sites.

In Figure 7, Wonderware system platform/InTouch and Siemens Simatic WinCC are presented separately from other software that are clustered together in the "Other" column. The sum of the factories that answered that they did not have an EnMS installed are presented in column named "None". The number of respondents that chose the respective alternative are on the y-axis. One can clearly see that there is an equal amount of factories that have Wonderware installed and that have other, local solution software. As mentioned before, Wonderware has been recommended to the factories previously, and that is probably one reason why it is the by far most common software. The software included in the "Other" category are listed in Table 7 below. The sites that use Siemens Simatic WinCC are Malacky Flatline and Kazlu Ruda Boards. A complete list of the answers to the questionnaire regarding energy monitoring software can be found in Appendix C.

Table 7: The names of the software that are other than Wonderware and Siemens Simatic

Software	Site
Controlweb	Jasna
Powergest	Lure
Energy Analytix by Iconics	Malacky
SEDMAX	Novgorod
Ecro.net	Orla
Gemos	Resko
LUMEL	Stepnica (Ivar)
VisionX9 scada system by Provicon Ltd	Sopron
Alpha Center	Tikhvin
Omron CX Supervisor	Älmhult

With local solution software, we mean software that has been purchased and/or installed by a local provider. The software itself usually originates from the same country as the site is located in. For example, SEDMAX is a Russian produced software which was purchased for and used at the Novgorod Boards site in Russia.

There are some interesting differences between the divisions when it comes to which software they use. The results from the same question as before, but displayed per division, can be seen in Figure 8 below.

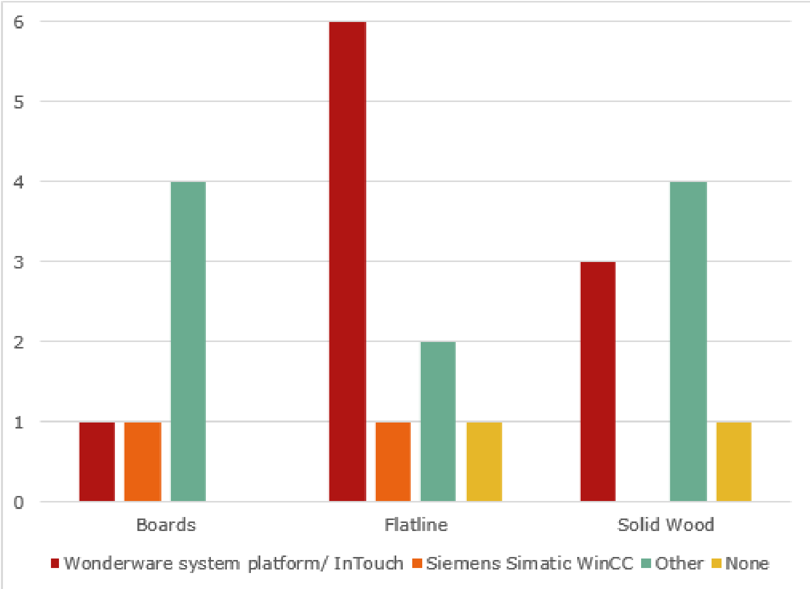

Figure 8: The type and amount of software used presented for each division.

Figure 8 shows the distribution of the different software types throughout the three divisions. Wonderware system platform/InTouch and Siemens Simatic WinCC are presented separately from other software that are clustered together in the "Other" column (green). Factories that answered that they did not have an EnMS installed are presented here in the yellow column "None".

Division Solid Wood and Boards seem to have installed mostly local software solutions. Flatline on the other hand, has the largest part of Wonderware installations at their sites. Two sites, Hultsfred from Flatline division and Chociwel from Solid Wood division have answered that they do not have an EnMS installed. Solid Wood division has no Siemens Simatic software installed. A large share of the Boards sites have installed local software solutions. It can also be seen that all of Boards division sites have an EnMS installed.

5.2 Satisfaction level with the Energy Monitoring Software

In the questionnaire, the respondents were asked to rate their level of satisfaction with the software on a scale between "Very satisfied" to "Absolutely not satisfied". As can be seen in Figure 9, the most common answer is "Satisfied" (36%) followed by "Neutral" (32%) and "Not satisfied" (23%). The answers on the outer range of the scale are far less common - the share of 5% for both "Absolutely not satisfied" and "Very satisfied" only represents one respondent each. Note that the two sites that answered that they do not have an energy monitoring software at all, Hultsfred from division Flatline and Chociwel from division Solid Wood, are excluded from the graph as they cannot express level of satisfaction with something they do not have.

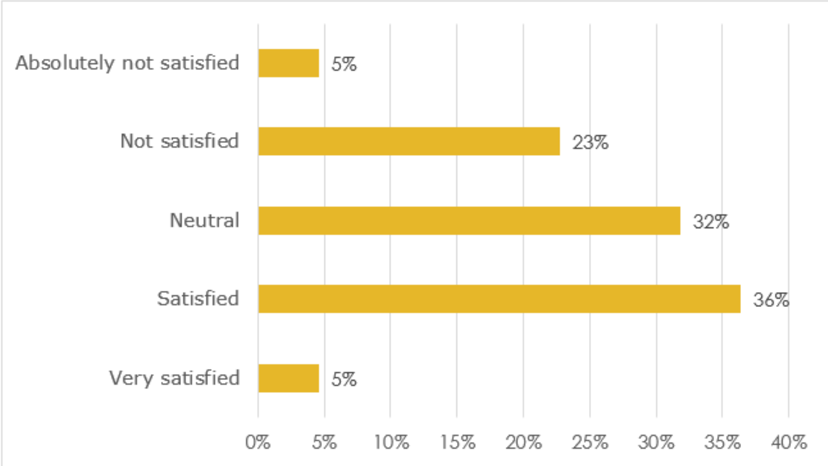

Figure 9: Overall level of satisfaction with the energy monitoring software.

Figure 10 below shows the answers from the questionnaire regarding satisfaction level, coupled to software. Note that there are only two sites that uses Siemens, while the two other categories have ten users each. As can be seen in Figure 10, the Wonderware users have answered that they are neutral or not satisfied, and to a smaller extent satisfied or very satisfied. Observe that Wonderware is a platform that can have different functions and designs which could differ from site to site. The Siemens users are either neutral or not satisfied. 70% of the sites that use other software have answered that they are satisfied with it. However, it should be noted that the satisfaction level is something subjective, and that the results cannot be translated to actual functioning of the software.

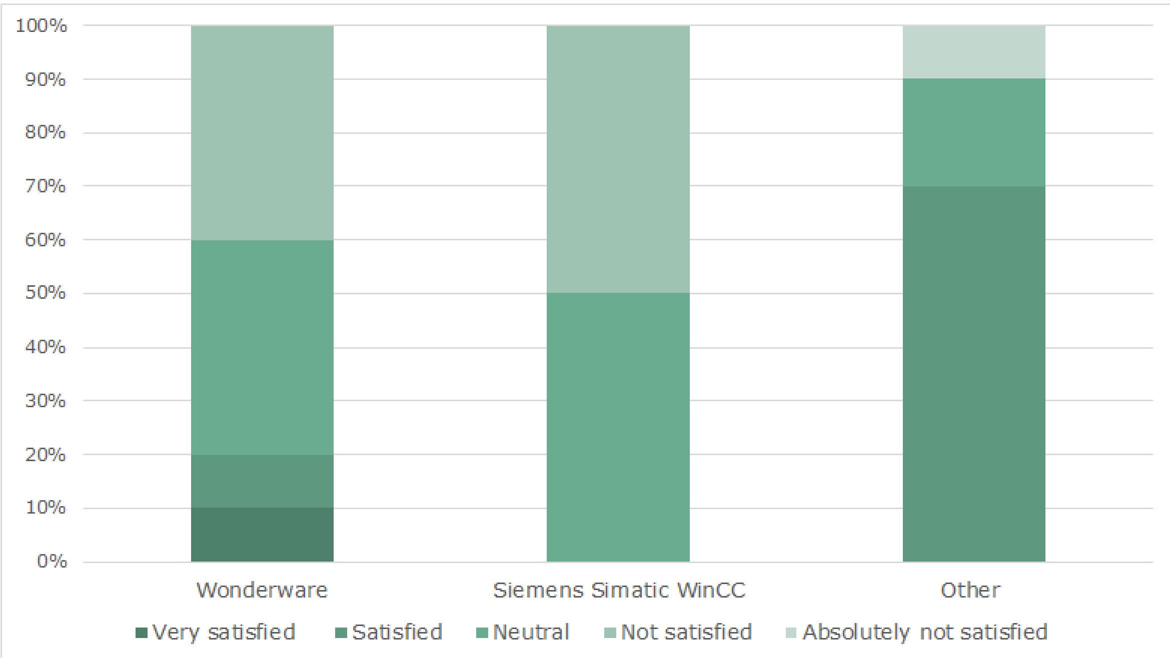

Figure 10: Showing the level of satisfaction per software used, from Very satisfied to Absolutely not satisfied.

The respondents do not see their EnMS in relation to other sites and therefore it is hard to draw any conclusions from the aggregated result. For example, the Wonderware system in Wielbark made a very good impression on us, as it has many useful features presented in a user friendly way. The system is described in more detail in chapter 7.3 *Wielbark*. Still, Wielbark responded in the questionnaire that they are not satisfied with their system. We have also noted a tendency of a protective attitude among the sites with smaller, locally developed software. They are proud of and used to their software and do not want to be forced to change. This might be a reason why the respondents in the “Other software” category are more prone to answer that they are satisfied.

5.3 What is missing from the EnMS?

The question *“What is missing/what could be better regarding the energy monitoring system?”* aims to point out important features that are missing from the EnMS in place. An overview of the answers is presented below. What the energy managers expressed was missing was:

- More user-friendly interface
- More features for producing automatic reports
- Better visualisation of the process
- Water monitoring
- Flexibility allowing local set-up solutions
- Automatic collection of data
- Alarms and organising of alarms
- EnPIs for specific areas, machines, production etc.
- Clearly defined reporting areas
- Better division of measurement areas
- Central definitions of what should be included in the EnMS
- Connection to cost and price of electricity
- Active/reactive energy output
- Alarms that are sent to selected staff
- Access for maintenance technicians
- Maximum/minimum borders for the energy diagrams
- Adjustable begin and end of the day for analysis purposes
- Deeper detail level

The responses vary a lot, which can depend on the fact that the sites have different EnMS with different maturity levels. Some answers, such as user-friendly interface, a reporting feature and good visualisation were often mentioned. This is an indication that the visual part and the reporting function have to be improved. Suggestions about such improvements are presented in chapter 8 *Visualisation and content* and chapter 9.3 *Reporting*.

Other answers point out that there is a need for the system to be flexible and clearly defined.

The users require more freedom regarding connection of measurement points, presentation of data and choice of time intervals. A general conclusion is that there is a need for guidelines about what should be included it the EnMS which can help organising the work at the sites. This problem can be solved by consulting the energy managers and writing an EnMS standard.

The respondents of the questionnaire have expressed a need for a standard that includes everything that is needed for the sites to know about installing an energy monitoring system, the features that should be included and the description of the desired output of the system. Therefore, some have answered that they have chosen to wait for guidelines from IKEA Industry's management for organising, installing and performing actions with an EnMS .

5.4 Reporting tools

Reports are used both for internal and external purposes. In chapter 2.2.1 *Energy management*, it is stated that the energy manager should produce energy reports that are to be sent to the unit/division management. These reports can also be used internally, for decision making processes and energy issues.

One of the questions that was included in the questionnaire is the following: *"Are the reports created automatically or manually? By manually we mean, for example, that you copy the data and paste it in excel and produce diagrams yourselves."*

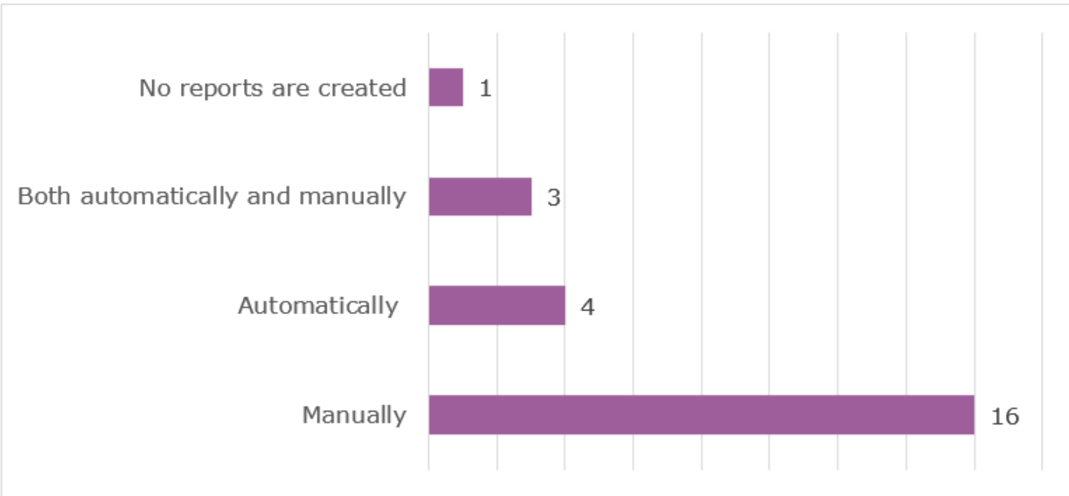

Figure 11: Method of report production at the sites.

As seen in Figure 11, most of the reports are created manually, which means that the data have to be extracted from the historian database and then inserted to Excel or a similar report-generating software to produce charts and diagrams. Some have answered that their reports are produced both automatically and manually. The site in Trnava (division Flatline), has answered that they do not use any reporting software which, in our opinion can be assumed that there was a misunderstanding of the question.

With automatically produced reports we mean that a predefined report can be created with the click of a button, without the need to manually move data from the historian. One software that can produce such reports is QlikView (see Figure 12). The majority of the questionnaire respondents that answered that they use Excel also answered that they conduct manual reports. However, some chose to answer “automatically” in the questionnaire in combination with answering that they use Excel, which does not correspond with the description we provided when we expressed the question. An explanation to why the respondents answered in this way is that they have pre-produced, standard formulas, tables and figures that produce output when the user pastes input data to Excel, which they consider to be a type of automatically produced report.

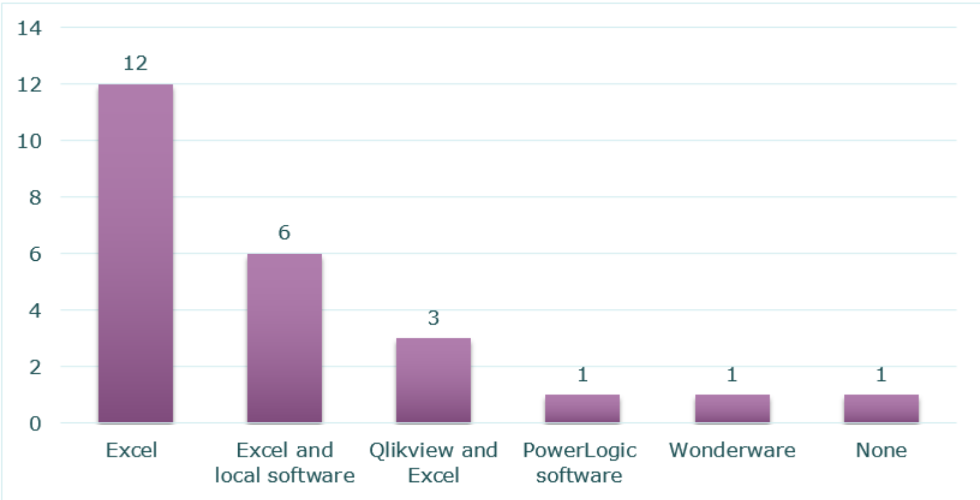

Figure 12: Number of sites that use a specific software for reporting.

As mentioned above, Excel and QlikView are software that can produce reports in the form of diagrams, figures and tables. Excel dominates IKEA Industry as a reporting tool and as seen in Figure 12, it is even used together with other reporting software. One site uses only PowerLogic for reporting and one other site uses Wonderware’s reporting function. The question that arises is why there is a need for more than one reporting software.

5.5 Energy managers

As mentioned in chapter 2.2.2 *The role of energy managers*, there should be an appointed energy manager at every site. Depending on the size of the site, the employment should be at least part-time. As can be seen in Figure 13 below, the majority of the respondents of the questionnaire have an energy manager employment of less than 25%. In other words, of the 24 energy managers that answered at the questionnaire, 14 have an employment corresponding to less than 25%. Only two people are working as full-time energy managers.

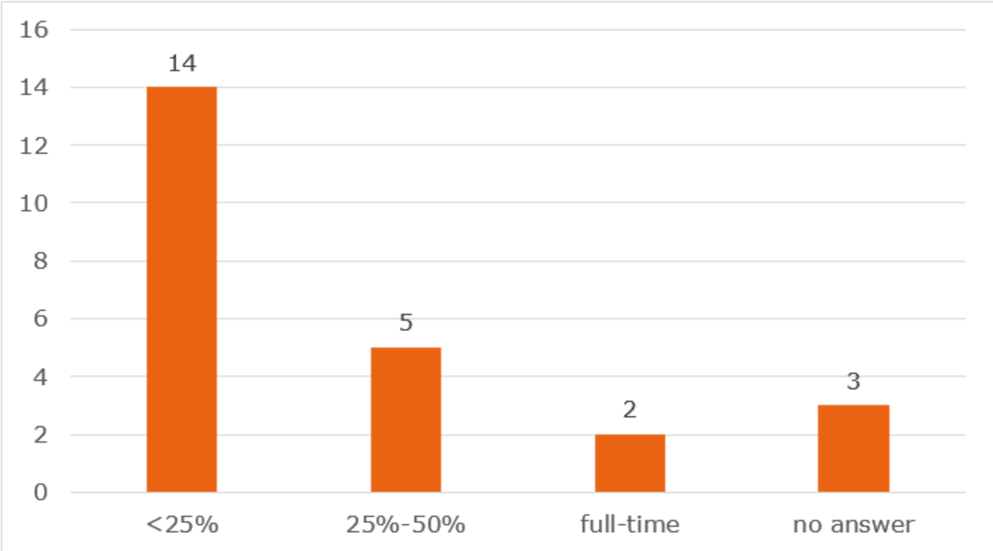

Figure 13: The extent of work of the employees in their role as energy managers.

The two sites that have full-time energy manager posts are Novgorod (Boards) and Tikhvin (Solid Wood) which can be compared with the size of the sites (see Table 8). Both Novgorod and Tikhvin are the largest sites in their division, regarding energy usage (GWh). Lubawa, which is one of the largest Flatline sites, has not appointed an energy manager yet. Instead, until an energy manager is assigned, the responsibility is accredited to an employee without the title energy manager.

In general, what can be seen in Table 8 is that the larger the size of the site, the higher the extent of energy manager employment. That these two factors go together seems reasonable, as there is more energy work to be done at a larger site. In contrast, Hultsfred and Orla from division Boards, together with Wielbark and Goleniow from division Solid Wood seem to have appointed energy managers with a less than 25% employment in their role. Since Hultsfred and Orla (Boards) are sites with high energy consumption, the role of the energy manager should be expanded.

Table 8: Factories that have answered the questionnaire and their respective size in terms of energy consumption in GWh in 2015. Source for the site size: e-mail from Glenn Karlsson (2018). The third column shows the sites' questionnaire answers regarding employment of the energy manager and is based on the answers from the questionnaire.

Division Boards	**Size (GWh)**	**Employment**
Novgorod	275.7	100%
Hultsfred	271.8	<25%
Orla	265.5	<25%
Kazlu Ruda	202.3	25%-50%
Lure	167.2	<25%
Malacky	137.3	N/A
Division Flatline		
Zbaszynek	174.8	25%-50%
Lubawa	72.5	N/A
Pacos de Ferreira	43.0	25%-50%
Danville	34.1	N/A
Älmhult	30.7	25%-50%
Nantong	15.1	<25%
Malacky	12.5	<25%
Hultsfred	9.9	<25%
Sopron	-	<25%
Trnava	-	<25%
Division Solid Wood		
Tikhvin	142.9	100%
Wielbark	95.6	<25%
Goleniow	47.7	<25%
Jasna	38.1	25%-50%
Konstantynow	21.	<25%
Stepnica (Ivar)	13.3	<25%
Chociwel	-	<25%
Resko	-	<25%

5.6 Off-the-shelf solutions

One of the research questions that we aim to answer regarding system features is "Are off-the-shelf solutions desirable?". According to BusinessDictionary (2018) the term off-the-shelf can be explained as:

> "Commercially available specialized software designed for specific applications [...] that can be used with little or no modification."

The question that was sent to the sites was the following: *"Would you prefer developing your own energy monitoring system or buying a system off-the-shelf?"*. The respondents of the questionnaire gave a variety of answers (all the answers are presented in Appendix C, Figure 35), but the general outcome was that the sites prefer developing their own system, or if an off-the-shelf system is to be purchased then it should be adjusted to fit the site's needs. Moreover, a common desire expressed in the questionnaire was to develop a system that can be used at all the sites and that has the same structure, but with small adjustments to the local configurations.

An advantage with buying an off-the-shelf system is that, as one respondent put it, “we would not need to develop the wheel again”. It could also result in a homogenised way of working with energy issues and facilitate identification of deviations and strong cooperation between the sites.

Disadvantages with off-the-shelf systems could be: hard to define what the features and functions of the off-the-shelf system should be, difficulty when producing a system that fits the needs of all sites and divisions, low flexibility when the site expands or changes in some significant way and limiting when the energy work is evolving and becoming more detailed.

5.6.1 Whole package energy solutions

Besides off-the-shelf solutions, the possibility of employing a company that takes over the energy work has been discussed many times during interviews with both energy managers and employees at the Malmö office.

Companies that provide whole package solutions have been a point of discussion within IKEA Industry and at the sites. The term whole package solutions expresses here that the company is responsible for identifying areas of interest regarding possible energy savings. Furthermore, they are responsible for installing meters and sensors that they connect to either a software that they provide or the software that is already installed at the site. The next step is calibrating the equipment and analysing the data. After the analysis, a list of recommendations should be created, as to what kind of energy actions that should be made to move towards more efficient energy use and energy savings. Some of the companies are also responsible for the implementation of the solutions and the follow up analysis of the energy actions.

The question about whether it is a good solution to hire an external company for taking care of energy efficiency became even more relevant when the Malacky Flatline site hired a consultancy company called ENGIE for a three month test period of their services (ENGIE Group, 2018). This pilot project was divided in three stages where twenty measuring points were installed at each stage. In this case, it was the sites’ employees that were responsible for deciding where be the measuring points would be placed.

According to ENGIE Group (2018) the project started in November 2017 and was ended in January 2018. The services that they provided are among other: the setting of operation parameters, a preliminary understanding of the crude data, set-up of the database, energy efficiency evaluation, monthly reporting and optimisation potentials. Some of the conclusions from the analysis of the data showed, according to ENGIE, that there are large variations in production during the week, the use of compressors and ventilation system needs a controlling system and there are significant issues regarding high temperatures in the working halls.

For further information about the ENGIE pilot project we recommend the report “Energy management at the Flatline production plant in Malacky, Slovakia Final report” written by ENGIE services, a.s., Bratislava January - March 2018 for IKEA Industry Malacky Flatline. The report contains the analysis and suggestions based on the energy data.

5.7 Energy Performance Indicators

Energy performance indicators are used by all IKEA Industry sites. The most commonly used EnPI today at the sites are kWh/m^2 for division Flatline and Solid Wood and kWh/m^3 for division Boards. Other EnPIs such as kW/month, EUR/kWh, kWh/ton (Solid Wood) are also being used locally, for internal analysis.

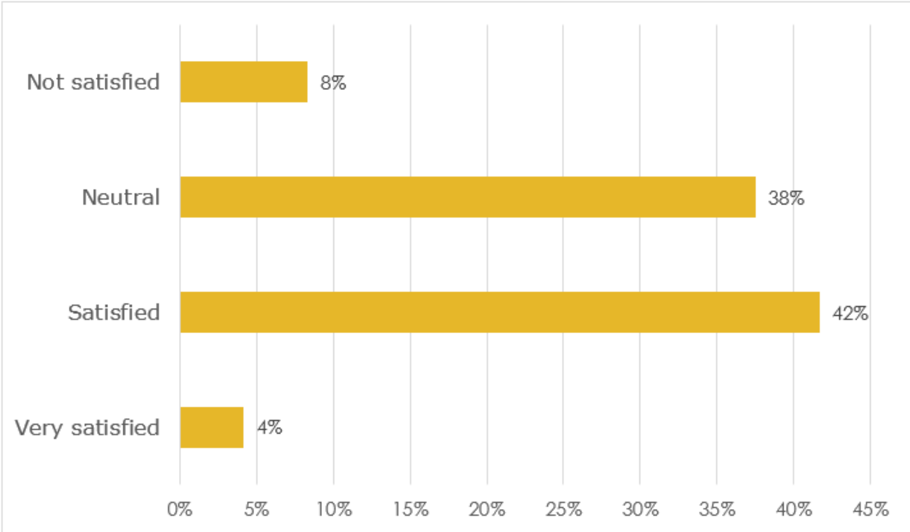

Figure 14: Satisfaction level coupled to the EnPIs that are used today.

When asked in the questionnaire about how satisfied the energy managers were with the EnPIs that are used today, 42% answered that they are satisfied. A slightly smaller percent answered that they are neutral towards the EnPIs. Surprisingly, only 8% answered that they are not satisfied. This does not correspond to the picture we got during our visits and meetings with some of the energy managers. Most of those we spoke to expressed the opinion that the kWh/m^2 and kWh/m^3 do not reflect reality in a good way. For example, by increasing production, you obtain a lower value which gives the impression that the energy use have been more efficient. This can be misleading.

There has to be a distinction between increasing efficiency and making energy savings actions. When the production increases you only increase efficiency, which is also a good way of utilising energy. However, if an energy saving action is implemented and production is lower than usual for various unrelated issues, then the EnPI will show an unfair result. This could result in situations were energy efficiency investments are hard to justify.

In Table 9, there is a list of EnPIs that we recommend should be used and be included to the output of the EnMS. The list is a result from the discussions during the reference group meetings. It is important to mention that the reference group stressed that there should be a standard (document) produced with these recommendations so that the definition of the EnPI becomes clear. The two first EnPIs are already used within IKEA Industry and the rest are recommendations that we have for the sites.

Table 9: EnPIs that are recommended for use for all divisions.

EPI	**Short description**
Total kWh	Total kWh for the whole site obtained by e.g. the invoice
kWh/m^2 or kWh/m^3	Same EnPI that is used today. Good for indicating efficiency and well established
kWh/process	See pyramid structure
kWh/specific line	See pyramid structure
kWh/ready goods	Future goal
kWh of total idle time	A way of identifying unnecessary energy losses due to idle run
kWh$_{idle}$/kWh	Indicator of energy use efficiency
kWh/m^3 for compressed air	Energy efficiency indicator coupled to the production of compressed air
Percentage of leakages in the compressed air use	Indicator of energy losses

The total kWh is an easily acquired and commonly used EnPI. It provides an insight to the trends of the overall energy usage, but not much more than that. The broadly used (within IKEA Industry) kWh/m^2 and kWh/m^3 are good indicators of efficiency but as said before, they are sensitive to fluctuations of production and can hide or exaggerate important effects.

kWh/process is a new proposed EnPI that can be coupled to the pyramid structure (see chapter 6.2 *Energy measuring methodology: the Pyramid* and Figure 22). This will provide the energy managers with a good indication about each process and can be used for identifying peaks in energy consumption above a certain pre-set normal level for each specific process. Moreover, the EnPI can help compare factories with similar processes with each other.

Complementary to this, the EnPI kWh/line can in the same way help monitoring the energy consumption of specific lines. Note that here there is a need for deeper measurements to be able to obtain this EnPI.

A future goal is to be able produce an output of kWh/ready goods. This is a hard EnPI to obtain because there is a need for a mature and well integrated energy monitoring system where there are clear connections between the MES and the process. There has been an attempt to connect production to energy consumption by division Flatline in Sopron Hungary (see chapter 7.2 *Sopron*).

Idle time is the time during which the machine is on but does not produce any products. It is purely wasted energy and therefore there is a need to try decrease it. The kWh$_{idle}$/kWh EnPI can be used to indicate efficiency of the process. It is the amount of kWh that are used during idle time per total kWh use. A small number would indicate a good result and a large number would indicate a need to take actions and look deeper to the reason of the poor result.

For the kWh of total idle time as well as for the kWh$_{idle}$/kWh to be useful and fair as EnPIs, there is a need to clearly define what idle time is. For example, some machines have a long start up time that makes it hard to shut them completely down without affecting production. Also, during service some machines need to be run even thought they do not produce and products. Therefore there should be a clear definition about what idle time is and what type of idle time is registered.

Compressed air is an important energy carrier that is used for numerous applications such as pneumatic devices and clean-blowing of dust and particles. Compressed air systems have an efficiency about 10%-15% (The Institute for Industrial Productivity, 2018) which means that there is a lot of electricity put in for a small amount of useful compressed air. For that reason there is a need to minimise losses in the system and identify leakages. Two EnPIs can be introduced for that cause: kWh/m^3 compressed air and percentage of leakages in the compressed air use. Note that there should be a common base for the comparison of m^3, for example a standard temperature and pressure so that it would be possible to compare the EnPI between different sites.

6 Measuring methodology

In this chapter, the level of detail regarding measuring at the sites is presented in the form of matrices, which stem from answers from the questionnaire. The work on level of detail then culminates in chapter 6.2 Energy measuring methodology: the Pyramid, where an approach to measuring the consumption is described.

6.1 Matrices regarding level of detail

Understanding at which level the sites measure their energy is an important part of the gap analysis. The question stated in the questionnaire was *"Down to which level do you measure energy?"*. The respondents could choose from three levels regarding energy that is used for the building and four levels regarding the production. For further explanation of the different levels see chapter 4.6 *Level of detail of measurements*. Concerning the process, they could choose "Not relevant" (N/R) since the types of processes vary from site to site. The processes that were included in the questionnaire were chip and dust extraction, compressors, compressed air use, kiln drying, lacquering, pumps and process heating. The respondents could also add processes that they found relevant, however that is not presented here. The expression N/A stands for "No Answer" and represents the questions that we got no answer to for various reasons.

For building, we chose the following four areas: ventilation, heating, lighting and water usage. The respondents could choose between answering site, building, sector and boiler room. The boiler room choice was coupled only to the heating category.

There is an explanatory figure for the matrices shown in Figure 15, one for building and one for process. Both start with the lowest level of detail at the top and end with the highest level of detail. The darker the colour the deeper the corresponding level of detail.

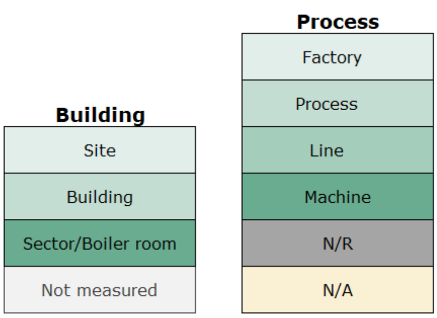

Figure 15: Explanatory Figure for the matrices.

The results for the process are going to be presented per division, with the production part first followed by the building part. The percentages that are presented below are further explained in Appendix D.

Division Boards

Figure 16 shows the result from the questionnaire regarding level of detail in the production in division Boards. The most common level of detail is the process level of detail which dominates with 53% in comparison with the other levels. Compared to the other divisions, this result stands out. However, it is not surprising since division Boards has a constant production process and they strive to differentiate between the processes. There is also a relatively low level of detail at some sites which can be seen at the amount of fade green, factory level answers (37%). Lacquering is not a Boards process but was included in the questionnaire because of the need for compatibility of the questionnaire with the other two divisions.

Site	Chip and dust extraction	Compressors	Compressed air use	Kiln drying	Lacquering	Pumps	Process heating
Hultsfred	Factory	Factory	Factory	N/R	N/R	Factory	Factory
Kazlu Ruda	Process	Machine	Process	Process	N/R	N/R	Process
Lure	Process	Factory	Factory	Process	N/R	Process	Factory
Malacky	Process	Process	Process	Factory	N/R	Factory	Process
Novgorod	Line	Machine	Line	Line	N/R	Process	Process
Orla	Process	Process	Process	Factory	N/R	N/R	N/A

Figure 16: Matrix presenting the level of measuring detail per site and process for division Boards.

The results from division Boards concerning the building processes can be seen below in Figure 17. 46% of the answers were that they measured down to site level, which is the lowest level of detail. It can clearly be seen that water usage and heating is measured on a lower level of detail than the other two processes. It is noteworthy that if lighting is measured at all, it is measured on either the highest or the second highest level of detail.

Site name	Ventilation	Heating	Lighting	Water usage
Hultsfred	Not measured	Site	Not measured	Building
Kazlu Ruda	Building	Site	Building	Site
Malacky	Not measured	Boiler room	Sector	Site
Orla	Sector	Site	Sector	Site

Figure 17: Matrix presenting the level of measuring detail per site and building process for division Boards.

Division Flatline

As can be seen in Figure 18 below, there is a large variation between the processes regarding the level of detail for division Flatline. Most of the sites seem to measure down to line level (38%), followed by process level (28%) and factory level (26%). Measuring per line is most common when it comes to lacquering and chip and dust extraction. Only 9% of the measurements are made on machine level, and in those cases it is within chip and dust extraction and compressors within sites Danville and Zbaszynek. Observe that 29% answered that some of the processes are not relevant for their site, as seen in the last four columns.

Kiln drying is a process that is not relevant for Flatline, as the raw material is chip boards that already are dry. The fact that Paços de Ferreira answered that they measure kiln drying on line level is probably an error.

Site	Chip and dust extraction	Compressors	Compressed air use	Kiln drying	Lacquering	Pumps	Process heating
Danville	Machine	Machine	Process	N/A	Process	N/A	Process
Hultsfred Flatline	Process	Process	Process	N/R	N/R	N/R	N/R
Lubawa	Process	Factory	Factory	N/R	Process	N/R	Factory
Malacky Flatline	Line	Line	N/A	N/R	N/R	N/R	N/R
Nantong	Line	Process	Factory	N/R	N/R	Factory	Line
Paços de Ferreira	Line	Factory	Factory	Line	Line	Factory	Factory
Sopron	Process	Process	Process	N/R	Line	Factory	Factory
Trnava	Line	Line	Line	N/R	Line	N/R	Process
Zbaszynek	Machine	Machine	Line	N/R	Line	N/R	N/R
Älmhult	Line	Line	Line	N/R	Line	N/R	Factory

Figure 18: Matrix presenting the level of measuring detail per site and process for division Flatline.

Moving on to building measurements, in Figure 19 below one can see that Flatline shows results that are overall almost evenly distributed between sector, building and site level of detail. Some patterns are distinguishable and noteworthy. Water usage is, as within division Boards, measured on site level to a high extent. Water usage and heating are measured at all sites. Site Zbaszynek stands out as they measure on the highest level of detail in three of the four building processes, all except water usage. It is interesting that there are quite large differences between the sites when it comes to ventilation and lighting - both the highest level of detail (sector) and not measuring it at all are common. A high variation of levels of detail makes comparison and benchmarking between sites difficult.

Site name	Ventilation	Heating	Lighting	Water usage
Danville	Building	Building	Building	Site
Hultsfred	Site	Site	Site	Site
Lubawa	**Not measured**	Boiler room	**Not measured**	Site
Malacky	**Not measured**	Building	**Not measured**	Building
Nantong	Site	Site	Site	Sector
Paços de Ferreira	Sector	Building	Sector	Building
Sopron	Sector	Building	Sector	Building
Trnava	Sector	Site	**Not measured**	Site
Zbaszynek	Sector	Boiler room	Sector	Site
Älmhult	**Not measured**	Building	Sector	Sector

Figure 19: Matrix presenting the level of measuring detail per site and building process for division Flatline.

Division Solid Wood

As seen from the matrix in figure 20, there is a high level of measurement detail regarding chip and dust extraction and compressors. Generally, Solid Wood shows a more detailed measurement level than the other two divisions but what that depends on is hard to pinpoint. A whole 29% of the answers are on machine level and 34% are on process level. However, there is also a higher share of N/A (no answer) which should be weighed in the result since it can affect the outcome. Some of the Solid Wood sites such as Chociwel and Stepnica, are sawmills and do not have a furniture factory, which makes some of the processes irrelevant to them.

Site	Chip and dust extraction	Compressors	Compressed air use	Kiln drying	Lacquering	Pumps	Process heating
Chociwel	N/A	N/A	N/A	Process	N/R	N/A	N/R
Goleniow	Machine	Machine	Process	Process	Line	Process	Machine
Jasna	Machine	Machine	Factory	Factory	Line	Line	Factory
Konstantynow	Process	Machine	Machine	N/R	Line	Line	Machine
Resko	Factory	Factory	Factory	Factory	N/R	N/R	N/R
Stepnica (Ivar)	Machine	Machine	N/A	Machine	N/R	N/R	N/A
Tikhvin	Process	Process	Process	Line	Line	Process	Process
Wielbark	Process	Machine	Factory	Process	Process	N/R	Process

Figure 20: Matrix presenting the level of measuring detail per site and process for division Solid Wood.

Division Solid Wood shows an evenly distributed level of detail between site, building and sector when it comes to level of detail in the building processes. See Figure 21 below. It can be observed that the water usage is measured on a overall higher level of detail than in the other divisions. This can be explained by the fact that water usage is important to the processes within Solid Wood. They use water to keep the moisture in the solid wood on such a level so that the wood does not crack. Observe that there is a large amount of answers “Not measured”. Again, there is a trend that the sawmill sites are overrepresented here. This can partly be explained with many of their operations being carried out outdoors, and therefore indoor measurements are not prioritised. Note that site Wielbark show a high level of detail compared to the other sites. The EnMS in Wielbark is studied in more detail in 7.3 *Wielbark*.

Site name	Ventilation	Heating	Lighting	Water usage
Chociwel	Not measured	Not measured	Not measured	Building
Jasna	Not measured	Site	Not measured	Site
Konstantynów	Sector	Site	Site	Building
Stepnica (Ivar)	Not measured	Boiler room	Not measured	Sector
Tikhvin	Building	Building	Building	Building
Wielbark	Sector	Boiler room	Building	Sector

Figure 21: Matrix presenting the level of measuring detail per site and building process for division Solid Wood.

The results from the matrices show some trends but it is hard to draw any specific conclusion about the current situation. The single most obvious conclusion is therefore that there is a large variation between the sites regarding level of detail of measurements. The variety of the answers can depend on the age of the factories, as it can be harder to connect new measuring points in old factories but easier for new ones. Also, it can depend on the type of processes a site includes; if there are large, energy intensive processes then they are going to be prioritized instead of, for example, monitoring the electricity consumed by the lighting of the building. Nonetheless, all sites should strive to increase the level of measuring detail so that the EnMS can be used to its full capacity.

6.2 Energy measuring methodology: the Pyramid

The pyramid in Figure 22 below is a tool for helping out with the energy work and can be used for all three divisions and all factories. The conceptual idea of using a pyramid for dividing different areas is to be credited to Janusz Nojman. We have used this idea and developed it. Based on the results from both questionnaires and after numerous meetings with different people at IKEA Industry as well as a long analysis of the material we have produced this pyramid.

So, what is this pyramid? It is a way of presenting what the measuring hierarchy could look like and can be used during decision making process. It is a part of the answer to the research question "In what way should the sites within IKEA Industry measure, monitor and analyse energy data?". The pyramid is divided into different levels of detail. The further down to the base of the pyramid you move, the higher the detail of measurements. The orange arrow is connected to the building part and the green arrow to the production part.

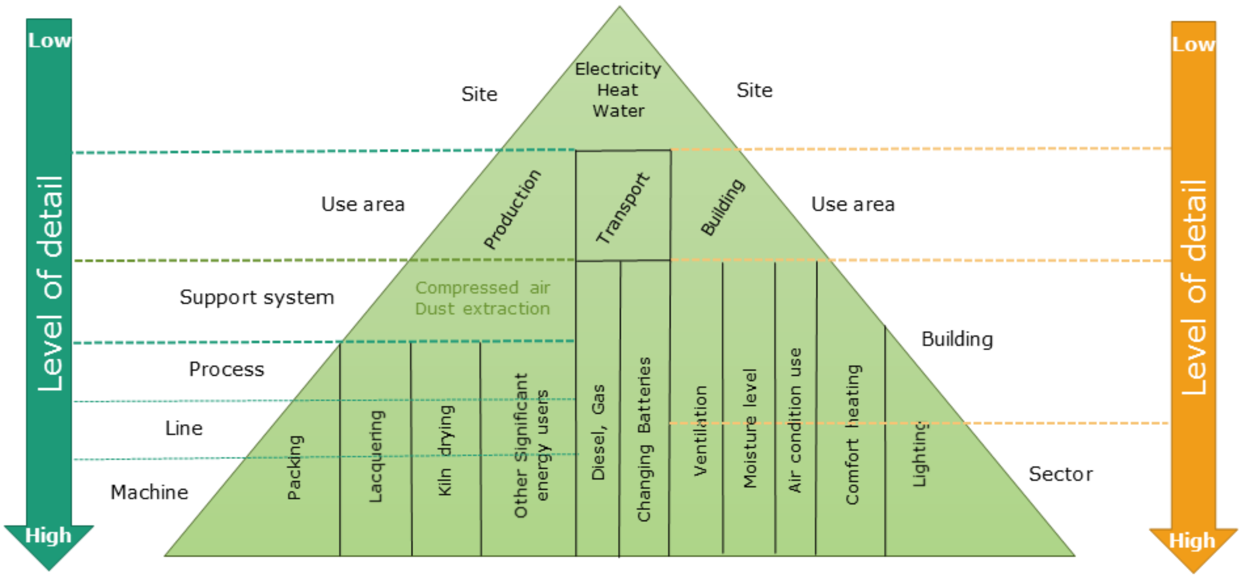

Figure 22: The pyramid: Visualisation of the measuring hierarchy.

One of the most important takeaways from the pyramid is that it is highly recommended to start from the top (lowest level of detail) and then work your way to the bottom (highest level of detail). Again, we want to stress the importance of analysing the measured energy data in order for it to be useful. It is better to measure on a lower level of detail and actually creating actions out of the data, then to have many meters but no time to analyse and follow up on the data that is logged.

As mentioned, the lowest level of detail is at the top of the pyramid. Note here that we have deviated from the first questionnaire where the lowest level was called factory level. We understood that the correct term should be *site* rather than *factory* since a site can include a number of factories. Factory within IKEA Industry is just a name representing a certain function; for example, at the *site* Wielbark, there is a glue board *factory* as well as a furniture *factory*.

Level two of the pyramid can be used as a tool for dividing according to three use areas: production, transport and building, according to the EU directive on energy efficiency (see chapter 2.4.2 *Energy audits and savings estimations*). Although dividing on this level does not provide any concrete instructions on how the meters should be placed practically, it contributes to a clear and simple way of structuring the EnMS.

Under the use area level named production there is a so-called support system level, which includes compressed air and dust extraction systems (in green colours). These two systems are not processes by themselves and are not a part of the production per se, but rather two enabling systems that exist parallel to the process, therefore we have created a level dedicated to them. Both systems have significant possibilities of energy savings.

The last three levels called process, line and machine levels are used to express detail for the processes existing in the production. These last three levels have been used in questionnaire 1 (see chapter 4.6 *Level of detail of measurements*). Each process should be measured and monitored. Since there are three divisions and processes vary from site to site, the processes presented here are only examples and more parts can be added to become more compatible to the division and site that the pyramid is going to be used for. Going deeper into each process, each line should be connected to the EnMS. Lastly, the highest level of detail is achieved when each machine or some machines are measured and monitored.

Following the orange arrow that is connected to the building aspect of the pyramid, one can see that there are not as many levels of detail as for production. The structure of this side of the pyramid was based on questionnaire 2. Note that site level and use area level are the same for both sides of the pyramid. The deviation begins under the use area level, where we have a so-called building level. A building in this case is one whole structure, separated from the outside with walls. A sector is inside a building but has a specific purpose (e.g it could be a glue board factory). The moisture level and air condition use were added at the final stages of the pyramid analysis (which means that they where not part of neither questionnaire).

Transports are not included in this thesis due to the fact that they are less interesting from en EnMS perspective, but nonetheless, they are mentioned here. This is an active choice we made due to the fact that the pyramid focuses on how to allocate energy use, and transports are a (sometimes large) part of the energy use at the sites.

During our meetings, it was expressed that there was a general desire for a written standard regarding measuring methodology that focuses not only in organising how they should measure energy, but also in the more technical issues such as what kind of meters and sensors that should be used.

7 Case studies

The four case studies in this chapter aim to cover the research question about ***methodology and mapping*** *"Are there practices at our units that should be highlighted and spread?". The EnMS at the four sites are analysed with focus on software, visualisation and features. Some examples of how the EnMS is utilised for energy work purposes are also included.*

It is important to emphasise that the four case studies that are presented below are only a small sample comparing to the thirty sites that exist in total within IKEA. There could be as many versions of EnMS as there are sites, but due to time limitations we focus on Paços de Ferreira (Portugal), Sopron (Hungary), Wielbark (Poland) and Älmhult (Sweden). These four sites were mainly chosen based on recommendations from our supervisor Glenn Karlsson.

7.1 Paços de Ferreira

Paços de Ferreira is an IKEA Industry site situated in northern Portugal, not far from Porto. It belongs to division Flatline and produces mainly kitchen fronts. The site employs 1500 people and is divided into two factories, Pigment factory and Board on frames factory, that share supporting systems such as compressed air distribution and dust extraction (Karlsson and Nojman, 2017*b*). At the site, important steps toward a sustainable energy system have been taken, including installing a large solar panel park on the roof of the building.

Also, every morning an email is automatically sent out to all managers with a PDF containing different KPIs. The email is produced by visualisation software QlikView, that collects the necessary data from a Wonderware system. However, most of the KPIs are not connected to energy use, as the file also consists of follow up on budget and other financial issues.[4]

The EnPIs in the daily email are electricity in kWh/production day and kWh/m^2, per respective factory located in Paços de Ferreira. There are green and red dots that indicate whether the current status is on par with budget or not. This may not seem overly advanced, but daily updates on energy performance can be good way of ensuring that energy issues always are thought of.

As mentioned before, the site has Wonderware installed, but they do not feel that it is adapted to their needs when it comes to functions and user-friendliness, at least not regarding the energy monitoring. Therefore, during a trial period of three months in the spring of 2018, they have tried the Microsoft data analysis software Power BI. A Portuguese consultancy firm (Ewen) has helped with the implementation. Power BI is an business analysis tool that can be used to visualise energy data. As it stems from the business management world, it focuses a lot on the cost of electricity - but lowering the amount on the electricity invoice can be a driving force as good as any when it comes to energy efficiency.

[4]Pacheco, N., Energy Manager IKEA Industry Paços de Ferreira. (11th April 2018)

Features of the Power BI system in Paços de Ferreira include:

- Division of the consumption per e.g. lighting, compressors, filters and machines (it could be argued that the term "machines" is a bit too wide to be useful). Visualised in a pie chart.
- Summary of the contents of the electricity invoices. This includes how much energy that has been consumed during certain periods of the day, as the market price of electricity varies with the hours.
- The division of the invoice - how much of the invoice that is taxes or penalty fees etc.
- Visualisation of consumption of reactive energy compared to active energy
- Benchmarking tools that can be used for follow up on energy efficiency goals
- kWh/m^2 per line, and plotted against the production in order to see whether the value is unusually high
- List of faulty meters that are not transmitting any data
- Consumption profiles - see Figure 23 and more detailed description below.

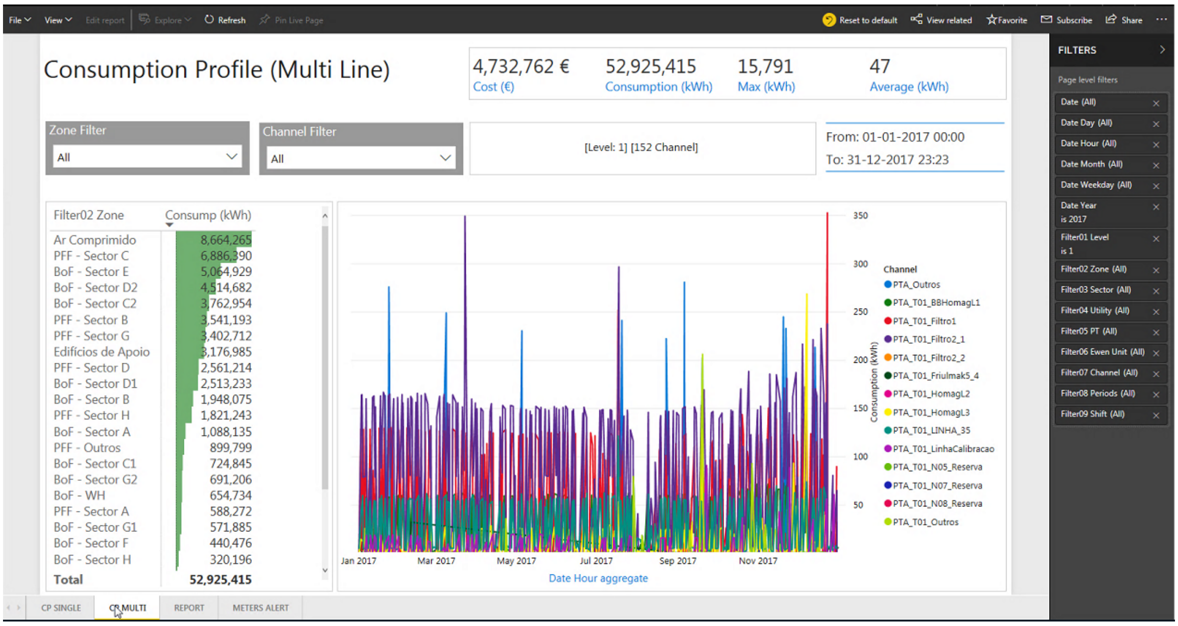

Figure 23: The energy consumption of several different lines in kWh, plotted against time in months. (Screenshot from Power BI, site Paços de Ferreira).

In the Power BI window in the screenshot in Figure 23 above, it is possible to plot several different consumption patterns in the same graph. Different combination of machine lines can be chosen by altering the filter settings ("Zone filter" and "Channel filter" to the upper left, or in the list of applied filters to the far right). The graphs can be used to for example compare the consumption between two lines that have the same equipment and therefore should have approximately the same consumption. The zones can also be compared to each other - for example, if one zone consumes more compressed air than the others, energy saving actions (such as detecting and stopping leakages) can be directed to that zone. It is a bit unclear what the meaning of *zone* is in this case, but we assume that it is similar to *sector* that we have used previously as measuring level when it comes to building.

Note that Paços de Ferreira in the questionnaire answered that the energy monitoring software that they use is Wonderware , but as can been seen in this case study, they are looking for other alternatives. It is unclear what will happen after the trial period has ended, but Power BI gives the impression of being user-friendly and easy to work with. It is possibly an interesting alternative to QlikView.

The integration of solar panels is another interesting aspect of the energy monitoring in Paços de Ferreira. Thus far, the supplier of the solar panels are managing them under warranty, and the supplier's own software is therefore used for the monitoring of the electricity production. In the future, it could be an advantage to monitor that data in the same software as the consumption data.

7.2 Sopron

Sopron is a Flatline site located in north-western Hungary. It has around 500 co-workers and has been delivering furniture for IKEA Industry since 2008 (Karlsson and Nojman, 2017*c*). They produce approximately 1500 different products, mostly kitchen fronts and shelf fronts. The energy monitoring software at the Sopron site is called Vision X9 and is developed by local, Hungarian company Provicon Ltd. Sopron is one example of a site that would be rather unwilling to change monitoring system to for example Wonderware. They are very happy with their software that they believe is well adapted to their needs. In any case, they have recently finished an interesting project regarding tracking idle time.

In the project, energy data from the EnMS Vision X9 and production data from the MES are merged and displayed in QlikView. The data, which is logged in ten minute intervals, can thereby be used to detect whenever energy is consumed without pieces being produced. In that case, the energy consumption is deemed unnecessary and marked red in the output (see Figure 24 below).

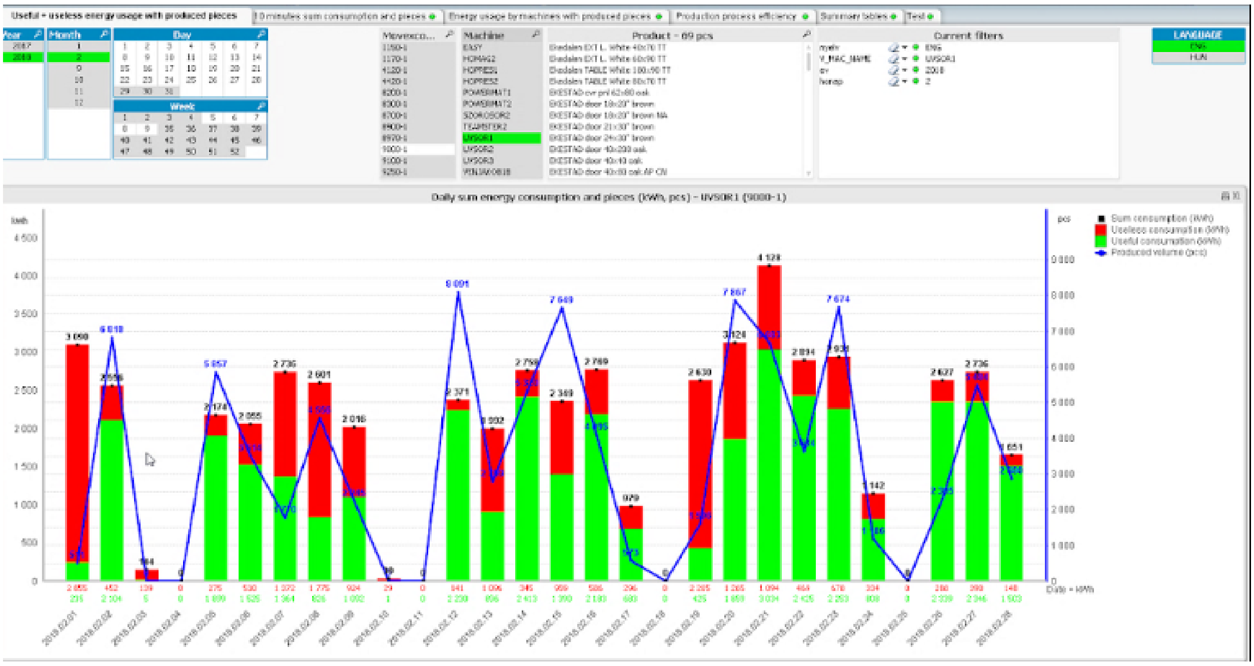

Figure 24: Visualisation of useful (green) and unnecessary (red) energy consumption in Sopron. The dark blue line shows the number of pieces produced. (Screenshot from QlikView, site Sopron).

In Figure 24, the bars represent the energy consumption and the dark blue line represents the number of pieces produced, both plotted against time which is on the x-axis. The green part of the bars show the useful consumption, i.e. energy consumption that has occurred while the production has been running. The unnecessary (red) part of the energy consumption shows possibilities to save energy. Note however that energy consumption marked as green is not necessarily efficient. Green classification only means that pieces were produced when energy was consumed. It does not provide further information about the flow of product through the process. Nonetheless, this is a good start towards developing a method of connecting production and production/idle time.

One bar represents one day, and a clear weekly pattern can be seen where the production is smaller on Saturdays and off on Sundays. With this particular machine, the operators seem to be good at turning it off on Sundays, as there is no unnecessary consumption during those days. However, some of the other days have a rather large share of unnecessary consumption. In QlikView, it is possible to show the data per day or per hour instead so that it is easier to examine when and why the energy consumption occur. Analysing the data on that level requires time. The technical manager in Sopron is currently also the appointed energy manager, and the working time spent as energy manager is less than 25 %. He expressed in the questionnaire that unfortunately, the energy team has limited resources to analyse the energy data. It could be a good idea to do a follow-up on actual energy saving actions that have been implemented because of data collected from the QlikView project. As emphasised before, the mere collection of energy data does not lead to an increase in energy efficiency.

7.3 Wielbark

Wielbark is a Solid Wood site in north-eastern Poland that is unique as it has both sawmill, glue board production and furniture factory in one site. It also has a pellet factory that creates value from the by-products. The Wielbark site opened in 2006 and has grown to employ around 1800 workers (IKEA Home, 2018*b*). The authors visited Wielbark on March 14th 2018 and were given a tour of the production site and an overview of the EnMS. Wielbark's EnMS is built in Wonderware and the design was made by an external IT consultancy company. Complementary systems are also used, such as the compressor manufacturer's own software for monitoring the compressors. The focus for the case study, however, is the Wonderware system. Its features include visualisation of:

- Overview of the site
- Active energy consumption
- Energy consumption per sector in the factory (daily, monthly and yearly)
- Overview of the transformators and their respective values of ampere (A), kilovar (kvar) and watt (W), and the possibility to view the values in a chart
- Average power consumption with 15 minutes interval
- Alarm when the power factor is outside a given threshold
- Energy price table - in Poland, the electricity price is different depending on the time of the day. There are three different time slots and the table in the EnMS shows the electricity consumed in the respective slots and the corresponding cost.

- Table of how often the consumed power is above the contracted power. This is something that should be avoided as everytime this happens, a penalty fee is issued from the distribution company.
- Water usage report

In the overview, the site is depicted from above and divided into sectors, see Figure 25 below.

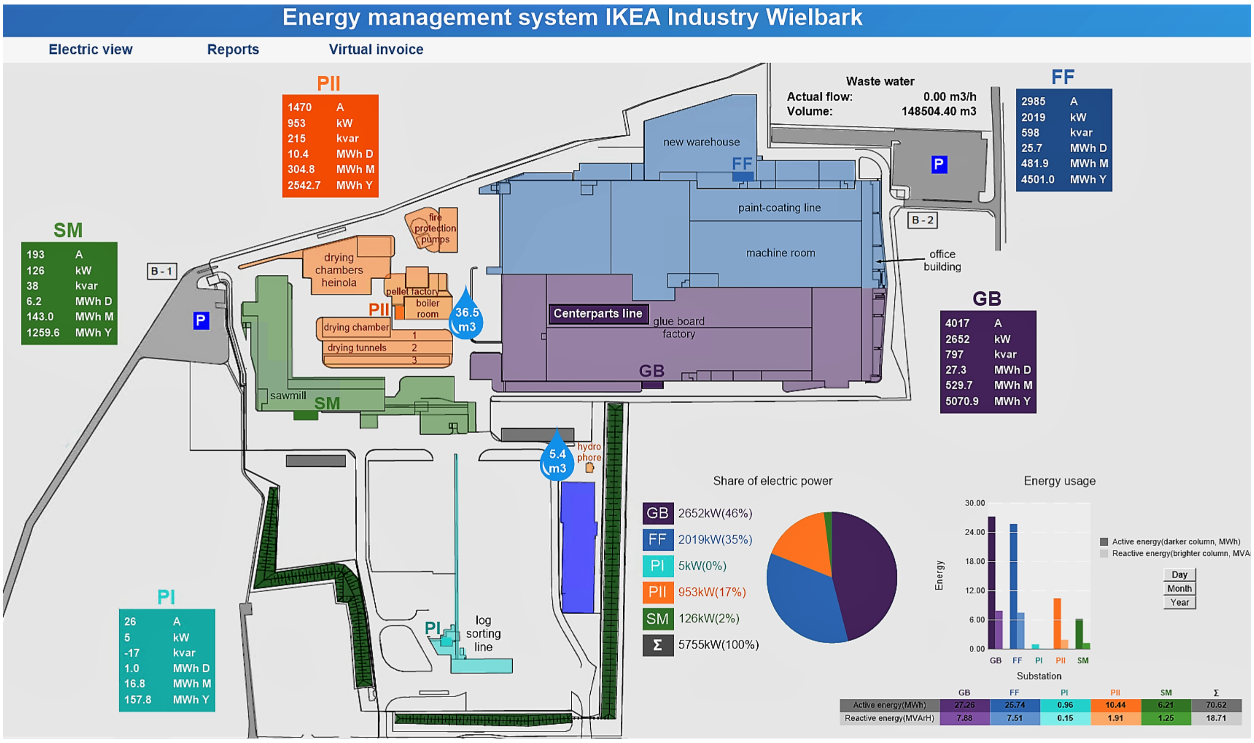

Figure 25: Overview of the site in Wielbark in the EnMS. (Screenshot taken from Wielbark's EnMS).

The first sector of the site is PI, where the incoming logs are sorted according to size. The logs are then cut in the sawmill (SM) and dried in PII. GB stands for glueboard factory, where the cut pieces are pressed together to form boards. The last part, FF, is the furniture factory. As can be seen in the pie chart in Figure 25, at the time of the screenshot, the largest share of electrical power can be attributed to the glueboard factory followed by the furniture factory. For each sector, the real-time current, power and reactive power can be seen, as well as the electrical consumption in MWh for a day, a month or a year.

If one wishes to get more detail, the historical data per meter can also be displayed, as in Figure 26. Here, the consumption can be seen both as a total of energy in MWh and of price in PLN (Polish Zloty), and as a graph of the variations over time.

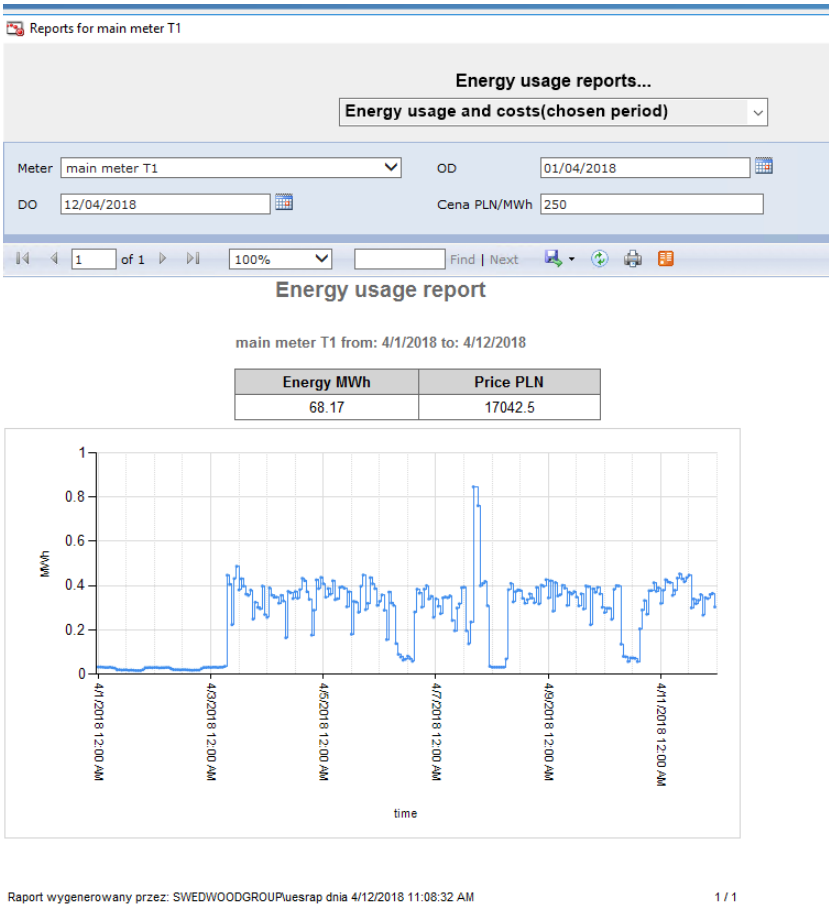

Figure 26: Energy consumption per counter, for any given period of time. (Screenshot from the EnMS in Wielbark).

An interesting function of the system is the tagging. When there is a peak in energy consumption in one of the stations, a tag is created, which can later on be controlled and analysed. In this way, it is easier to control and follow anomalies in the process. The tags are stored in Wonderware historian. When required for analysis, the tags can be extracted from the historian to Excel with a custum-made Excel function.

The energy monitoring system in Wielbark has been used for 2 years during which the data have been saved in the historian. Reports can be produced with daily, monthly and yearly data. Energy cost is well presented in the system. What is lacking is perhaps the ability to produce prognosis in both energy use and purchase. Also, visualisation of KPIs such as kWh/m^2 could be useful. In the questionnaire, the energy manager in Wielbark expressed a wish to have everything in one place, i.e. not having additional software and not having to export data to Excel to conduct analysis. It should be possible but it is not the case today.

7.4 Älmhult

Älmhult is a Flatline factory situated in Småland, Sweden. There are 260 employees and the end products are kitchen furniture. During our two study visits to the site, we got to see a monitoring system that was built from scratch from the energy manager (employment of 25%-50% in this role) Waine Franzen, who also is the infrastructure manager of the site. The current monitoring system that is used is a visualisation of the process programmed by the energy manager in the Omron CX-Supervisor software. A decision has been made to switch to Wonderware system platform in the near future.

According to the homepage Omron Industrial Automation (2018), the software by itself does not provide any control of the process, it only helps to produce a user friendly HMI that visualises machines and whatever distinct data the user programs it to include (see Figure 27). It takes a lot of work and time to program such visualisation processes since each part has to first be programmed and then the measurement data has to be inserted. Another drawback with this kind of system is that there is no way of visualising energy flows, since each part of the system is independent from other parts. This makes it impossible to follow energy through the process and see how the different processes affect each other. Another essential point is the structural capital aspect. This system is build by one person and that person is the only one who can use it and understand its composition. However, an advantage of this system is that it is flexible because more parts can always be programmed and changed.

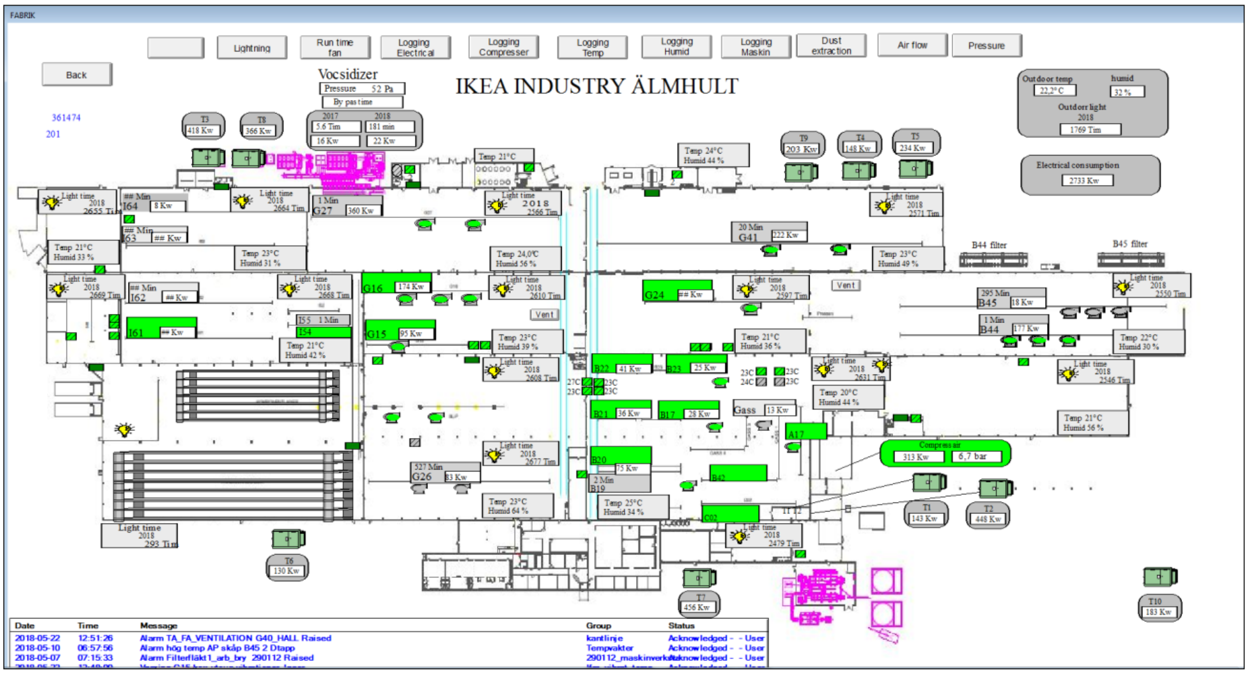

Figure 27: The visualisation of the site presented by the monitoring system. (Screenshot taken by Waine Franzen, CX-Supervisor, site Älmhult)

Figure 27 shows an overview of the factory. A lot of different data is displayed among others temperature, humidity, power, pressure etc. One can also see the transformers, the green cabinets and their location in the factory. The total electrical consumption is showed on the top right part of the figure.

The output is real-time based data. Historical values that are saved in a historian database but are deleted after 1 year due to that the data is not requested or used by others than the energy manager.

Features

Some of the features that are included in the energy monitoring system that is currently used are presented here.

There is a large number of alarms and warnings programmed in the system. Alarms are pre-specified and reflect specific issues that have to be resolved. Alarms are not saved in a database at the moment but are logged on the screen, see the lower part of Figure 27. Warnings are colour coded and blink with their respective colour when a value is above or below a specific value that has been set by the energy manager. Something that we thought was missing is an indication of how long the warning has been appearing on the screen. We would also recommend that to clearly prioritise alarms and warnings, a function that is presently missing. This could help during troubleshooting. Alarms can be seen as more acute problems and have to be manually clicked as resolved to disappear from the screen. The warnings can disappear when the value is back to its normal level.

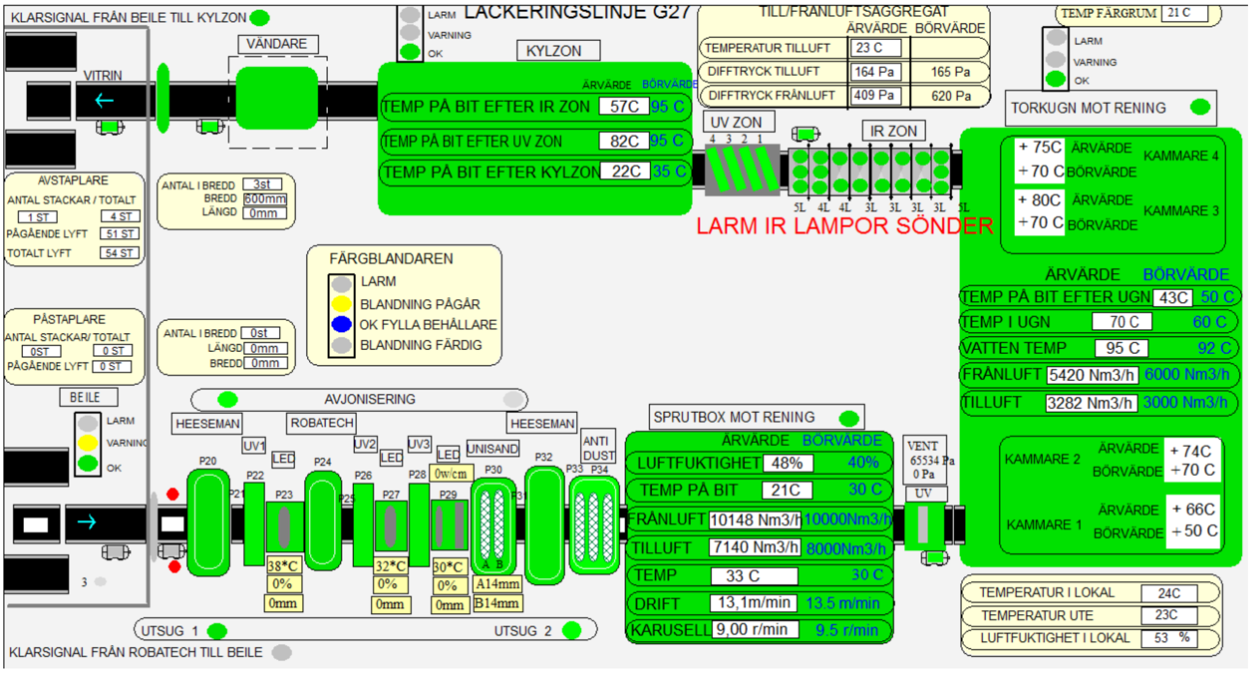

Figure 28: The visualisation of a specific alarm on a lacquering line presented by the monitoring system. (Screenshot taken by Waine Franzen, CX-Supervisor, site Älmhult)

An example is presented in Figure 28. Here, there is an alarm in red colour: “LARM IR LAMPOR SÖNDER” which is translated as “Alarm IR lamps are broken”.

Additional real example: This system contains an alarm that blinks red and is registered on the screen when the air-moisture value is below 30%. As stated by the energy manager[5], this kind of alarm visualisation have helped to identify problems faster and easier. Before this system was in place, a red lamp was the only indication of process or machine needing attention and it could be easily go undetected in the busy factory floor. This is an easy and

[5]Franzen,W., Energy Manager and Infrastructure manager IKEA Industry. Interview (30th January and 14th May 2018)

effective way of detecting abnormalities.

Another useful feature of this system is the visualisation of the chip and dust extraction. There is an indication showing when a filter is being cleaned by flashing the word "cleaning" next to the filter that is currently being cleaned, circled in Figure 29. There is another alarm, currently not active, that is displayed when the differential pressure is above a certain level. This can indicate leakage and that a certain filter needs maintenance or changing. This helps closing the gap between the factory floor and the office environment.

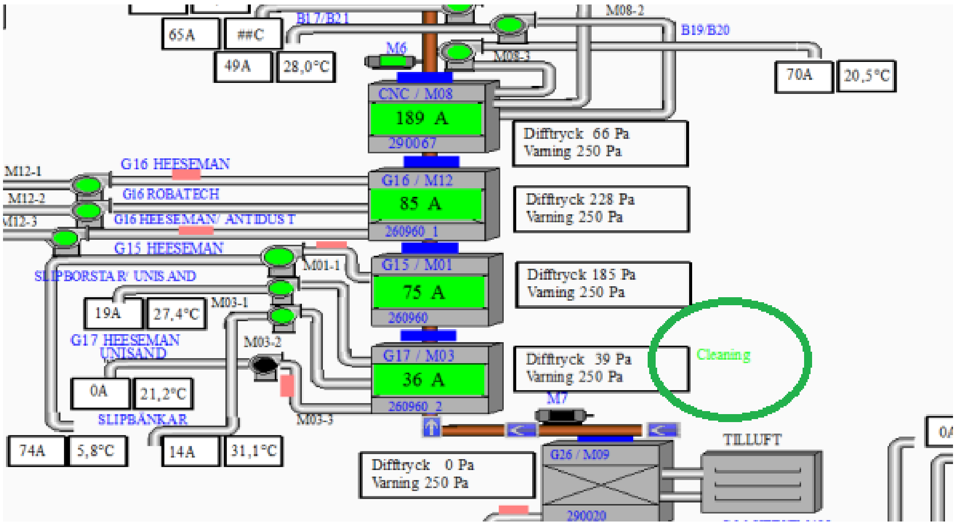

Figure 29: The visualisation of a Cleaning operation presented by the monitoring system. (Screenshot taken by Waine Franzen, CX-Supervisor, site Älmhult)

Pictures of machines and lines can be inserted in this system. When the schematic picture of a machine is clicked on the system, the respective real picture taken at the factory can also be seen.

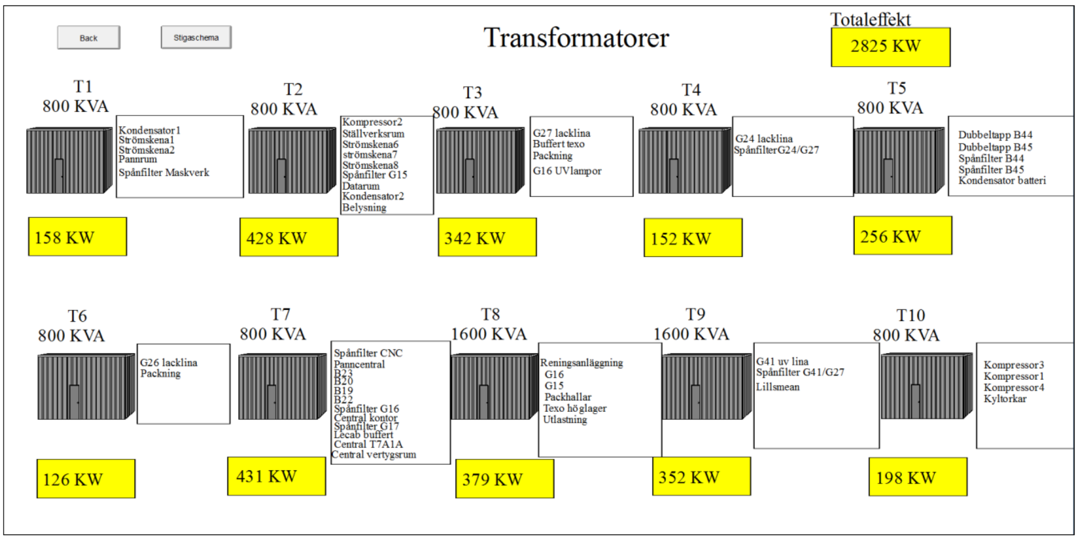

Figure 30: The visualisation of the transformers and the connections presented by the monitoring system. (Screenshot taken by Waine Franzen, CX-Supervisor, site Älmhult)

Beside each transformer there is a list of the machines that are connected to it (see Figure 30). This is an easy and organised way of understanding how everything is connected in the site and makes it easy for new employees to use the system.

Energy work

An interesting and practical use of the monitoring system in Älmhult is the visualisation and data collection of the lighting use for the building. As seen in Figure 27, light bulbs placed in the site map show the total amount of hours that the light was on during the year 2018. The hours when the lights have been on are counted for and a cost was coupled to that use. This smart calculation, with data provided by the monitoring system, has helped the energy manager to identify unnecessary use of lighting and correcting these deviation by turning the lights off during non operational times. It has also made it easier to calculate the savings of this action. The same method could be used for efficiency purposes on individual processes or machines.

Reporting

At present, there is no tool for report creation thus everything is produced manually in Excel. A request of a reporting tool has been stated in the Energy Audit conducted by Karlsson and Nojman (2017*d*), referring to the need for reports for individual lines, ventilation and compressed air that can be produced for different time intervals could help with the energy work. Today, the analysis is done by looking at the data from the monitoring system without being able to perform deeper analysis without exporting the data to Excel.

8 Visualisation and content

*The aim of this chapter is to answer the research question about **system features**, "What features should be included in an energy monitoring software regarding visualisation and other functions?". A figure is used as a visual tool for the presentation of the suggestion combined with explanatory text. This chapter includes recommendations that are based on the input from the reference group, questionnaire answers, the study visits and interviews regarding the four case studies.*

A picture is worth a thousand words. A good visualisation of data makes management of data easier. Key points are communicated in short and clear way and after a while, the user of the EnMS is going to be able to identify issues and handle them a lot faster. The closer the visual output can come to the human way of thinking, the more easy it will become to understand and learn to use the system. Moreover, a clear, logical structure and visualisation can increase accessibility for new users.

The following recommendations are the result of our analysis of the reference group interviews, the study visits, the four case studies and the answers of the questionnaire in part 5.3 *What is missing from the EnMS?*.

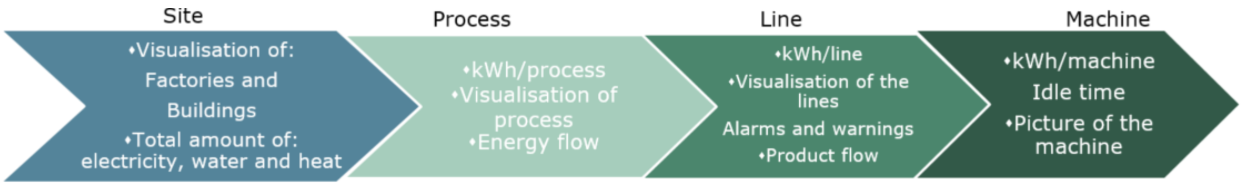

Figure 31: General suggestion for visualisation in EnMS.

Our recommendation about how the visualisation of the EnMS should look like is presented in Figure 31. It is similar to the pyramid structure (chapter 6.2 *Energy measuring methodology: the Pyramid*). One could divide visualisation in four categories: Site, processes, lines and machines.

Beginning with the first picture, the site should be presented in the starting screen of the EnMS. It should include an overview of the site, with all the factories and buildings illustrated and their areas clearly defined. Total electricity, heat and water use can also be presented here, perhaps as numerical values with a deviation from normal levels displayed at the side. For example, a numerical value of the electricity use is shown in kWh and next to it one can see that there is a 2% deviation from the normal levels. It can be challenging to define the normal energy and water use levels, but if chosen correctly, it will become possible to present an indication of the overall performance of the site.

Moving on to the next category, the process visualisation. Here, all the processes of the site can be presented as a whole, continuous process with energy flows clearly presented in relevant places. Compressed air, chip and dust extraction should also be included here. The user should be able to click on specific processes and get an even more detailed structure with more data connected to that specific process. Naturally, the EnPI kWh/process (which was a discussion point at the reference group meetings) can be presented here as well.

The next category is line visualisation (see Figure 31). Correct visualisation of all the lines and their energy and product flows is crucial. The user can click from the process category to a specific line or lines. There should be a function that allows multiple selection of lines (the same applies for the other categories) so that they can be seen side by side. Alarms, warnings and other operations that influence production should be clearly visualised (e.g. colour coding). The EnPI kWh/line should be shown in big numbers and, if possible with an indication regarding its performance with pre-set levels. It should be possible to see if the line produces any products and preferably show the number of products that go through it. Reject product should be also registered (manually or automatically). This EnPI can also be used for comparing similar lines to each other, at the same site but also at different sites.

Machine visualisation is the last category and the most detailed regarding measuring level. kWh/machine should be presented for each machine, with the exception perhaps of machines that have significantly low energy use. Note that this level requires a mature and well structured EnMS. Idle time for each machine should also be presented here and it can be coupled to production flow. A picture of the machine could also be included.

Hopefully, given these categories and their features, the visualisation of the EnMS can become easier to construct for the IKEA Industry sites. It is important to stress that this is only a suggestion of visualisation and that the employees of the sites should choose the points that they consider to be helpful for their energy work. Furthermore, our recommendation is to start at the top, with coarse information in the beginning and then build and expand the EnMS moving to higher detail. This recommendation could be used as a template when trying to set goals concerning the EnMS.

9 Output and Features

In this chapter, the aim is to describe what should happen with the output form the EnMS. Depending on their working position, different people want different things from the energy data that is collected. This is what we aim to describe in the first part of the chapter called User stories. In the subsequent section, important features when it comes to alarms and information sharing are discussed. Lastly, reports and the way they are handled are studied. Here, we return to the questionnaire and list what the respondents answered on the question "What are the reports used for?"

9.1 User stories

User stories are an informal way for expressing which features one desires from a software (Mountain Goat Software, 2018). They are not intended to be an absolute truth, but rather a starting point for discussion. By identifying users of the EnMS the output can be designed so that it is relevant for their everyday tasks. The results that are presented below is based on two meetings with the reference group.

There are several different ways of formulating the template, the one that was used in the discussions with the reference group can be seen below.

"As a <role>, I want <capability> so that <benefit>"

Identifying who is going to use the EnMS is the first step in creating user stories, then what they are going to use it for and for what purpose. The reference group answered those questions and they are the base for the following user stories. We, then decided that the users should be divided into primary and secondary users. Primary users work with the EnMS everyday and a large amount of their work depends on the output of the system. Secondary users work with the EnMS occasionally and need to use only a part of the information provided by the EnMS. This distinction between two classes of users could be used to produce different outputs depending on what need the user has of the EnMS. It can also help define a clear area of application of the system, which is lacking today.

9.1.1 Primary users

Identified primary users of the software were the energy manager and the maintenance engineer, who both benefit from working directly with the output from the EnMS.

As an energy manager...
... I want EnPI's that are not dependent on the production volume or the weather, so that I can monitor the actual energy efficiency work that has been carried out.
... I want to see when the electricity consumption is above a certain power level, so that I, after a meeting with the production manager, can shift loads in order to avoid peaks.
... I want to be able to see long-term trends visualized in an intuitive way, so that I can monitor the energy efficiency work.

... I want to see when the electricity consumption is above the ordered power, so that I can identify and tag the events, and regulate the ordered power (or report to the person responsible for that).

As a maintenance engineer...
... I want to see if the energy consumption peaks in certain lines/machines, so that I can make the decision on which part that need replacing (e.g. change filter in the dust extraction system).
... I want to be able to detect leakages in the compressed air system, so that I can fix them.
... I want to obtain the runtime of the machines, so that I can have an overlook of the process efficiency, and decide on replacements etc.

9.1.2 Secondary users

Secondary users are in this case production managers and operators of the machines, that could use the energy data for optimising the production. They do not necessary have access to the energy monitoring software, but could receive information for example on screens in the production areas.

As a production manager
... I want to be able to produce product recipes so that I can readjust parameters for an optimized process.
... I want to keep track and adjust the idle time and run-time, so that I can minimize the energy wasted when we are not producing.

As an operator...
... I want alarms that tell me when the electricity consumption is out of the statistical process control intervals so that I can regulate the process.

Note that there are other stakeholders that come in contact with the energy data at some point in the course of their work, mostly when they receive reports. However, since they do not usually come in contact with the energy monitoring software itself, they were not classified as users. These roles include sustainability manager, electrical managers, purchasers of energy and budget managers.

9.2 Alarms and information sharing

Alarms, together with warnings and informative pop-ups, are important parts of an EnMS. They indicate deviations, issues and situations that need to be attended to. Alarms represent urgent matters that need to be acknowledged and solved by the person responsible for that area. These alarms should be saved in a database and require an active input from the user of the EnMS to disappear from the screen. The input can be provided when the matter is acknowledged and solved. Alarms should also be coded to be sent to the person that is responsible for the solving of the situation that has occurred. It should be possible to resolve the issue by checking it as resolved from both the factory floor and the office environment.

Another important feature that should be included when designing an EnMS is that there should be specific outputs from the system that are presented on the factory floor, on big screens beside each line. Only relevant information about that line should be presented there, such as alarms, warnings, lunch breaks, idle time and breakdowns.

There should also be a clear prioritisation of alarms and warnings which can help organise troubleshooting. A recommendation is to connect alarms and output energy diagrams so that if a peak was created during some problematic situation where an alarm has been created, the user of the EnMS could easily be informed about it without having to look at the alarm log.

9.3 Reporting

Reports are an important tool for communication between different stakeholders, both internal and external. Today, each site uses information from their energy monitoring system to produce reports for various tasks. The respondents of the questionnaire have answered to the question *"What are the reports used for?"* and their statements are presented below. The reoccurring answers are presented at the top of the list.

The reports are used for:

- Internal reporting
- Budget calculations
- Energy network meetings
- Local energy meetings
- Investment payback calculations
- Monitoring trends, cases and issues with machines/lines
- Product calculations
- Future estimations
- Process control
- Identifying abnormalities in energy consumption
- Analysis before and after the implementation of energy measures
- Ordering electricity
- Looking for connection for new machines
- Knowledge spreading
- Control of pilot installation performance
- Annual environmental reporting

As can be seen in the list above, a primary use of the reports that are based on the output of the EnMS is for internal purposes and for budgeting. This should be taken into consideration when taking decisions about what kind of reports the EnMS should produce. A number of this reports could easily be produced by using a predefined template and connect it to the historian database of the system to avoid manual labour and produce accurate reports in a standardised way. By keeping the same template for a specific type of report, one can learn to easily identify the relevant information about the task that is planed for execution.

Colour coding can also be used to provide fast information about areas that show negative or deviating results (red), areas that show no difference (grey), areas that start to show some negative results (yellow) and areas that are doing OK or produce good results (green). This kind of communication strategy is used in Paços de Ferreira (see chapter 7.1 *Paços de Ferreira*). There is of course a need to be careful when using this kind of reports, since there has to be a clear definition about what a good and what a bad result is. Also, there has to exist a certain level of flexibility when making changes in the factory, such as adding or changing machines or updating the EnMS, so that the template and colour coding of the reports remain up to date.

Important here is that the reports are produced in English, so that everyone can understand them. It could be necessary to produces templates in the native language as well, but then it is important that it is also possible to change the language to English. The reason for taking down linguistic barriers is that knowledge and data can then be spread and communicated throughout IKEA Industry.

10 Discussion

In this chapter, the results and analysis from the preceding chapters are discussed. The discussion is divided into three sections - first, the research question regarding "In what way should the sites within IKEA Industry measure, monitor and analyse energy data?" is discussed. The second part focuses on the methods used for the thesis work, and the third section on propositions to further research. After this chapter, there is a section with concluding remarks.

10.1 How should IKEA Industry work with energy?

As with any other industry, there is a need to clearly set milestones when getting from the starting point A to the desirable outcome in point B. Clear guidelines can help the energy managers together with other employees at the sites to organise their work, set budgets and generally understand which direction they should head. Similarly, it can help the people working at the main office to follow the progress of the sites with their energy work.

A first milestone could be to identify significant energy users of the process, by perhaps installing temporary meters. Then, an Energy Monitoring System, that fits the sites needs should be purchased and installed. The next milestone could be the connection of more measuring points. One important milestone, that can be connected to the need for new standards, is the implementation of certain meter, visualisation and report criteria. The last milestone could be reaching a specific energy savings goal for that specific site. Good examples of energy actions should be shared and communicated.

10.1.1 Energy managers

Energy managers have a key role regarding energy management and energy monitoring systems. During our time at IKEA Industry, we had the opportunity to talk to a lot of dedicated people working with energy. From the results of the questionnaire, a simple conclusion can be drawn: it would be beneficial if the role of the energy manager was extended and corresponded to the size of each site.

As can be seen in Figure 13 and Table 8 in chapter 5.5 *Energy managers*, there is a large share of energy managers that have a less than 25% employment. That means that apart from being responsible for the energy work, they have other time consuming tasks such as managing maintenance or the electrical work. By increasing the role of the energy manager, one can expect a shift of focus where energy matters are prioritised at the same time as there is more time for analysis of the output of the EnMS. Furthermore, there will be more time for the energy manager to organise and take energy related actions faster. In an ideal world, there would be a full-time energy manager employee at the largest sites at least.

There is a need for further clarity and transparency regarding the role of the energy manager. An interesting finding from our visits and meetings with the energy managers is the need for a standard way of working with specific areas. Some of the sites already have an EnMS installed but have waited with carrying out measurements due to the lack of clear directions.

In other words, the goals that have to be reached should be clearly defined but the freedom of how to fulfil the goals and which type of approach they choose to take should be left to the site management. Standards, such as the MES standard etc., that have been requested are the following:

- Standard about how to measure energy. What type of meters should be used and which units should the measurements be expressed in?
- Where should the meters be placed? This is a question that we partly have answered with our pyramid structure. But nonetheless, there is a need for a deeper technical approach.
- Which KPIs should be produced by the EnMS? This is also a question that we have recommendations for.

Another essential point when working with energy efficiency is the need for communication between the energy manager, energy team and the production side. It is understandable that the production is priority number one for the production manager and the production team. The role of all of the sites is to produce output and without output there is no IKEA Industry. Nonetheless, the necessity of participation of the production team to the energy management cannot be stressed enough. It is the people that work and manage the machines on the factory floor that have the power to directly effect energy use. They are the ones that by following routines and becoming aware of energy use, can effect the energy bill. Therefore they should be included in discussions about energy matters, be educated on energy issues and should be there to have a critical voice when balancing production versus energy savings.

Sharing the knowledge between energy managers is another important factor. An interesting, reoccurring question asked by energy managers was “How do the other sites do it?”. This is a question that has been stated in different ways: Which energy monitoring system do the others have? How do they work with their system? How does their hierarchy regarding measuring look like? Are they satisfied with their system? Is it a good system? What kind of output do they have and how is it visualised? A good way of answering such questions is sharing the knowledge and highlighting best practices. This can be done via Skype meetings or via pre-recorded clips that go through the EnMS of a site and its functions. By learning from the mistakes and success of others, both time and resources can be conserved.

Documentation and sharing of knowledge are both connected to structural capital. The structural capital within a company refers to the routines and procedures that enables the human capital (the employees) to do their work. The structural capital is well functioning if there is no severe interruption in the every day business when a co-worker changes employment, leaves or retires. Within IKEA Industry, we have seen some examples where one dedicated employer knows everything about the EnMS, or even created it themselves. This is of course not negative in itself, but it can become a problem if that one person leaves the company and the knowledge they possessed is not passed on. Generally, there seem to be consensus that it is good to have in-house knowledge of both the EnMS and energy issues in general. In many places, there is will to carry out energy saving actions, but a lack of time or funding dedicated to the issue.

10.1.2 Outsourcing

Working with energy issues and energy efficiency is a demanding task. To do so, the energy manager has to have knowledge about where and what kind of meters and sensors have to be placed, how a historian database is organised and can be used and how to use the energy monitoring system. They also need to decide what features and alarms should be used as well as how to produce relevant reports. Moreover, the most important part is analysing the data and being able to draw conclusions about what kind of issues exist and how to solve them. One could say that working with energy efficiency is like solving a puzzle by putting different puzzle-bits together. Could a solution to this puzzle be the hiring of an external company? This alternative is introduced in chapter 5.6.1 *Whole package energy solutions*.

There are, of course, both advantages and disadvantages with such solutions. One of the advantages is that by hiring an external company with broad competence within the energy efficiency areas, you get a holistic approach towards energy issues and people that have clear specialisations. Therefore the gap between the different parts of energy monitoring and actions is closed. Another advantage is the faster learning curve and shorter time between measuring and taking energy actions, since the work is going to be managed by people that have experience in this branch.

The disadvantages of his type of dealing with the energy work is that the responsibility is moved from an IKEA Industry employee to an external employee. There is a risk of leaving too much of the energy work to the hands of the external company and that the IKEA employees become alienated from the thought of energy efficiency and energy savings. It is important to engage all IKEA Industry employees towards achieving the energy goals. Additionally, the energy work becomes "locked", since the deeper knowledge of the system is in the hands of the external company and is possibly not shared in detailed with the energy manager. The role of the energy manager could become unclear if a large part of the energy work is moved to external consultants. Also, the energy manager has an advantage in knowing the workings of the site. Knowing the local as well as the IKEA way of doing things facilitates the implementation of energy actions. Last but not least, hiring an external company for a site will not be in line with the general vision of "sharing the knowledge". If each site has it's own consultant company, it could become harder to share good examples between them.

A conclusion that can be drawn from the above is that it is more beneficial to extend the energy management role and to invest in internal energy work instead of hiring external resources for the handling of energy monitoring and energy actions.

Another question that is worth discussing is if it should be a human that does the energy optimisation work at all, whether they work at the site or for a consultancy company. Introducing AI as a processor of large amounts of energy data is a prospect that is promising, as it would save both time and money to not have to go through the data manually. However, the implementation of AI requires a quite high level of technology, that we do not believe is available at the sites at present.

10.1.3 The Pyramid structure

The idea of visualising levels of detail when it comes to measuring has been a part of our work from the very beginning. The pyramid is constructed so that it can be applicable for all three divisions. Initially we found difficulty in making the pyramid relevant for all the divisions and we discussed the possibility of making a separate, cluster-formed structure dedicated to the Boards division. Our scepticism was based on the fact that Boards sites have a continuous flow throughout their process. Put simply the machines are more interdependent than in the other divisions. Therefore it would not make sense to measure individual machines if the process is not measured as a whole.

Boards is also the division where there are large energy consumers which means that every energy saving action can save a lot of energy and of course money. Since there were no objections from the Boards division, the pyramid is accepted as being applicable for all three divisions.

As mentioned before, there is a requirement in the Electrical Standard to measure all equipment above 75 kW. This requirement is not that applicable to division Boards. Their equipment is so much larger than the one used in the other divisions, so to comply to the standard, they would have to measure many small parts in the machines. For example, one motor could be as big as 1 MW, and then there are a lot of components in the motor that has a power larger than 75 kW. In order to create guidelines that are applicable for all divisions, it is hard to make any concrete limits to what should and should not be measured.

It would be wiser to first identify large consumers of energy, for example by placing temporary meters. Temporary meters allow mapping energy consumption on a certain place during a certain period of time, and then it is possible to move them to another spot. In that way, the measuring is more cost effective and flexible, but also less consistent and less holistic. After the initial measurements, the large energy consumers can be optimised and after meeting a certain level of satisfaction move on to other parts. This differentiation may be hard to distinguish in the pyramid, still, the main point with the hierarchy was to make a pyramid that fitted all three divisions.

Last but not least, the practice of common sense should be applied when connecting measuring points to the EnMS. The more parameters that are added, the more complex the results. More details do not necessary result in better outcome. What is emphasised in this pyramid is the need to start form the top and work the way to the bottom, which is our recommendation.

10.2 Method

Sending out a questionnaire induces a risk of the questions being misinterpreted. For a complete picture, one would have to visit all the factories and look at their system in the same way that we did in Älmhult, Hultsfred, Lubawa, Orla and Wielbark.

This is especially true since we created and sent out the questionnaire during our first six weeks at IKEA Industry. Looking back at the questionnaire, some questions could have been phrased in a better way, or the alternatives were confusing or incomplete. Also, some of the questions were hard to analyse in a useful way and could therefore have been left out from the beginning. All in all, though, the questionnaire provided a good basis for the result section and gave us the overview of the current situation that we were aiming for.

The meetings with the reference group also proved to be fruitful. It gave us an opportunity to check our findings with a qualified group of people with experience from IKEA Industry, and it also gave us valuable input on the analysis part.

10.3 Proposition to further research

There is a clear need for further research in the areas of energy monitoring systems, energy management and data analysis. Pilot projects should be prioritised where energy monitoring systems can be calibrated to fit each industry's needs. There is also a need for the development of digitalisation of industrial processes and the integration of information and control of the different parts of the process. Future energy monitoring systems should also be connected with production. There is a need for data communication development between different software so that the allocation of the energy input of each product will become possible. By doing this, the understanding of the life cycle of the product and its effect on the environment will become feasible. The use of Artificial Intelligence for energy data analysis should also be researched further and its potentials should be investigated.

The following propositions are specific for IKEA Industry:

There should be put focus on production of an new standard dedicated to the structure and organisation of EnMS. There is a need for further development of the management of the energy work. Additional research focused on the content of the reporting function can contribute to a harmonised output that can be used for comparing between different sites. For the same purpose, the development of a method for benchmarking of the sites could be initiated after the EnMS has been installed and operated in a longer period.

Future studies should also aim towards integration of solar panels and other renewable energy sources to the EnMS. This can contribute towards the goal of increasing the renewable energy share (according to the goals mentioned in chapter 2.4 *Energy efficiency within IKEA Industry*).

To obtain KPIs such as kWh/finished product, there is a need for an advanced and sophisticated DIP, where the Manufacturing Execution System is completely synced with production and energy monitoring. This is something to strive for now so that the transition from the systems of today to the systems of tomorrow will follow a natural and organic progress.

11 Conclusion

The results from the analysis of the questionnaire answers show that there are large differences between the sites, both when it comes to energy efficiency work in general and when it comes level of implementation of an EnMS. This indicates a gap between the current situation, and a future one where the energy monitoring is more structured and standardised. It is not necessary to homogenise which energy monitoring software or meters that are used, however, the output from the system should be the same to enable benchmarking and comparison between sites. The important thing is that reliable values of relevant EnPIs are obtained and reported. However, some of the sites have expressed a wish of having very clear guidelines, for example in the shape of a new IKEA Industry standard. There is also a need for additional EnPIs. The main ones that are used today, kWh/m^3 for division Boards and kWh/m^2 for divisions Flatline and Solid Wood, are too dependent on changes in the production.

Our recommendation is to start with coarse measurements in the beginning and then build and expand the EnMS moving to higher detail. This recommendation could be used as a template when setting goals concerning the EnMS.

The results from the questionnaire show that automatic creation of reports is one of the most important desired features of an EnMS. Obtaining output in the form of reports from the EnMS should require little or no manual work. Other features that the energy managers deemed important include a user-friendly interface and good visualisation of the energy flows.

Regarding off-the-shelf solutions, the general outcome from the questionnaire was that the sites prefer developing their own system, or if an off-the-shelf system is to be purchased then it should be adjusted to fit the needs of the site. Also, a reoccurring comment from the energy managers was that it was desirable to have a system that can be used at all the sites and that has the same structure, but with small adjustments to the local configurations. This emphasises further the need for a standardised way of working with energy monitoring.

We have met a lot of passionate and dedicated people during our time at IKEA Industry, both at the factory floors and at the main office in Malmö. Important here is to point out the importance of the employees at the sites. The energy managers are key when developing an EnMS and organising the energy work, and it is important that they have time and resources to focus on energy issues. Sharing knowledge and experience between the sites are also important in order to obtain energy monitoring systems that are efficient and user-friendly. At the end of the day, it all comes down to the commitment and devotion of the people working every day at IKEA Industry.

In a broader perspective, there are some conclusions that can be drawn that are applicable not only for IKEA Industry but for manufacturing companies in general. For example, in order to achieve energy efficiency improvements, it is important that the energy work is structured and feedback based, and that the employees have time and resources to carry out energy saving actions and follow-up on them. By implementing an EnMS, one can get an overview of the energy flows over time, which enables structured energy work and follow-up. Taking the step of investing in an EnMS is made easier if there are good examples in the same company or in the same type of business. Sharing of the knowledge is therefore a cornerstone in the strive towards a more sustainable industry sector.

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A Appendix: Questionnaire 1

This is the first questionnaire that was sent out for the purpose of conducting a gap analysis.

1. General

1.1 Division?

1.2 Site name?

1.3 Name and title of persons filling in the questionnaire?

1.4 To the energy manager: What is the extent of your work as energy manager?

2. Measuring

2.1 For processes: Ventilation (building), Heating (building), Lighting (building), Chip and Dust extraction, Compressors, Compressed air use, Kiln drying, Lacquering, Pumps and Process heating the following questions were asked.

2.2 Is this process relevant for your site?

2.3 What kind of energy is measured? More than one answer is possible. E.g. Electricity, compressed air, water etc.

2.4 Which measuring unit do you use?

2.5 Do you conduct manual measurements? E.g. someone reads of the meters directly and notes the value in Excel.

2.6 Do you have wireless meters installed?

2.7 How detailed are you measuring your energy flow? Please fill in the highest detailed level measured.

2.8 Does the situation regarding question 2.7 look the same for the whole factory? E.g. Do you go down to line level for all lines or just a few ones? Please elaborate.

3. Monitoring

3.1 What kind of energy monitoring system do you use?

3.2 If you use another, please specify:

3.3 How satisfied are you with the energy monitoring system you use now, in general?

3.4 What is missing/what could be better regarding the energy monitoring system? E.g. reporting system, alarms, user-friendly interface.

3.5 Would you recommend the software to other sites?

3.6 Does your energy monitoring system contain an alarm function? E.g. an alarm occurs when a value of an energy process is above or below a certain interval. Note that we do not mean fire alarms etc.

3.7 Are the alarms saved in a database?

3.8 How well would you say that you have implemented the PLC, PC and SCADA standard, chapter 6.6 Alarm and message handling?

3.9 Is there anything missing from the alarm function?

3.10 What kind of historian do you use? A historian is a software which stores measurement data in time series.

3.11 How well would you say that you have implemented the PLC, PC and SCADA standard, chapter 6.12 Data historicize?

3.12 How would an ideal monitoring system look like? E.g. in terms of overview, user-friendly report function etc.

3.13 Would you prefer developing your own energy monitoring system or buying a system off-the-shelf?

4. Analysing, Reporting

4.1 Who is responsible for the analysis and reporting of energy data?

4.2 What are the reports used for? E.g. Internal energy review, used for energy meetings, budgeting.

4.3 How often do you produce energy reports? E.g daily, weekly, monthly, yearly.

4.4 How much time do you spend on each energy report? E.g. Two hours per energy report.

4.5 How much time do you spend on analysing the results of the energy reports?

4.6 What software do you use for the energy reporting? E.g. QlikView, Excel.

4.7 Are the reports created automatically or manually? By manually we mean, for example, that you copy the data and paste it in excel and produce diagrams yourselves.

4.8 How well would you say that you have implemented the PLC, PC and SCADA standard, chapter 6.9 reports?

4.9 What KPI's (Key Performance Indicators) do you use in your site?

4.10 Why do you use these ones? E.g. We use them due to habit, not reflected upon, easy to obtain.

4.11 How satisfied are you with the KPI's you use?

4.12 Do you think that there would be other KPI's that you are currently not using that would be fruitful to use? E.g. kWh/product or CO_2/ m^2, or anything else that you think would be useful.

The following figures consists of the extracts from the standards that were referred to in question 3.8, 3.11 and 4.8.

6.6 Alarm and message handling

6.6.1.1 Categorizing message

- Process and designated system alarms shall be enunciated, displayed and stored in history files.
- Alarms and messages shall be grouped to allow the user to readily identify and respond to alarms and conditions (e.g., in priority sequence) in his area of responsibility.
- For any process alarm, it shall be possible, by no more than one operator action, for an operator to access a display from which he may take corrective action.
- The five highest priority and newest alarms shall be displayed at the alarm banner in descending order of priority. It shall also be possible group alarms from the same unit/cell to generate only one banner display to reduce repeat display of alarms of the same root cause.
- Actual alarm state shall be displayed on Header area continuously.
- Alarm messages with high priority must be acknowledged by operator to indicate that operator knows about each alarm.
- Alarms shall be divided to categories and classes according priority (alarm, warning, message, operator activity,...) and technology relevancy (technology part).
- Incoming alarm shall be indicating by sound also.
- Actual alarm status is indicating by colour of text and background.

Figure 32: The alarm part included in question 3.8, obtained from the PLC, PC and SCADA Standard (Hesselgård, 2015c).

6.9 Reports

A reporting utility shall be provided. It shall be possible to use any variable in the system or the history files in a report. It shall be possible for all reports to be displayed on a workstation screen as well as printed on a report printer. Hourly, daily, monthly, end-of-month, quarterly and yearly reports shall be supported. Reports shall be printed and/or saved to disk when a process event occurs. It shall be possible to activate a report in the following manner:

- Upon demand (operator request)
- Scheduled (shift, daily and monthly)
- Upon event occurrence

It shall be possible to transfer data via standard off-the-shelf software tools to generic report writers.

Figure 33: The report part included in question 3.11, obtained from the PLC, PC and SCADA Standard(Hesselgård, 2015c).

6.12 Data Historicize

A configurable, real time and historical data collection package shall be available to support trending, logging and reporting. The CS shall be able to support multiple historian packages. It shall be possible to collect historical parameters on multiple workstations providing historical backup capability. It shall be possible to supply redundant on-line storage media.

On-line process point collection and storage shall not require any additional configuration other that the normal module configuration. It shall be possible to enable data historicize for each module within its standard configuration.

The historian shall be capable of collecting continuous history for up to 10,000 parameters. History data must be stored in open format and easily available to remote desktop PC's, using standard, off-the-shelf viewing and analysis software, including Microsoft Excel, Access and QlikView.

The historian shall be integrated into control strategy configuration, such that a separate historian configuration database does not need to be maintained. Each control strategy would maintain its own historical configuration information. When a new control strategy is created and downloaded, it shall include the history definition and the history definition is downloaded to the historian.

Figure 34: The data part included in question 4.8, obtained from the PLC, PC and SCADA Standard(Hesselgård, 2015c).

B Appendix: Questionnaire 2

This was the second questionnaire sent to get clearer answers regarding the building part of the gap analysis. The results were also used for the construction of the pyramid structure. Figure 6 was used in the questionnaire as a guideline.

Please fill in your site name.

Please choose your division.

1. Ventilation (building): How detailed are you measuring your energy consumption? Please fill in the highest detailed level measured. (Site, building, sector, not measured)

2. Heating (building): How detailed are you measuring your energy consumption? Please fill in the highest detailed level measured. (Site, building, boiler room, not measured)

3. Lighting (building): How detailed are you measuring your energy consumption? Please fill in the highest detailed level measured. (Site, building, sector, not measured)

4. Water usage: How detailed are you measuring your energy consumption? (Site, building, sector, not measured)

C Appendix: Answers from questionnaire 1

Division	Site	Answers to the question 3.13 Would you prefer developing your own energy monitoring system or buying a system off-the-shelf?
Boards	Hultsfred	Same system for all factories, a simple system, easy to handle, easy to get reports from the system
Boards	Kazlu Ruda	Develop
Boards	Lure	N/A
Boards	Malacky	Developing own monitoring system, or buying a fully adjustable and configurable system
Boards	Novgorod	N/A
Boards	Orla	Off the shelf and tailor made implementation
Flatline	Danville	We own an off-the-shelf system that needs to be fully deployed
Flatline	Hultsfred Flatline	N/A
Flatline	Lubawa	Definitely we should develop existing software
Flatline	Malacky flatline	To buy, the company works/are developing the systems for year, we don´t need to develop "the wheel" again
Flatline	Nantong	Buying a system off-the-shelf
Flatline	Paços de Ferreira	It should be designed to fit our needs, but there are already good monitoring systems in place where we can benchmark for support and make our system stronger.
Flatline	Sopron	Our system is a base software which is able to implement any of systems. Do NOT want to change! (This software is used in Hungary almost water station and nuclear power station)
Flatline	Trnava	YES
Flatline	Zbaszynek	Buying a system off-the-shelf solution always needs certain level of customization, so it's better to develop own system but according to established standard.
Flatline	Älmhult	Own system: it is not so expensive but risk is that only one knows about the system Off-the-shelf: same for all factories
Solid Wood	Chociwel	N/A
Solid Wood	Goleniow	N/A
Solid Wood	Jasna	Own energy monitoring system reflecting local conditions, with a common IKEA Industry interface where all main data are transferred to, and presented in a comprehensive way familiar to managers from i.e. Division level.
Solid Wood	Konstantynow	N/A
Solid Wood	Resko	Should be designed for our needs but can be developed to many factories. It has to have some AI that focus on deviations and need to be checked by qualified stuff to describe what the reason was.
Solid Wood	Stepnica (Ivar)	I prefer own energy monitoring system
Solid Wood	Tikhvin	We would like to buy platform to develop it for our site
Solid Wood	Wielbark	Of course develop

Figure 35: The answers from the first questionnaire regarding question 3.13 Would you prefer developing your own energy monitoring system or buying a system off-the-shelf?

Division	Site	Energy monitoring system	Satisfaction level connected to software
Boards	Orla	Erco.net	Satisfied
Boards	Malacky	Iconics Genesys64 with Analytix	Neutral
Boards	Lure	POWERGEST	Satisfied
Boards	Novgorod	SEDMAX	Satisfied
Boards	Kazlu Ruda	Siemens Simatic WinCC	Not satisfied
Boards	Hultsfred	Wonderware system platform/ InTouch	Not satisfied
Flatline	Hultsfred Flatline	None	
Flatline	Älmhult	Omron Cx superviser	Satisfied
Flatline	Malacky flatline	Siemens Simatic WinCC	Neutral
Flatline	Sopron	VisionX9 scada system by Provicon Ltd	Satisfied
Flatline	Danville	Wonderware system platform/ InTouch	Neutral
Flatline	Lubawa	Wonderware system platform/ InTouch	Neutral
Flatline	Nantong	Wonderware system platform/ InTouch	Not satisfied
Flatline	Paços de Ferreira	Wonderware system platform/ InTouch	Not satisfied
Flatline	Trnava	Wonderware system platform/ InTouch	Neutral
Flatline	Zbaszynek	Wonderware system platform/ InTouch	Neutral
Solid wood	Tikhvin	Alpha Center	Neutral
Solid wood	Jasna	Controlweb	Satisfied
Solid wood	Resko	Gemos	Absolutely not satisfied
Solid wood	Stepnica (Ivar)	Lumel	Satisfied
Solid wood	Chociwel	None	
Solid wood	Goleniow	Wonderware system platform/ InTouch	Satisfied
Solid wood	Konstantynow	Wonderware system platform/ InTouch	Very satisfied
Solid wood	Wielbark	Wonderware system platform/ InTouch	Not satisfied

Figure 36: The answers from the first questionnaire regarding question 3.3 How satisfied are you with the energy monitoring system you use now, in general?

Site	Software	What is missing?
Goleniow	Wonderware system platform/ InTouch	Problem with connections production machines network for reading machines parameters. Access for maintenance technician for information eg. via tablets.
Hultsfred	Wonderware system platform/ InTouch	No details in the factory
Jasna	Other	Alarms to selected staff /Temperature and humidity indication in production halls
Kazlu Ruda	Siemens Simatic WinCC	User friendly, Missing separate monitoring lever,Vizualization, Better comparison, Reporting
Lubawa	Wonderware system platform/ InTouch	More friendly interface, Not clear reporting area. Not all measurements are connected to system (electrical, heat etc.), Better splitting of measurements equipments (actually some area are measured together)
Malacky	Other	reporting system, adjustable begin and end of the day for analysis
Malacky flatline	Siemens Simatic WinCC	better interface for charts, flexibility in charts local set up, data collection - DTB , when exporting to EXCEL, no max/min border / no tachometer visualisation
Nantong	Wonderware system platform/ InTouch	automatic data collection, alarms, user-friendly interface,rerporting system
Orla	Other	Add up new PDC part, Steam & condensate monitoring, Water monitoring, alarms, possibility to use on-line reporting
Paços de Ferreira	Wonderware system platform/ InTouch	Central definition with local support of a specification with all the necessities. IT / IS department support to verify internal tools meet needs, Wonderware and / or Qlick View. If not, invest in the software and improve the missing hardware in the points to measure against its relevance. Nothing satisfied, hence you are using other resources. It must be well worked in good monitoring software with user-friendly interface from all the required specifications of EnMS, reporting, billing with energy price market online, active and reactive energy, central alarm and local per area/line/machine/process/user, by product typology, influence in the definition of planning so that all units can easily speak the same language and can act in the reduction of consumption and costs, making us more sustainable
Resko	Other	Historical data, More detailed measurement provided, Information of energy consumption on line level provided for operators' screens
Stepnica (Ivar)	Outsourced (outside of IKEA-server)	alarm function
Tikhvin	Other	We would like to have SCADA system like Wonderware
Wielbark	Wonderware system platform/ InTouch	All data in one place, detailed KPIs for areas, machines, production etc, better and in one place visualization for alarms
Zbaszynek	Wonderware system platform/ InTouch	reporting system, alarms, visualisation
Älmhult	Other	Reporting system (automatically generated reports e.g. like monthly reports for specific lines, halls etc), Web base interface

Figure 37: The answers from the first questionnaire regarding question 3.4 What is missing/what could be better regarding the energy monitoring system?

D Appendix: Analysis of the matrix

In this part of the Appendix, the calculation of the detail of measuring is presented here for the three divisions as it was calculated in Excel. Note that it is the bold black percentages that were used in the thesis.

Flatline							
Count factory	Count process	Count line	Count machine	No Answer	Not Relevant	SUM of all	SUM without N/A N/R
12	13	18	4	3	20	70	47
Percent							
26%	**28%**	**38%**	**9%**	4%	29%		
Solid Wood							
Count factory	Count process	Count line	Count machine	No Answer	Not Relevant	SUM of all	SUM without N/A N/R
8	14	7	12	6	9	56	41
Percent							
20%	**34%**	**17%**	**29%**	11%	16%		
Boards							
Count factory	Count process	Count line	Count machine	No Answer	Not Relevant	SUM of all	SUM without N/A N/R
11	16	3	0	1	9	40	30
Percent							
37%	**53%**	**10%**	**0%**	3%	23%		

Figure 38: The response rate regarding the measuring detail for the production part.

Flatline						
Site	Building	Sector	Boiler room	Not measured	SUM	SUM without Not measured
12	10	10	2	6	40	34
Percent						
35%	**29%**	**29%**	**6%**	**15%**		
Solid Wood						
Site	Building	Sector	Boiler room	Not measured	SUM	SUM without Not measured
4	7	4	2	7	24	17
Percent						
24%	**41%**	**24%**	**12%**	**29%**		
Boards						
Site	Building	Sector	Boiler room	Not measured	SUM	SUM without Not measured
6	3	3	1	3	16	13
Percent						
46%	**23%**	**23%**	**8%**	**19%**		

Figure 39: The response rate regarding the measuring detail for the building part.

How much energy do your IKEA furniture cost?

by Jenny Abrahamsson and Nefeli Gavriilidou

Producing wooden furniture is a process with many steps that need electrical energy and heat. In order to map the energy flows in the factories, IKEA Industry has decided to look closer into digital energy monitoring systems. Having a good overview of how much energy the different processes consume makes it easier to see where the energy saving actions should be directed, and it also helps in seeing which actions that are most efficient.

In the future, it can be possible to allocate the energy consumption to every single piece of furniture. Imagine a world where the price tag shows the energy that has gotten into the furniture you have just purchased!

But why is it important to know how much energy it takes to produce a piece of furniture? The industry sector stands for a large share of the total energy use in the world. To keep the earth's average temperature at safe levels, the way the industry functions today has to change.

All actions, large and small matter. Picture taken by Nefeli Gavriilidou

You can manage only what you measure

Energy monitoring systems are important not only for IKEA Industry, but for all manufacturing industries in the world. A great start down the long road of energy efficiency is the use of an energy monitoring system which consists of both software and hardware components. But what does an energy monitoring system do? It does exactly as the name says: It monitors the energy that is used in the production of your IKEA furniture. In this way, the people responsible for energy issues at the furniture factories can easily see peaks and dips in the energy use and therefore do something about it.

Where we are today

A gap analysis showed that there was a large variation regarding energy monitoring systems and way of working with energy issues. Nonetheless, it is clear that the people are on-board the energy efficiency ship. They are awaiting clear guidelines regarding how they should measure, monitor and manage energy at the factories.

Measure

Ancient egyptians build pyramids to help their pharaohs with their transition to the next life. Pyramids can be used in another way as well; they can help the energy managers organise the energy measurements at the sites. The pyramid that we talk about is a structure that visualises how thw measurement should be organised. Starting with general measurements at the top of the pyramid all the way down to the bottom. The top represents the total energy at the factory and the bottom energy measurements from each and every machine.

Monitor

Living in the information era, there is a need for a platform where both machines and human can communicate. A picture is worth a thousand words, therefore the visual part of information of the energy flows in the factory should be as clear and informative as possible.

Manage

After measuring and monitoring comes the most important step towards energy efficiency: energy actions. Guidelines and sharing knowledge are important parts of this process. Then, as it is always the case, it is up to the people at the factories taking the right actions.

IKEA Industry manufacture furniture for the people. Besides a lot of love, energy has been put in making these furniture that you sit on, sleep on and use in your everyday life. You, as a consumer are also a part of the chain. It is time for both the industry and for you, the consumer to reflect upon "How much energy do your IKEA furniture cost?".