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POSITIONING ENERGY MANAGEMENT SYSTEMS ON AN EVOLVING ENERGY MARKET

Master of Science Thesis

Examiners: Esa Vakkilainen
and Jussi Saari

ABSTRACT

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Positioning energy management systems on an evolving energy market

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The European energy market has been evolving significantly in recent years. Increased use of renewable energy has brought more non-dispatchable form of energy generation to the market. That has led to more difficult matching of energy demand and supply as the availability of it largely depends on weather conditions. That has increased the demand for flexible systems that can optimize the supply of energy and adjust inevitable energy price fluctuations. Furthermore, the increased amount of available data has created some challenges in data processing and brought new opportunities in exploiting it through data-driven decisions.

The aim for this thesis is to study how the energy market evolves in Europe and investigate what kind of influence it has on energy management. Through market research and empirical study, some common characteristics are collected for the energy management systems that are in demand according to the market needs and the interviewees' feedback. During this thesis, the outlook for energy management systems and their role are also reviewed with the international targets that further promote the demand for energy management systems. The thesis is focused on the European energy market in process industry.

The demand for energy management systems will grow in Europe. Enterprises in process industry already have increased expectations for them. The systems can be used for many purposes such as: Overseeing plant's operations, optimizing and reporting the energy supply and use, abiding with regulatory standards and electricity trading. The systems need to enhance communication within different users and other systems and support new emerging technologies. On top of that, the strategical and operational level targets for enterprises and governments need to be aligned with proper energy efficiency measures. Through that the EU energy and climate targets would be more achievable, and that could result in more significant cost savings and environmental benefits.

TIIVISTELMÄ

LUT-yliopisto

Energiatekniikan koulutusohjelma

Pauli Nieminen

Energianhallintajärjestelmien asemointi kehittyvillä energiamarkkinoilla

Diplomityö

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Euroopan energiamarkkinat ovat kehittyneet merkittävästi viimevuosina. Uusiutuvan energian lisääntynyt suosio on tuonut markkinoille enemmän ei-säädettäviä energiantuotantomuotoja. Tämän vuoksi energian kysynnän ja tarjonnan kohtaaminen on vaikeutunut, sillä kyseisten energiantuotantomuotojen saatavuuteen vaikuttaa merkittävästi vallitsevat sääolosuhteet. Tämä on lisännyt kysyntää joustaville järjestelmille, jotka voivat optimoida energiantarvetta ja käyttöä sekä hallinnoida energian hinnan vaihteluita. Tarjolla olevan datan määrä on myös kasvanut, mikä on aiheuttanut haasteita tiedonhallintaan, mutta tuonut samalla uusia mahdollisuuksia hyödyntää dataa päätöksenteossa.

Diplomityön tavoitteena on tutkia, miten energiamarkkinat kehittyvät Euroopassa ja selvittää, millainen vaikutus niiden kehityksellä on energianhallintajärjestelmiin. Markkina- ja empiirisentutkimuksen avulla kootaan yhteen oleellisia energianhallintajärjestelmien ominaisuuksia. Työssä tarkastellaan myös sitä, millainen rooli energianhallintajärjestelmillä on kansainvälisten energia-ja ilmastotavoitteisiin saavuttamisessa, sillä ne ovat osaltaan lisänneet järjestelmien kysyntää. Työssä keskitytään Euroopan energiamarkkinoihin prosessiteollisuudessa.

Energianhallintajärjestelmien kysyntä lisääntyy Euroopassa ja prosessiteollisuuden yrityksillä on kasvaneita odotuksia niiden suhteen. Niitä voidaan käyttää moniin tarkoituksiin, kuten: Laitosten operatiiviseen valvontaan, energianhankinnan ja -käytön optimointiin ja raportointiin, säädösten vaatimusten täyttämiseen sekä sähkökauppaan. Järjestelmien on parannettava viestintää eri käyttäjien ja muiden järjestelmien välillä sekä tuettava uutta teknologiaa. Lisäksi, strategiset ja operatiiviset tavoitteet yritysten ja hallitusten välillä on oltava yhdenmukaisia asianmukaisten energiatehokkuustoimenpiteiden ylläpitämiseksi. Tällöin EU:n energia- ja ilmastotavoitteet olisivat saavutettavampia, mikä voisi johtaa yhä merkittävimpiin kustannussäästöihin ja ympäristöhyötyihin.

PREFACE

This Master's thesis was written for CPM Business Unit in ABB's Industrial Automation Division in Helsinki, Finland. Writing this thesis has been a great learning process for me, and I have enjoyed researching and studying about energy markets and energy management systems in process industry. Energy management systems are quite advanced products and the need for them will continue to grow as the ways we use energy will develop even further.

I would like to thank all the people who have supported me throughout this thesis. This thesis hasn't been an easy task, but it has been very valuable experience for me. This would have not been possible without the help of Panu Karhu and Jukka Kostiainen from the CPM Business Unit. They have persistently been guiding me to the right direction and providing me with the best possible tools to write this thesis in a great environment. Many thanks to ABB and the whole CPM Business Unit for helping me with their valuable expertise and collaboration.

Special thanks to my examiners Esa Vakkilainen and Jussi Saari in LUT University for their valuable input, and to all the interviewees who gave useful feedback about their company's energy management. The feedback and comments really gave this thesis concrete content that is very valuable. Finally, I'd like to thank my family and friends who have supported me during my studies and throughout this thesis, especially my fiancée Taru, who has always supported me in everything I've decided to do.

In Pori, Finland, on 31st of March 2019

Pauli Nieminen

CONTENTS

ABBREVIATIONS AND NOTATION

CO_2	Carbon dioxide
COP	The Conference of Parties
DSO	Distribution System Operator
EED	Energy Efficiency Directive
EMS	Energy Management System
EU	European Union
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KPI	Key Performance Indicator
TSO	Transmission System Operator
UNFCCC	United Nations Framework Convention on Climate Change
VDI	Association of German Engineers

1 INTRODUCTION

Every enterprise and household need energy to operate and function in society. Majority of people don't even need to know where the used energy is coming from as long as they have access to it. Energy systems and markets are backbones of our sustainable economic lives and they ensure the accessibility of energy to end-users, that essentially everyone is. It would be discouraging to imagine the standard of living people would have, even in the welfare states, if there weren't functional energy systems and markets. Without them everyone would have to produce the energy for their daily activities themselves. The existence of energy systems and markets makes everything more effective in the whole economy and society.

The supply for energy is one of the most important things energy producers and actors could think of. Without sufficient supply for energy, almost no enterprise is able to function nor make profit. Energy management on the other hand has been rarely one of the first priorities for enterprise operations. There can be profitable and functional ventures without proper energy management as long as the sales margin is sufficient. Energy management has been sometimes one of the last targets to be invested in because there hasn't been imminent need for it, or it has been too difficult to properly integrate to an industrial facility.

In recent years, business owners and energy companies have realized the potential that energy management has. Energy management today isn't just monitoring energy management or calculating energy consumption, but it can be much more. Nowadays energy management can for example be used for locating savings potential, securing energy price and optimizing energy use. Different industry actors implement their energy management according to their understanding and needs. Some have greater focus on long-term solutions and some focus on short-term savings.

1.1 Background

Everything people do consumes energy. Society that functions effectively needs an incredible amount of energy every day. Great energy sources can be differentiated into renewable energy sources like hydro, wind, solar, biomass and geothermal energy or non-renewable energy sources like oil, coal, nuclear and natural gas. Energy price and energy impact for nature varies greatly for different energy sources, locations and applications. For that reason, it is important to know what kind of energy sources would be reasonable to use for certain areas or facilities and how the supply and use of it could be optimized.

Due to technological improvements and the evolution of energy supply, there has been a growing demand for energy management. The global demand for increasing energy efficiency as well as the lowering environmental impacts have increased the attention toward energy management (Sa et.al 2018, 2). That has resulted for example in an increased use of renewable energy, especially wind and solar, and they have been one of the major drivers to increase importance for energy management. Renewable energy production varies depending on the weather and time of the day, which makes it necessary to use energy more effectively when it's available and manage it in the way that ensures minimized costs and maximal benefits.

Another great driver for energy management has been the increasing intensity in trades in energy markets. For instance, electricity markets in Europe enable the trade intensity of one hour and soon 15 minutes in many market places. In the coming years the time period is most likely to be even shorter, which means that the energy producers and traders need to have a comprehensive understanding of their energy need and use continually. On top of that they will have means to reduce their costs and maintain their secured supply with proper energy management systems.

International targets and regulatory standards aim to direct industry operators toward developing constantly better energy management systems. Throughout EU and in many regions worldwide, climate change and human caused emissions, have been taken seriously. To mitigate and adapt to climate change, there are certain targets and directives that endorse the application of energy management systems even further. One of these directives include ISO 50001, which is a global energy management standard that has been launched in June 2011. The standard provides the framework for industries and utilities to create a policy for more efficient use of energy. Thus, by setting and measuring performance targets, it can enable continuously improved energy management. (ISO 2018, 1, 9)

1.2 Context and the research problem

This thesis concentrates on the role of energy management systems on a constantly evolving energy market in Europe. Energy markets face new opportunities and threats all the time and energy management can play a vital role in maximizing the benefits of the coming opportunities and minimizing the effects of upcoming threats.

According to VDI 4602 standard in Germany, energy management is considered as the forward-looking, organized and systematic coordination of the procurement, conversion, distribution and utilization of energy. It is meant to cover energy requirements that any enterprise or facility have, and it can take both ecological and economic objectives into consideration. The term "energy management system" includes the organizational and information structures required for implementing the energy management system, also including the technical resources such as software and hardware that are needed for that. (Envidatec 2013, 17)

The European Commission has set regulations and directives to help nations and enterprises to combat climate change and mitigate its consequences. Through directives, they promote for instance energy efficiency, renewable energy and carbon neutrality, which have direct impact on the demand and need for energy management systems. Through these regulations, directives and predicted outlooks, energy management systems should be one of the most invested products there are in energy industry. However, there is a general feeling that the strategical level targets don't always reach the operational execution of things, which could have hindered even larger investments toward energy management.

According to industry experts, it's possible that energy management systems haven't reached their full potential yet. There are many possible reasons that could hinder their development and the investments toward them. This thesis is set to improve understanding of the market the energy management systems are in, investigate what kind of current market trends there are, study how they affect the demand of energy management and research what the interviewee companies expect from their energy management systems now and in the future.

1.3 Objectives and research questions

Thesis' main objectives and the research questions are:

- How will the energy market evolve in Europe and what is the influence on energy management?
- What kind of energy management systems there should be on the market according to market needs and response?
- How does the outlook for energy management systems compare to the international targets?

The focus in the research will be on European energy markets and on energy management in process industry.

1.4 Structure of the thesis

The idea for the thesis structure is to give the reader an extensive overview of the work and content that it includes.

Chapter 2 is the literature review of the thesis. It includes essential information about energy markets and electricity trading, European Energy and Climate policy, Energy management generally and energy management solutions in process industry.

The first section of chapter 2 introduces market places where energy is traded. After that, energy market liberalization process that has or is happening around Europe and elsewhere is presented. This chapter also introduces an overview of global electricity markets and the different types of market status there are. In addition to this, European power exchange is introduced with its mechanisms and the major trends that are and will affect the energy markets drastically.

The second section of chapter 2 is about European Energy and Climate policy. IPCC reports and the Paris Agreement are introduced with their major targets. After that EU Energy and Climate targets are presented for the 2020, 2030 and 2050 frameworks. The section concludes by introduction of Energy Efficiency Directive that has a major impact on the required characteristics of energy management systems.

The third section of chapter 2 presents the concept of energy management. It introduces its objectives and challenges with its main characteristics. The section concludes by giving an overview of the industrial energy management systems.

The fourth section of chapter 2 is about energy management solutions in process industry. The solutions are collection of common products that are offered for industrial customers. The section introduces specifically what kind of benefits each product has and what features are included in them.

Chapter 3 is about the thesis methodology. Research design is introduced with general information about the interviewees and the interview objective. Data collection and data analysis are also presented in this chapter.

Chapter 4 presents the interview results. The chapter includes what kind of energy management priorities interviewees have and what are the main uses for their energy management systems. The results also present how the interviewees' energy management systems answer their energy management needs, what kind of opportunities could be utilized in the systems and how they should be developed in the future.

Chapter 5 analyzes the literary based information and the interview results more deeply. Energy management system demand and their development is reviewed based on the learnings discovered during the thesis. The chapter concludes with thoughts on how the interview results compare to the international targets.

Finally, chapter 6 draws together the learnings from the work conducted during the thesis. It concludes the thesis by giving a brief overview of key findings and results.

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2 LITERATURE REVIEW

This chapter introduces the concepts and topics that are central and relevant for this thesis. The theory and the literature of this thesis are introduced throughout this chapter by using existing literature and the expertise of enterprises that operate in energy markets. Firstly, this chapter introduces energy market and electricity trading. After that, this chapter presents the driving forces in energy market development. This chapter also presents energy management with its objectives, challenges and systems. Lastly, the chapter introduces some of the important energy management solutions that operate in process industry.

2.1 Energy market and electricity trading

This section covers the energy market situation in Europe. Different types of energy markets are presented, and important market players are introduced. This section also presents energy market liberalization process that has or is happening around Europe and elsewhere. This section gives an overview of electricity trading, presenting what kind of electricity markets there are around the Globe and focuses on how the power exchange operates in Europe. The common market structures within power exchange are also presented in this section as well as the trends that play major role in energy markets.

2.1.1 Market places for energy

Energy markets are the venue for the trade and supply of energy. There are different trading commodities of which commonly traded are electricity, oil, gas, coal and CO_2 -emissions. Energy trading ensures that through supply and demand, the energy price can be reasonable and efficient for energy producers and consumers.

European energy markets have four major markets. These are power, gas, environmental and financial markets. Energy trading takes place at energy exchanges, but also outside of them on a bilateral basis. The main markets within energy exchanges are a spot market that is used for short-term trading and a forward market, where physical delivery of energy, such as electricity or gas, takes place at a future date. The significance of energy trading has grown rapidly throughout Europe for example as a result of increased energy demand as well as the market integration. Thus, there aren’t many countries that can cover their own energy needs from their own resources today. Energy trading offers possibilities to ensure the needed supply of energy and it also protects from supply shortages and price fluctuations. (Vattenfall 2018)

There are many important players that can operate in energy market, but energy exchanges are the platforms that enable the trade and use of energy commodities, such as gas and electricity. In Europe, Europex is a non-profit association of European energy exchanges with currently 26 members. It includes exchange-based wholesale electricity, gas and environmental markets. The main focus for Europex is on development of the European regulatory framework for wholesale energy trading. It provides a discussion platform at a whole European level (Europex 2018). The largest and important members of Europex and exchanges are presented in the figure 1 below.

Figure 1. Major Europex members and large energy exchanges in Europe.

The most liquid exchanges in Europe are the European Energy Exchange (EEX) in Leipzing, Germany and the Nord Pool Spot/Nasdaq Omx Commodities in Oslo, Norway. Nord Pool Spot is also the largest electricity market in Europe. (Vattenfall 2018)

2.1.2 Energy market liberalization

Europe has gone through major transformations in the energy markets during the last two decades. State owned monopolies have changed to liberalized markets, where private entities compete with one other. Main purpose for liberalization has been to achieve lower prices and increase in efficiency. As a result of liberalization, the markets have become more transparent as well. Originally, the intention has been to create a single European energy market that produces benefits for the final consumers throughout the whole Europe. Through this, lowered prices and more competitive environment could be achieved. The process was devised for the main energy sectors, which are natural gas and electricity. Both of these sectors have undergone parallel processes, in which there have been the creation of similar laws and following of the same objective. This objective is privatization to foster competition and to make the system more efficient. (Serena 2014, 1)

After liberalization, regulated energy markets become deregulated energy markets. The differences between these markets are quite clear and evident. Regulated energy markets, such as regulated electricity markets, contain utilities that own and operate all electricity. In that case the utility has complete control from the generation of electricity to the metering. The utility company also owns the whole infrastructure and transmission lines, then sells it directly to the consumers. Utilities must abide by certain electricity rates by public utility commissions. This type of market is usually considered as a monopoly due to its limitations on consumer choice. Deregulated markets on the other hand, such as deregulated electricity markets, allow the entrance of competitors that can buy and sell electricity through permitting market participants with investing in power plants and transmission lines. After that, generation owners can sell the wholesale electricity to retail suppliers. Retail electricity suppliers can set prices for consumers, allowing more reasonable electricity prices for them. (Energywatch, 2018)

The shift from regulated energy market to deregulation doesn’t happen overnight and the execution may differ depending on the area’s global energy procurement strategy or market situation. According to E&C, there are five phases in the development of energy market (E&C Consultants 2018). They are:

1. Fully regulated markets that have follow-up tariffs
2. Regulated energy markets that have room for maneuvering. This could include for example exemptions management, capacity optimization, tariff optimization and auto-production
3. Regulated markets with an ongoing deregulation process and beginning of exploring possibilities of the open market. This includes organizing energy tenders
4. Premature deregulated markets, including roll-out price management in line with markets' possibilities
5. Mature deregulated energy markets that have roll out full-scale energy price management

Many other countries and regions have been looking into and still are considering whether they should maintain regulated energy market structure or start shifting toward deregulated energy market-model. There is at least one important thing to consider though that encourages shifting to deregulated energy markets. In regulated markets, monopolies charge fees for energy individually. That may result in unjustifiably high prices without proper adjustment in price by competition. In economy, the energy sector is a huge player determining the competitiveness of the entire economy or at least affecting to it massively. If energy price is unreasonably high for a certain economy, then as a result, everything that economy produces is unreasonably expensive as everything they produce require energy. That problem could be one of the reasons that has driven many countries and regions to unbundle their monopolies in the energy sector and starting the process of deregulating to achieve more liberalized energy markets.

2.1.3 Electricity markets globally

The structure and design of electricity markets and electricity trading vary in different countries. Some areas have been focusing on electricity market liberalization and have liberalized electricity markets. Others are currently developing their electricity markets, and some go through reformation. There are still many areas that trust on regulated electricity markets and some areas have closed markets.

International electricity markets have been transformed from centralized markets to more open and competitive arrangements. The old vertically integrated utilities were broken up into discrete elements of the supply chain. That resulted with competing generators and retailers and a regulated network sector. The purpose for the changes was primally to widen markets, facilitate energy trade across national and state borders as well as optimize the use of infrastructure. There have also been significant retail reforms, which have resulted in having more consumers that are satisfied with having a choice in their own supply arrangements. (Sioshansi 2013, 31)

To get a better perspective on electricity markets globally, electricity markets can be divided into liberalized, developing, reforming and closed electricity markets. Liberalized markets are the most efficient market places that have a great deal of competition and trade that can benefit the whole area. Many countries are currently developing and reforming their electricity markets to be more effective and closer to liberalized electricity markets. In some areas, electricity markets still remain closed. The differentiation in electricity markets are illustrated in figure 2.

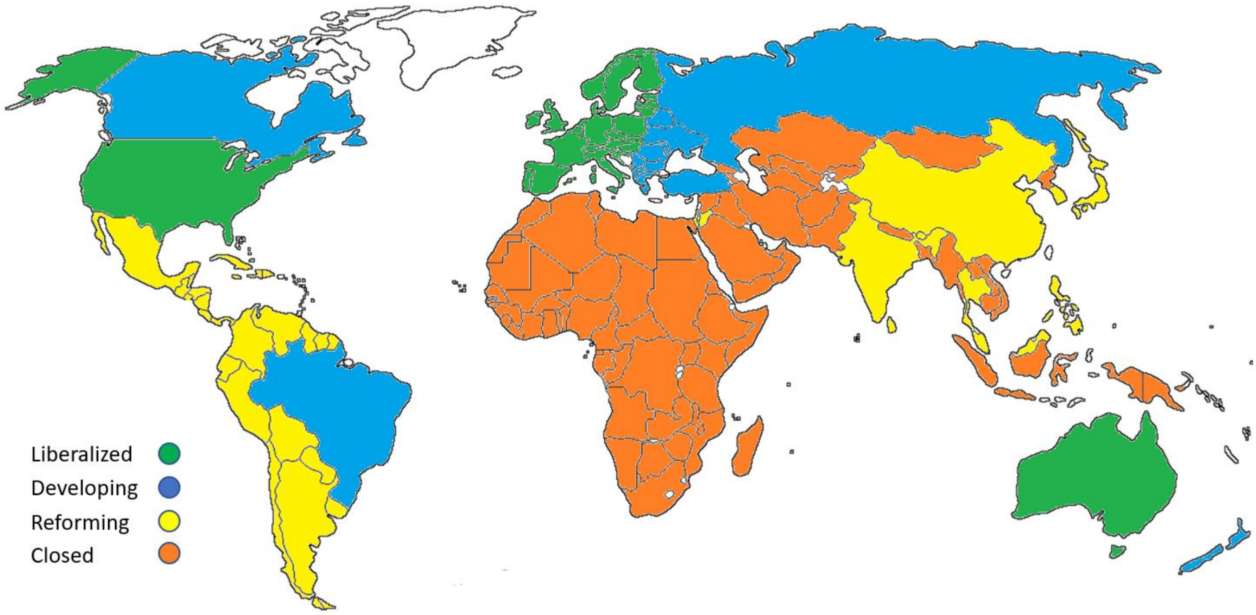

Figure 2. Electricity markets globally in 2015 with liberalized, developing, reforming and closed areas (Leigh 2015, 3).

The countries in the EU have deregulated electricity markets and there are many different types of markets within Europe, meaning that regulations and practices differ greatly from country to country. In the US, the electricity markets are regulated and deregulated, depending on a State. Russian electricity market has become more competitive, but it's limited to a forward market. Brazil is electing wholesale market and it grows liquidity with auctions. In India, there are multiple regulators and the competition is only for the wholesale market. In China, the prices tend to reflect the primary source of generation, whereas in Africa, there's a monopoly market. Energy is political tool there and there is only one buyer and one seller in the market. (Leigh 2015, 3)

2.1.4 Power exchange in Europe

Electricity is an unconventional commodity. The supply and demand need to be balanced every moment and even every fraction of a second. Electricity is extremely difficult to store cost-efficiently, thus the most efficient way of managing it is by having a functional electricity system and a power exchange where it can be traded.

Electricity market has many different players that play an important role for the whole supply chain of electricity. The producer generates electricity in a power plant, transmission system operator (TSO) transmits electricity in large plants over long distances maintaining the demand and supply balance, distribution system operator (DSO) distributes the electricity to the end consumer, who uses electricity to drive industrial processes, household appliances or providing lighting etc. Regulator guards the level-playing field of the free market and ensures that the TSO and DSO are not abusing their market power. Electricity suppliers sell the electricity to households and small companies by consumer choice (Next Kraftwerke 2018). Figure 3 illustrates the overview of a common and functional electricity system with different players.

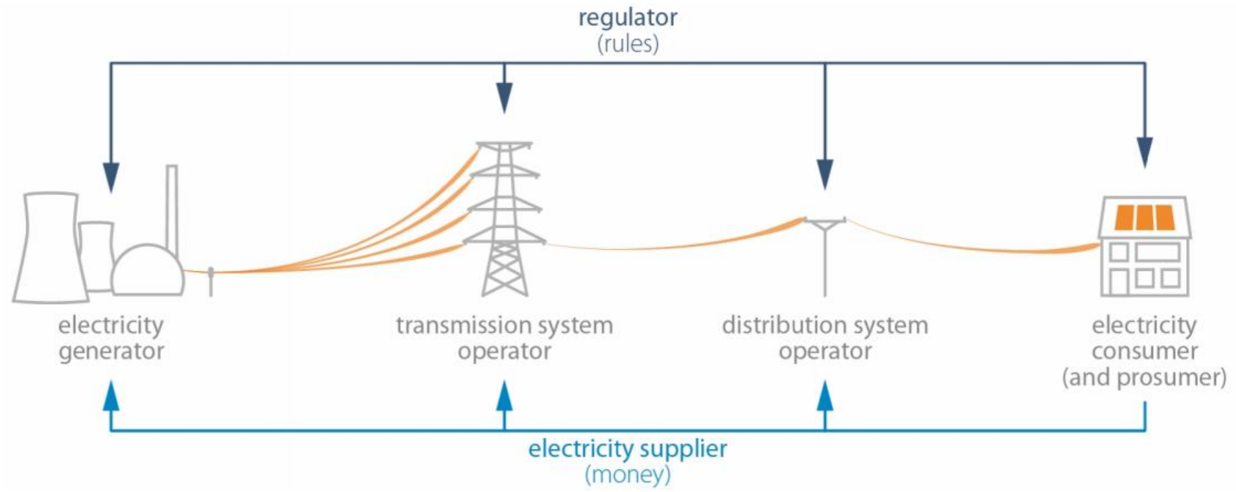

Figure 3. Overview of the electricity system and of the different players in it (EPRS 2016, 3).

Power exchange is the center of electricity trading and it is the market place for energy producers, distributors and consumers. It has been functional in Europe only for couple of decades. Prior to that, the entire electricity sector in Europe was organized as a state-owned and -controlled monopoly. Every member state had one or more vertically integrated companies that were responsible for the whole generation, transmission, distribution and supply of electricity. The European Union began to open electricity sector to competition, through launching the first electricity-related directive in 1996. The directive consists of common rules for the internal market for electricity (EPCEU 1997, 27). The idea for the directive and for the following directives in 2003 and 2009 was to create a competitive internal European electricity market. In November 2016, the European Commission published a “Clean Energy for All Europeans” package that consists of numerous legislative proposals. The package was finally put forth in December 2018. The key objectives of it are demonstrated below. (Beus M. et al. 2018, 1-2)

- Establishment of a common electricity market design across the EU
- Efficient integration of produced electricity from renewable sources into the market
- Advancement of energy efficiency and cleanliness, which are needed to achieve the European Union targets along with the support of renewable energy

- Promotion of end-users and other distribution grid-users (For example: energy storage, electric vehicles, charging stations and distributed generation) to take active roles in the electricity market
- A further push toward market-based pricing and free access to electricity and balancing markets for all users in the grid

These objectives in the market are driving the market liberalization in Europe for the countries that still have regulated electricity markets. Successful markets in Europe encourage other areas to do the same, thus similar actions have been noticed elsewhere as well. Electricity trading arrangements can vary within certain countries and areas in Europe. There are for instance some physical differences in electricity generation structure, grid design and market concentration. The competition and the level of it within different regions also fluctuates a lot. On top of this, pricing methods, bidding procedures, dispatching of certain power plants, settlement systems, congestion management and even transmission pricing are typical elements that are implemented differently in one wholesale market to another. (Ruska & Similä 2011, 47)

As a result of coordinated collaboration, European electricity markets are increasingly integrated. The electricity market is typically organized into both financial electricity markets and physical electricity markets. This structure can be applied to most of the European electricity markets such as Germany, France, the Netherlands and the Nordic countries. The largest physical electricity market is the day-ahead power market. There is a spot market price for electricity for each hour of the day. The prices are determined by supply and demand bids of all market participants. Bidding is set to close 12-36 hours before the delivery hour for the day-ahead power market. Intraday market on the other hand is a continuous trading market. There adjustments to trades are done in the day-ahead market. The trades are usually made until one hour prior to delivery. Intraday market opens right after the day-ahead market has closed. (Ruska & Similä 2011, 48)

The regulating or balancing electricity market is a great tool for the transmission system operator to keep balance between generation and consumption in real time. After the electricity market has been liberalized, transmission system operators no longer have generation resources in direct ownership. That is why balancing services need to be usually procured

(Ruska & Similä 2011, 48). In figure 4, the structure of power trading is illustrated, and the markets are explained separately below.

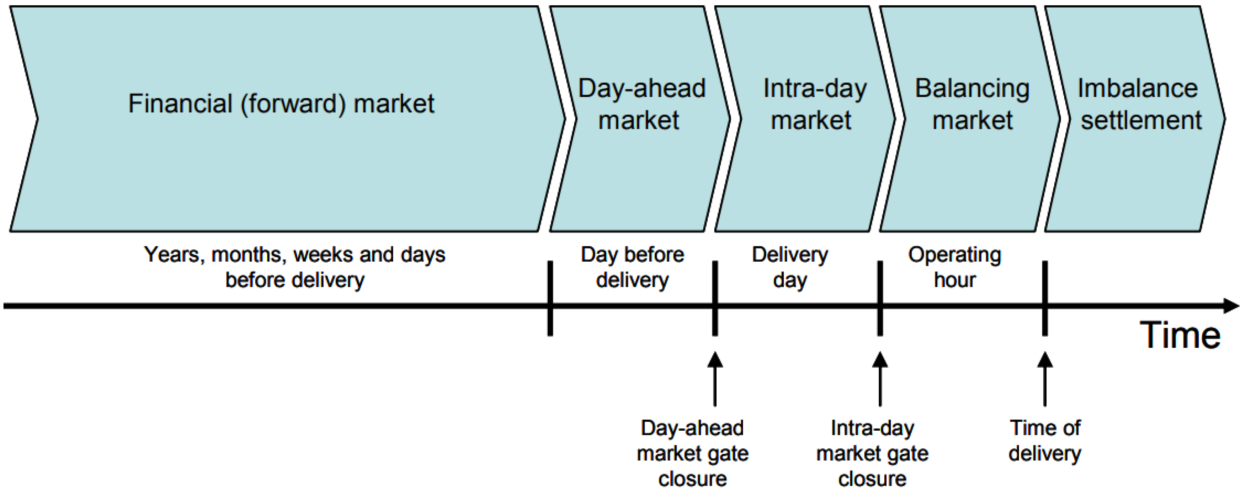

Figure 4: General structure of electricity trading. Gate closure is referring to the moment after which the bids that have been submitted to the exchange, cannot be modified. (Ruska & Similä 2011, 48)

Financial forward market

The numerous products that are traded in the European forward electricity markets, are to offer market participants hedging opportunities against short-term price uncertainties. That gives the participants possibility to improve the stability of the cash flows. The different performance of competition and even liquidity across the various forward markets can determine, whether market participants can hedge the short-term price risks well enough at a competitive price. Forward markets also have various financial products that can be traded on various platforms such as forwards, futures, options, swaps and contracts for differences. (ECA 2015, 1)

Day-ahead market

There are generally two categories the power exchanges in Europe could be differentiated into, they are power pools or power exchanges. Participation in power exchanges is voluntary, but power pools are mandatory to have in Europe. Power exchanges are owned privately, and they are meant to profit institutions in the market. For example, Nord Pool and EPEX are organized as power exchanges. Power pools on the other hand, are regulated institutions, whose income depends largely on approved costs for approved tasks. Italian GME is a good example of an organized power pool. Power pools are typically performing many tasks that are much more than just providing trading services. Some examples of that could be having additional task of allocating capacity services or managing internal congestions in the country. (Ruska & Similä 2011, 48)

Intra-day market

Right after day-ahead market's gate-closure, market participants may often have to adjust their generation and consumption plans. This can happen for example due to unplanned plant outages or unanticipated changes in consumption patterns or weather conditions. Also, the growing share of variable renewable energy generation in Europe have increased the uncertainty of power production in the day-ahead markets. Effective intra-day market has been allowing the system to be re-dispatched after the gate-closure in spot-market. This reduces the costs for electricity generation because of increased start-up and part load costs as well as the need for larger amounts of more expensive balancing reserve capacity. (Ruska & Similä 2011, 51)

Balancing market

The existence of a balancing market makes sure that the producers that would have difficulties to fulfill their commitments to the spot market, but have no flexibility in their own generation, can still meet those who can rapidly regulate their production (Ilieva & Folsland 2014, 59). Transmission system operators are usually the people that deal with the balancing of electricity in the market. They need to be able to manage sudden deviations from trading schedules that are in day-ahead or even hour-ahead. Balancing markets deviate significantly from one European country to another due to historical national specificities. The management has been historically entrusted to individual transmission system operators, since they are the single entities with adequate information on system frequency, national generation, consumption and network topology to efficiently balance the system (EUETS 2018).

2.1.5 Trends shaping energy markets

Energy markets are facing many trends that are shaping them completely and most likely toward more effective and competitive markets. One of the major trends is the increased use of renewable energy, especially solar and wind energy. That alone is rapidly making energy industry having to respond to it with altered energy mix. Another major trend is the increased use of data that enables the multiplex amount of information that can be used for the benefit of market and industry actors. Behind all the major changes, the governments have policies and incentives to direct enterprises in energy field to respond to changes aligned with the current and future policy.

Increased use of renewable energy

The European Union has already committed itself to achieve the main target of keeping the global warming less than 2 degrees Celsius compared to pre-industrial levels. The target requires the whole European Union to cut their greenhouse gas emissions as much as 80 % to 95 % by 2050. This huge reduction in emissions means that basically all electricity has to be generated from sources that are carbon-neutral. In the next decades, the whole electricity generation structure needs to change completely as well. At the moment, still majority of fossil-fuel-based energy systems need to change toward systems that are based on renewable energy sources or other non-carbon emitting technologies. They may even be fossil fuel plants that are fitted with new carbon capture and storage technology, or even nuclear power. A large portion of the electricity production is going to be based even more on wind and solar power, which has already been happening around the Globe and especially in Europe. On top of that a local small-scale generation will also increase significantly. (Ruska & Similä 2011, 9)

As the wind and solar power have been established as a major share of electricity production, there are some prominent challenges ahead as well. Wind and solar power are considered as non-dispatchable forms of energy generation in the traditional sense. This essentially means that they can only generate power when the energy source such as sun or wind is available. That creates a major challenge for the whole power system as electricity production won’t follow demand. Many other sources of energy can be much more conveniently adjusted based on the demand. In the future power systems, demand has to become more flexible and match the supply better. The changes in electricity supply structure are also some of the central drivers for Smart Grid technologies. These concepts are currently under intensive research and development, and they are commonly characterized as the electricity network of the 21st century. Making the grid smarter means that there are more added information and communication technology for the whole electricity system. (Ruska & Similä 2011, 9)

As the amount of renewable energy sources will increase significantly, that means reaction times from the perspective of energy management will shorten essentially as the renewable energy production has a great volatility. This would also mean that system operators are possibly no longer able to execute all the things they could manage before as the greater volatility of energy production require for instance more demanding optimization capabilities and data processing. For this reason, it would be helpful if future automation systems could support things such as real-time optimization and data management even better as the renewable energy production volume grows.

Increased amount of available data

As the technological inventions have gone forward, the volume for available information has grown exponentially. Nowadays it’s possible to gather a lot of data from different patterns, components, devices, systems, processes and almost from anything that can be read, monitored or experienced. The excessive amount of data and information enables new possibilities for data processing and collection as the information is much more accessible than before, and it can be merged to databases to be used effectively. Thus, the making use of the data is much easier and all the possibilities with the excessive data are yet to be discovered. Since there are a lot of available data almost everywhere, the key is to focus on the most relevant data and make the best use of it.

In Europe, the imbalance settlement and electricity trading has been done hourly for many years. The trading intensity already is already a quarter of an hour in Germany and the same practice will be applicable soon for many other EU countries as well. Every EU country need to shift from one-hour imbalance settlement to a quarter of an hour imbalance settlement by the end of 2020 (Fingrid 2019). This means that there will be increased amount of data to be processed within a quarter of time. Also, a quarter hour intensity in electricity trading and balance settlement will probably be a temporary step toward even more frequent intensity.

This means that the challenge for data management will grow exponentially throughout the time as the data needs to be managed continuously more frequently with a higher volume. Thus, the demand for energy management will also rise and the potential and need for automated systems will increase significantly.

Government policies and incentives

Government policies and incentives play also a major role in the evolving of energy markets. Through the policies and incentives, governments can guide and direct the use of energy and the market structures by endorsing the means and practices that are beneficial for societies especially in long-term.

As the energy markets are constantly changing, their design and regulation need to be properly addressed. For example, faltering economic growth, wavering commitment to nuclear generation and changes in the relative cost of fuel, can create an uncertain future for generation investment. Markets that have mature infrastructure, the combination of aging networks, rising peak of demand and more stringent reliability standards are driving higher costs. These drivers, on top of the higher costs of low-carbon investment, may even crowd out the social acceptance of further reform, slowing the rate of transformation. (Sioshansi 2013, 31)

Lower communication costs and technological advances in photovoltaic technology and demand management could also mean that the traditional one-way generation to consumer supply chain is evolving. While energy market reform has to date been focused on competition in generation and retail, the industry could soon see the consumer at the center of competition between local or self-generation, demand management, storage, and even grid services. Similarly, as the telecommunications sector has been rapidly transformed from the monopoly supply to an integrated service, the electricity supply industry could transform to a new interaction with consumers and a diversity of service and supply. (Sioshansi 2013, 31)

While there are clear opportunities to develop new services such as local generation and storage, it still remains unclear who will be the provider for such services. Extension of monopoly network regulation into these areas, risks forgoing the opportunities for innovation that would naturally flow from a competitive market for services. A key challenge for market design and regulation is to find the right mix of incentives for efficient investment to deliver the energy services required by consumers. The main challenge is to allow markets to evolve, but at the same time ensure there is a level playing field with not one party enjoying the privilege of incumbency. (Sioshansi 2013, 31-32)

The international governing bodies and the national governments have many regulatory policies and incentives to help industry parties to manage evolving of energy markets. The increased use of renewable energy and the increased use of data available have tremendous opportunities and threats for instance for process optimization, data management and system security that need to be taken into consideration. One important and rising field for the operations in industry enterprises is energy management. It seems that it’s one of the necessary solutions to answer the needs of constantly evolving energy markets and increasing volume of available data. The challenges and opportunities for energy management generally are discussed in the section 2.3 and the governmental regulations that concern and possibly promote it are introduced in the section 2.2.

Government policies and incentives play a significant role on how the renewable energy development is going to play out. Through the policies and incentives, governments and decision makers can put significant pressure on enterprises and on their future strategies and investments. A growing number of governments favor a significant role for renewable energy sources in their generation mix. That is not only to meet low-carbon targets but also for other significant reasons, including job creation, sustainable growth, energy security, and so on. Ambitious mandatory renewables targets are becoming and has become a norm especially in Europe. There are ongoing debates on how to best meet such ambitious targets, through generous feed-in-tariffs, renewable portfolio standards, production tax credits, government loan guarantees, or a combination thereof. The growing penetration of renewables in the energy generation mix leads to new challenges for market operators that need to be also considered from regulatory point of view. (Sioshansi 2013, 7)

2.2 European Energy and Climate policy

Climate change is a concern that many people face today. Climate has a natural tendency to change over time, but discoveries indicate that most of the changes today are due to human activities, which are resulted in very harmful events around the globe. Climate change can be seen for instance by global temperature rise, warming of oceans, decreased snow cover, glacial retreat, rising of sea level, and the shifting of rainfall patterns.

One significant evidence of human caused climate change is the increased amount of atmospheric CO_2. It has increased since the Industrial revolution in 18th century. Since then, humans have produced unsustainable amounts of greenhouse gases that have been accumulated into atmosphere. Burning of fossil fuels like coal and oil, which are used in various of industrial processes such as heating and manufacturing, transportation and electricity generation, increase the concentration of atmospheric carbon dioxide. Normally, the sunlight passes through the atmosphere and warms the Earth's surface radiating back toward space. With the increased amount of atmospheric carbon dioxide, most of the outgoing heat is absorbed by greenhouse gas molecules and then re-emitted in all directions, warming the surface of the Earth and the lower atmosphere. Temperature rise through increased amount of CO_2 has launched a chain of events that threatens the life conditions around the globe even now and especially in the future. Figure 5 indicates clearly how the carbon dioxide level has increased in atmosphere throughout the recent decades. (NASA 2019)

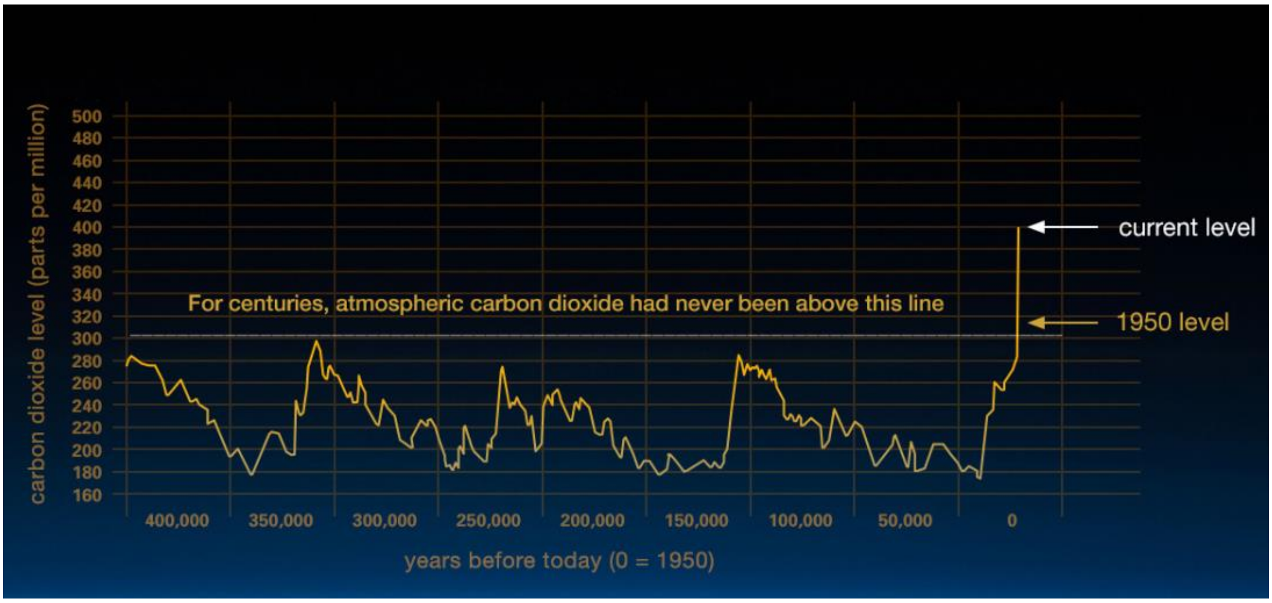

Figure 5. Carbon dioxide levels throughout history, with significant rise in the recent decades (NASA 2019).

2.2.1 IPCC reports and the Paris Agreement

Intergovernmental Panel on Climate Change is the United Nations body for assessing the science related to climate change. The IPCC was created to provide policymakers with regular scientific assessments on climate change and its implications and potential future risks. Through the assessments, they are to put forward adaptation and mitigation options for climate change. In this way IPCC supports the climate political decision-making. IPCC prepares comprehensive assessment reports about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate of on-going climate change. Thus, it also produces special reports on topics that are agreed by its member governments. (IPCC 2019)

As the IPCC is the body to assess the science related to climate change, UNFCCC, United Nations Framework Convention on Climate Change, is the global forum for developing policy solutions to it. Within the UNFCCC, the Conference of the Parties (COP) is the supreme decision-making body of the convention. All states that are selected parties to the convention are represented at the COP. There they review the implementation of the Convention and any other legal instruments that the COP adopts. Through that they make decisions that are necessary in promoting the effective implementation of the Convention, including institutional and administrative arrangements (UNFCCC 2019). The COP meets annually and the first meeting COP1 was held in Berlin in 1995. COP 21 was held in Paris in 2015 and it has been one of the most significant COP up to date.

In COP 21, the Paris Agreement was introduced and ratified later. The central aim for the Paris Agreement is to strengthen the global response to the threat of climate change by keeping the global temperature rise well below two degrees Celsius above pre-industrial levels. Additionally, member countries should pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Thus, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach the ambitious goals Paris Agreement states, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place. That ensures supporting action by developing countries and the most vulnerable countries, that are in line with their own national objectives. (UNFCCC 2019)

The Paris Agreement requires that all parties put forward their best efforts through nationally determined contributions, with strengthening the efforts in the coming years even further. This includes certain requirements such as all parties reporting regularly on their emissions and on their implementation efforts. By the end of 2018, 184 parties of 197 parties in the Convention have ratified the Agreement highly emphasizing its importance for the collective actions. (UNFCCC 2019)

After the Paris Agreement, the IPCC received a task to prepare a special report on the impacts of global warming of 1.5 degrees Celsius above pre-industrial levels and related global greenhouse gas emission pathways, mainly in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (IPCC 2018, 4). The report highlighted many different impacts of climate change that could be avoided by limiting global warming even to 1.5 degrees Celsius compared to the planned 2 degrees Celsius. For example, global sea level rise would be 10 cm lower with global warming of 1.5 degrees Celsius compared to 2 degrees Celsius by 2100. The probability of an Arctic Ocean free of sea ice in summer would be only once per century with global warming of 1.5 °C, whereas it would occur at least once per decade with 2 °C temperature rise. With global warming of 1.5 °C, coral reefs would decline by 70-90 percent, whereas almost all (over 99 %) would be lost with 2 °C temperature rise. (IPCC 2018, 7-8)

The report also presents that limiting global warming to 1.5 degrees Celsius would require rather rapid and far reaching transitions in land, energy, industry, buildings, transport and cities. Also, global net human-caused emissions of carbon dioxide would need to reduce significantly by about 45 percent from 2010 levels by 2030, reaching net zero by around 2050. This basically means that any remaining emissions would need to be balanced by removing CO_2 from the air (IPCC 2018, 5). The difference in consequences between 1.5 °C and 2 °C temperature rise above pre-industrial levels are staggering and significant. The main concern could be that the window for the possibility of limiting the temperature rise to 1.5°C might close soon without proper adjusting measures for climate change mitigation. To achieve the target, there should be rapid changes in human consumption behaviors and significant technological advancements helping in emission reducing, such as an effective carbon capture and storage technology.

2.2.2 EU Energy and Climate targets

European Union is in the forefront of fighting against the climate change and the mitigation of it. There are many targets and frameworks that help EU to contribute to the mitigation and to abide with international agreements. The 2020 climate and energy package set by EU leaders in 2007 is a set of binding legislation to ensure that EU meets its climate and energy targets for the year 2020. The package includes 20 % cut in greenhouse gas emissions from 1990 levels, 20 % of EU energy from renewables and 20 % improvement in energy efficiency (European Commission 2018).

Some of the member countries can abide by the target of 2020 energy package, but for the whole EU it is going to be rather difficult to achieve the targets in time. However, the next target after 2020 is 2030 climate and energy framework. It includes at least 40 % cuts in greenhouse gas emissions from 1990 levels, at least 27 % share for renewable energy and at least 27 % improvement in energy efficiency in EU. The framework was adopted by EU leaders in October 2014 and it builds on the 2020 climate and energy package. (European Commission 2018)

EU countries have different ways to pursue energy and climate targets and they can decide what actions are the most suitable for them. The increased share of renewable energy has been evident almost throughout the whole Europe, and it has been a common action for the member countries in striving toward achieving the targets. Also, reducing coal fired energy production and investments in new technologies such as carbon capture, electric cars and smart grids have taken place around Europe. Figure 6 illustrates what has happened in Germany's electricity mix since the beginning of 21^{st} century. For example, the renewable energy has increased almost 500% in 15 years, which outlines the rapid changes that have occurred and continues to occur in energy markets today.

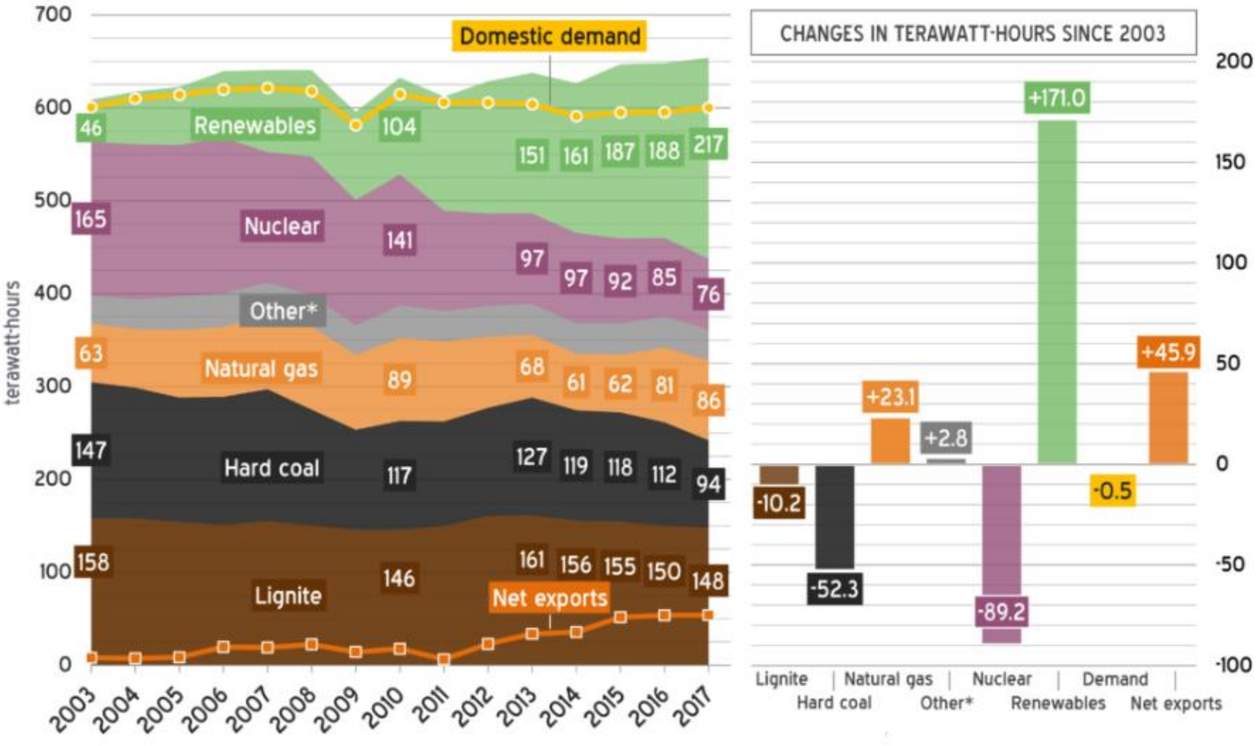

Figure 6. Germany's electricity mix development from 2003 to 2017 (Energy Transition 2018).

The long-term strategy for EU is a vision for a prosperous, modern, competitive and climate-neutral economy by 2050. If succeeded, the strategy would show how Europe can lead the way to climate neutrality through investing into realistic technological solutions, empowering citizens, and aligning action into key areas such as industrial policy, finance, or research, while also ensuring social fairness for a just transition. (European Commission 2018)

2.2.3 Energy Efficiency Directive

To help member countries to achieve mutual and national targets, European Commission can launch different directives to direct and guide member countries to targeted direction. The Energy Efficiency Directive 2012/27/EU, EED that was entered into force on December 2012, is an EU directive that establishes a set of binding measures to help the EU reach its 20 % energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the whole energy chain, from production to final consumption (European Commission 2018). This directive has also been one of the great drivers that has increased the demand for energy management systems throughout the EU as they can have great influence on energy efficient production.

According to the directive, the national measures must ensure major energy savings for consumers and industry alike. Some of the measures that involves industry actors are for example (European Commission 2018):

- Energy distributors or retail energy sales companies have to achieve at least 1.5% energy savings per year through the implementation of energy efficiency measures.
- Energy consumers should be empowered to better manage consumption. This includes easy and free access to data on consumption through individual metering.
- National incentives for small and medium-sized enterprises should undergo energy audits.
- Large companies need to make audits of their energy consumption to help them identify proper ways to reduce it.
- Efficiency levels should be monitored in new energy generation capacities.

On 21st of December 2018, the EU released the Clean Energy for all Europeans package that has for instance recast Renewable Energy Directive and amending Energy Efficiency Directive, as well as the new Energy Union and Climate Action Governance Regulation. This package is EU’s updated energy policy framework that will facilitate the clean energy transition and make it fit for the 21st century. Finalizing these changes will mark a significant step toward the creation of the Energy Union that ensures Europe’s safe, viable and accessible energy supply and brings EU closer toward delivering on the Paris Agreement commitments. (European Commission 2019)

This new policy framework empowers European consumers to become more active players in the energy transition and fixes two new targets for the EU for 2030. The targets are a binding renewable energy target of at least 32 % and an energy efficiency target of at least 32.5 %. For the electricity market, the policy framework confirms the 2030 interconnection target of 15%, following the set 10 % target for 2020. The goals for the ambitious targets are to stimulate Europe's industrial competitiveness, boost growth and jobs, reduce energy bills, help tackle energy poverty and even improve air quality. (European Commission 2019)

A further part of the package is to establish a modern design for the whole EU electricity market, adapted to the new realities of the market. They are to be more flexible, more market-oriented and placed better to integrate a greater share of renewable energy. These new rules aim to put consumers at the center of the transition. This is in terms of giving them more choice, strengthening their rights, also enabling everyone to be able to participate in the transition themselves through producing their own renewable energy and feeding it into the grid. When electricity is allowed to move freely to where it's most needed and when it's most needed via undistorted price signals, consumers would benefit from cross-border competition. This is meant to drive the necessary investments that can provide security of supply, whilst decarbonizing the European energy system. (European Commission 2019)

The European Commission publishes guidance notes to help officials in EU countries to implement the Energy Efficiency Directive. One of the guidance notes is Article 8 that is about energy audits and energy management systems. An energy audit basically means a systematic procedure that has the purpose of obtaining sufficient knowledge of the energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy saving opportunities, and reporting the findings. Energy audit is an essential tool through which energy savings can be achieved. They are necessary in assessing the existing energy consumption and identifying the whole range of opportunities in energy saving. That could then result in proposals of concrete energy saving measures for the energy user. Thus, energy audits allow the identification and prioritization or ranking of opportunities for improvement. This way, energy audits can tackle the information gap that can be one of the main barriers to achieving energy efficiency. (EUR-Lex 2019)

According to the Article 8, EED requires member states to comply with the following main obligations (EUR-Lex 2019):

- Promote the availability of high quality and cost-effective energy audits to all final customers carried out by qualified experts or supervised by independent authorities
- Ensure mandatory and regular audits for large enterprises and carried out by qualified experts or supervised by independent authorities

- Establish transparent and non-discriminatory minimum criteria for energy audits
- Establish in national legislation requirements for energy auditors, and for supervision by national authorities
- Ensure the development of programmes to encourage small and medium-sized enterprises to undergo energy audits and to implement the recommendations from these audits
- Ensure that development of programmes raise awareness among households about the benefits of energy audits.

Energy management systems are exemptions for the mandatory energy audits. Usually, when a large company has an energy management system in place, a continuous energy review process is carried out to manage, control and reduce energy use. This process is resulted in detailed review of the energy consumption profile and the identification of opportunities for energy saving is equivalent to that of discrete, regular energy audits (EUR-Lex 2019). Energy management systems are key in abiding with the national and international commitments, but they are also helpful in achieving additional benefits that are discussed in the further chapters of this thesis. ISO, International Organization for Standardization, has released ISO 50001 directive for energy management systems. It states what kind of energy management systems need to be in place for those enterprises that belong to the area of that directive's jurisdiction. This directive currently applies for instance for enterprises in Germany and later for many other EU countries as well.

ISO 50001 provides a framework for managing energy performance and addressing energy costs. It helps companies to reduce their environmental impact and meet their emission reduction targets. ISO 50001 is designed to help organizations to improve energy performance through improving energy-intensive assets. Improved energy performance can provide rapid benefits for different organizations by maximizing its use of energy sources and energy-related assets, which can reduce both cost and consumption. ISO 50001 is used by large and small organizations all over the world and its benefits can take many forms. For some, it can be about reducing the environmental impact and enhancing reputation; for others, the aim could be to drive down costs and improve general competitiveness (ISO 2018, 3).

In a way, ISO 50001 Directive is building on Article 8 and it helps industrial companies to improve their climate protection efforts, which can also result in great energy and cost savings. Energy management systems enable continuous improvement of energy efficiency in the facility by providing real time monitoring, planning and even optimization of energy consumption and use. The main characteristics of an Energy Audit and ISO 50001 Energy management system are presented on the figure 7 below:

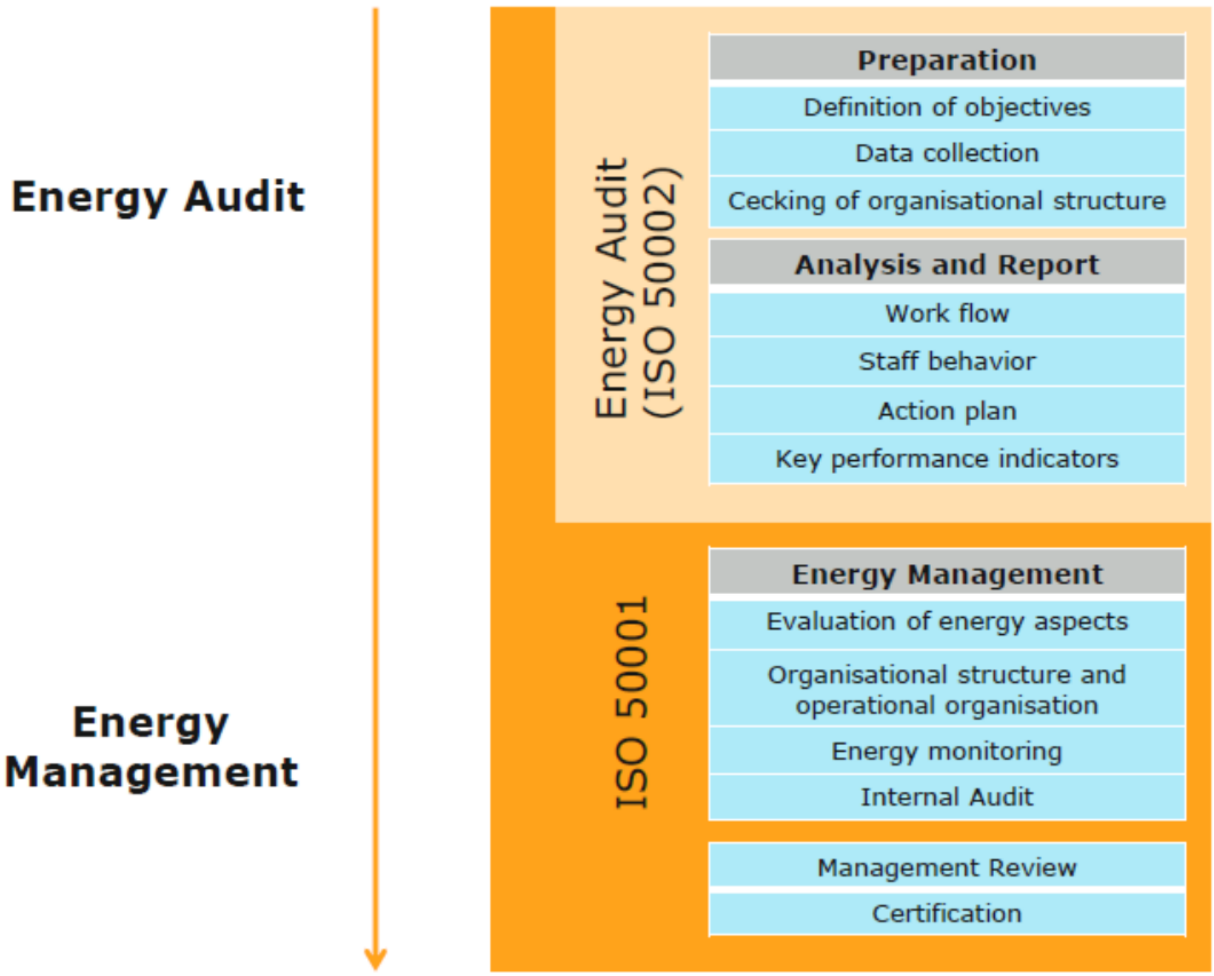

Figure 7. Energy Audit is a solid starting point for an ISO 50001 energy management system (Arqum 2015, 11).

2.3 Energy management

This section gives a general understanding of energy management in process industry. It presents important objectives for energy management and some common challenges it faces.

Furthermore, the section gives insights for the characteristics of energy management systems and for their common uses. Energy management itself is considered as a cross-sectional task that includes the planning, management, organization, and monitoring of operational energy use, with the goal of achieving continuous improvement (Freie University 2018, 2).

Energy can often be the largest component of an enterprise cost structure especially in the process industry. Most companies today have formalized energy management programs, and many use automation and control technologies to help minimize their energy costs. However, it has been evident that many companies have to take their efforts to the next level by monitoring and optimizing their energy use in real time, and through more widespread adoption of advanced automation technologies as well as energy management applications. Enterprises can achieve significant reductions both in energy costs and in greenhouse gas emissions as these efforts are executed together with cross-functional responsibilities and reporting, including the financial, operational, and environmental departments. (ARC Advisory Group 2019)

2.3.1 Objectives and challenges

Energy management isn’t a new concept, it has been done for decades and even centuries in some sense. Whether that were done by storing backup gasoline for car in containers or having fuses to cut electricity spikes in a house or adjusting water flow in dams, all of that could be considered as energy management. Energy management has evolved quite a bit throughout the decades, and nowadays there are a lot that can be achieved through energy management. As previously mentioned, energy management could be used for example for storing energy, protecting energy supply and optimizing energy use. Through proper energy management systems, there are countless of opportunities that can add value in technological enterprises especially in process industry. Through EMS, industry actor could for instance oversee operations at a factory level, report energy use to all required parties, reduce energy costs, or even trade electricity. The reason why energy management has been so vital in the past decades, is because through energy management it’s possible to conserve energy, protect climate and achieve significant cost savings.

Energy management can be often in action since an industry actor wants to know more about their energy use, needs to protect their processes, wants to increase their revenue, needs to abide by regulatory standards, wants to direct their energy usage or share energy information further. Energy management is sometimes seen as an added feature to a power plant’s or a factory’s operations. Nowadays it’s almost necessary to have a proper energy management system in an enterprise that operates in process industry. An energy expert of a market leading company said in an interview conducted during this thesis: *”No one in this field can operate without proper energy management system anymore.”* Since almost everyone knows how important it’s to have an energy management system, industry actors try to fulfill their energy management potential and needs by implementing the best possible systems with the lowest costs. It’s not an easy task since there are a lot of possible things that can still be achieved through energy management systems that haven’t been discovered yet.

Many industry experts, also the ones that have been interviewed during this thesis, have realized many uses for their energy management systems. Possible uses for energy management systems include, but are not limited to:

- Energy supply optimization
- Energy security
- Energy monitoring and documentation
- Forecasting energy demand and use
- Securing the energy price
- Locating savings potential
- Optimizing energy use
- Improving in energy efficiency
- Open and fast communication between systems
- Improving data security
- Fulfilling the requirements for official and regulatory standards
- Reducing CO_2-emissions
- Energy storing
- Utilizing digitalization
- Environmental responsibility and reporting
- Realtime electricity trade
- Automatic energy meter readings

- Sharing key process information between people
- Surveillance of powerplant operations

Energy management system can add a lot of value through these features, but the applications aren’t always that easy to implement. Energy management faces a lot of challenges that need to be overcome. Energy management isn’t often among the first priorities in plants or factories. Utilization and safety of powerplant operations and processes are almost always the first priorities according to some industry experts that were interviewed during this thesis. It’s noted in energy efficiency literature, that energy management, through its practices and its systematic approach, is recognized as a supporting function for the industrial energy system (Sa et.al 2018,2). Sometimes the demand and interest that the benefits of an energy management system can bring, are dismissed. It’s also possible that benefits don’t seem great enough compared to the required investment and there might not even be enough budget for the energy management system in the first place.

To attract customers, energy management systems need to add significant value to enterprise’s operations. The best value is most likely the profit it can bring. Perhaps the greatest issues with energy management systems could be that they don’t always add distinct enhancement to enterprise’s cash flow. Another reason that underlines why energy management systems don’t necessarily reach their full potential, is its interdisciplinary nature. Energy management involves multiple criteria and knowledge such as technological, political, social, financial and managerial aspects. All of these practices and processes need to be implemented and supervised, which make it harder to attract customers (Sa et.al 2018,2).

Another challenge energy management could face according to Cross Company in industrial applications is that energy usage has to be collected and monitored for multiple types of energy and not just electricity. Additional energy sources for energy management could include natural gas, water, compressed air, steam, and inert gases. The requirements for hardware devices can also be very high and the system must be flexible enough to expand as the manufacturing plant grows. (Cross Company 2013)

2.3.2 Industrial energy management systems

An energy management system is a systematic process for continually improving energy performance. It is defined in Energy Efficiency Directive as a set of interrelated or interacting elements of a plan, which sets an energy efficiency objective and a strategy to achieve desired energy managing results. An energy management system can be applied to any organization but is regarded particularly beneficial for energy-intensive processes. It is a process of continuous improvement, which requires that organizations continue to seek out new opportunities for energy savings in all areas of activity. (Serrenho et al. 2015, 6) Figure 8 illustrates some of the components and energy flux that need to be overseen with an industrial EMS, including power, steam, fuel, water and waste.

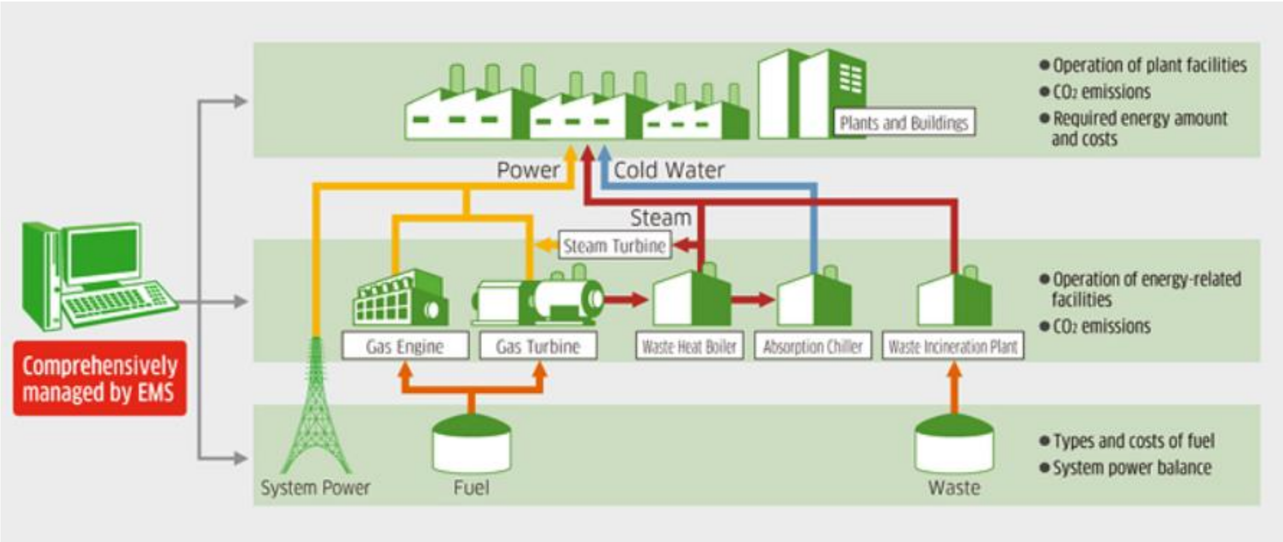

Figure 8. An example of how an energy management system can oversee production and manage processes in a power plant (Kawasaki 2018).

In practice, an energy management system systematically records the energy flux and serves as a basis for investments in improving energy efficiency. A functional energy management system can help companies to comply with the commitments that have been made in their energy policy and it can continuously and systematically improve the energy performance. The system encompasses all elements of an organization that are necessary for creating an energy policy, also defining and achieving strategic objectives. Thus, it includes the organizational and informational structures that are required for implementing energy management, including resources. It can formulate and implement the energy policy, including the strategic and operational objectives and the action plan. Thus, it includes planning, introduction and operation, monitoring and measurement, control and correction, internal audits, and a regular management review. (BMU 2010, 14)

Energy management systems in industrial use are used for example in managing power generation, transmission and distribution. Generally, they allow an organization to gather real-time information on the energy usage for instance through monitoring, assessing and visualizing energy consumption. It can also help in data-driven decisions and it augments enterprise level operations and financial decisions (Mordor Intelligence 2018). This enables the operations in the market to be more energy efficient. Proper documentation ensures that the organizations are more aware and accountable of their energy consumption and targets through which they can operate better. Figure 9 illustrates different functions of an energy management system, and it presents how an energy management system can be positioned to improve energy efficiency in an enterprise level.

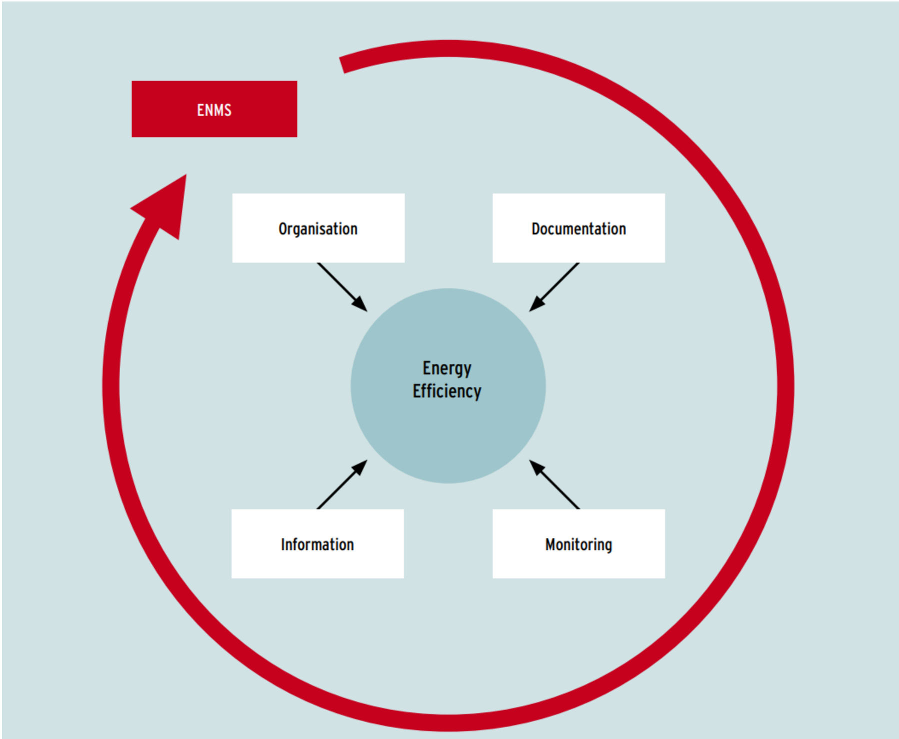

Figure 9. Key aspects of an energy management system and the aim of achieving energy efficiency (BMU 2012, 15).

When an industrial energy management system is equipped properly in an enterprise it can lead to several benefits, one of which is energy efficiency. Some other benefits it can lead to are collected below (Envidatec 2018, 43-44):

- Reduced costs and energy consumption
- Increase in productivity
- Environmental protection and reduced greenhouse gas emissions
- Increase in competitiveness
- Improvement of the external representation of the company
- Improved communication between different departments of the company

The needs for certain energy management systems may vary between different process industry enterprises. Commonly an energy management system is in practice to add more value to the enterprise's operations. There has been a study made previously about how relevant certain features are in terms of energy management. The interview was done to 10 energy-intensive companies in Sweden, both medium and large size. Interviewees rated certain feature from 1 to 7, where 1 is irrelevant, 4 is somewhat relevant and 7 is highly relevant. The results are presented in table 1 below:

Table 1. The results of energy management assessment in Sweden (Sa et.al 2018, 5).

Size		Medium Size							Large Size				
Use Case	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Improvement of the energy efficiency of process machinery	EnMA1	7	6	6	7	7	6.6	6	5	6	7	6	6
Energy efficiency of buildings	EnMA2	7	4	6	5	7	5.8	2.8	2	3	4	2	3
Reuse of heat, combined heat, and power plant, use of renewable energies	EnMA3	3	2	3	3	4	3	2.8	4	3	2	3	2
In time monitoring system	EnMA4	7	6	5	7	6	6.2	2.6	4	2	3	2	2
Total understanding about the people who are working within the company	EnMA5	6	6	7	5	6	6	6	6	7	6	5	6
Existent of a defined target	EnMA6	5	5	6	5	5	6	6.6	6	6	7	7	7
Existent of a full-time energy manager	EnMA7	7	2	1	1	7	3.6	5.2	4	4	7	4	7
Root-cause analysis	EnMA8	6	7	7	7	6	6.6	6.4	7	6	6	7	6
Monitoring and alarming	EnMA9	7	4	4	7	5	5.4	5.2	4	4	5	6	7
Reduce energy consumption in critical situations	EnMA10	7	7	7	7	7	7	6.6	7	6	6	7	7
Smart-grid functionality	EnMA11	1	1	1	4	1	1.6	4.6	4	5	1	6	7
Calculation of energy costs	EnMA12	1	1	1	4	1	1.6	4	5	1	4	5	5
Post calculation: identify significant deviations	EnMA13	1	3	3	3	1	2.2	3	1	5	3	3	3
Energy footprint of production	EnMA14	1	2	3	1	1	1.6	5	3	5	6	5	6
Implementation of a certified Energy-Management-System according to ISO 50001 as requested by public bodies or customers	EnMA15	1	1	1	1	4	1.6	4.6	4	3	5	4	5
Establishing services to support Carbon-Emissions Trading (forecast, sourcing)	EnMA16	1	2	1	1	1	1.2	3	2	3	4	2	4

The study indicates for example that the improvement in energy efficiency of process machinery, in time monitoring system, root-cause analysis and reducing energy consumption in critical situations are in very high relevance to have in energy management. Services to carbon-emissions trading and post calculations were slightly irrelevant functions to have.

Even though improving energy efficiency or reducing energy consumption are in high relevance to have, they can be challenging to do with an energy management system. The capabilities an EMS has depend mostly on the investments and efforts one is willing to put forth for energy management. An EMS is often used as a tool for energy monitoring, documentation, reporting and forecasting of energy consumption. That usually requires rather small investment and is one clear benefit energy management system can bring for any enterprise. When invested more in energy management system, it can for instance predict outages, locate savings potential, optimize the current energy use, trade energy and secure the energy price and use. In those cases, an EMS need to have deeper integration for the whole plant level and greater data analytics tools, capabilities and personnel to make use of the whole system potential.

2.4 Energy management solutions in process industry

This section presents some important energy management solutions in process industry. The solutions are a collection of common players in energy management field in Europe. Interviewees in this thesis had some experience and knowledge of some of these products and the information collected in this section is mainly accessible from supplier websites. These solutions are products and services that enterprises offer to customers in pulp and paper, mining and metal industry.

2.4.1 cpmPlus Energy Manager

ABB's cpmPlus Energy Manager is a software product that allows industrial customers to monitor, manage and optimize their energy usage. It results in improved efficiency and cost savings. Focusing on the business side of energy management, Energy Manager can be a key element in any company's energy management program. (ABB 2018)

Energy Manager provides the tools to set targets for example on energy consumption, efficiency, cost, CO_2 -emissions and other energy performance indicators. It can also monitor the actual performance against the targets. Planning and scheduling tools are available to analyze energy demand and optimize energy use and supply. Energy Manager is a modular product that supports energy efficiency improvements and cost reduction at industrial plants. It allows an implementation to start small and grow over time. (ABB 2018)

As configured, the software tool can support energy and cost analysis as part of a larger energy management system. The tool can inform users of the relative energy consumption as compared across key activities in manufacturing and industrial facilities, and where appropriate, it can be used to quantify the cost for direct energy inputs. Energy managers who effectively use this tool can therefore identify energy and costs efficiencies associated with production and facility operations. Reference database, conversion factors and other supporting functions are suitable for inclusion in an analytical platform for the calculation of carbon credits. (ABB 2018)

ABB’s Energy Management system can be implemented by configuring the following main three Energy Manager modules:

- Module 1: Energy Monitoring and Targeting
- Module 2: Energy Demand Planning
- Module 3: Energy Optimizer

Energy Monitoring and Targeting includes tools to monitoring, reporting, analyzing, and set targets on measured energy performance. Energy Demand Planning includes tools to predict energy demand and use based on plant production schedules and what-if scenarios. Energy Optimizer is the optimization of industrial energy systems using a holistic approach. Depending on the application it can mean optimizing the commitment of own power generation capacity, energy procurement and sales, energy mix or use of plant’s production lines for maximum total profitability. It can also mean optimizing production of some energy consumers, for example production of thermo-mechanical-pulping in Pulp & Paper mill. (ABB 2018)

All modules are seamlessly integrated so that they provide information to each other. The modules are built upon the cpmPlus foundation consisting of the cpmPlus History database and Vtrin graphic user interface visualization tools. The basic structure and architecture are presented in figure 10 below.

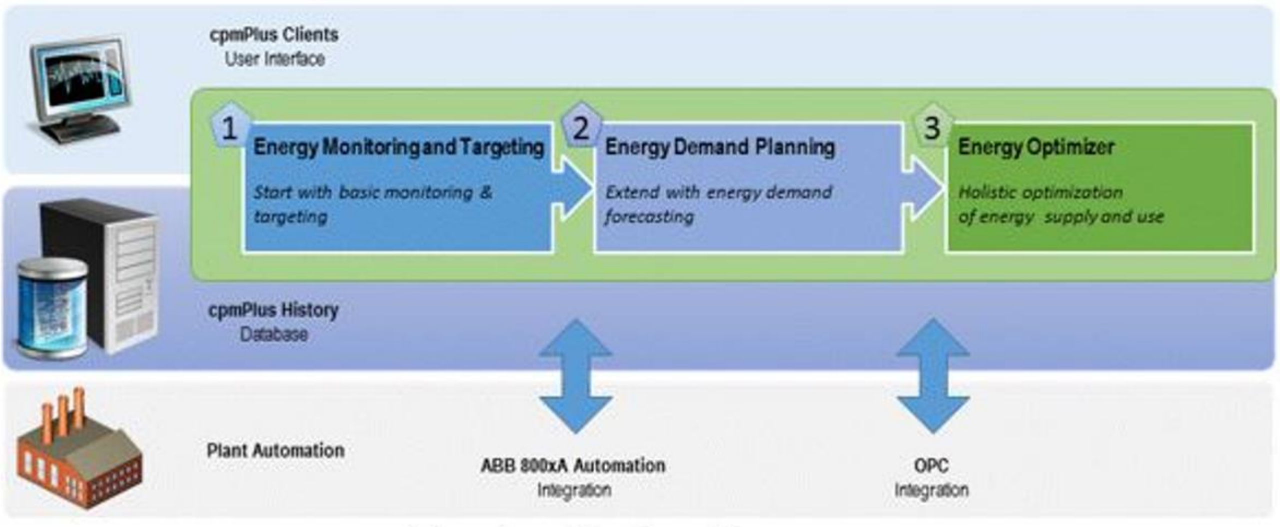

Figure 10. cpmPlus Energy Manager architecture (ABB 2018)

The system can generate energy and cost savings for instance through (ABB 2010, 2):

- Lower electricity purchase prices due to accurate consumption plans and real time electricity monitoring
- Avoiding price peaks and penalty charges
- Employing optimal resources in the supply of electric power
- Enhanced awareness of energy consumption and energy costs
- Early detection of poor performance based on real time monitoring of performance compared to set targets.

2.4.2 SIMATIC Energy Manager

Siemens has SIMATIC Energy Manager for company-wide energy analysis. With SIMATIC Energy Manager, it's possible to visualize energy flows and consumption values in processes in detail. They can be assigned to the relevant consumers or cost centers and they identify why changes have occurred. It can also be used to evaluate implemented efficiency measures, optimize energy procurement, and compare energy efficiency across plants and locations – in a scalable, transparent, and future-proof way. (Siemens 2018)

SIMATIC Energy Manager has powerful, scalable energy management system that links energy and production data, thus helping to calculate the productivity of energy consumption. SIMATIC Energy Manager has user-specific dashboards, meaningful energy indicators and versatile interfaces for measuring energy data. Figure 11 illustrates the structure of the SIMATIC Energy Manager PRO. (Siemens 2018)

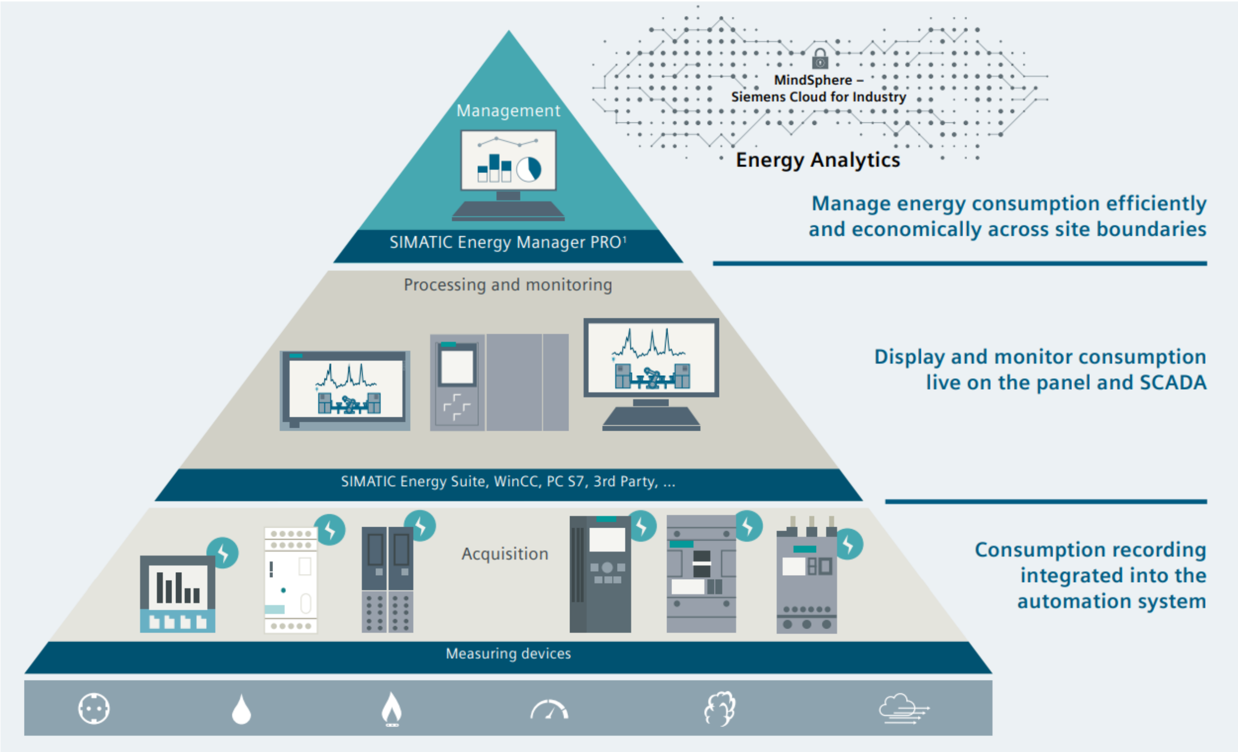

Figure 11. SIMATIC Energy Manager PRO architecture (SIEMENS 2017, 3).

SIMATIC Energy Manager is available in two versions for applications of varying complexity: Basic and PRO. The Basic version provides a simple way to get started with energy management. It can be easily configured for the application in question via web engineering in interaction with the automation system and for manual data acquisition. Predefined templates for reports and configurable dashboards support reporting. SIMATIC Energy Manager Basic can be upgraded to SIMATIC Energy Manager PRO at any time with a license key. (Siemens 2018)

The PRO-version provides additional functions for comprehensive, ISO-compliant energy management. The software supports the user with extensive reporting for recording and visualizing performance indicators and consumption data and with tools for calculating performance indicators for more complex situations. Energy Manager PRO also permits batch-related or material-related consumption analysis and forecasts of energy consumption. Various automation-level systems can be integrated via numerous interfaces. The main differences of these versions are listed in table 2:

Table 2: Features for SIMATIC Energy Manager Basic and PRO (Siemens, 2018)

Functionality	SIMATIC Energy Manager Basic	SIMATIC Energy Manager PRO
Configuration	Simple configuration via web engineering	Full client configuration with numerous options and web engineering
Interfaces	Data link via OPC UA, Energy Suite, SIMATIC WinCC, and Modbus	Data link via OPC UA, Energy Suite, SIMATIC WinCC, Modbus, ASCII, OLE DB, and S7; connectivity with S7 Energy Efficiency Monitor incl. template/instance concept; and connectivity with MindSphere
Data preprocessing	Data point configuration; create, change, or delete a matrix for manual data entry	Plus loop/prototype calculation stage 1 for preprocessing the data
Reporting	Create, change, and delete reports based on predefined templates	Comprehensive report functionality with user-specific or adapted report templates
Performance indicators	Simple	Extended (if-then, threshold values, etc.)
Dashboards	Create, change, and delete dashboards; use various widget types (chart, pie, tacho, traffic light, diagram, text, value, table, Sankey, alarm, heat map)	Create, change, and delete dashboards; use various widget types incl. advanced widgets (baseline management, map, multiple regression)
Analyses	Basic functionality	Detailed batch and material analyses
Forecasting tools	No	Yes (reference day forecast, production-plan-based forecasting, regression model)
Measure planning	No	Definition and analysis of energy efficiency measures
File upload	No	Yes, documents can be uploaded

2.4.3 Valmet DNA Energy Management

Valmet has a Valmet DNA Energy Management for energy management. It is a modern, modular database software system meant for energy companies. It offers tools for load and price forecasting, energy production optimization and electricity trading. Separate modules also allow each user to receive a tailor-made system without the need for expensive and time demanding software customization. The main features for the system include (Valmet 2018):

- Heat load forecasts
- Electricity forecasts
- Measurements
- Spot trading
- Production optimization
- Long-term optimization
- Excel reports

The system can automatically calculate new production plans at a rate that is set by the user. The system operates with several time horizons, and it’s able to calculate for example 24 hour and 7-day optimization. Apart from the automatically generated plans, it is also possible to run an optimization manually. The main benefits for the system include (Valmet, 2018):

- Online corrected automatically updated forecasts that are as accurate as possible
- Plants modelled with easy-to-use and easy-to-modify graphical user interface
- Optimal production plan for heat and electricity production
  - lowest costs
  - optimal starts and stops
  - cheapest fuel
- Optimal production plan for the physical trading on the energy markets, e.g. derivate, day-ahead and intraday-market: making the most of electricity market
- Versatile and customized reporting and data export and import possibilities with Business Intelligence figures
- The common system increases the quality of planning and transparency
- The same way to plan for every shift

Valmet DNA Energy Management forecasts heat demand and optimizes production. That allow units to achieve the best total economic costs and to determine the optimal times for unit startups and shutdowns. (Valmet 2018)

2.4.4 Schneider Electric EMS

Schneider Electric’s energy management system is Schneider Electric EMS. The EMS can be deployed either fully integrated with their ADMS, Advanced Distribution Management System, or as a stand-alone system. Main benefits of the EMS include (Schneider Electric 2010, 6):

- Identify and spot increase and decrease in energy usage pattern.
- Draw energy consumption trends (weekly, seasonal, operational)
- An effective tool to determine future energy use when business plan changes
- Only tool which helps in diagnosing and controlling specific areas of energy wastage
- Can compare how the energy and business changes in the past
- Draw baseline and develop performance targets for energy management programs

- Improve power supply reliability by preventing disturbances in frequency and power flow
- Minimize electric system operating cost

2.4.5 KRIS³

KRIKO Engineering has KRIS³ product that is a professional tool that offers all preconditions to display energy flows ongoingly, clearly and transparently. For that reason, the KRIS³ Energy Management Module can be combined with all other modules of the Process Information System KRIS³ (KRIKO Engineering 2018). The Energy Management component is part of a process information system KRIS³, it is presented in figure 12 below:

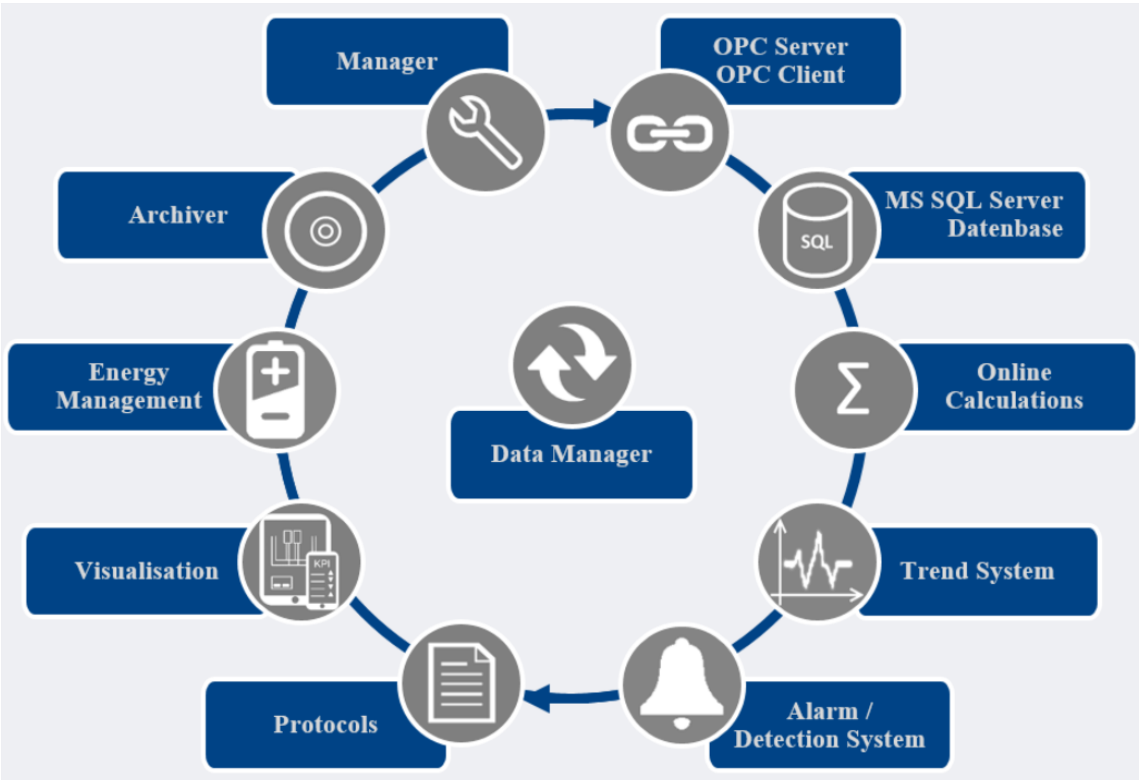

Figure 12. KRIKO system including Energy Management component (KRIKO 2018)

KRIS³ implies many functionalities that go far beyond the basic requirements specified in the ISO 50001. Some of them are unique features compared to similar products of other suppliers. These include for instance functions like the dynamic display of Sankey diagrams or the possibility to measure and analyze not only time triggered but also product and charge triggered energy consumption. (KRIKO Engineering 2018)

KRIS³ has 2 different modules, Monitoring and Measuring and Energy Balance and Calculation of Saving Options. With Monitoring and Measuring module, the added value is (KRIKO Engineering 2019):

- Clear display of energy use and energy flows
- Control of process values and KPI using individually designable displays with access from computer, tablet or smartphone
- Continuous target-performance comparison of defined indicators
- Time-controlled meter-reading
- Product-controlled meter-reading for batch processes
- Administration of energy readers
- Calculation functions for virtual readers, calculated readers with correcting values, energy readers in tree structure
- Mobile data acquisition using bar code label

With Energy Balance and Calculation of Savings Options, the added value is (KRIKO Engineering 2019):

- Standardized sorting of energy flows based on media
- Online balancing of highly complex processes
- Dynamic Sankey diagrams
- ABC analysis with pareto evaluation
- Pie graphs with comparison of time periods
- Trend graphs of energy development
- Electronic comparison with energy provider with standardised transfer of metering data
- Heating day computation for norming the measured heating values over heating periods

2.4.6 Honeywell Energy Management Systems

Honeywell's solution for energy management is their customizable portfolio Energy Management Systems. Energy Management Systems is a comprehensive offering that can combine energy and process optimization and also where appropriate, incorporate the solution into online advanced control and optimization strategies. Honeywell's Energy management Systems help manufacturers to use energy more efficiently, purchase and produce it more economically and responsibly, and also improve overall process efficiency, while reducing the environmental impact and improving regulatory compliance. Additional components of the solution include (Honeywell 2018):

- Heat and power recovery within and across process units using pinch analysis for improved integration
- Steam and power system optimization
- Calculation of dynamic energy and emission targets
- Feedstock selection
- Energy contract management
- The introduction of renewable energy sources such as biofuels
- Services that sustain and even improve results over time

Energy Management Systems can be implemented in stages starting with smaller-scale that have quick return-on-investment projects and then moving toward more comprehensive, higher-value projects. (Honeywell 2018)

3 METHODOLOGY

This chapter introduces the methodology that is used in this thesis in order to gather information from target companies that operate in Europe in Process industry. The research design and the research process are also presented in this chapter. In addition to this, this chapter introduces the interviewees and the study objectives. In the end of this chapter the data collection and analysis are also explained briefly.

The empirical part of this thesis is mainly focused on researching the energy management needs the interviewee companies have, what kind of energy management systems they currently use and what could be done better so that the companies could achieve desired targets. The aim in this research is to position the energy management systems on the constantly evolving energy markets with the help of literacy and interviewees' feedback.

3.1 Research design

This research is chosen to be qualitative in its nature. That is mainly because the chosen research questions and the topics that this thesis have are aligned with a qualitative research. In this research customer values, feedback and future targets are studied, which are difficult to be measured quantitively. For this reason, the aim in this research is to perceive the concepts and the bigger picture of the energy market, energy management systems and the policies behind them, in order to be able to address the research questions properly.

A case study is chosen to be the correct research approach for this thesis. Through case study, researcher can gather reasonable insights to real-life events for example through conducted interviews, documents, reports and observations. Yin mentions that a case study is meant to be an empirical inquiry that can investigate contemporary phenomena in depth and within its real-life context. This is the case for instance when boundaries between context and phenomenon aren't necessarily clear. A case study would be a good choice for the study for instance when research objectives might need more consistency than just certain data points. Also, a case study could be chosen, when there are not necessarily any obvious results that could be generalized. (Yin 2009, 13-18)

To conduct a qualitative research, methods such as using the data that exists, general interviews, questionnaires, observation and even action science can be used. In the research of this thesis, the interviews were selected to be as the research method, so that the qualitative data can be easily collected. This study uses non-probability sampling of results. For that reason, the results shouldn't be used for proper statistical conclusions as they are collection of subjective views of the interviewees. (Saunders et al. 2011, 151).

3.2 Interviewees and the objective

Interviews are targeted to companies in process industry that have industrial energy management systems. The participants vary between Finnish and European companies, and between market leaders and smaller regional enterprises. All the interviewee companies have large demand for energy and high interest in energy management systems generally.

Objective for the interviews is to gather information to better understand the energy management market needs in Europe. The interviewee needs in energy management and feedback about their energy management system can for instance help energy management system suppliers to position themselves in the constantly evolving market, enabling better products and services for their industrial customers.

3.3 Data collection

In this thesis, data collection is done by interviews that are semi-structured. In total there were 8 interviews conducted for total of 11 people for total of 8 different enterprises in process industry. The interviewees consist of Energy and System Engineers, Energy Management Experts, Operations Managers, a Production Manager and a CEO. All the roles for interviewees are presented in the table 3 below:

Table 3. The roles of the participating interviewees and their quantity

Interviewee role	Quantity
Energy and System Engineer	4
Energy Management Expert	3
Operations Manager	2
Production Manager	1
CEO	1

The basic interview structure consists of three parts, A, B and C. The structure was the baseline for the interviews, but additional questions were also asked as they were relevant for the situation and for the target company. The duration of the interviews varied from 30 minutes to 2 hours. The interview structure is presented below separately for each part.

In part A, the interviewees were asked to assess each of the presented 16 categories, whether they were 1st, 2nd or 3rd priority in terms of their energy management system needs for their future energy management. Each category was the discussed, and the interviewees assessed them from 1-3 and gave additional feedback to justify their assessment. The idea of the part A was to map out the energy management needs interviewees had for now and for the future, and to get better understanding of which categories weren't that relevant for their energy management. The part A of the interview, which included the table 4 are presented below:

A) There are 16 energy management categories below. Please assess each category whether it's 1st, 2nd or 3rd priority in terms of your energy management system needs for your future energy management.
1st priority = Almost mandatory to have
2nd priority = Would be good to have
3rd priority = Not necessary to have

Table 4. Energy management categories for the interviews

Energy supply optimization	**Energy security**	**Energy monitoring and documentation**	**Forecasting energy demand and use**
Securing the energy price	**Locating savings potential**	**Optimizing energy use**	**Improving in energy efficiency**
Open and fast communication between systems	**Improving data security**	**Fulfilling the requirements for official and national standards**	**Reducing CO_2-emissions**
Energy storing	**Utilizing digitalization**	**Environmental responsibility and reporting**	**Something else?**

In part B, the interviewees were asked to assess how well their current energy management system answers to their energy management needs from 1 to 3. Again, the categories were assessed one by one and the interviewees gave additional feedback to justify their assessment. The purpose of the part B was to find out what features and categories their current energy management systems already excelled in and which categories of the systems still needed improving. The part B of the interview that included the table 5 is presented below:

B) Now consider how well does your energy management system answer to your energy management needs in each category from 1 to 3.
1 = Answers to the need very well
2 = Answers to the need partly
3 = Doesn't answer to the need at all

Table 5. Energy management categories for the interviews

Energy supply optimization	**Energy security**	**Energy monitoring and documentation**	**Forecasting energy demand and use**
Securing the energy price	**Locating savings potential**	**Optimizing energy use**	**Improving in energy efficiency**
Open and fast communication between systems	**Improving data security**	**Fulfilling the requirements for official and national standards**	**Reducing CO_2-emissions**
Energy storing	**Utilizing digitalization**	**Environmental responsibility and reporting**	**Something else?**

Part C and the concluding part of the interview consisted of 7 questions. The questions were about the interviewees energy management systems and about the collaboration with their system supplier. Interviewees were asked to answer the questions as well as they could based on their knowledge and understanding. The purpose of part C was to receive authentic feedback and comments by asking certain questions. The part C is presented below:

C) There are 7 questions below about your energy management system and about the collaboration with your system supplier. Answer each question as well as you can.

1. What is your energy management system used for and what can be done with it?

2. Why did you choose your system supplier and their energy management system as a part of your energy management?

3. What are the main benefits that your energy management system has?

4. What are the main weaknesses that your energy management system has?

5. What should be done so that the product would add more value to you?

6. What would you say about the collaboration with your system supplier? Is there something they could have done better?

7. What could be developed in your energy management system now or in the future?

3.4 Data analysis

After the conducted 8 interviews, data analysis started by reviewing the received data. The assessments for the part A and B were listed in Microsoft Excel and the average scores for each category were calculated. Through average scores, it was possible to organize different categories in order in terms of priority interviewees collectively had. Through this practice, it was evident that some of the categories were clearly priority 1, almost mandatory to have in energy management systems and some were closer to 3rd priority, not necessary to have in an energy management system. Similarly, in part B, some categories were assessed close to 1, which means that their current energy management system answers to the need well and some were closer to 3, which means that the current energy management system doesn't answer to the need almost at all. All the explanations interviewees gave for different assessments helped in verifying that the interviewees understood each category fairly similarly, although the level of success in interpreting an answer for certain category is hard to measure.

The comments from part C were listed in Microsoft Word and common comments and feedback that kept repeating were emphasized more in the results section of this thesis. Many interviewees had individual and specific feedback that was mostly applicable only for that specific interviewee's EMS or system supplier. In that case some of the specific comments have been left out in this thesis as they didn't add value in the bigger picture that was searched for through this empirical study. However, many specific comments and individual concerns were applicable for energy management systems in general, so they received greater attention in the interview results section.

Every single thought and comment that was presented during the interviews and that is presented through this thesis, can't be considered as a truth per se or fact based. In fact, most of the thoughts are subjective to the person interviewed, and there is even the possibility for data to be lost in translation when the thoughts are carried out through this thesis, which is a quite relevant point in assessing the credibility of the results. However, the general overview of the comments and the views each interviewee had for their energy management needs and energy management system development ideas, can give the results that were aimed for in this thesis. That is to gain better understanding of how to position energy management systems on an evolving energy market through literature-based analysis and the empirical research.

4 INTERVIEW RESULTS

This chapter introduces the empirical study findings and results. This chapter summarizes different process industry interviewee’s feedback and comments on energy management generally and on their energy management systems. This chapter focuses on the most important energy management needs interviewees have and on the most important improvement ideas and suggestions the development of energy management systems generally require according to the interviewees. The next chapter focuses deeper on how the energy management systems should be positioned in the market and on how their demand responds to the requirements of international and national targets.

4.1 Energy management system priorities

During the interviews, the first task was to map out the interviewee’s energy management needs. To do that, the interviewees prioritized the most important categories and features their energy management system should be used for now and in the near future. The categories are examined from the energy management system’s point of view, meaning that whether the energy management system should add value on a certain category or not. Some of the categories might be more important for the operation of the enterprise per se, but perhaps not relevant enough to be done through their energy management system.

The categories were divided into 16 different energy management features. Interviewees chose whether a category is first, second or third priority for their energy management needs. First priority meaning almost mandatory category to have in energy management system, second priority meaning it would be good to have in energy management system, and third priority meaning not necessary to have in energy management system. The categories are presented below:

- Energy supply optimization
- Energy security
- Energy monitoring and documentation
- Forecasting energy demand and use
- Securing the energy price
- Locating savings potential

- Optimizing energy use
- Improving in energy efficiency
- Open and fast communication between systems
- Improving data security
- Fulfilling the requirements for official and regulatory standards
- Reducing CO_2-emissions
- Energy storing
- Utilizing digitalization
- Environmental responsibility and reporting
- Something else?

After the interviews, the categories that received the average score of 1-1,3 priority are marked light green, the score of 1,4-1,6 marked dark green, the score of 1.7-2 marked yellow, the score of 2.1-2.4 marked orange and 2.5-3 marked red in the table 6 below.

Table 6: Energy management needs according to the interviewees

Energy supply optimization	**Energy security**	**Energy monitoring and documentation**	**Forecasting energy demand and use**
Securing the energy price	**Locating savings potential**	**Optimizing energy use**	**Improving in energy efficiency**
Open and fast communication between systems	**Improving data security**	**Fulfilling the requirements for official and regulatory standards**	**Reducing CO_2-emissions**
Energy storing	**Utilizing digitalization**	**Environmental responsibility and reporting**	**Something else?**

Priority 1 from the something else category included:

- Realtime electricity trade
- Automatic energy meter readings
- Good information for all employees in the mill
- Surveillance of powerplant operations

Energy management needs varied between different process industry companies. However, according to the interviewees the most important things that should be done with an energy management system are securing the energy price, forecasting energy demand and use and optimizing energy use.

Securing the energy price is important as the price can fluctuate a lot and an energy management system can be the right product to do the securing. Tools in an energy management system can enable efficient operations in the electricity market. The process industry companies use a lot of energy in their plants and factories in manufacturing and in energy generation, so it's vital that their energy management system can help them to be on top of the energy demand and its use by forecasting the projected energy requirements. Constantly increasing amount of available data is one of the driving forces why interviewees might require optimization of their energy use to be done with an energy management system. That can result in great energy savings allocated into significant financial benefits.

Features that interviewees said that would be quite irrelevant to have in an energy management system would be energy storing and reducing CO_2-emissions. Energy storing wasn't that necessary for the interviewees as for now. If there were proper energy storing opportunities and more attractive business opportunities in the market such as cost-efficient large batteries, the interest for storing energy might enhance. As for now, most of the interviewees said that energy storing isn't that necessary for their operations. Reducing CO_2-emissions was an important factor for the interviewees, at least in a strategic level. The main way to reduce it is through fuel selection and different power plant processes, instead of through an energy management system. That's why most interviewees said that reducing CO_2-emissions is quite irrelevant primal feature to have in an energy management system. Of course, if energy efficiency increases and an energy management system is able to produce energy savings, it reduces CO_2-emissions secondarily.

4.2 Feedback for the energy management systems

After the energy management needs were targeted for each interviewee, they were asked to evaluate their current energy management system and give feedback to it according to their experience and understanding. In this section the interviewees have evaluated how their energy management system responses to their energy management needs, what kind of main uses and benefits the system has for them, what kind of things they have noticed operationally and finally, they have commented on user experience and the development ideas for their system. An energy management system, EMS, that is mentioned by the interviewees, refers to an energy management system that they have in their plants or factories.

4.2.1 Main uses and benefits for the systems

Interviewees were asked what their EMS is mainly used for. They had different EMS products and variety of uses for them, but the most important uses for their systems according to them are collected below:

- Operational monitoring in a power plant
- Reporting on energy use, procurement and distribution (For example: Fuel, emissions, electricity, heat)
- Monitoring energy consumption throughout the plant at a very detailed level
- Electricity trading in spot and midterm markets
- Production balance management
- Optimizing production and consumption
- Handling of different alarms in production
- Optimization of energy supply and use as a whole
- Balance clearing
- Data collection from automation system for operation instructions
- Generating monthly reports, computing and billing sheets

Some of the interviewees said that their EMS is an essential system that oversees the plant's operations. Through it the system key figures are presented, and proper reporting is done for all required parties. For some EMS is also a helpful tool for electricity trading. Production balance management is done hourly in Finland and every quarter of an hour in Germany. The role of an EMS is essential for production balancing, especially if the timeframe for it narrows down even further. Optimization of energy supply and use as a whole requires quite advanced EMS. Some of the interviewees had systems that had operational optimizing tools that could result in great energy savings through optimizing their energy demand and use and locating their savings potential.

Energy management systems have generally great benefits for the process industry actors. Depending on an EMS, the benefits and the size of required investment may vary, but there were some evident benefits that the interviewees mentioned that had been the main drivers for their investment in the first place. They included for instance:

1. Overseeing the plant's operations
2. Reporting of energy use to all parties
3. Abiding with the regulatory standards
4. Optimization of energy supply and use
5. Tools for electricity trading

Most interviewees have had their system for several years and even for few decades, and they have usually upgraded it every 5 to 10 years. Usually during an upgrade, there have been new features or uses that the interviewees have realized together with their supplier. The roles of the systems also vary within the interviewees. For some, their EMS is one of the many other systems adding only a marginal impact to the whole operation of the plant. For some it's a critical and central system that has a major impact to the whole plant's operation and revenue.

4.2.2 Response to the energy management needs

The interviewees evaluated how their energy management system answers to their energy management needs according to their experience and understanding. Evaluation was done by presenting the same 16 energy management categories that were presented in the section 4.1. Interviewees were asked to assess how well their energy management system answered to their needs for each category from 1 to 3, 1 meaning answer to the need very well, 2 meaning answer to the need partly and 3 meaning doesn't answer to the need at all.

After the interviews were conducted, the categories that received the average score of 1-1,3 are marked light green, the score of 1,4-1,6 marked dark green, the score of 1.7-2 marked yellow, the score of 2.1-2.4 marked orange and 2.5-3 marked red in the table 7 below.

Table 7: Average score how well energy management systems have answered to customer needs

Energy supply optimization	**Energy security**	**Energy monitoring and documentation**	**Forecasting energy demand and use**
Securing the energy price	**Locating savings potential**	**Optimizing energy use**	**Improving in energy efficiency**
Open and fast communication between systems	**Improving data security**	**Fulfilling the require-ments for official and regulatory standards**	**Reducing CO_2-emissions**
Energy storing	**Utilizing digitalization**	**Environmental respon-sibility and reporting**	**Something else?**

In general, interviewees were very satisfied with how their energy management system helps them to be environmentally responsible through reporting their energy usage. It also helped them in electricity trade and in securing the energy price. Optimizing energy use and improving in energy efficiency was also usually achieved at least partly with the system. Interviewees were extremely happy with how flexible their system is with its connectivity with other systems in the factories.

On the other hand, there were quite a lot of requirements for the energy management systems of the interviewees that didn't meet their requirements properly for now. Energy storing wasn't really a relevant need for the interviewees, but they still felt that if it were, their system wouldn't be that helpful with it. On top of that, energy supply optimization, energy security, forecasting energy demand and use and reducing CO_2-emissions didn't get very good ratings. The interviewees generally felt that there should be more tools for energy supply optimization in their systems. Energy security is probably the most important need for every interviewee, but their energy management system wouldn't add too much value for it, since it's usually managed elsewhere. Forecasting energy demand and use could be one of the most important features that any EMS has, but there were only few interviewees who felt that their system would be very good with it. Some interviewees were also hoping more modern tools for their energy management systems and better user-friendliness.

4.2.3 Operational observations

To get a better understanding on the scores of the table 5, the interviewees gave brief comments on why they chose certain scores for their energy management systems. Comments are quoted directly as they were said or translated from Finnish to English. Interviewees had valuable input on what they think are great benefits in their energy management system, or what could be done better with it.

Getting familiar with an EMS can take some time, orientation and a lot of learning. When one gets used to the system, there are a lot of different things that can be done with it. One of the interviewees said: *"As you learn to use our EMS, you can really get information on all the variables and you can easily do simple reports and graphs that can be helpful in energy management."* Other person continued adding: *"We can make a lot of things in one system, without having to integrate many systems together. We chose this EMS partly because it has a relatively open environment through which we can do a lot of things by ourselves. Whenever there has been a need to be solved, we have been able to build a solution with the system."*

Many of the interviewees used their system in electricity trade in electricity markets. Some of them were really satisfied about the tools their system has for procurement and for electricity markets. One of the interviewees said: *"Forecasting energy demand and use optimization has good tools on the procurement side."* Other interviewee had good experiences about the securing energy price, and he said: *"Securing the energy price works well on the spot and intra-day markets through our system."*

Many of the interviewees thought that the energy use monitoring and documenting is a very important feature to have in an energy management system. There was someone who felt that the features their EMS has are essential for their plant energy monitoring and documenting. He mentioned: *"This energy management system is essential for energy use documenting and monitoring. Through this system it's possible to abide by the energy efficiency standards."* Other interviewee said that their system can be used even further to locate savings potential and to direct operators to the right operating area: *"Locating savings potential works through the system. Through this system we can find the wasting points and can direct our operators to the right operating area."*

When the interviewees were asked about their system's clarity, reliability and connectivity, one person said that: *"Our system is clear and has very good graphs and interfaces. It also has logical selection tree. On top of that the reliability is one of its strong traits and it is extremely important to us."* It was also stated that: *"This energy management system has integrated to our other systems throughout history very well and all the integrations are in good condition."*

The price of the system was also discussed and usually it seemed that the price for an energy management system was decent compared to the benefits it brings to the plant's operations. One interviewee mentioned about the price the following: *"The price quality ratio in our energy management system is quite good and it's tailor-made for our energy management. There are complete helpful blocks, such as electricity procurement. Time series database works also well for our purposes."*

The interviewees were also able to present their concerns and weaknesses they've found from their systems. The weaknesses varied from data archiving to reporting and to monitoring tools. Some of the issues are just making their work little slower, but some have greater impact on the plant operations if not properly addressed.

A couple of the interviewees really appreciate their EMS, but they mentioned that there are sometimes difficulties to keep the system content up to date: *"Our system is very versatile, and it answers to our energy management needs very well. You can add almost anything to this system and the potential for it is excellent. You should also maintain and develop the content within the system since it isn't always up to date. Partly it is also our fault due to limited resources."* Other interviewee continued by saying the following: *"The system is quite good in energy supply and energy optimization, but the problem is that the reports aren't necessarily up to date. Their maintenance is a bit challenging and it could be much simpler. We may not be able to use these system reports in some cases, because they are quite complex."*

Data archiving was one of the concerns some of the interviewees had about their EMS. They thought that it could be managed better in a way that authorities require. One of the interviewees said: *"Data archiving could be managed better. There should be certain durations for billing data to remain unchanged according to the requirements of authorities. There* *should also be easy to find tools to help with regulatory standards."* Other person said that data archiving shouldn't be left for the user so heavily and he stated: *"Proper file archiving has been left to the user's responsibility. There are just custom tables for archiving data and individual variables that can't be changed later."*

In energy management systems, calculations can be quite complex for the user. They should be more straightforward. One interviewee said about their system the following: *"In our system the direct access to the computation level is not that straight forward. The traceability of the results is poor and it's a big thing for us."*

4.2.4 User experience

User experience and the level of it is one of the first things EMS users notice in their systems. People are used to very user-friendly and logical user interfaces in the products they use in their daily lives such as mobile phones, banking services etc.. Same expectations are often transferred to industrial world, although the reality might not always be there yet. According to one of the interviewees, user experience in industry related products almost always comes behind of the consumer used products.

There are some system users that are used to and comfortable with the user interfaces that have been same for years. They know how to operate the system after they have orientated for it for years and there's no need for change as long as it works like before. It always requires extra work to adapt to changes, and often it's more convenient to stick to familiar way of doing things. Most of the system users however demand and expect that their systems are easy to use, and they should be developed constantly. For them it's essential that systems support the latest technologies and are easily adapted for the new employees that are using the systems. In that case, it's vital that the systems are effective in delivering the key information for the user and self-explanatory to use.

Many of the interviewees wished that their energy management system would be easier to use. The core people around the EMS knew what to do with the system, but for newcomers, familiarizing with the system is a difficult and time demanding task. The most common target for critique in energy management systems was often their user-friendliness. Some interviewees were dissatisfied with the user interface and wanted to be able to manage systems more efficiently. Some interviewees felt that their systems user interface could be much easier to use and that it should be more logical. One of them said: *"The user interface could be more logical. In a way you shouldn't have to know everything you can do, but you could learn by simply playing with the user interface."*

Energy management systems are often complex and include myriad of tools for reporting and optimizing. Interviewees generally benefited for the added value the tools bring, but some of them were just way too difficult to use and require far too extensive training, instead of being self-explanatory to use. One interviewee said: *"Energy optimization tool in the system has very complex balance structures including all types of equations, that require couple days of training to understand what you can do with it."*

The interviewees were very pleased about how their EMS communicates with other systems. Often, it's manageable to modify or tailor systems to work with almost any other system used in the plant or factory. However, some of the interviewees said that it's not enough that systems communicate with each other. It's a vital thing that they do, but equally or even more vital is that the systems improve the communication between people. Generally, the interviewees said that one of the most important features any EMS has, is that it would present key information in a way that it's easily understandable and the most relevant for different system users. One of the interviewees said: *"At the factory site, our energy management system communicates fairly well with our other systems. However, we should be able to use the system in a way that it would improve the communication between people as well. User interfaces should always guide and not mislead to uncertainty, which can happen if the information is distributed too complexly."*

4.2.5 Opportunities to be utilized in energy management systems

The interviewees pointed out a lot of specific functionalities and features that they would want to have in their EMS-product. Some of the things that are missing are tools that can help and optimize the daily use of the system, and some of them are things that are essential to have in future systems.

Some interviewees emphasized that, it's important that their EMS supports the latest technologies in the market. That would help them to work efficiently, take full advantage of system benefits and abide by all regulatory standards. Utilizing of digitalization and benefiting from almost unlimited data are interests many system users have. Analyzing tools and automatic processes to exploit data are important for energy savings and increasing of lifespan of different machinery and systems. Some interviewees said specifically that their EMS needs to support well known tools such as Microsoft's Power BI and OPC UA to make their energy management more convenient. Web-based data query from the database will be important for the future as well. One of the interviewees mentioned: *"Our new system update includes OPC UA, which is a great step ahead. I have seen in many instances that you could also have web-based data query from the database. That could be a nice feature to have in the future in our system as well."*

Data archiving has become more important than ever as the amount of available data have multiplied. In Finland, Fingrid is developing a Datahub service that will speed up, simplify and improve processes for every market party in electricity information exchange (Fingrid 2019). One interviewee said that it's essential that their EMS is compatible with services like Datahub. He said about Datahub the following: *"Fingrid is working on a datahub, a database that stores electricity consumption figures for billing information for example. Everyone, who operates on electricity market needs to join that soon. Datahub would also solve some of the problems we have with data archiving."*

For the future marketing and sales of energy management systems, many interviewees emphasized how important it is that the product is packaged well. It needs to have all the essential elements and required features for a production critical product. To attract the investors and customers, energy management systems need to have proper marketing materials and self-explanatory user interface. They need to be easily integrated for factory level with functional meter reading and optimizing tools. Also, a 24/7 product support would be important to have for ensuring maximal uptimes.

5 DISCUSSION

This chapter focuses on analyzing the interview results and their relation to the literature-based analysis. In this chapter the results are reviewed in a perspective of energy management systems, and further discussed how they should be positioned on an evolving energy market according to the literature-based analysis and interviewees' feedback. This chapter presents discussion about the growing demand for energy management systems and their development. This chapter discusses also about how the interview results reflect to the international energy and climate targets.

5.1 Growing demand for energy management systems

Energy management systems are important products and the demand for them in process industry will almost inevitably grow. Thus, not only grow, but their features and intelligence also have a great potential to be developed further. The interviews conducted in this thesis assured that energy management is vital for any industrial company and that energy management systems are the products and solutions that are the key for achieving proper energy management.

Another thing that has become clear through literacy-based analysis and empirical study through this thesis is that energy management is connected to myriad of different aspects in an enterprise level that need to be assessed. For a proper energy management, which is effective and international target complying, it's not adequate to have a technically great system. On top of the technical side of energy management systems, organizational aspects need to check out properly as well. Energy consumption has to be transparent, energy supply needs to be secured and strategic level targets have to meet operational targets and vice versa.

There are economical aspects of energy management that need to be taken into consideration as well. Reducing energy costs to an effective minimum is not often an easy task. Cost allocation might also be demanding since the system savings aren't always that easy to point out. On top of this, ecological and social aspects of energy management play also significant roles in functional energy management. It's hard to put a price tag on environment, even though it's consumed in many places on a daily-basis with rather costly consequences. Thus, strategically ambitious plans to combat climate change could be some of the greatest drivers to increase greater investments in energy management systems, as their direction tends to help increasing energy efficiency and managing environmental impacts of power plants and factories.

As the amount of available data has increased greatly, energy management systems enable the proper and efficient use of it. That is another key why the demand for the energy management systems is increasing rapidly in process industry. According to ARC, a data-driven approach to energy management is recommended as it is both the most objective and repeatable. Acquired data provides more visibility into the amount of energy that is consumed, enables trending, and identifies specific energy hogs. New low-cost wireless and internet-connected sensors could also lower the cost of obtaining previously stranded energy management related data. Energy and asset performance management are inextricably linked as improvement efforts in one area to have a direct impact on the other. Generally, a smoothly operating process that increases asset availability is a more energy-efficient process (ARC Advisory Group 2019).

5.2 Energy management system development

One of the main purposes for energy management systems is to improve energy efficiency. When an energy management system is considered as a major tool for improving energy efficiency, there also needs to be a financial incentive in place. In order to attract investors, an energy management system should be proven to provide financial benefits for the buyer. The financial benefits can be demonstrated for instance by calculating annual energy savings through energy consumption optimization actions or by improving energy supply acquisition and managing its distribution more effectively.

Energy management systems must also abide by legal requirements. Governmental impact and incentives have often been in a key role of promoting or demoting of certain technologies and their development. For instance, feed-in tariffs for wind energy have been enabling or at least largely promoting their rapid development and popularity throughout the latest years. Similarly, by having mandatory requirements for energy monitoring and improving of energy efficiency, energy management systems could be favored by the governmental directives and incentives. Even though there aren't major financial tariffs or punishments for energy management systems, at least for now, the pressure for more energy efficient operations help industry actors realize the importance of proper energy management systems. Some of the interviewees said that it's important that their energy management systems abide by the legal requirements already for now so that when there will be more pressure from the government, all the necessary requirements will check out.

Energy management systems are also important for the strategic reasons and for the image improvement of a company. According to some of the interviewees, energy management systems are often aimed to bring long-term savings and it's essential that their strategical value is evaluated as well as their return of investment. Also, as most of the international and national energy and climate targets are reviewed in long-term, energy management systems could be great tools that could bring anticipated long-term results, many of which are already seen in different industrial companies.

The image improvement could be surprisingly important factor for the new investments for energy management systems. In the times when the greener appearance is better and the environment could be one measurement of prosperity, everything that can help achieving collective goals for mutual benefits, are needed. Moreover, an energy management system can be rather small investment for a major industry actor, still adding a lot of value for understanding of one's supply and consumption patterns and reporting them to all required parties. This would also result in having better means to act upon the gathered information and making better data-driven decisions.

As mentioned before, energy management systems are great tools to be used for instance for overseeing plant's operations, reporting of energy use, abiding with regulatory standards, optimizing energy supply and use and providing tools for electricity trading and documentation etc.. However, there are some major stumbling blocks that the energy management might face. One of the concerns the interviewees expressed was the insufficient communication between different departments. Systems are used to increase the knowledge between people, but if there's not proper collaboration, the system potential is not reached.

It’s essential that energy management systems inform the relevant information in a way that everyone can understand it and make proper use of the presented information.

Other issue for the energy management system development might be the diverse energy management needs and targets different industry actors have. For that reason, it’s common that EMS-products are custom made for a specific industry customer. Many system suppliers have standard product packages, but usually the product is modified according to diverse expectations and target needs of different enterprises that need to be fulfilled with the system. That is often a good thing as the exact needs and desired outcomes can be responded, but it has its downsides as well. When a big share of a system is custom-made only for one customer, the supplier often tends to develop that side of the system based on the feedback from that particular customer and in that case the cost is allocated only to them. If a system was packaged similarly to several customers, it would be easier to divide the costs accordingly.

According to the interviewees, the most important tasks for energy management systems are to secure the energy price, optimize energy use and forecast energy demand and use. Other features they need to have for instance are: Energy monitoring and documentation, locating savings potential, open and fast communication between systems, improving data security, fulfilling the requirements for official and regulatory standards, and environmental responsibility and reporting. Industry actors have realized at least the part of the potential their systems could and should have, so it’s also up to system suppliers to deliver certain level of added value and improvements to those systems. As for energy management systems, the interviewees value systems that enhance the information sharing between people, self-explanatory user interfaces, proper reporting and optimizing tools, constantly developing content within, and supporting of new technology.

It’s not an easy task to offer and maintain an EMS that satisfies every need people have in the market. The demand for the system evolves based on the new possibilities and opportunities that emerge within the market. However, if the users collaborate with their system developer regularly, there is a better chance that they are able to respond to the next steps in the market properly. It’s a constant ongoing development in an ongoing pursuit to save energy even one kilowatt-hour at a time.

5.3 Results compared to international targets

Strategically, energy management systems are vital and almost necessary to have in any enterprise that operates in process industry. Demand for energy and its use is rather high in manufacturing and in energy generation, so an investment in an EMS will most likely pay off rather sooner than later. Figure 13 presents a simple strategy of how an EMS investment could play out for investors below.

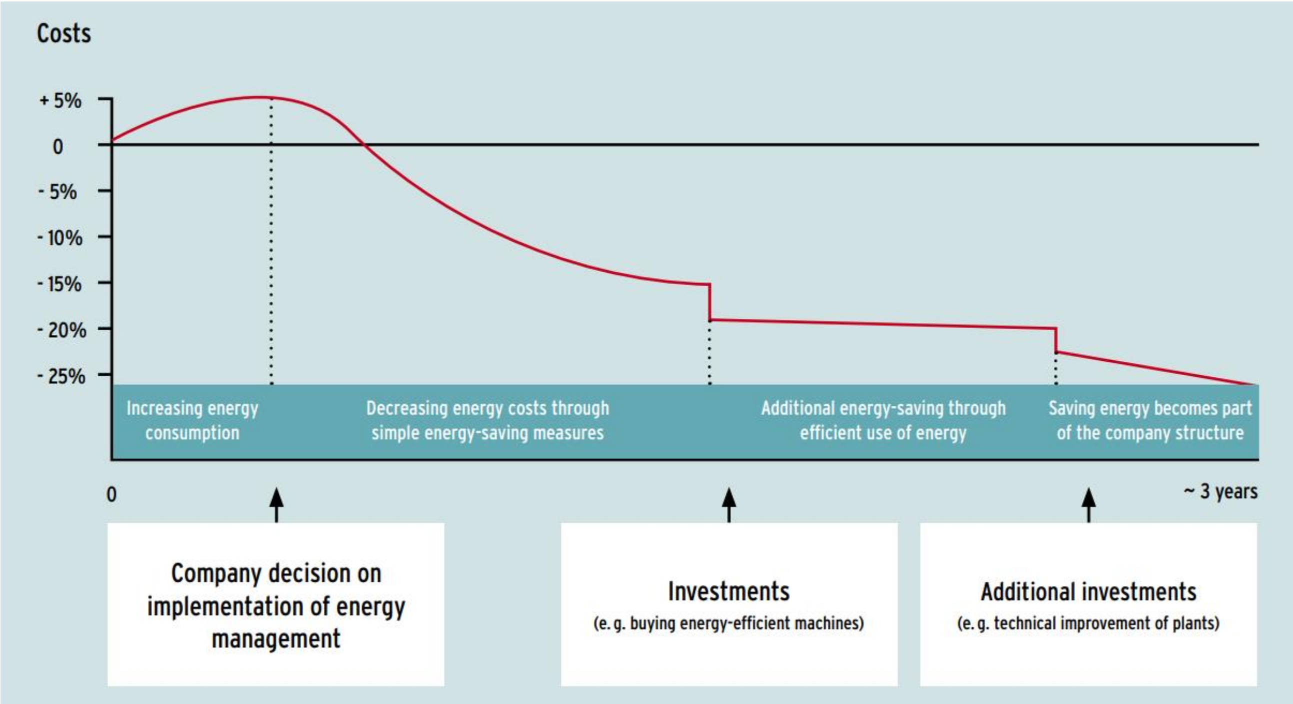

Figure 13. Cost development through energy management system according to German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU 2012, 19).

For instance, a rising energy consumption in a plant can lead to a desire to invest in an energy management system. Strategically EMS could decrease energy costs through simple energy-saving measures, which enables reasonable investments for buying energy-efficient machinery. As seen from the figure 14, this can bring the cost further down as there are additional energy savings available. Throughout the time span of 3 years, saving energy becomes part of the company structure. In this presentation in figure 13, the costs for energy came down 25 % in 3 years. This would not only mean that the environmental impact would reduce significantly, but also that the cashflow for the enterprise could potentially multiply, depending on the sales margin they had for their energy or production before.

In an operational level and in practice, the investment could pay out like presented in figure 13, but according to some industry experts discussed during this thesis, it's not always nor even that often that simple. As mentioned before, energy management systems are often the secondary products that are seen to add value after the other aspects of production and processes (E.g. Uptime and safety) are properly addressed. In fact, implementing of an EMS could often improve those aspects as well, but due to its complex and multidisciplinary nature, it can also be seen as a risk factor. As long as an EMS is a secondary product in a plant level, it's not likely that projected cost savings could be achieved through simple energy-saving measures with an EMS. It's easier to monitor, report and forecast energy demand and use, than to have concrete energy savings through an EMS investment. To optimize energy use and enhance energy efficiency through an EMS, it requires a system that is well integrated to all other systems in a plant level and a system that has advanced analytics to execute required saving measures. These energy management systems are the systems that really take the energy efficiency and energy savings in a power plant to the next level.

Learnings from the interviews indicated at least to some degree that there was a distinct gap between the strategic level objectives and the operational level objectives for the energy management systems. It could sometimes be the case, that strategic visions are more optimistic than the operational results so that the strategic visions could better attract investors. That would make sense, as after the finance would be acquired, the actual promised results could be delivered as the investments allow the greater emphasis on the estimated results. Interviewees that were working on an operational level, generally realized the current system limitations better and were more critical for the benefits that can be achieved through their energy management systems, evaluating more the current actual execution of things with the system. Interviewees who made decisions on a strategic level were usually more focused on a longer timeframe and estimated the benefits and requirements for their energy management systems differently and in longer-term.

A similar gap between strategic objectives and operational execution can also be seen in a regulatory level. Some of the targets and estimations that European Commission has assessed, do not always find their way to the operational level for a single industry actor, at least not for everyone. There are many things and moving parts going around in operations that can bypass directives that are ambitious in nature and quite light in penalties. It seems that strategical targets reach operational level easier when something is mandatory to do or financially beneficial. There are many new targets and directives emerging at certain intervals, and it’s up to member countries and their enterprises to prioritize which are the most important directives to act upon right away and to consider what is their capabilities to abide by them.

According to some feedback from the interviewees, the collective targets are viewed as very important and necessary things to have, as they direct the work and efforts to the right direction. However, in the end of the day, there are many new strategical targets that won’t necessarily find their way to a desk of an operative worker, as long as there aren’t adequate risk and reward included in them.

The general impression from the interviews is that the operations of industrial enterprises are going to a right direction all the time in terms of their sustainable production and increased efficiency. There has been impressive development in different processes in factories, especially through new technologies, more competitive markets and increased available information. Also, energy management has been one of the fields that has improved in recent years significantly and more profitable opportunities for it has emerged.

The changes that occur throughout industries are happening for the better, but there’s some concern that they are not necessarily happening by the rate that the international targets and the mitigation of climate change would require. One thing is certain though, the evolution of energy markets has brought countless opportunities, such as matching the demand and supply of energy more competitively and increase in more energy efficient products, through which industry actors have been able to improve their operations for the better. This has brought everyone one a step closer to reaching the necessary and the collective targets.

Based on the literary-based analysis and the empirical study conducted during this thesis, it seems that the energy management systems continue to play a vital role in a constantly evolving energy markets, and probably with even more significant role than before. It’s necessary that the system suppliers can offer products that fulfill their customer needs and are aligned with the international and national targets. It’s also up to the customers to maximize the potential of their energy management systems and ensure that their company has enough resources for it. Through that their energy management systems can be integrated to the whole plant level so that they can have a great influence in the monitoring, planning and optimizing of the whole energy supply and consumption of the plant. That should improve the processes in a way that it would produce more cost and energy savings, which would increase the cashflows of the enterprises and decrease the unnecessary emissions they release.

6 CONCLUSIONS

The aim for this thesis was to study how energy market evolves in Europe and investigate what kind of influence it has on energy management. Through market research and empirical study, some common characteristics were found for the energy management systems that are in demand according to the market needs and interviewee feedback. During this thesis, the outlook for energy management systems and their need were compared to the international targets that also promote the demand for energy management systems. The work was focused on European energy market in process industry.

The European energy market has been evolving significantly in recent years. Increased use of renewable energy has brought more non-dispatchable form of energy generation to the market. That has led to more difficult matching of energy demand and supply as the availability of it largely depends on weather conditions. That has increased the demand for flexible systems that can optimize the supply of energy and cover inevitable energy price fluctuations. Furthermore, the amount of available data has increased rapidly opening some challenges in processing all available data and opportunities in leveraging it for significant benefits. Gathering more useful data in a plant level, can help enterprises to gain more holistic views of their processes and operations so that addressing potential development areas and issues could be more effective. All of this has increased and will most likely continue to increase the demand for energy management systems even further. Through an energy management system, it's possible to optimize energy supply and use as well as collect and exploit data for data-driven decision making. That makes energy management systems being almost necessities in energy-intensive enterprises today.

Enterprises in process industry have increased expectations for their energy management systems. They can be used for many purposes and according to the market needs and interviewee feedback, some of the important features and uses for energy management systems include for instance: Overseeing the plant's operations, optimization of energy supply and use, reporting energy use, abiding with regulatory standards and electricity trading. Key thing with energy management systems would be that they allow organizations to gather information real-time and to do data-driven decisions based on the performance of their operations, which could lead to significant cost savings and environmental benefits.

The European Union has several Energy and Climate targets that help nations to mitigate the effects of the climate change and collectively fight it. The aim for the targets is to increase the use of renewable energy, cut greenhouse gas emissions and improve energy efficiency. The purpose for the targets is to ensure sustainable world and reduce global warming to 2 degrees Celsius and even push further to 1.5 degrees Celsius. The common goals have launched myriad of events around Europe, which have included for instance massive increase in renewables, reducing coal fired energy production and expanding electric transportation. While the new investments have been massive and there have been huge improvements in technology and in public reception for change, the ambitious targets may still be quite difficult to be achieved collectively, at least for some. Some member states seem to have put more effort in achieving the targets than others, which makes it hard to set collective targets that are achievable for all. If the commitments for achieving the targets are moderate, then the measures that take place operatively could be also quite moderate compared to the measures they could potentially be. Furthermore, even if the commitments for achieving the collective goals are high, it doesn’t guarantee that all necessary measures reach operational level in a required timeframe.

Energy management systems have and could have, a great role in achieving the collective international targets as their main benefits include for instance increasing energy efficiency and potentially reduce greenhouse gas emissions. They are systems that are strategically seen as necessities to have in today’s factories, but operationally their significance can vary a lot, depending on an industrial actor or enterprise and on how they have been implemented in a factory. For some, energy management systems are core systems in their plant that optimize energy supply and use, and for some they only add value in monitoring the plant operations or help reporting energy consumption. The variation in energy management measures and commitment to it could indicate, that in some cases there is a gap between the strategical targets of achieving energy and climate targets and operational execution of the optimizing measures.

In order to meet energy and climate targets that probably every party would like to achieve, the gap between strategical decisions and operational execution of improving measures should be narrowed. It has been narrowed throughout the years for instance through different directives and agreements that have had concrete proposals on how to improve operations in a sustainable way. Despite of the great improvements, it still seems that there should be more to be done to narrow the gap even further. Incentives in energy efficiency or energy management could play some role in that, as incentives have for instance played a significant role in triggering the increase of wind energy in the past. Also, accountability in improving measures in national and enterprise level could help bringing international targets closer to the operational level. Making achieving targets more profitable for enterprises would help a lot, but it could be difficult to set optimal incentives and penalties, without interfering too much with the competitive market.

Energy management systems aren't the only means to help with achieving energy and climate targets, but they certainly have a major role in the task. Through them, the progress can be monitored real-time, reported to correct parties and the saving measures can be executed even automatically. Energy efficient factories and plants need monitoring, optimizing and collaboration efforts today more than ever, due to the constantly evolving market and increasing focus on the mitigation of climate change. Energy management systems are now in the market to do all that, and if properly invested in, they'll have a remarkable role in combating the climate change and in improving the cashflows of the process industry companies.

REFERENCES

ABB. (2010). Energy management solution for the process industry, cpmPlus Energy Manager, p. 2. Available (accessed on October 2018): https://bit.ly/2VxduV1

ABB. (2018). Energy Manager Introduction. Internal document, (accessed on October 2018).

ARC Advisory Group. (2019). Energy Management and Sustainability. Available (accessed on January 2019): https://bit.ly/2HersHp

Arqum. (2015). Energy Managent Systems in Germany, p. 11. Presentation available: https://bit.ly/2Trw4At

Beus M. Pavic I. Stritof I. Capuder T. Pandzic H. (2017). Electricity Market Design in Croatia within the European Electricity Market – Recommendations for Further Development, pp 1-2.

BMU. (2010). Energy Management Systems in Practice. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, A guide for companies and organizations, pp. 14-15, 19.

E&C Consultants. (2018). Cutting-edge advice on energy markets. Available (accessed on August 2018): https://bit.ly/2EHoWrR

Cross Company. (2013). Energy Management System Challenges in Industrial Manufacturing. Available (accessed on December 2018): https://bit.ly/2HbnDD2

ECA. (2015). European Electricity Forward Markets and Hedging Products – State of Play and Elements for Monitoring, p. 1. Available (accessed on October 2018): https://bit.ly/2Tn3wZc

Energy Transition. (2018). Germany's energy consumption in 2017. Available (accessed on December 2018): https://bit.ly/2F7Br0K

Energywatch. (2018). Regulated vs. Deregulated Electricity Markets. Available (accessed on July 2018): https://bit.ly/2VxuaM6

Envidatec. (2013). Energy Management Systems according to ISO 50001, pp. 17, 43-44. Presentation available: https://bit.ly/2tLiucT

EPRS. (2016). Understanding electricity markets in the EU, European Parliament Briefing November 2016, p. 3.

EUETS. (2018). European Union Emissions Trading Scheme – legal point of view. Available (accessed on September 2018): https://bit.ly/2GWzLIU

EUR-Lex. (2013). Commission staff working document, Article 8: Energy audits and energy management systems. Guidance note on Directive 2012/27/EU on energy efficiency.

European Commission. (2018). 2020 Climate & Energy Package. Available (accessed on December 2018): https://bit.ly/2HHEWJF

European Commission. (2018). 2030 Climate & Energy Framework. Available (accessed on December 2018): https://bit.ly/2tvvYHG

European Commission. (2018). 2050 long-term strategy. Available (accessed on December 2018): https://bit.ly/2ofhopk

European Commission. (2019). Clean energy for all Europeans. Available (accessed on January 2018): https://bit.ly/2BlLleh

European Commission. (2018). Energy Efficiency Directive. Available (accessed on December 2018): https://bit.ly/1Q5uf3d

Europex. (2018). Association of European Energy Exchanges. Available (accessed on September 2018): https://bit.ly/2NF9qiW

Fingrid. (2019). Varttitase eli 15 minuutin taseselvitysjakso. Available (accessed on January 2019): https://bit.ly/2TmxbBL

Freie Universität. (2018). Energy Management and Climate Protection at Freie Universität Berlin, p. 2. Available (accessed on December 2018): https://bit.ly/2TeAnQm

Honeywell. (2018). Energy Management Systems. Available (accessed on October 2018): https://bit.ly/2GU1KZD

Ilieva I. & Folsland T. (2014). An Econometric Analysis of the Regulation Power Market at the Nordic Power Exchange, Norwegian University of Life Sciences, p. 59.

IPCC. (2019). The Intergovernmental Panel on Climate Change. Available (accessed on January 2019): https://www.ipcc.ch/

IPCC. (2018). Summary for Policy makers, pp. 5, 7-8. Report available (accessed on January 2019): https://bit.ly/2H9nPCC

ISO. (2018). ISO 50001 Energy management systems, pp. 1,3, 9. Available: https://bit.ly/2XBS76L

Kawasaki. (2019). Energy Management System (EMS). Available (accessed on January 2019): https://bit.ly/2tO9Omc

Kriko. (2018). Process Information System KRIS[3]. Available (accessed on October 2018): https://bit.ly/2VxvoHc

Kriko Engineering. (2018). Energy Management System KRIS[3]. Available (accessed on October 2018): https://bit.ly/2SDGA3h

Kriko Engineering. (2019). Energy Management System KRIS[3]. Available (accessed on January 2019): https://bit.ly/2EGzRli

Leigh T. (2015). The Interconnectedness of Global Power Markets & Implications for Corporations, p 3. Presentation available (accessed on September 2018): https://bit.ly/2TmwMzf

Mordor Intelligence. (2017). Europe Energy Management Systems Market By Type. Available (accessed on December 2018): https://bit.ly/2EHJFvA

NASA. (2019). Climate change: How do we know? Available (accessed on January 2019): https://go.nasa.gov/2la2ISR

Next Kraftwerke. (2018). Power market players. Available (accessed on October 2018): https://bit.ly/2SGIyQu

Ruska M. & Similä L. (2011). Electricity markets in Europe, Business environment for Smart Grids, VTT Research notes 2590, pp 9, 47-48, 51.

Sa A. Thollander P. Rafiee M. (2018). Industrial Energy Management Systems and Energy-Related Decision-Making, pp. 2, 5. Available (accessed on October 2018): https://bit.ly/2XAdvJV

Saunders, M. Lewis P. Thornhill A. (2011). Research methods for business students, fifth edition, p. 151.

Schneider Electric. (2010). Measuring, Monitoring and sustaining energy efficiency using metering system, p. 6. Presentation available (accessed on October 2018): https://bit.ly/2IR639Q

Serena, R. (2014). The European Electricity Market Liberalization, Master’s Thesis, p. 1 Available (accessed on August 2018): https://bit.ly/2GXT44h

Serrenho T. Bertoldi P. Cahill C. (2015). Survey of energy audits and energy management systems in the Member States, JRC Science for policy report, p. 6.

Siemens. (2018). SIMATIC Energy Management Software. Available (accessed on October 2018): https://sie.ag/2C0qUl3

Siemens. (2017). SIMATIC Energy Manager PRO, p. 3. Available (accessed on October 2018): https://sie.ag/2GVV4du

Sioshansi F. (2013). Evolution of Global Electricity Markets, pp. 7, 31-32. Available (accessed on August 2018): https://bit.ly/2TmwxUR

The European Parliament and the Council of the European Union. (1997). Directive 96/92/EC of the European Parliament and of the Council, p 27.

UNFCCC. (2019). Conference of the Parties (COP). Available (accessed on January 2019): https://bit.ly/2DQCxhZ

UNFCCC. (2019). The Paris Agreement. Available (accessed on January 2019): https://bit.ly/2EVSoXT

UNFCCC. (2019). The Paris Agreement – Status of Ratification. Available (accessed on January 2019): https://bit.ly/2yRc1CN

Valmet. (2018). Energy management for enhanced production optimization. Available (accessed on October 2018): https://bit.ly/2NDPjla

Vattenfall. (2018). Facts about the energy markets. Available (accessed on July 2018): https://bit.ly/2C0mXwI

Yin, R. (2009). Case Study Research, Design and Methods Second Edition, pp.13-18.

APPENDIX A: INTERVIEW QUESTIONS FRAME

A) There are 16 energy management categories below. Please assess each category whether it's 1st, 2nd or 3rd priority in terms of your energy management system needs for your future energy management.
1st priority = Almost mandatory to have
2nd priority = Would be good to have
3rd priority = Not necessary to have

Energy supply optimization	Energy security	Energy monitoring and documentation	Forecasting energy demand and use
Securing the energy price	Locating savings potential	Optimizing energy use	Improving in energy efficiency
Open and fast communication between systems	Improving data security	Fulfilling the requirements for official and national standards	Reducing CO_2-emissions
Energy storing	Utilizing digitalization	Environmental responsibility and reporting	Something else?

B) Now consider how well does your energy management system answer to your energy management needs in each category from 1 to 3.
1 = Answers to the need very well
2 = Answers to the need partly
3 = Doesn't answer to the need at all

C) There are 7 questions below about your energy management system and about the collaboration with your system supplier. Answer each question as well as you can.

1. What is your energy management system used for and what can be done with it?

2. Why did you choose your system supplier and their energy management system as a part of your energy management?

3. What are the main benefits that your energy management system has?

4. What are the main weaknesses that your energy management system has?

5. What should be done so that the product would add more value to you?

6. What would you say about the collaboration with your system supplier? Is there something they could have done better?

7. What could be developed in your energy management system now or in the future?