Industrial energy efficiciency drivers and barriers, and global sustainability

A case study of a polymer compounding company

Mile Mišić

Supervisor

Torbjörn Brorson

Thesis for the fulfilment of the
Master of Science in Environmental Sciences, Policy & Management
Lund, Sweden, June 2016

MESPOM Programme:
Lund University – University of Manchester - University of the Aegean – Central European University

Erasmus Mundus Masters Course in Environmental Sciences,
Policy and Management
MESPOM

This thesis is submitted in fulfilment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

Supported by the European Commission's Erasmus Mundus Programme

Education and Culture

Erasmus Mundus

Published in 2016 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

I would like to express my gratitude to Hexpol Compounding, and especially to Hexpol Compounding Hückelhoven, for making my thesis research possible. Thank you Andreas, thank you Bastian, thank you rest of the team, for letting me in your company; for answering all my questions; for beeing nice and friendly.

I would also like to thank MESPOM consortium for the Erasmus Mundus scholarship for a life-changing experience. My special gratitute goes to professor Naoko Tojo for her patience, helpfulness and friendliness throughout the entire program.

Abstract

This master thesis was written in a time when major changes in global sustainability and climate architecture were happening. Aim of this thesis is to look into how a single manufacturing company can, through enhanced energy efficiency, contribute to global sustainability in multiple ways. This study contributes to the existing body of literature in three ways. Firstly, it gives structure literature review of current research on industrial energy efficiency. Secondly, it seeks to understand in which ways can single manufacturing company asses its actions against global sustainability criteria. Finally, this thesis focuses on energy efficiency enhacement practices in a rubber compounding factory. Crucial part of the research for this thesis was conducted in a polymer compounding factory. Methodology utilized in this thesis is rather transdisciplinary and it was chosen based on appropriability to the research question.

Keywords: energy efficiency, drivers and barriers, sustainable development goals, business strategy, polymer compounding

Executive Summary

Energy efficiency is often mentioned as a win-win situation that is beneficial for businesses and society in general. Pervasiveness and severity of global problems influenced human way of thinking and in the last decades, humanity is talking about global problems, and global solutions. Energy efficiency has its place, as part of solution, in this complex story made of interconnections between global, national and local level. Industrial energy efficiency, has its role as well. This study is trying to understand which factors are inhibiting, are which are enhancing energy efficiency and energy conservation in polymer compounding industry. There are three reasons why this specific industry was chosen. First, research on this specific industry is vastly underdeveloped. Second, polymer-compounding companies are using significant amounts of energy, especially electricity. Third reason is a more personal in nature. Author had a chance to be an assistant to the plant management in Hückelhoven, Germany, and to work on energy-related issues.

This study has three research questions:

- RQ1: What are the main energy efficiency drivers and barriers in the manufacturing industry?
- RQ2: What are the specificities regarding energy efficiency drivers and barriers in the rubber compounding industry?

  Specificities refers to drivers and barriers that might exist only in the rubber compounding industry. Moreover, it can also refer to drivers and barriers that exist in other industry-sectors, but are or are perceived to be more important in the rubber compounding industry.
- RQ3: How the single polymer compounding manufacturing company can align its strategy with global goals?

An answer on first research question was provided through analysis of the existing literature. Many studies from different sources were gathered, analysed and presented in a structured manner. The literature revealed many known energy efficiency drivers and barriers, as well as multitude of research approaches to investigate this question. Second research question was answered through a single case study of Hexpol Compounding . As aformentioned author had a chance to spend longer period of time in the company, to conduct interviews, and to have an acess to multitude of data. Third research question is also using Hexpol Compounding as an example. This question was seeeking to understand what should company do, in order to align its activities with global societal goals.

This study revealed numerous until now identified barriers and drivers for industrial energy efficiency, in various contexts and industry sectors. Moreover, one of the findings is that different various research approaches can be utilized to research this topic. Findings regarding

RQ2 pointed out energy efficiency barriers that are potentially sector specific. It is related to high costs of information acquiring regarding energy consumption in processes of compound production. Moreover, several other drivers and barriers, both sector-specific and the plant-specific were outlined. Lastly, regarding RQ3, study revealed strong points, weaknesses, opportunities and threats of Hexpol's AB alignment with global societal goals.

The major limitations of this study are related to the research method. Single case-studies are often criticized as beeing not representative enough. Other limitations are related to the lack of experience of the researcher, and to the lack of common and sound methodology for a research on energy efficiency in companies. Doing a case study with several polymer compounding factories represents a potential for future research.

Abbreviations

SDG – Sustainable Development Goals

EE- Energy Efficiency

CO_{2eq} – Carbon dioxide equivalent

kWh – kilowat hour

COP21 – 21st Conference of the Parties (1992 UN Framework Covention on Climate Change)

WBCSD – World Business Council for Sustainable Development

GHG – Greenhouse Gas

IEA – International Energy Agency

OECD – Organization for Economic Cooperation and Development

IPCC – Intergovernmental Panel on Climate Change

UNIDO – The United Nations Industrial Development Organization

KPI –Key Performance Indicators

EE – Energy Efficiency

Table of Contents

List of figures

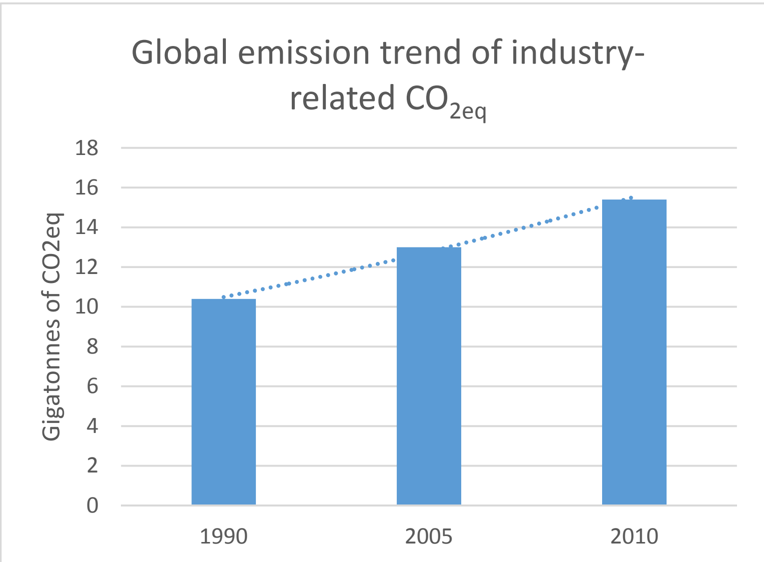
List of tables

1 Introduction

1.1 Background and problem definition

The year 2015 represents a milestone in global efforts for global change. “Transforming our world: the 2030 Agenda for Sustainable Development” and the Paris Agreement (COP21) are keystones of a new paradigm of action regarding global issues. There is a clear global call for all stakeholders to participate, with the role of businesses emphasised more than ever before. United Nations Secretary-General, Ban Ki-moon, has stressed several a lot of times that businesses should step in and take action. “You recognize that responsible businesses have enormous power to create decent jobs, open access to education and basic services, unlock energy solutions and end discrimination. I count on you to drive global progress”, said Ban Ki-Moon to global business leaders at the 2016 Global Economic Forum in Davos, Switzerland ("World of business must play", 2016). Moreover, he continued, “I ask all the CEOs here today to help us. Your advocacy and example can drive action to achieve a life of dignity for all people” ("World of business must play", 2016). Due to its urgency, severity and pervasiveness, there is a special emphasis on the issue of climate change. “It is time for business to be more transparent, accountable and responsible by working individually and through trade associations to support – and not block – climate policy”, said the Secretary-General at a meeting of the UN Global Compact Caring for Climate Business Forum in December of 2015 ("Business must be more transparent", 2015)

Businesses are seemingly answering the call, and both participating in decision-making and taking action. During the preparation of Sustainable Development Goals speaking on the behalf of the Global Business Alliance, Tom Jacob stated, that societies depend upon "both government and businesses to deliver their needs and wants on a social scale". Moreover, Mr Jacob continued "For business, this amplifies our traditional role in economic growth and innovation, to meet those needs and wants affordably and sustainably. (Tom Jacob, 2015)



Moreover, the World Business Council is acknowledging the changing landscape and has stated, “Tomorrow’s business leaders need the skills and competencies to cope with an increasingly complex world as well as the social and environmental challenges across a changing competitive landscape” (WBCSD, 2015)

Figure: 1-1 Global emission trend of industry-related CO_{2dq}

Source: based on IPCC (2014, pg. 749)

Since the beginning of the 21st century, "global CO_2 emissions have increased by 46 percent and global atmospheric CO_2 levels are up 8 per cent" (UN Global Compact, 2015, pg. 92). Global industry and waste/waste water GHG emissions have increased from 10.4 $GtCO_2eq$ in 1990 to 13.0 $GtCO_2eq$ in 2005.In 2010, it was 15.4 $GtCO_2eq$. Out of 15.4 $GtCO_2$, 5.3 $GtCO_2eq$, or around 34 percent is direct, energy-related CO_2emissions. Indirect CO_2 emissions from the production of electricity and heat for industry is around 5.2 $GtCO_2$, or 33 percent of total industry-related emissions. Processing CO_2 emissions are responsible for 2.6 $GtCO_2$, or 17 percent. The rest are non-CO_2 emissions and waste/waste water emissions. (IPCC, 2014, pg. 749)

According to the International Energy Agency (IEA) "The industrial sector uses more delivered energy than any other end-use sector, consuming about one-half of the world's total delivered energy" (2016, pg. 113) Moreover, there is a prediction that industrial energy consumption will continue to grow 1.4 percent per year in the period between 2010 to 2040. The consumption in its baseline year is estimated at approximately 211 exajoules (EJ) and it is expected to peak to approximately 323 EJ in 2040. This would represent around a 70 percent increase. In comparison, the total world energy consumption in 2010 is estimated to be, according to the IEA, approximately 553 EJ. Moreover, the non-OECD countries are expected to have an average growth in energy consumption of 2.3 percent per year, while OECD countries are expected to have around 0.4 percent per year. According to the IEA, the total global energy consumption in 2010 was approximately 363 EJ. Out of this, industry is approximately 134 EJ or, roughly, 37 percent.

However, there are also predictions about possibly saving energy. These predictions say that it is technically feasible to reduce energy consumption by 25-37 EJ per year, or "600 to 900 million tonnes (Mt) of oil equivalent per year or one to one and a half times Japan's current energy consumption" through energy efficiency measures (IEA, 2007, pg. 19) The potential for industry-related CO_2 emissions "amounts to 1.9 to 3.2 Gt per year" (IEA, 2007, pg. 19)

However, these potential savings are not taking place for various reasons. There are many known factors inhibiting the development of energy efficiency toits full potentials. These factors vary depending on the specific country, industry sector, or even the company. And are dispersed on multiple levels, from a personal and individual, to a societal and global level. It is still unexplored how global societal goals, such as the goals stated by the Paris agreement and SDGs, might influence the aforementioned energy efficiency drivers and barriers. In line with this, it is also unknown how companies might, through work on energy efficiency, influence global societal goals in a positive manner.

1.2 Research Purpose

The aim of this thesis is to contribute to the knowledge on energy efficiency drivers and barriers in the rubber compounding industry. Research on drivers and barriers for industrial energy efficiency in this specific industry is, except for a few technical guidelines, vastly underdeveloped. Moreover, this study asks to understand the relations between different global and societal goals, outlined in the SDGs and the Paris Agreement, and drivers and

barriers for industrial energy efficiency. This thesis attempts to understand global societal goals by using the concepts of energy efficiency drivers and barriers as tools for analysis.
In line with the aforementioned purpose, the research questions are defined as follows:

- RQ1: What are the main energy efficiency drivers and barriers in the manufacturing industry?

- RQ2: What are the specificities regarding energy efficiency drivers and barriers in the rubber compounding industry?

  Specificities refers to drivers and barriers that might exist only in the rubber compounding industry. Moreover, it can also refer to drivers and barriers that exist in other industry-sectors, but are or are perceived to be more important in the rubber compounding industry.

- RQ3: How the single polymer compounding manufacturig company can align its strategy with global goals?

The reason why this specific industry was chosen is threfold. Firstly, literature on energy efficiency drivers and barriers in rubber and polymer compounding industry is vastly underdeveloped. Moreover, this industry represents a significant consumer of energy, especially electricity. Lastly, the author of this study had an opportunity to work on energy-related issues in polymer compounding company.

1.3 Overview of methodology

In order to answer the research questions, a multitude of data sources and methods for analysis have been applied. This is better explained in the Chapter 3 of this thesis. In order to address RQ1, a thorough literature review has been conducted. Findings from this literature review have served as a basis for the design of interviews, used to collect data for RQ2 and RQ3. When it comes to RQ2, the main method applied has been a review of the scarce literature regarding the relationship between global societal goals, energy efficiency and the manufacturing industry. The literature review is followed and amended by expert interviews. RQ3 uses a case study.

1.4 Limitations

There are several limitations in this study. A major, overall limitation is the fact that the case study, which is the main source of the findings, is based on a single manufacturing company. Single case studies are quite often criticised. Zeev Maoz criticises single case studies from a methodological point of view. He states, the "use of the case study absolves the author from any kind of methodological considerations. Case studies have become in many cases a synonym for freeform research where anything goes" (2002, pg. 165). The same issue is raised by Yin (2009 and Bennet and Elman (2010) Secondly, single case studies are limited in regard to the replicability of their analysis and criteria for analysis (Berg and Lune, 2010)

Lastly, single case studies have an issue or limitation of external validity or generalizability. It is the question of how a single case can offer anything beyond that same single case.
Besides the theoretical limitations of the single case study as a research method, there are several more limitations on a practical level. Something that has limited the literature review regarding energy efficiency drivers and barriers is the fact that there is no literature or research available regarding, specifically, the rubber compounding industry. Therefore, the literature review is for the manufacturing industry in general.

Research regarding global societal goals has been undertaken using a literature review and, partially, interviews. The limitation regarding this is the non-existence of scientific literature. Therefore, the findings regarding global societal goals are not necessarily scientifically proven. When it comes to interviews, it has been difficult to find experts on this topic. Moreover, as a limitation, the criteria for the selection of experts has generally encompassed those with publications somehow related to the topic. Therefore, the level of expertise of the interviewees is unknown. Lastly, the findings from interviews reflect only specific views of particular people. This effect is multiplied if the topic in question is rather new and unexplored. Thus, the generalizability of these findings is limited.

Moreover, the author's educational background in the humanities and lack of knowledge in some technical aspects of energy efficiency have posed difficulty in conducting the research. This can also be understood as a potential limitation to the research findings.

1.5 Ethical considerations

Ethical considerations in this master's thesis are especially relevant when it comes to interviews and the case study. When it comes to interviews, Brinkman and Kale, (2009) argue that informed consent and confidentiality are the two most important factors to be considered regarding ethical interviewing. Informed consent means that interviewees are clearly and unequivocally informed about the purpose and the nature of the research. In this case, the interviewee is in a position to decide whether to participate in the research or not, having in mind all potential implications and consequences. According to Sieber, confidentiality is defined as an "agreement with persons about what may be done with their data" (1992, p. 52). Data, in this case, is defined as both information gathered during the interview and the personal data of the interviewee. In order to prevent any issues regarding ethical considerations, it is required to inform potential interviewees, in advance, about the nature and goal of the research, and to obtain written confirmation that the potential interviewee is willing to participate in the study. Moreover, the code of practice requires sending the questions to the interviewee in advance together with an explanation that the content of the interview might be included in the text of the thesis but only after explicit permission from the interviewee is obtained. All of the aforementioned ethical considerations are applicable for a case study as well. However, confidentiality requirements are even more important in this case, since the researcher might be in position to have an access to confidential data. This issue is solved by signing a confidentiality agreement.

1.6 Audience

Parts of this thesis represent novel research in two fields. First, according to the author's knowledge, this is the first empirical research on the barriers to, and drivers for, industrial energy efficiency in the rubber compounding industry. Second, it is also probably the first attempt at understanding global societal goals, outlined in SDGs and the Paris Agreement, through concepts of energy efficiency drivers and energy efficiency barriers. Therefore, it may be interesting for a variety of people. On the one hand, researchers, students or anyone who might have a scientific approach can find facts and figures relevant for this field, or inspiration on how to do a research in this field. Moreover, the thesis could help to identify gaps in knowledge and could lead to further research. The presented theoretical framework, based on transdisciplinarity, is rather new and this thesis might serve as a source of inspiration for how to use these frameworks.

On the other hand, this thesis might be interesting also for business professionals of various vocations, from people working in the consulting industry, to managing directors and plant managers. For business consultants, this thesis might be an additional source of information and inspiration when consulting with companies in the manufacturing industry. For managing directors, plant managers, energy managers or anyone responsible for energy and energy efficiency within a company, this thesis might help to identify their own drivers and barriers for industrial energy efficiency. Moreover, it might clarify the benefits that company managers could expect when engaging with energy efficiency projects, as well as drivers and barriers they could expect during that journey, which could help them in decision-making.

Finally, since energy efficiency drivers and barriers in industry are tied with public policies for industrial energy efficiency, this thesis might be interesting for policymakers as well.

1.7 Disposition

The research study has been organized in a following way:

Chapter One is an introductory chapter which gives an overview of the research problem. This chapter includes research purpose, as well as brief explanation of methodology, followed with limitations, ethical considerations and audience to which this research has been mainly addressed to.

In Chapter Two, there is a thorough literature review on energy efficiency drivers and barriers in manucatruing industry. Studies from various sources are brought together, analysed and presented in a structured manner, in order to present EE drivers and barriers in a comprehensive way.

Chapter Three presents Unitend Nations Sustainable Development Goals, as well as how these goals together with changes happening on a global level might affect businesses. Also, there is a tool that might help companies to assess their activities and to link them to global sustainability efforts.

Chapter Four is dedicated to research guidelines and analytical framework. This chapter gives and overview of methodology used in this thesis.

Chapter Five is presenting a case study – a polymer compounding company. It starts with brief overview of the company, and continuous with presenting findings on polymer compounding industry in general, as well as on findings specific for this company.

Chapter Six is dedicated to discussion of findings and results. Also, in this chapter, limitations and shortcomings of this study are listed.

Chapter Seven gives concluding remarks, as well as summary of key results, explanation how this study contributes to the body of literature, and suggestions for future research.

2. Energy Efficiency in Manufacturing Industry

2.1 Industrial energy consumption and energy efficiency

2.1.1 Trends in industrial energy consumption

Industrial sectors are consuming more than fifty percent of world's total delivered energy, which is more than any other end-use sector (IEA, 2016). It also seems that industrial energy consumption will continue to grow 1.4 percent per year from 2010 to 2040. In other words, from approximately 211 EJ in 2010, it is expected to rise to approximately 323 EJ in 2040. This would represent around a 70 percent increase. In comparison, total world energy consumption in 2010 is estimated by IEA to be approximately 553 EJ. Not all the countries are expected to have same pace of growth. The non-OECD countries are expected to have an average pace of growth in energy consumption of 2.3 percent per year, while the OECD countries are expected to have a growth of around 0.4 percent per year. This increase in industrial consumption seems to be a continuation of a long-lasting process. The IEA (2005) claims that from 1971 to 2004 the total energy consumption of industry rose 2 percent annually, which represents an increase of 61 percent.

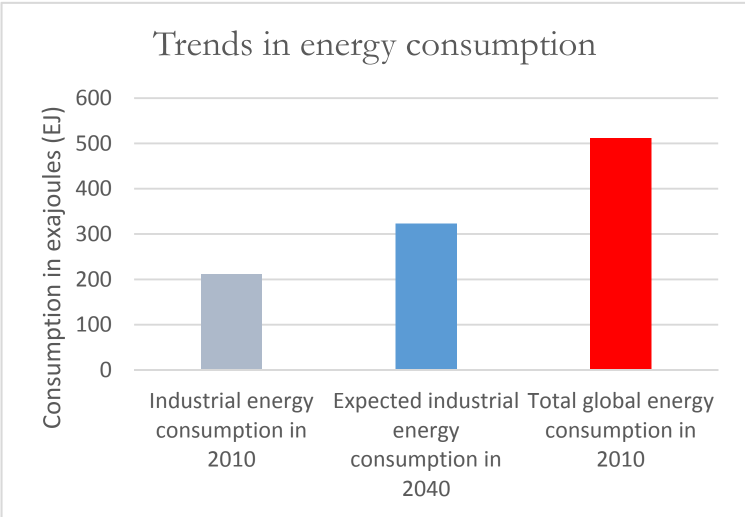


Figure: 2-1 Trends in industry-related energy consumption

Source: Based on data from IEA, 2016

On the other hand, despite the increase in energy consumption, industrial energy efficiency is also constantly being improved. According to Worrel,"industry has almost continuously improved its energy efficiency over the past decades" (2009, pg. 93). Despite this trend, there is still a lot of space for improvement. The IEA claims that the energy intensity of most industrial processes is at least fifty percent over theoretical minimum (2005). Moreover, the IEA (2007, pg. 386) claims that it is technically feasible to use energy efficiency measures to reduce energy consumption by 25 to 37 EJ per year, or "600 to 900 million tonnes (Mt) of oil equivalent per year or one to one and a half times Japan's current energy consumption. Through this reduction, potential for industry-related CO_2 emission reduction "amounts to 1.9 to 3.2 Gt per year" (IEA, 2007).

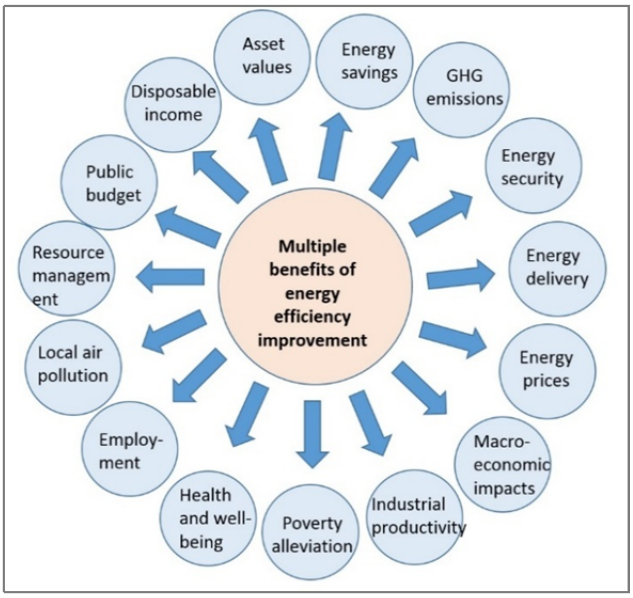
2.1.2 Defining energy efficiency

Energy efficiency might represent a win-win situation for industry, on the one hand, and society as a whole on the other, with an opportunity to "do good by doing well". Energy efficiency has a normative meaning, and it is considered as positive and desirable. It can be defined in several different ways. Irrek & Thomas define it as a "ratio between the benefits gained and the energy used" (2008, pg. 3). The IEA has a more descriptive definition, which says, "something is more energy efficient if it delivers more services for the same energy input or the same services for less energy input" (IEA, 2014, pg. 112).

The US Department of Energy (2015, pg. 3) defines industrial energy efficiency as, "the energy efficiency derived from commercial technologies and measures to improve energy efficiency or to generate or transmit electric power and heat, including electric motor efficiency improvements, demand response, direct or indirect combined heat and power, and waste heat recovery".

2.1.3 Benefits of industrial energy efficiency

The most obvious benefit of increased energy efficiency is financial savings in operating budgets. Energy efficiency reduces energy intensity per unit of production and, consequently, total energy consumption as well, if the volume of production remains the same. Therefore, energy costs are also lower. Besides obvious financial savings, there is one more set of benefits called "productivity benefits" (Worrel et al., 2003) or "non-energy benefits".



Worrel et al. (2003) make a list of these benefits and include, improved indoor environment, noise reduction, labor and time savings, improved process control, increased amenity of convenience, water savings and waste minimization and direct and indirect economic benefits from downsizing or elimination of equipment as productivity or non-energy benefits. According to Mills & Rosenfeld (1994), non-energy benefits are actually crucial and play a key role in consumer decision making. High-energy efficiency might represent an indicator that a company is doing well in general. Boyd and Pang concluded, "best practice firms are systematically more energy efficient, holding prices and learning constant" (2000, pg. 297).

Figure: 2-2 Multiple benefits of energy efficiency Source: Based on Worrel et al. (2003)

2.1.3.1 Non-energy benefits of industrial energy efficiency

The IEA (2014) working paper gives a comprehensive typology of non-energy benefits of industrial energy efficiency divided into five categories: production, operation and maintenance, working environment, environmental non-energy benefits, and business competitiveness and strategic objective.

Benefits in production are based on the assumption that through work on energy efficiency improvements, a company also might improve efficiency of its processes overall. As a consequence, there could be production improvements due to, for instance, shorter production time and less input materials consumed. Moreover, product quality and consequently product value could also be improved. Finally, it might positively affect plant capital since process and efficiency improvements could defer equipment replacement. Extraordinary, some equipment might even become unnecessary (IEA, 2014).

Energy efficiency improvements might lead to a reduction in maintenance, both in terms of materials and labor (IEA, 2014). Benefits related to operation and maintenance "are sometimes as large as the direct energy cost reductions". Worrel *et al.* found that improvements in energy efficiency lead to a reduction in need for engineering controls, and have "lowered cooling requirements, increased facility reliability, and reduced wear and tear on equipment/machinery and reduction in labor requirements" (2003, pg. 1083).

Working environments benefit in several aspects. Overall improvements in thermal comfort, lighting, acoustics and ventilation might lead to a more attractive working place. Moreover, this is also related to improved health, safety and reduced insurance and medical costs. A potential indicator for measuring this is the total number of sick days taken by staff. It can also positively influence worker safety. For instance, a reduced number of work-related accidents and costs related to these accidents might be used as an indicator (IEA, 2014).

Environmental non-energy benefits are mainly tied to emissions reduction. With the development of carbon pricing, relevance of this benefit might increase even more. Less energy consumed means less emissions. As a consequence, permits and licenses are easier and cheaper to attain (IEA, 2014).

Lastly, IEA (2014) claims that energy efficiency improvements might positively influence market sharing and the ability to enter new markets of a company. That is, they might improve competitive advantages and reduce corporate risk.

2.1.3.1.1. Quantification of Non-Energy Benefits

A usual issue in research regarding non-energy benefits is the fact that they are difficult to quantify. Pye and McKane (2000) claim that the quantification of non-energy benefits would be beneficial for companies, especially for understanding and assessing potential financial investments in energy efficiency technology. In addition, energy savings should not be the focus of analyses for investments in energy efficiency. Instead, energy savings should be perceived as just a part of a larger picture, with many benefits.
According to Worrell *et* al. (2003), a proper understanding and evaluation of non-energy benefits as wells as their incorporation into decision-making processes could drastically change a company's cost analysis of energy efficiency technologies.

IEA (2014) offers a list of steps companies could take in order to assess non-energy benefits of industrial energy efficiency. At the beginning, there should be a list of possible benefits relevant for that specific company. Second, develop a methodology of how to choose key benefits and how to measure them. After key benefits are chosen, there should be a system for data collection and analysis. Most importantly is deciding which indicator is going to be used. It might happen that relevant data already exists in the company since it has been gathered for some other purpose. Moreover, a baseline should be developed to enable future comparisons. After a specified period, collected and analysed data on non-energy benefits should be quantified and subjected to some kind of cost assessment analysis. Results of this analysis can be compared to results of regular cost assessment analyses (excluding non-energy benefits) in order to get an approximated value of non-energy benefits.

Methodology for how to quantify collected data on energy benefits is crucial. Unfortunately, there is still no common methodological approach. The currently available methods are lifecycle cost assessment, benefit to costs ratio, net present value, internal rate of return, total resource cost and costs of conserved energy (IEA, 2014).

2.2 Energy efficiency and sustainability

In order to answer the question of whether energy efficiency is sustainable, the question of what is sustainability has to be answered. This thesis understands sustainability as a set of principles. Robert and Broman (2011) have developed a set of four principles, three of them related to nature and one to society. According to these principles, nature should not be subjected to increasing "concentrations of substances extracted from the earth's crust, concentration of substances produced by society and degradation by physical means" (author, year, page). In a sustainable society, "people are not subject to conditions that systematically undermine their capacity" (Robert and Broman, 2011)

The affect of energy efficiency on the first three principles is straightforward. Energy efficiency leads to decreased energy consumption and this has multiple benefits for society. Since more than 80 percent of total global primary energy supply in 2013 was from fossil fuels, decreased energy consumption directly correlates to at least the first two sustainability principles. The first one, related to concentrations of substances, in this case carbon in the form of CO_2 and other substances with a global warming potential, is particularly important (NEAA, 2014). Moreover, global CO_2 emissions peaked, with a value of 35.3 billion tonnes (Gt), in 2013 (NEAA, 2014). Compared to the previous year, this is a increase of 2 percent and a continuation of a long-lasting trend that has only slowed during the world economic recession in previous years.

2.2.1 Rebound effect

The usual argument of non-causality between increased energy efficiency and decreased energy consumption is the so-called "rebound effect". The rebound effect or RE is a phenomenon of increased energy consumption due to a decreased price in energy per unit of service. For instance, if a car is more energy efficient, hence it uses less gasoline per kilometer, it becomes cheaper to run for that kilometer. Therefore, due to the decreased price in running, a car can drive more kilometers at the same price and, presumably, this would lead to increased energy consumption. Gillingham et al. summarise it as: "Buy a more fuel-efficient car, drive more" (2014, pg. 1).

The same is applicable for the companies. If the energy-related operational costs are lower per unit, an assumption is that the company will consume more.

Apparently, this is a theoretical construction based on classical economic theory. However, there have been studies that confirm the existence of the rebound effect, but how large this rebound effect is is still a topic of a debate.

In order to understand this better, there must be a distinction made between direct, indirect and economy-wide rebound effects (also called macro-economic rebound). Bentzen says, "the direct effect is a price effect where a new technology might increase energy efficiency corresponding to a reduction in the price of energy services that eventually results in increased demand for energy" (2004, pg. 124). Moreover, according to Bentzen, indirect effect is when "energy activity lowers overall energy costs leading to more money left to spend on other goods and services" (2004). There are also economy-wide effects, referring to "further adjustments in other markets of the economy affecting both consumers and producers" (Bentzen 2004, pg. 125).

Greening et al. (2004), in their literature review on rebound effect, found that the potential size of the direct rebound is 0-20 percent. Moreover, the potential size of the economy-wide rebound is estimated to be 0,48 percent. Bentzen (2004), in a study of the US manufacturing sector from 1949 to 1999 based on time series data from the US Bureau of Labour Statistics, found direct rebound to be approximately 24 percent. According to Bentzen (2004), indirect and economy-wide rebound effects are too complicated to empirically estimate. Referring to energy efficiency investments in general, Gillingham et al. conclude, "in most cases we do not expect the total rebound effect to exceed 60 percent" (2015, pg. 23). Based on the above, it is reasonable to conclude that many things regarding the affects of EE on energy consumption are still uncertain, but, overall, EE will lead to decreased energy consumption.

2.3 The Energy efficiency gap

Probably the most important issue related to general and industrial energy efficiency is the so-called, energy efficiency gap. It is a wonder that energy efficiency measures considered cost-effective are not implemented to their potential, or even at all (Backlund et al., 2012).

There are currently three perspectives on the energy efficiency gap: economic or neoclassical, behavioural and one based on organisational sciences (Marchesani & Spallina, 2012).

2.3.1 Economic or neoclassical perspective on the energy efficiency gap

Jeffe and Stavins (1994) explain the existence of the gap through market failures and barriers to energy efficiency. Market failure is a term from neoclassical economic theory and represents any deviation from a theoretically perfect market. Market failure is, for example, imperfect competition or when a situation blocks firms from entering or exiting a market. Market barriers (or just barriers) to energy efficiency is much broader term and includes "economic, organizational, and behavioral obstacles" (Marchesani & Spallina, 2012).

According to Jeffe and Stavins (1994), it is not clear what the potential or hypothetical extent of energy efficiency in any one society is. They explain three different perspectives on energy efficiency potentials: *hypothetical potential*, *economists' economic potential* and *technological economic potential.*

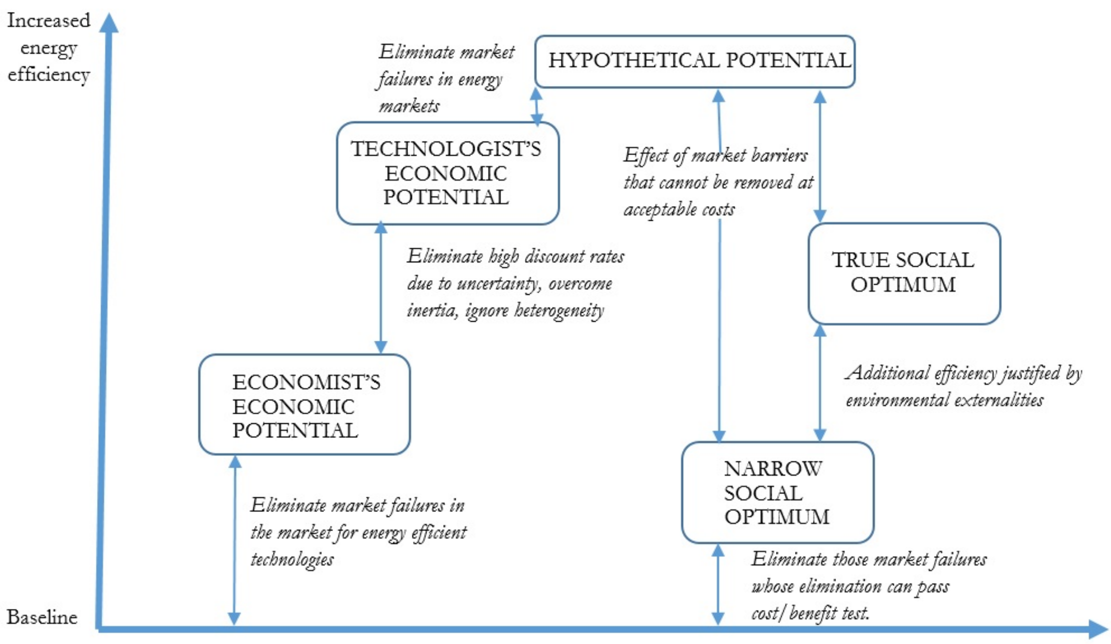


Figure: 2-3 Energy efficiency gap

Source: based on Jeffe and Stavins (1994)

As it can be seen on the picture 2-3 *economists' economic* view on societal energy efficiency potential assumes that only market failures in markets for energy efficient technologies are removed. Neoclassical economic theory is interested in market barriers only, since they are perceived as market imperfections. Public policies then serve as tools for market barrier removal. As it can be seen on the Y axis, the *economists' economic* potential for energy efficiency is significantly higher as compared to the baseline, or business as usual.

Above the economists' on the Y axis, there is the *technologists' economic potential*. This perspective assumes that, besides market failures, market barriers in the market for energy efficient technologies are also removed. Moreover, societal energy efficiency potential is higher when compared to the *economists' economic* view. Next is the *hypothetical potential*, and this perspective takes a step outside of energy efficient technology. It assumes that market failures in the energy market are removed. The reason why energy markets are also included is possibly to get additional energy efficiency improvements if energy prices are right. As we know from neoclassical economic theory, one of key reasons for price distortions in any market are various market failures. However, the hypothetical potential is not possible to reach, nor is it desirable, since the removal of all market failures would simply be too costly (Jeffe and Stavins, 1994).

When the effects of policies that would be too costly to implement go neglected, what is left is called a *narrow social optimum*. "It represents the energy efficiency achieved by instituting all available programs to encourage energy efficiency that pass an appropriate cost-benefit test" (Jeffe and Stavins, 1994).

Finally, there is the *true social optimum*, which assumes that environmental externalities of energy consumption are internalised. The assumption is that the internalisation of costs related to negative externalities of energy consumption (e.g. CO2 emissions), will incentivise consumers to improve energy efficiency, consume less and consequently emit less.

2.3.2. The Behavioural Perspective on the Energy Efficiency Gap

The second perspective is called the behavioural perspective, derived from behavioural economics and psychology. Its main assumption, contrary to that of neoclassical economy theory, is that human beings are not fully rational. Therefore, according to behavioural perspective, it is not enough to remove market failures or market barriers and to expect societal optimum. Quite often this hypothesis of human rationality is criticised, but it still remains a crucial assumption of many economic models.

According to Sorrel et al, "individuals do not make decisions in the manner assumed by economic models, but are instead subject to severe constraints on attention, resources and their ability to process information" (2000, pg. 180). This is also often called bounded rationality. For example, a consequence of this behaviour is that firms tend to pay more attention on their key business activities, and less to ephemeral activities such as energy efficiency improvements (Sorrel et al., 2000). Moreover, firms tend to undervalue so-called opportunity costs. Certain outcomes are weighted more than uncertain ones and "choices depend strongly on how a decision is framed, that is, on the reference point" (Marchesani and Spallina, 2012, pg. 33).

For instance, bounded rationality might be a rather significant barrier to energy efficiency or energy efficiency technology markets if these markets are rather complex and/or information costs are high. Since firms are faced with many constraints, time-constraint being one of the most important, it is expected that complexity and high information costs "will encourage the neglect of energy efficiency in individual and organizational routines and reinforce the bias in favor of energy consumption and against efficiency purchases" (Sorrel et al., 2000, pg. 180). Because of not taking into account bounded rationality, economic models for energy efficiency potential assessment based on neoclassical theory may significantly miss the target. Consequently, policies based on these models might turn out to be ineffective.

2.3.3 Organizational perspective on the energy efficiency gap

The third perspective comes from the organisational sciences. It represents a blend of various disciplines and ideas and it is mainly aimed at understanding behaviour on a company level. It is compatible to the neoclassical economic perspective and behavioural economic perspective. There are two crucial ideas in this perspective. One is the idea of power, or how power relations within the firm might affect energy efficiency uptake. The second is culture, or how organisational culture, values, principles or norms might affect decision making regarding energy efficiency. Besides these two, energy management within the firm can also be considered as part of the explanation for the energy efficiency gap. This claim is based on the work of Backlund et al. (2012). According to them, there is a lot of potential for energy efficiency in energy management practices. Backlund et al. (2012) outline a concept of extended energy efficiency potential, which would be even higher than the hypothetical potential of Jeffe and Stavins (1994). Backlund et al. (2012) claim that most of the studies on the energy efficiency gap are focused on energy efficiency technology diffusion, and only few of them are focused on energy management and possibilities for in-house efficiency improvements. There is no single definition of what energy management is. The narrowest definition says that energy management is energy efficiency projects' implementation and inefficient equipment removal. Some authors include energy management maintenance and taking care of equipment to keep desirable level of efficiency. Moreover, audits to assess the situation, trainings to raise awareness and good housekeeping measures to reduce energy consumption, as well as data gathering on energy consumption and data analysis, can be described as a part of energy management (Backlund et al. 2012).

2.4 Barriers to industrial energy efficiency

In Section 1.2, the existence of the energy efficiency gap is explained through the concept of barriers. Moreover, three perspectives on these barriers are outlined. According to Sorrel et al, the barriers to energy efficiency could be defined as a "postulated mechanism that inhibits investments in technologies that are both energy-efficient and economically efficient" (2004, pg. 11). As it is shown in the previous chapter, focusing the energy-efficiency gap only on market barriers for technology diffusion might be too narrow. Therefore, this definition should be understood in a broader sense, including barriers derived from all three perspectives.

2.4.1 Theoretical barriers for industrial energy efficiency

Thollander and Palm (2013) develop a classification of barriers in four large groups, with several theoretical barriers within each group. However, it is important to note that these barriers are theoretical and not all of them are necessarily manifested in reality. As Thollander and Palm state, "These barriers are explanatory variables," with origin in various disciplines or even sciences (2015, pg. 39).

2.4.1.1. Market Failure/Market imperfection

2.4.1.1.1 Imperfect Information

If there is no information on cost-beneficial energy efficiency measures, it might not be implemented. This lack of information may vary, from a lack of the existence of technological options at all to a lack of information or uncertainties about the accuracy of data regarding energy performances of certain solutions.

Moreover, there also might be a lack of information about transaction costs regarding solutions and about the costs of the assessments and evaluations of energy efficiency opportunities. For instance, the value of an energy audit is known only after auditing is performed (UNIDO, 2011a). O'Malley et al. (2003) point out the information-related barrier that there is a lack of awareness regarding financial institutions that offer financing to companies for energy efficiency projects. This kind of financing might reduce the cost of capital consequently, affecting economic viability of the project, and influence decision making within firms O'Malley et al. (2003).

2.4.1.1.2 Adverse Selection

Adverse selection is a form of information asymmetry where "one party involved in transaction has more information than another" (Dillingham et al. 2009, pg. 15). In terms of energy efficiency, this is a situation where the seller of energy efficient products has information on energy performances of a product. However, the seller is unable to perfectly transfer this information to the buyer, so the buyer is not using this information in his/her decision making to its full extent, or even at all. Consequently, the decisions made about investing in certain technologies or products might be on "the sole basis of price or visible aspects such as color and design", excluding superior energy performance (Thollander and Palm, 2013, pg. 40.)

There is one more consequence of adverse selection. If the consumer is not aware of the superior energy performances of a certain product or technology, he/she is also generally unwilling to pay a higher price for this premium product, assuming that the more efficient product costs more. Consequently, more of less efficient products will be placed on market (O, Malley et al. 2003).

An additional problem is the fact that the energy efficiency of some products changes or depends on external factors. Weather and temperature are probably the easiest to understand (O'Malley et al., 2003).

2.4.1.1.3 The Agency Dilemma/Principal-Agent Relationship

The agency dilemma or principal-agent relationship (PA) is a theory derived from neoclassical economics. PA occurs every time "two parties engaged in a contract have different goals and different levels of information" (IEA, 2007, pg. 11). For instance, companies have their operational and capital investment budgets divided and maintained by separate and, quite often, distant administrative divisions. There is, almost indubitably, imperfect communication between them. Consequently, one department does not know completely what the other department is doing. Hypothetically speaking, when the division that maintains an operational budget wants energy efficiency investments to reduce operational costs, it might encounter a lack of understanding that operates with capital investment budgets. Moreover, energy efficiency projects are never only projects to be considered by capital investment divisions. According to the IEA,"It is reasonable to hypothesize, therefore, that these PA problems could create nationally significant amounts of energy use that are effectively insulated from energy price signals" (2007, pg. 36).

2.4.1.1.4 Split Incentives

The issue of split incentives is rather similar to the PA problem. Theoretically, if a person or a department in charge of taking energy efficiency measures will not benefit from them, the measure will not be taken. For instance, if a manager is at the company for only a short period it is quite likely that he/she will not attempt to make investments with a long payback period (UNIDO, 2011b). Quite often general practice in large companies is to rotate managerial positions. It is reasonable to assume then that a manager would avoid investments in energy efficiency, no matter how cost-effective they may be in the long run, if the capital investments are considered undesirable. Moreover, in large companies where departments are paying their own electricity bills, it is possible that the head of a department is not interested in paying for energy efficiency investments that will bring savings to a different department (UNIDO, 2011; Thollander and Palm, 2013). Also related to purchases, a purchase manager is usually responsible for capital investments. Therefore, he/she will not be interested in operational costs of a purchased product (O'Malley et al., 2003).

2.4.1.2 Non-Market Failures/Non-Market Imperfections

2.4.1.2.1 Hidden Costs

Hidden costs are "any costs which are not conventionally included within engineering-economic models" (UNIDO, 2011b, pg. 21). Manifestations of hidden costs may vary, but they come from three main sources (UNIDO, 2011b). General overhead costs are costs of employing or training specialists (e.g. an energy manager) and costs of systems for energy management monitoring. For instance, collection and analysis of energy-related data might be an overhead cost, since it requires time and personnel (UNIDO, 2011b).

In addition, there are individual technology costs related to potential investment identification and analysis. Formal procedures for investment are also costly, as well as additional training or replacement of staff. For instance, information gathering on energy efficiency investment is estimated to be three to eight percent of total investments costs (Hein & Blok, 1994).

Potential utility losses due to investment are also hidden costs as well as costs of production disruption due to new technology installed. Additionally, hidden costs might be those related to "problems with safety, noise, working conditions, service quality, etc. (UNIDO, 2011b).

2.4.1.2.2. Access to Capital

A lack of capital and lack of access to capital for energy efficiency investments is one of the most cited barriers. Neoclassical theory sees access to capital as a market barrier, not as market failure. Even in perfect, there would still be differences in costs of capital. This is because "the capital is allocated to projects with the highest, risk adjusted, rate of return" (O'Malley et al., 2003). A consequence of this is that borrowers who are perceived as high-risk borrowers, usually low-income firms of individuals, have difficulty borrowing at reasonable interest rates and have to pay a higher price for capital (O'Malley et al., 2003). This is especially true in developing countries, where a smaller banking sector cannot support the spread of energy efficient technologies (UNIDO 2011b). In general, there are two components of the "access to capital" issue. One is the lack domestic capital for energy efficiency projects, and the second is difficulty borrowing or accessing share-related external capital (UNIDO, 2011b, pg. 26). Moreover, companies might have strict rules on their borrowing or payback periods, which would make the situation even more difficult.

2.4.1.2.3 Risk

Risk is multidimensional and might arise from a wide range of sources. A crucial element is the perception of risk, as opposed to risk itself. The perception of risk can be influenced by many factors and does not always have to be rational. Moreover, risk perception varies "with the individual country, sector, business and technology" (UNIDO, 2011b, pg. 15), and is subject to change over time.

There are three broad categories of risk. External risks might include general economic trends such as the general direction of economy, inflation or interest rates, potential modifications to governmental policies, the price of commodities or financing risks such as the "anticipated reaction of capital markets to increases in borrowing" (UNIDO, 2011b; O'Malley, 2003).

Technical risks might be related to specific technology, such are reliability of that technology, compatibility with other technologies used or possibilities of production disruptions (UNIDO, 2011b; O'Malley, 2003). However, O'Malley et al. (2003) claim that many of the technologies for industrial energy efficiency are proven technologies and it is unlikely that they might be perceived as risky technologies. Finally, business risk might be related to sectorial business trends, individual business economic trends, or to trends in financial markets (UNIDO, 2011b; O'Malley, 2003).

2.4.1.2.4 Heterogeneity

Heterogeneity is a problem for the general and specific applications of certain technologies. For instance, although a certain technology might appear to be cost-effective in general, it is not necessarily in every specific situation. Even if specific technology is cost-effective for every consumer, it will almost surely not bring the same savings for everyone. Companies that are more specific in their products or that are working in a more specific environment might expect larger deviations from "average" cost-effectiveness. For instance, "heat exchanger may not function on an exhaust ventilation flow that contains too much process-related particulate matter" (Thollander and Palm, 2013, pg. 44). Moreover, according to Jaffe et al., variables of cost-benefits might be "the purchaser's discount rate, the investment lifetime, the price of energy, the purchase price, and other costs" as sources of heterogeneity (2004, pg. 86).

2.4.1.3 Behavioural Barriers

2.4.1.3.1. The Form of Information

The consideration of the form of information as a barrier is derived from social psychology and marketing. In these disciplines it is well known that individuals react differently to the same information depending on how the information is transmitted. When it comes to energy efficiency, US evaluations of energy efficiency programmes reveal that people might ignore useful information, even if it is costless (O'Malley, 2003). Therefore, it often happens that information is transferred to the intended recipient but, due to insufficient attention, it is not received or processed properly. Psychologists say that people are often quite selective in "assimilating information" and there should be certain elements to the information to better ensure successful processing (Thollander and Palm, 2013).

In order to be successfully transmitted, information should be personalised and tailored to specific needs of a firm or individuals. For instance, individual energy audits are more effective than general information on cost savings (O'Malley, 2003).

Moreover, information should be framed in ways that are interesting, tangible and vivid (O'Malley, 2003; Thollander and Palm, 2013). O'Malley (2003) gives interesting examples of studies that show that people who watched videos on the implementation of domestic energy saving measures were more inclined to actually reduce their own energy use than people who received brochures with the same content. In addition, information should be clear, simple and easily understandable (O'Malley, 2003). Finally, information should be transmitted close to the time of actual investment decision making (O'Malley, 2003).

2.4.1.3.2 Credibility of Trust

Besides content, who is disseminating the information and their perceived credibility is also important. This is more a question of social psychology and who is, in society, perceived as an authority on certain subjects. For impact in this field, the information should be perceived as worthy of trust. This is especially true when it comes to information on the cost of investments. In the case that there is no trustworthy information company, it may be required to use that which is the most credible (Thollander & Palm, 2013). To illustrate this, Thollander and Palm (2013), give an example from the 1980s. In New York pamphlets with explanations on how to save electricity with domestic air-cooling systems were distributed to households. One-half of the households received the pamphlet from the local electricity provider, and the second half from the governmental regulatory agency for utilities. Surprisingly or not, those who received information from the state agency consumed eight percent less energy compared to those who received it from the local utility company.

O'Malley et al. (2003) point out variables that might influence public perception of the credibility of information sources. The nature of the source is generally important. For instance, if the source is private, governmental or aim-specific, such as a pressure group, it is considered credible. Moreover, having previous experience with the information source or the type of connection to the source also play roles. O'Malley et al. argue that interpersonal contacts, from colleagues to acquaintances, will matter more "than labels, pamphlets and paper qualifications" (2003, p.). Thollander and Palm (2013) argue that consultants are often considered as the most trustworthy and credible.

2.4.1.3.3 Values

There are still no available scientific findings on the role of values in industrial energy efficiency. However, Pellegrini-Massini and Leishman (2011), in their study on the role of employees' values in the uptake of energy efficiency measures in office buildings, found that employees' personal beliefs and convictions might influence the behaviour of entire organisations. In their specific case study, pressure from employees to save energy contributed to the overall energy savings of the organisation. Their conclusion is that there is "an indication that pro-environmental attitudes play a role within the companies influencing internal dynamics" (Pellegrini-Massini and Leishman, 2011, pg. 5417) It is also reasonable to assume that a lack of these kinds of pro-environmental values, or values that conflict with pro-environmental values might negatively affect "green" actions.

2.4.1.3.4 Inertia

People do not like to change their ways of living or habitual behaviours (Thollander and Palm, 2013). This phenomenon is called inertia and, from the point of view of behavioural science, it might be one explanation for the existence of the energy efficiency gap. Similar to values, there is still no scientific research about inertia with industry-related energy efficiency improvements, but there are interesting insights from research on households.

One of Jensen's (2005) findings from his research on inertia in Danish households is that individuals hesitate to invest in energy efficiency because it does not bring anything "visible". Jensen states, "Money is important, but what money can make visible, is more important" (Jensen, 2005, pg. 1333). These findings confirm "prospect theory". One of the postulates of this theory is that gains are treated differently from losses. Since losses are considered as undesirable, and investments in energy efficiency are considered as losses due to the need for capital investment, there is a strong inclination towards undervaluing future energy savings (O'Malley, 2003).

Yang and Yu (2015) explain inertia as having two factors, psychological and financial. On a psychological level, individuals tend to keep old, less efficient equipment because of aesthetic, sentimental or some other value, or because they dislike the new, more efficient substitute. On a financial level, individuals prefer higher annual operational costs over high capital investments in new technologies.

2.4.1.3.5 Bounded Rationality

Bounded rationality is a concept originating from the work of Herbert Simon in the 1950s. He distinguishes substantive and procedural rationality. Substantive rationality is behaviour and decision making according to formal optimisation models. Procedural rationality, or bounded rationality, "implies that people make decisions subject to constraints on their attention, resources and ability to process information" (O'Malley, 2003). Therefore, actual individual choices might differ from predicted choices given by the optimisation model.

Sanstad and Howarth (1994) explain, "Individuals and firms do not always behave according to the logic of economic rationality but they should" (1994, pg. 812). In other words, a consequence of procedural rationality is that firms and individuals, due to various constraints, will not seek the optimum solution, but rather a solution that is perceived as satisfactory.

Moreover, decision making is usually constrained by time. Consequently, decision making might shift from analysis, expected by the optimisation model, towards "imperfect routines and rules of thumb" (UNIDO, 2011b). Empirical studies confirm the existence of bounded rationality as a market barrier. However, it is methodologically difficult to calculate the contribution of bounded rationality as an energy efficiency gap.

2.4.1.4 Organisational Barriers

2.4.1.4.1 Power

Seeing an organisation as a political system with power relations inherent in its organisational structure is a perspective originating in political science, and, partially, organisational science. The focus is on the ability of individuals or departments within an organisation to make or influence decisions. Morgan defines organisations as "networks of people with divergent interests who gather together for the sake of expediency" (1986, pg. 156). Since interests are different, and resources to achieve those interests are always limited and lead to competition, there have to be some kind of power relations established to make decisions. O'Malley explains, "Power influences who gets what, when and how" (2003, pg. 26).

According to Morgan, there can be several factors of organisational power, perhaps the most important being formal authority or positions in a formal organisational structure (1986, pg. 198). For instance, a company's CEO has more power within an organisation than anyone else. Moreover, there is a control of scarce resources. It is most visible when it comes to the control of money, that is, the allocation of finances and budgeting. The control of scarce resources also can be the control of raw materials, specific technologies and skills. The level of decentralisation or, conversely, centralisation, is particularly important.

management. Consequently, energy efficiency is often considered as the responsibility of low-ranking individuals or lacking departments within the organisational structure. For instance, maintenance or technical departments. Since these departments are detached from financial resources and the power of decision making within an organisation, "the best people will not be attracted to energy management if the compensation and prestige are less than the rewards of other positions" (O'Malley, 2003, pg. 27).

2.4.1.4.2 Culture

According to O'Donnel and Boyle (2008, pg. 4) organisational culture "gives organizations a sense of identity and determines, through the organization's legends, rituals, beliefs, meanings, values, norms and language, the way in which 'things are done around here'". Similarly to individual values, if organisational culture is somehow in conflict with concepts of energy efficiency, it might inhibit energy efficiency measures from being taken (Thollander & Palm, 2013). According to Hatch,

> The essence of a culture is its core of basic assumptions and established beliefs. This core reaches outward through the values and behavioral norms that are recognized, responded to and maintained by members of the culture. The values and norms, in turn, influence the choices and other actions taken by cultural members. (Hatch, 1997, pg. 135)

The role of upper management is especially important for organisational culture. Morgan claims that: "the attitudes and visions of top corporate staff tend to have a significant impact on the ethos and meaning system that pervades the whole organization" (1986, pg. 126).

Companies are actively working on reshaping their organisational culture. Some consultancies are even promoting the concept of organisational energy culture. It is defined as "A shared mindset that creates and sustains an environment conductive to continual improvement of the energy performance of the organization" (Choy, 2015).

2.4.2 The literature review on empirical studies on barriers for industrial energy efficiency

All of the aforementioned barriers are rather theoretical and derived from multiple scientific disciplines.

A review of empirical research gives an overview of the representation of the aforementioned theoretical barriers to different industries and different countries. There are a total of eleven empirical research papers reviewed. Only papers published in the last 10 years are reviewed. There is no geographical nor industry related criteria for paper selection. Most of the papers (7) are related to countries in the European Union, i.e. "developed" countries. Out of these seven, three are related to Sweden and one to Italy, Germany, Belgium and Greece, respectively. The rest of the papers (5) are related to the Ukraine, China (2) and Ghana. Six papers are not sector-specific (Kostka et al. 2011; Apeaning and Thollander, 2013; Schleich, 2009; Sardiniou, 2009; Liu, 2014; Timilsina, 2016). The pulp and paper industry is researched by Thollander and Otosson (2007); foundry industry by Rohdin et al. (2006); iron and steel industry by Brunke et al. (2014); metallurgical SMEs by Trianni et al. (2013); and the ceramic, cement and lime industry by Venmans (2014).

2.4.2.1 Methodology Used in Reviewed Papers

Case studies, questionnaires and cross-sectional surveys are the three main methods used in the reviewed papers. Cross-sectional surveys have been used in researching entire branches of industry, or even entire national industries (Timilsina et al., 2016; Kostka et al., 2011; Shleich, 2009). This research has large samples, from several hundred to even several thousand (Schleich, 2009). Data collection is done through face-to-face interviews using standardised questionnaires in all three cross-surveys. Case studies and multiple-case studies are the most often used methods of research (Lin, 2014; Venmans, 2014; Trianni et al., 2013; Apeaning and Thollander, 2013; Rohdin et al., 2006). This type of research has smaller samples, usually counted in dozens, and is used for a more specific research subject. Data collection is predominantly implemented through a mix of multiple semi-structured interviews and questionnaires. Questionnaires are used as a research method in almost all of the projects. However, only a few of them (Brunke et al., 2014; Thollander and Otosson, 2007; Sardiniou, 2007) are based on the questionnaires. In the case of Brunke et al. (2014), questionnaires are followed up with phone interviews.

Author	Year	Country	Industrial sector	The most significant barriers
Timilsina et al.	2016	Ukraine	Several industries	• High upfront investment costs • Access to capital (cost of capital) • Lack of governmental policies
Brunke et al.	2014	Sweden	Iron and steel	• Limited access to capital • Technical risks • Other priorities for capital investments
Liu	2014	China	Several industries	• Lack of financial incentives to stimulate low carbon innovation • Lack of common definition of low carbon production • Lack of detailed implementation plans and mechanisms to monitor implementation
Venmans	2014	Belgium	Ceramic, cement and lime	• Other priorities for capital investments • Low demand risk: efficiency investments entail fixed costs that may be cost-inefficient when there is overcapacity during economic downturns.

				• Technical feasibility wasn't studied before
Trianni et al.	2013	Italy	Metallurgical SMEs	• Investment costs • Information issues on energy contracts • Hidden costs
Apeaning and Thollander	2013	Ghana	Several industries	• Lack of budget funding • Access to capital • Other priorities for capital investments
Kostka et al.	2011	China	SMEs	• Lack of information about energy saving technologies and practices
Schleich	2009	Germany	Commercial and service sector	• Split incentives • Lack of information about energy consumption patterns
Thollander and Otosson	2007	Sweden	Pulp and paper	• Technical risks (production disruption) • Costs of production disruption/hassle/inconvenience • Technology is inappropriate at the mill
Sardiniou	2007	Greece	Several industries	• Limited access to capital • Increased perceived cost of energy conservation measures • Slow rate of return of the investments
Rohdin et al.	2006	Sweden	Foundry	• Access to capital • Technical risk (production disruption) • Lack of budget funding

Table: 2-1 Findings from the literature review on the most significant barriers for energy efficiency

Source: Various sources

2.4.2.1.1 Empirical Findings on the Most Important Industrial Energy Efficiency Barriers

Financial barriers are one of the top three barriers in almost all findings. Kostka does not mention financial barriers, but gives an explanation about why they are not included:
First, the enterprises for the survey were selected from a bank's database, i.e. they were already customers at a bank. So the dataset may just contain enterprises who actually had the choice whether to use debt finance or not. Second, 46 percent of SMEs used cash accruals and 15 percent used own funds to finance existing equipment. (Kostka, 2011, p)
When in comes to specific barriers within finance, high upfront costs, costs of capital investment and costs of capital in general are proven to be the most important. Moreover,

technical barriers are also often mentioned as barriers. Within this group, production disruption has been mentioned the most often.

2.5 Drivers for industrial energy efficiency: definition and classification

Energy efficiency drivers are not an extensively researched topic compared to energy efficiency barriers. In fact, existing research on energy efficiency drivers is usually coupled with research on barriers and often pays less attention to the drivers. Drivers for energy efficiency, like barriers, can be generated by various sources. Moreover, one driver can have several directions for action and can be directed at overcoming multiple barriers.

There is no common definition for what these drivers are. Marchesani and Spallina define drivers as factors "that will help uptake of energy efficiency technologies and practices" (2007, pg. 70). One of the issues related to this definition is its narrowness. It seems this definition covers only drivers for investments and does not say anything about decision-making processes. Thollander and Otosson have broadened the concept of energy efficiency drivers, stating: "A driving force might be seen as the opposite of a barrier, in other words, different types of factors that stress investments in technologies that are both energy-efficient and cost-effective" (2008, pg 5.). Although this definition broadens the concept of the driver, it does not seem right that drivers are represented as negative to barriers. This is not true since some barriers, such as management and awareness, might be helpful in overcoming some barriers (Marchesani & Spallina, 2012).

Marchesani & Spallina give the broadest definition, saying drivers are "factors that force towards the adoption of energy-efficient and cost-effective technologies or practices, influencing a portion of the company or a part of the decision making in order to provide a thrust towards energy efficiency" (2012, pg. 71).

There is no common or generally accepted taxonomy of energy efficiency drivers. Reddy and Assenza (2007) classify drivers into four categories: awareness, decrease in technology price

Table: 2-2 Classification of energy-efficiency drivers

Source: Based on Marchesani and Spallina (2012)

levels, increase in energy prices, technological appeal, non-energy benefits and environmental regulations. Thollander and Otosson (2008) also categorise drivers into four categories: market-related driving forces, policy instruments, current and potential energy policies, and behavioural and organisational-related driving forces. Marchesani & Spallina (2012) classify barriers into three categories: internal drivers, mixed drivers and external drivers.

The classification given by Marchesan i& Spallina (2012), with some adjustments, is used in this thesis. The reason for this is that most of the literature on energy efficiency drivers does not make distinctions between public policies for energy efficiency and drivers for energy efficiency. This is crucially important on a practical level, where companies should be able to understand what to do in order to overcome inefficiencies. A novel method of classification proposed by Marchesani & Spallina (2012) makes a distinction between three groups of energy efficiency drivers. The first group is composed of drivers that are completely independent from a company's actions and a single company cannot influence them. The second group are of "something that the company is able to implement and continue independently to achieve efficiency" (Marchesani & Spallina, 2012, p.). There is also a third group called mixed drivers, or drivers that are neither internal nor external.

2.5.1 Internal drivers

Internal drivers	Mixed drivers	External drivers
Long-term energy strategy	Voluntary agreements	Green image
People with real ambition	Programmes of education and training	Increasing energy tariffs
Management with real ambition and commitment	External cooperation	Public investments
Willingness to compete	Knowledge of non-energy benefits	Managerial and technical support
Cost reduction from lower energy use		External energy audits/submetering
Implemented Energy Management System (EMS)		Awareness
		Technological appeal
		Availability, clarity, suitability and trustworthiness of information

A crucial difference between internal or mixed drivers and external drivers is related to decision making. External drivers are purely derived from policies that are decided, drafted and implemented by the people that are not working in the company or for the company. In this case, the company does not have any strength to change or influence the specific policy, and can choose "whether or not to exploit them" (Marchesani & Spallina (2012). The only exceptions are legal requirements or standards that companies are forced to comply with. Zeng et al. (2011) divide external drivers into three categories: a) drivers related to governmental actions (subsidies, efficiency due to legal requirements, other actions aimed at promoting energy efficiency); b) drivers related to market (e.g. building green image); c) social driving forces (e.g. general availability of information).

According to Zeng et al., a company's "Internal driving forces are resulted from company's internal motivation (enterprise itself)" (2011, pg. 1428). A prerequisite for internal drivers is having a sufficient level of awareness about the issue and a commitment to working on it. Marchesani & Spallina (2012) have listed four driving forces as internal, while author added two more, which are the existence of an energy management system on a company's level and existence of clearly defined KPIs.

2.5.1.1 Long-Term Energy Strategy

The literature review has revealed that a long-term energy strategy is an important internal driving force for industrial energy efficiency. Rohdin and Thollander (2006), in their study of barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden, found it as one of the key drivers, especially at the plant level. In a study related to SME's in Sweden and energy efficiency policies, Thollander et al. (2007) found that a long-term strategy, together with people with real ambition, is the most important driver. Rohdin et al. (2007) have the same finding from their study of energy efficiency barriers and drivers in the Swedish foundry industry. This finding is reinforced with findings from Thollander and Otosson (2008). They focus on drivers and barriers in the Swedish pulp and paper industry and long-term strategy happens to be third most important driver, after energy cost reduction due to reduction in consumption and people with real ambition. Brunke et al. (2014) have found that having a long-term strategy is the third most important driver for energy efficiency, after commitment from upper management and cost savings. Moreover, Marchesani & Spallina claim that a long-term energy strategy also supports energy and environmental management systems that are, if this kind of strategy is adopted, "more likely to be successful" (2012, pg. 74)

Recently, companies have started to develop climate strategies. Most of the time they are closely related to a company's energy strategy. Birkin (2013) gives five reasons why developing a climate strategy is good for a company. First, an aim of reducing emissions relies on energy consumption reductions. Since the company is paying for energy, the reduction of costs can bring distinct cost-competitive advantages. In order to reduce energy consumption, there could be different methods applied, most of them related to using less raw materials (Birkin, 2013) or optimising transportation. Second, there are advantages related to risk-management. Climate strategy can contribute to risk mitigation including "regulatory risks, capital market risks, changing customer preferences, and changes to the physical environment" (Birkin, 2013). Moreover, though often neglected, climate strategy can contribute to keeping a company's operational permits and licenses. Third, a benefit might be an improvement in a company's position regarding "green-conscious" consumers. For instance, implementation of corporate climate strategy would probably lead to towards improving or creating more environmentally friendly products. Fourth, benefits are related to these completely new "green" markets and industries. For instance, there are markets of wind turbines, electric vehicles, etc. A climate strategy might help a company to become a part of these new markets (Birkin, 2013). Lastly, climate change strategies improve a company's reputation in stakeholders' eyes. Birkin explains,

> In essence, the GHG Protocol's advantage is in its conceptual strength and the guidelines it provides for the setting of organizational and operational boundaries for GHG inventories, for consolidating inventories across multiple organizational levels, for choosing a base year for emissions reporting, and for setting GHG reduction targets. (Birkin, 2013, pg. 707)

2.5.1.2 People with Real Ambition

Several empirical studies have found people with real ambition to be one of the most important drivers, usually one of the three most important drivers, as perceived by companies (Rohdin and Thollander, 2006; Thollander et al., 2007; Rohdin et al., 2007; Thollander and Otosson, 2008; Brunke et al., 2014). Marchesani & Spallina claim that an ambitious staff will contribute to "the overall efficiency of the enterprises, with a more appropriate use of the available resources, including energy" (2012, p). This driver derives from organisational science and social psychology. A well-motivated staff with real ambition helps organisations to implement new technologies and practices. In fact, staff with real ambition might increase the overall level of efficiency in an organisation, and achieve a reduced level of consumption of energy and other resources (Marchesani & Spallina, 2012).

2.5.1.3 Management with Real Ambition and Commitment

Management with real ambition and commitment is, together with ambitious and devoted staff, probably the most important driver for industrial energy efficiency. As presented in sub-chapter 2.4.1.4.1, an organisation can be perceived as a structure of power relations, where various agents have different levels of power for influencing decision making. Management of an organisation, and especially upper management, is, by definition, the most powerful and the most influential factor in decision-making processes. Therefore, if management does not consider energy management and energy efficiency important issues it is possible that energy efficiency will not be percieved as important. Managerial ambition and commitment have proven to be decisively important in various organisational, pro-environmental initiatives and activities (Zeng, & Jorge, 2010).

2.5.1.4 Willingness to Compete

Energy efficiency might help an organisation to improve its overall efficiency in its core business and, consequently, to increase its competitiveness. It is the same in the opposite direction. Organisational willingness to compete and to improve its position on the market might enhance energy efficiency investments, if energy efficiency is helpful for overall competitiveness of an organisation. According to Cooremans (2011), firms prefer to make most of their investments in their core business area. This is especially true for investments that improve overall comparativeness of the firm.

Once firms realise that energy efficiency closely relates to their competitive performances, energy and energy efficiency questions will not longer be perceived as peripheral. Instead, energy efficiency will be treated as a tool to obtain strategic gains (Marchesani & Spallina, 2012).

2.5.1.5 Cost Reduction from Lower Energy Use

The reduction of energy-related costs is one of the most obvious drivers of industrial energy efficiency. Besides pure financial reasons, cost reduction is an influential driver because results are immediately perceivable. Thollander and Otosson (2008) define cost-reduction as a market-related driving force. This is because incentives to reduce energy consumption, and consequent costs, are exogenous in nature. These incentives can be attributed to market conditions outside of the company, according to Thollander and Ottosson (2008).

2.5.1.6 Existence of an Energy Management System

There is a difference between energy management and energy management systems (EnMS), although these two terms are often used interchangeably. Energy management is, simply, strategic work or using different procedures on issues related to energy in a company. In some ways, EnMS represents "a tool for implementing these procedures" (Thollander & Palm, 2013, pg. 85).

The main benefit of EnMS is that they provide frameworks for "culture of continual improvement" (CITE). Therefore, work on energy performances is not occasional, but rather part of everyday activities. Two of the most widely used systems for energy management are the ISO50001 and EN16001. Both of these systems are based on the Plan-Do-Check-Act (PDCA) cycle. A PDCA cycle framework has already proven to be successful for industrial firms for improving "quality, environment and safety practices" (UNIDO, 2015).

The reason why the existence of EnMS is considered as a driver is the fact that implementing an EnMS "allows companies to systematically track, analyze, and plan their energy use, thereby enabling greater control of energy performance as well as operational performance" (OECD, 2015. pg. 12). Moreover, EnMS allows companies to make operational changes and save energy without capital investments in new, more efficient technologies (OECD, 2015).

According to UNIDO, the energy performance improvement rate of firms with EnMS implemented is "more than double that of enterprises without EnMSs" (2015, p). Moreover, companies that were totally new to any kind of energy management, achieved consumption reductions ranging "between 10 and 20 per cent of baseline consumption" (UNIDO, 2015, pg. 2).

2.5.1.7 Clearly Defined Energy-Related Key Performance Indicators (KPIs)

According to May et al., "measuring the energy efficiency performance of equipment, processes, factories and whole companies is a first step to effective energy management in manufacturing" (2013, pg. 258). The reason for this is the fact that key performance indicators (KPIs) provide data on energy performances that is crucial for decision-making processes regarding energy-efficiency investments. Jasch (2000) perceives energy indicators as crucial to a wide range of activities, from environmental energy-related targets and goals, to environmental reporting. Moreover, Mathews states that "Key performance indicators (KPIs) help an organization define and evaluate how successful it is, typically in terms of making progress toward its long-term organizational goals" (2011, pg. 88). Dillenburg et al. puts it simply by saying that "what gets measured gets managed" (2004, pg. 170). In other words, "What's measured, improves" (Siemens, 2014, pg.1).

There is no single methodology for how to measure energy efficiency improvements. Different firms, due to different settings, require different approaches. Categories of KPIs known in the literature include: thermodynamic, physical-thermodynamic, economic-thermodynamic, economic-physical and eco-efficiency (May et al., 2013).

It often happens that companies develop their own performance indicators to fit their needs. For instance, Siemens has developed nine specific energy-related strategic indicators or

Key indicators	Purpose	Unit of measure(Siemens, 2014)
Energy cost index	Total annual energy costs (everything included)	Currency. May be expressed as total costs in absolute numbers or a percentage of change over time.
Site energy use intensity	Total energy consumption in absolute numbers (electricity, gas & water)	Energy units {British thermal units (Btu) or kilowatt hours (kWh)} per air conditioned square feet over time (generally expressed over a year or month)
Source energy use	Total energy consumption plus "all energy transmission, delivery, and production losses" (Siemens, 2014)	Energy units (British thermal units, Btu, or kilowatt hours, kWh) per air conditioned square foot over time (generally expressed over a year or month)
Productivity indices	"Measures the rate at which energy is consumed per unit of input" (Siemens, 2014)	Energy units. Examples: Btu/person, kWh/lb, gallons water/lb
System performance	"Measures the efficiency of mechanical systems at a single point in time per unit of output" (Siemens, 2014)	Energy units; energy input per desired output generated; common metrics. Examples: kW/ton cooling, kWh/gallons pumped, Cubic Feet – Minute/Horsepower air
Load factor	Changes in consumption over time in different time frames	Power (kW); average demand/peak demand
Average minimum demand	Average daily demand with the lowest demand pointed out	Power (kW); generally best identified during least productive part of day (e.g. 2am)
Sustainability index	"Ranks the entity with regard to others across a multitude of variables" (Siemens)	Multiple. Examples: The Dow Jones Sustainability Index, Carbon Disclosure Project, People and Planet Green League
Emission generated	Emission of greenhouse gases (GHGs)	Equivalency of CO2 metric tons; Carbon Dioxide, Methane, Nitrous Oxide, Fluorinated gases

Table 2-3: Energy-related performance indicators in Siemens

Source: Siemens, 2014

KPIs that have proven to be multiply beneficial for companies. According to Centindamar & Husoy (2007), KPIs related to energy might represent a win-win situation. On the one hand, they help environmental performance improvement, and on the other they help to cut costs. This driver is directly related to long-term energy strategy, since it allows for tracking and measuring efforts toward goals stated in long-term strategies.

2.5.2 Mixed drivers

Some energy efficiency drivers can be both external and internal. For instance, voluntary agreements between industry and government is considered as a mixed driver. The reason for this is that both sides are included in the negotiating, design and implementation of voluntary agreements. Besides voluntary agreements, other mixed drivers are educational programmes and training, external cooperation and knowledge of non-energy benefits (Marchesani & Spallina, 2012).

2.5.2.1 Voluntary Agreements

Voluntary agreements are, in essence, "a contract between the government and industry, or negotiated targets with commitments and time schedules on the part of all participating parties" (CITE). They prove to be a relatively good solution as a pro-environmental policy. One of the reasons for this is the level of freedom companies have to decide how to deal with governmental decisions to take action on certain, usually, environmental issues (De Groot et al., 2001). Voluntary agreements for industrial energy efficiency have been used since 1990. A crucial characteristic of this kind of agreement is that it focuses on energy efficiency goals (Price, 2005).

2.5.2.2 Education Programmes and Training

Education and training as a driving force is closely related to awareness and, indirectly, staff values. Liu et al. states, "t*he employee's ability could be enhanced by school education and job training. The education level of employees and the frequency of internal training on energy saving are adopted as proxies of learning capacity*" (2012, pg. 81) Educational programmes and training can be arranged at different levels of the firm's organisational structure. These programmes can be organised and arranged by the firm, or by suppliers, manufacturers of equipment, the government or some other stakeholder (Hasanbeigi et al., 2010; Marchesani & Spallina, 2012).

2.5.2.3 External Cooperation

External cooperation is beneficial for firms because it produces an exchange of information. This is a way for companies to update their information on specific questions and to remain knowledgeable. Since it is mainly happening specifically within the industrial sector, it also helps build competitiveness within that sector (Thollander & Ottosson, 2008). Marchesani & Spallina (2012), see the manifestation of this driver as a "collaborating with suppliers, working with designers to reduce and eliminate product environmental impact and working with customers to change product specification" (2012, p). According to Möllersten & Sandberg (2004), firm's cooperation with ESCOs can be of particular importance since it might help to develop new core competencies regarding efficient production and business case. The role of ESCOs in industrial energy efficiency improvements has always been highlighted as important in the EU. Diabat & Govindan (2011) point out that cooperation with suppliers might be one of the most efficient ways to find substitute materials and advanced equipment for lowering environmental impacts.

2.5.2.4 Knowledge of Non-Energy Benefits

Section 1.1.3 has shown that non-energy benefits might play a crucial role in decision making for energy efficiency investments. Therefore, it is important to include non-energy benefits in the cost-benefit analysis as much as possible. The first step is to have an awareness of the existence and extent of these benefits. Knowledge of non-energy benefits, as a driver for energy efficiency, is related to programmes of education and training, and external cooperation. Various actors, both internal and external, enhance this. According to Qi et al. (2010), learning about non-energy benefits might help a firm's efforts on health and safety issues.

2.5.3 External drivers

External drivers are mainly related to public policies. A crucial characteristic of external drivers, from a company's point of view, is that a company cannot have any influence on the design or implementation of these policies. The only thing a company can decide is whether to exploit these drivers. If a policy contains a legal requirement, this freedom is even less visible, and companies are forced to comply or to bear consequences (Marchesani & Spallina, 2012). External drivers include technical support, technological appeal, private financing, increasing energy tariffs, support for management, external energy audits, awareness and drivers somehow related to information provision (Marchesani & Spallina, 2012).

2.5.3.1 Green Image

Corporate green image is enhanced through corporate social responsibility activities. Since companies are part of a larger socio-economic system, how they are going to be perceived in that system by other actors and stakeholders is important. Companies are aware that "public interests are strongly tied with business strategies in any industries" (Marchesani & Spallina, 2012). Currently, according to Rohdin et al. (2012) and Zailani et al. (2012), firms are under scrutiny by many actors, including "community groups, environmental organizations and other potential lobbies" (Marchesani & Spallina, 2012) to disclose and improve their environmental performances. This pressure is increasingly penetrating the entire business chain, and many actors across this chain require certain CSR activities from their business partners both, upstream and downstream. Moreover, increased awareness amongst consumers also generates pressure on firms to behave responsibly (Zhu & Sarkis, 2006). On the other hand, dedicated work on energy efficiency improvements and sustainability in general might allow companies to charge a "premium" or extra price on their products. (Marchesani & Spallina, 2012). According to Aflaki et al. (2012), working on environmental issues is not just a matter of reputation management for companies, and these issues are becoming part of the core strategy of businesses.

2.5.3.2 Increasing Energy Tariffs

In order to increase efforts in the reduction of GHG emissions, many countries are increasing taxes and duties on energy. Consequently, the price of energy goes up and companies become incentivised to reduce their energy consumption. According to Streimkiene et al. (2008), rising energy tariffs represents an economic policy instrument for promoting energy efficiency. According to Glatt, "the most effective way to directly impact industrial energy efficiency through tax incentives is with an energy efficiency targeted incentive" (2010, pg. 4). Moreover, governments are also providing incentives for energy efficiency improvements through tax rebates. In Sweden and Germany, companies get part of the tax paid back if they have a certified energy management system in place. One of the issues to keep in mind is that companies are, in the first place, working to decrease their expenditures on energy, not to save energy (Hasanbeigi et al, 2010). In addition, firms are looking at the share of energy costs in total product costs. In the case this share is low, "it is likely that companies will limit their efforts for energy efficiency".(Marchesani & Spallina, 2012, pg. 75).

2.5.3.3 Public Investments

Public investments in firms' energy efficiency might take various shapes, but often come in the form of grants or subsidies. According to the IPCC (2007, pg. 481), subsidies for industrial energy efficiency include: "grants, favorable loans and fiscal incentives, such as reduced taxes on energy-efficient equipment's, accelerated depreciation, tax credits and tax deductions". Grants or subsidies are defined as "public funds given directly to the party implementing an energy efficiency project" (UNIDO, 2008, pg. 25). The basic idea behind these public investments is to reduce investment costs for firms and incentivise action on energy efficiency improvements. On a societal level, the goal of this kind of public investment is to "promote energy efficiency measures until they achieve market acceptance level and can be funded on their own" (UNIDO, 2008, pg. 25).

There are many examples of this kind of governmental action. According to WEC (2004), 28 countries have some kind of public investments, in the form of grant or subsidy, for investments related to industrial energy efficiency.

2.5.3.4 Management and Technical Support

Often, firms lack technical and managerial capacities to design and implement energy efficiency projects (Aflaki et al. 2012). A lack of capacities is more emphasised in smaller firms, who have to ask for external assistance. ESCOs are one of the main providers of, in addition to financing, "technical engineering expertise and consultancy (e.g. audits), equipment supply/installation/operation/maintenance/upgrade and monitoring and verification of performance and savings" (IEA, 2014). Moreover, ESCOs are tasked with designing and developing energy efficiency projects, optimising project performances and guaranteeing savings. Besides ESCOs, support might come from technology suppliers, installers (Bleischwitz& Schmidt-Bleek, 2009), or even the government. Recently, besides ESCOs, suppliers of industrial equipment are increasingly offering value added services such as:

2.5.3.5 External Energy Audits/Submetering

External energy audit or "submetering" can be defined as "an inspection, survey and analysis of energy flows" (Marchesani & Spalinna, 2012) in order to cut energy consumption without affecting the final output. According to Abdelaziz et al. (2011), energy auditing is a reliable, systematic approach and represents one of the key factors in industrial decision making. Moreover, benefits of auditing include: an approximate 20-30 percent cost reduction in operating costs by systematic analysis, improved general performances, profitability and productivity, and avert equipment failure (Abelaziz et al. 2011). Helby (2002) gives an example of a Swedish programme called Eko-Energi. This was a completely voluntary scheme that offered promotions and free audits for companies willing to certify according to a ISO140001 standard. External audits are recognised as one of the main incentives for companies.

2.5.3.6 Awareness

Awareness as an external energy efficiency driver is tied to knowledge, and, indirectly, to programmes of education and training. Education and training contribute to overall knowledge on energy efficiency and potential benefits. Moreover, awareness plays a crucial role in any kind of energy efficiency investments. It helps to close the knowledge gaps and increase the performance of reasonable actions that had been often overlooked due to ignorance (Trianni and Cagno, 2012). The reason why awareness is listed as an external driver is that "it derives mainly from advertising campaigns" (Marchessani & Spallina, 2012).

2.5.3.7 Technological Appeal

According to Reddy & Assenza (2007), "modern", "appealing" and "fashionable" equipment has a higher chance of being purchased. This might depend on the nature of the company or on the place where the equipment is placed. If it is hidden or hardly accessible, it is more likely that its technological appeal will not play an important role in the decision making. Moreover, "these non-economic motivations, in general, dominate the decision primarily of high-income groups, for whom technological appeal is the major driving force" (Marchesani & Spallina, 2007).

2.5.3.8 Availability, Clarity, Suitability and Trustworthiness of Information

Firms need a great deal of information for making decisions regarding energy efficiency. This information might be related to the "available energy efficiency improvement measures, comparative final consumer profiles or objective technical specifications for energy-using equipment" (Marchesani & Spallina, 2012). According to the European Commission, market operators are responsible for information provision while the role of governments is to set up frameworks and enable an environment for this to happen (European Comission, 2006). Moreover, Marchesani & Spallina state that information should be presented in appropriate forms and sufficient enough for companies to be able to design and implement "energy efficiency improvement programmes, and to promote and monitor energy services" (2012,). Moreover, as already stated in sub-chapter 2.4.1.3.1 the source of information has to be perceived as credible. On top of that, real costs are an aspect still not in focus, but one that might become more relevant in the future. Real costs would include not just market-energy prices, but also all costs of the negative externalities of energy consumption. For instance, with the assumption that costs of CO_2 emission are internalised, real costs of energy consumption are much higher (Hasanbeigi et al., 2010). Some companies are already actively preparing for market-wide carbon pricing through internal carbon pricing.

3. Global societal goals

According to the UN Secretary-General, Ban Ki-Moon, the year 2015 was one of the most important ones since the foundation of the UN in terms of global development, and it might "not come again in our generation" (UN, 2014b). Two globally important, high-level meetings occurred in 2015. The first one was the third International Conference on Financing for Development, in Addis Ababa, held from July 13-16, 2015. The second was the United Nations Sustainable Development Summit in New York, held from September 25-27, 2015. Both of these meetings produced documents that might serve as corner stones for future global development.

3.1 United Nations Sustainable Development Goals

We resolve, between now and 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of woman and girls; and to ensure the lasting protection of the planet and its natural resources. We resolve also to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities.

This is the third paragraph of the resolution "Transforming Our World: The 2030 Agenda for Sustainable Development", adopted on the morning of 25th September 2015, at the fourth plenary meeting of the 70th session of the United Nations General Assembly. An overall goal of the Agenda is to be a charter "for the people" in the 21st century. Although the Sustainable Development Goals (SDGs) are not legally binding, the Agenda shows a global commitment to work on sustainability, will serve as a guide and its role will be to serve as a normative framework for action.

The 2030 Agenda represents a continuation of the Millennium Development. The core of the Agenda is the set of seventeen new global goals known as Sustainable Development Goals or SDGs.

Each of the aforementioned goals has its targets. There are, in total, 169 targets. That is, on average, around seven targets per goal. Goal 17 has 19 targets on its own. Moreover, every target within every goal has its own set of indicators. In the time this thesis was written, indicators were not developed nor adopted.

The Sustainable Development Goals have several important advantages over the Millennium Development Goals in several aspects. Firstly, the SDGs have a more wholistic approach with better interconnection between social, environmental and economic dimensions of sustainability. Moreover, they cover aspects that were not covered adequately or at all in current trends by MDGs. Examples of these aspects are: increasing inequalities, increased urbanisation and, maybe most importantly, climate change. For this thesis, the crucial difference is an urgent call for business actions, stated several times by both the UN Secretary-General and in the 2030 Agenda.

No.	Goal
Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Table: 3-1 Sustainable Development Goals

Source: Based on thet the 2030 Agenda for sustainable development

3.1.1 The road to SDGs

The Millennium Development Goals had a 2015 expiration date. At the 2010 High-Level Plenary Meeting of the UN General Assembly there was an official initiative to start discussing how to continue after 2015. The aim was not just to quicken the progress, but also to advance and improve. The first official formulation of these aspirations came two years later, at the Rio +20 United Nations Conference on Sustainable Development, held in Rio de Janeiro in June, 2012.

UN Member States reached an agreement to develop and establish a set of Sustainable Development Goals as a continuation of the efforts started with MDGs. However, the SDGs are only one part of the mosaic called the "Post-2015 Agenda". The Post-2015 Agenda includes "issues of war and peace, ridding the world of nuclear weapons, as per the Non-Proliferation Treaty, and addressing macroeconomic challenges such as reforming the global financial systems to prevent a repeat of the devastating 2008 financial crisis" (UN, 2014a). The specific quality of the SDGs is the way they have been negotiated. While the

MDGs were formulated mainly by technocrats from the UN and the OECD, the creation of SDGs has involved a much larger number of stakeholders through a process of deliberation and consultation. This immense negotiation process has included "all member states, the entire UN system, experts and cross-section of civil society, business and, most importantly, millions of people from all corners of the globe" (UN, 2014b). This process is, due to its comprehensiveness and inclusiveness, probably unparalleled in the history of global governance (UN, 2014b).

In order to lead the process, several auxiliary bodies have been created: the UN System Task Team on the post-2015 Development Agenda, the Sustainable Development Solutions Network, and the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda. Moreover, the General Assembly of the UN got the intergovernmental Open Working Group on the Post-2015 Agenda.

3.1.2 What to expect from the SDGs

As already pointed out, SDGs will serve as a overall, normative framework. It is still rather unknown how this will influence the business world. However, there are several categories where companies might expect changes and certain benefits if they align their work with the SDGs.

Benefit (GRI et al., 2015)	Context	Examples of specific benefits
New future business opportunities	SDGs are not just raising global and pervasive issues. They are also helping in the development of new markets for existing technologies, and even new markets for new technologies. Moreover, SDGs are helping in redirecting "global public and private investments" (GRI et al., 2015).	• Technical and technological solutions regarding "energy efficiency, renewable energy, energy storage" (GRI et al., 2015). • Technological and technical solutions related to "healthcare, education, energy, finance and ICT" (GRI et al., 2015)

Strengthening concept of corporate sustainability	CSR is already a well-established concept. SDGs are strengthening this concept, but also pointing out where companies should focus their intentions. SDGs are hinting at future trends regarding SDGs. It is expected that non-sustainable behaviour of businesses might become increasingly more expensive, in different forms, in the future.	• Integration of the SDGs into business strategy can help companies to internalise their externalities before they are legally required to do so. In this way, companies can set their own pace to adjust to, for instance, mandatory carbon pricing. • Moreover, integration of the SDGs can help companies to adjust to increasingly strict sustainability-related requirements from consumers. • There is a trend among well-educated people to "value responsible and inclusive business practices" (GRI et al., 2015). These kind of employees find sustainability performances of a potential employer as an important factor. Integration of the SDGs shows a company's commitment to sustainability, and this might be an important factor in the "war for talents" (GRI et al., 2015). On top of that, "employee morale, engagement and productivity" (GRI et al., 2015), might be strengthened and/or increased.
Empowered relations with stakeholders and being on top of policy developments	SDGs have an ambition to consolidate expectations of all global stakeholders. They also show what the direction of future policies in regional, national and international level might look like.	• Companies that integrate SDGs might reduce their risk of being exposed to legal or reputational sanctions. Besides reputational legalities and reputational risk, a company builds resilience to future cost legislation. In line with this, licenses to operate might be strengthened. • Moreover, a company is strengthening relations with "customers, GRI et al., 2015). employees and other stakeholders" (GRI et al., 2015).
Stabilising societies and markets	In order to do business, companies need certain contexts. It is desirable for businesses to work in prosperous societies. Through SDGs, businesses can contribute to the development of societies and markets.	• Enabling environments for businesses, with the "existence of rules-based market, transparent financial systems and non-corrupt and well-governed institutions" (GRI et al., 2015).

Production improvements	In order to align with SDGs, companies are required to assess their entire value chain and to focus specifically on negative sustainability-related impacts they might have. This assessment could reveal possibilities for improvement in a company's level of resource-efficiency.	• An opportunity to improve energy and resource efficiency. • Cost reduction related to resource consumption, and emission and waste permits.

Table: 3-2 Potential benefits for business if they align work with SDGs

Source: Based on various sources

3.1.3. Where is the place of energy efficiency in the network of the SDGs

Positive, sustainability-related effects of energy efficiency are often shown as related only to emission reduction, and, consequently climate change mitigation. However, companies should be aware that energy efficiency can have several sustainability-related positive impacts for them. As shown in the table 3-3, energy efficiency is clearly related to four SDGs and targets.

Number the goal	Issue addressed	Target related to energy efficiency
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all.	7.3 By 2030, double the global improvement in energy efficiency.
Goal 9	Build resilient infrastructure, promote sustainable industrialisation and foster innovation.	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
Goal 12	Ensure sustainable consumption and production patterns.	12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries. 12.2 By 2030, achieve the sustainable management and efficient use of natural resources.

Table: 3-3 Links between energy efficiency and global goals

Source: Based on thet the 2030 Agenda for sustainable development

3.2. United Nations Framework Convention on Climate Change 2015

The opening day of the Paris Summit in November, 2015 was "the largest ever single-day gathering of heads of state" (C2ES, 2015), with 150 presidents and prime ministers from all around the globe present. Moreover, similar to the broad and inclusive process of negotiation in the preparation of the SDGs, a large number of non-state actors was there as well. These included local governmental and business-related public figures. The conference and negotiations ran until the 12th of December, when an agreement was finally reached, 24 hours after the deadline. The negotiations are described as "hard fought" and "painstakingly slow" (C2ES, 2015). The summit was an apex of a four-year negotiation process and the new treaty represents a landmark, "charting a fundamentally new course in the two-decade old global climate effort" (C2ES, 2015). Moreover, it unifies efforts by making a common framework that requires all countries, no matter if they are "developing" or "developed", to invest their best efforts. With this, the clear distinction between developed and developing countries does not exist anymore.

The Paris Agreement brought several important decisions. It reaffirmed the goal of keeping the annual global temperature rise below 2 °C, "while urging efforts to limit increase to 1.5 °C" (C2ES, 2015). The agreement grounded mandatory commitments by all parties to establish "nationally determined contributions" (NDCs), and to create domestic measures with a goal of achieving respective NDCs. Parties have to report to the UNFCCC routinely on emissions and "progress made in implementing and achieving" their NDCs. These reports will be reviewed by other UNFCCC members. In addition, there is an expectation of continual improvement in the NDCs, submitted every five years. The agreement explicitly states that the next set of NDCs has to "represent a progression" in comparison to previous ones. For the first time, developing countries are explicitly encouraged to contribute voluntarily. On the other hand, the "obligations of developed countries under the UNFCCC to support the efforts of developing countries", (CE2ES, 2015) are reaffirmed. When it comes to financing, the current deal to mobilise $100 billion a year has been extended until 2025, with a "higher goal to be set for the period after 2025" (CE2ES, 2015). Moreover, there is a requirement for the parties involved in international emissions trading to avoid double counting (CE2ES, 2015). Also, a new mechanism, similar to the Clean Development Mechanism (CDP) under the Kyoto
Protocol, is expected to be established. This mechanism will enable emission reductions to be counted toward the NDCs of one country, even if those reductions physically happen in another country. Meaning, countries can work on their NDC achievement through investments in other countries. Lastly, the methodology for addressing the "loss and damage" result[ing] from climate effects will be extended. However, it is explicitly stated that this will not "provide a basis for any liability or compensation" CE2ES, 2015).

The legal status of the Paris Agreement is still being discussed. Since it is an international treaty regulated by international law, only provisions expressed as "shall" are considered as legally binding.

3.2.1 Paris Agreement and Businesses

Like in the case of the SDGs, the Paris Agreement also calls for a decisive contribution from the business side. It is also not clear how the Paris Agreement will affect businesses. Table 3-3 shows a summary of the key areas and effects that the Paris agreement might have on businesses.

Key areas	How Paris agreement affects
Corporate social responsibility	• Requirements for CSR reporting are becoming increasingly stringent. Moreover, through good CSR practices, transparency in work and clear communication, companies could build their position on the climate change topics, which can help to protect brand and reputation. (KPMG, 2015) ERM predicts that "GHG accounting and reporting will become mandatory for all major industries, in all major economies" (ERM, 2015)
Cooperation with government	• On a strategic level, companies could work more closely with government in order to understand how the national climate policy is developed and in which direction is going. There should be an understanding what kind of effects policy might have on the company through "regulation, penalties and incentives". (KPMG, 2015).

Risks regarding climate change in general	• Companies should anticipate and prepare for all possible "financial, environmental and social" impacts climate change might have on them, or on their supply chain. • More specifically, companies should consider and prepare for "the effects of extreme weather such as storms and flooding on critical suppliers" and other disruptions of supply chain. (KPMG, 2015)
Risks relating future legislation	• Companies that are producing, transforming or delivering energy or raw materials directly to end users will be expected to lower carbon intensity of their products and to provide "higher levels of carbon-free or lower-carbon energy and power or carbon-neutral feedstock and commodities". (ERM, 2015) Those who fail to do so might expect to lose their market share from a more progressive company. • The same expects companies that consume "energy, power, commodities and feedstock" for their own production. They would have to reduce their own carbon intensity, both in own operations and across the value chain, "from the carbon footprint of upstream suppliers or downstream customers". (ERM, 2015) Same as in the previous case, those who fail might expect to lose their share of the market from someone more proactive • Companies should understand how commitment of their respective countries under the UNFCCC framework might affect them immediately, or in the future.
Preparations for carbon pricing	• In order to fully understand scenario where carbon-pricing system is introduced, some companies are already using internal carbon price. This practice helps their business planning and risk management and helps "to drive investments in emission reduction" (KPMG, 2015). It is already expected that carbon-pricing regimes "will spread all across the globe". (ERM, 2015) Moreover, costs related to emissions of carbon "will become increasingly material through 2020s" (ERM, 2015). High price of carbon should lead to increased profitability of "low-carbon, efficient assets". Related to that, energy efficiency in general might be reinforced, "as a critical enabler of the transition" to economy with a lower GHG emission.
Investment opportunities	• There is also increasing space for companies to "benefit from increased investment flows into clean technology and low carbon solutions". Moreover, governments are often providing "clean technology incentives and subsidies".

Table 3-4: Summary of key areas where the Paris Agreement might affect businesses

Source: various sources

3.3 Tools to Assist Companies to Align their Strategies with Global Goals

One of the most important things is to realise is that companies are vastly different and there is no one-fits-all solution for aligning businesses with sustainability principles (Haas, 2016, personal communication). This differences might depend on the type of business the company is doing and the size of the company. Moreover, relationships with the key stakeholders and their expectations are some of the most important factors. Therefore, every company has to find its own way (Haas, 2016, personal communication). Currently, these activities are mainly undertaken by large enterprises and some of them are already working on aligning their principles with the SDGs. (Ismaiel, 2016, personal communication).

Figure: 3-1 Steps towards SDGs

Source: Based on SDG Global Compass (GRI, 2015)

In order to help companies tofind their way of adjusting to global goals, many guidelines have been published. Probably the most comprehensive distinctive guide on how to position a firm in the network of SDGs is the "Sustainable Development Goals Compass: The guide or business action on the SDGs", developed by the Global Reporting Initiative, the United Nations Global Compact and World Business Council for Sustainable Development. The SDG Compass offers "the tools and knowledge to put sustainability at the heart of your strategy" (GRI, 2015). It is designed mainly for large, multinational enterprises, but it also might be used at an "entity level, [or] may be applied at product, site, divisional or regional level as required". Some of the large, international enterprises are already working on aligning their principles with the SDGs (Ismaiel, 2016, personal communication).

According to the GRI (2015), there are five hierarchical steps for adjusting. As it is pointed out already in Chapter 3.1.2 the SDGs might enhance the development of new markets and the enlargement of current ones. Therefore, as a first step, it is important for companies to understand this and to realise emerging business opportunities. Ismaiel (personal communication, 2016) states the first step to a company aligning their strategies to the SDGs is that they have to understand why are they are doing so and what they can get from it. Moreover, there should be an understanding of the common responsibility that all companies are sharing.

The second step begins with the assessment of the company's impacts regarding global issues defined in the SDG goals. It is often not obvious what the area of largest impact is, and having a systematic impact assessment is recommended if possible. The GRI (2015) recommends identifying impacts across the value chain, "from the supply base and inbound logistics, across production and operations, to the distribution, use and end-of-life of products" (GRI, 2015). This initial assessment of the value-chain does not have to be detailed, it is more of a high-level mapping to highlight a "company's core competencies, technologies and product portfolio" that might, potentially, be beneficial for one or more SDG (GRI, 2015). Aside from potentially positive factors, activities across the value chain that might have a negative impact should also be pointed out. Based on assessment, a company should develop the most suitable indicators for their data collection. This data should serve as basis for analysis of what the most appropriate measures to be taken are (Ismaiel, 2016, personal communication).

Simultaneously with the previous actions, companies have to set goals for their actions. An action should be scoped to previously defined priorities. An optimal solution is "to set goals that cover all their defined priorities across the economic, social and environmental aspects of sustainable development" (GRI, 2015). Each particular goal has to have its baseline clearly defined. This work is a continuation of the impact assessment from the previous step.

Companies can choose between having absolute goals, or relative or intensity goals. Absolute goals take only cumulative results of the KPIs. For instance, emissions reduction by a certain percentage in a certain period. Relative goals take units of output into consideration. For instance, the level of emission per unit of production. The whole process is tied with a company's level of ambition. Companies should take into consideration their previous experiences, "current and historical trends" as well as global trends. Both ambitious and unambitious goals can have impact on company's reputation (GRI, 2015).

The inclusion or integration of sustainability principles into a business strategy is based on understanding how sustainability goals are bringing "value for the company" (GRI, 2015). Once companies have a clear understanding of this, results should be included in reviewing and renumeration processes within the organisation.

Lastly, companies should announce their commitment to the principles and report their results. Result reporting is in line with the overall trend of CSR disclosure (GRI, 2015). Companies can use already existing GRI principles of sustainability reporting: "stakeholder inclusiveness, sustainability context, materiality, completeness, balance, comparability, accuracy, timeliness, clarity and reliability" GRI, 2015). The issue is that linking global level goals to an individual company is extremely difficulty (Farrel, Lister and Deshpande, 2016, personal communication), as scientific methodology to do this still does not exist (Haas, 2016, personal communication).

4. Research guidelines and analytical framework

4.1. Guiding assumptions and research design

The nature of this research is mixed. On the one hand, it is explorative in nature. This characteristic is related to the part of the research where drivers and barriers in the polymer industry are researched. Moreover, an analysis of the potential of the Paris Agreement and the 2030 Agenda for Sustainable Development in terms of energy efficiency drivers and barriers is also a novelty. On the other hand, this research also seeks to confirm current knowledge on energy efficiency drivers and barriers, in general, using a case study.

The complexity of the issue in question has imposed itself upon the research methodology. The methodology is supported by triangulation, or a combination of data sources and methods for research. The idea behind this research is to get insights into energy efficiency drivers and barriers in the rubber polymer industry and into the affects that global goals might have on these.

There are several assumptions used in the research design. Firstly, there is a guiding assumption that industrial energy efficiency has a positive impact on global GHG emission, and a potentially positive impact for the achievement of global goals. Secondly, there is an assumption that the currently insufficient uptake of energy efficient technologies can be explained through the concept of barriers. Similar to this, the concept of drivers is used to describe factors that might enhance industrial energy efficiency. The third assumption is that global goals, exemplified in the Paris agreement and SDGs, have certain potentials to influence industrial energy efficiency.

4.2. Methodology for data collection and analysis

The question of energy efficiency is often discussed from a narrow, technical perspective, although the issue is more complex than that. Moreover, if we expand the boundaries of how the problem is perceived and look at it from a global perspective, keeping the focus on problem solving on a local level, the complexity is multiplied. Therefore, the specific aim of this thesis requires a specific approach. Thollander and Palm emphasise, “a variety of perspectives, theories, methods, and models can be used to analyse energy systems, all of which help improve our understanding of the energy systems” (2015, pg. 5). The analytical framework of this thesis will follow an interdisciplinary approach by applying the most suitable theories to different parts of the analysis. Interdisciplinarity has three crucial components: depth, breadth and synthesis. Depth is “the extent of knowledge within a single knowledge perspective” (Thollander and Palm, 2015, pg. 5). Breadth refers to “the number of knowledge fields with which one is adequately familiar” and synthesis is the “integration of a variety of knowledge perspectives into a ‘whole’ representing greater knowledge” (Thollander and Palm, 2015. pg. 5).

4.2.1 Literature review

A comprehensive literature review has been conducted. This literature review is based on available journals, books, reports and other kinds of relevant publications. The literature review establishes a basis for findings on RQ1, and is used as the only method to answer RQ1. It is important to notice that the research regarding barriers is more thorough since there is much more literature available. There have been several intentions behind this literature review besides answering RQ1. Firstly, the literature review is used to get the state-of-the-art knowledge on industrial energy efficiency drivers and barriers. Moreover, the literature review provides understanding of energy efficiency in general, thus the research context. Secondly, the literature review is used to get information on important issues regarding industrial energy efficiency, and this information has been used for both the case study and interview design.

4.2.2 Interviews

Interviews have been used for answering both RQ2 and as a part of the case study for RQ3. For RQ2, semi-structured expert interviews are used. In the case study, the semi-structured interview is also chosen, but with the company's staff.

The advantage of semi-structured interviews is their flexible structure. They allow freedom for both the interviewer and interviewee to lead the discussion towards what they consider the most optimum results. At the same time, prepared thematic guidelines provide structure for the interviews. According to Mason, "the relatively open, flexible, and interactive approach to interview structure is generally intended to generate interviewees' accounts of their own perspectives, perceptions, experiences, understandings, interpretations, and interactions" (2004, p. 1021). An expert interview requires people with specific knowledge and/or profession. According to Flick, an expert would be "mostly staff members of an organization with a specific function and a specific (professional) experience and knowledge" (2009, p. 166).

Expert interviews have been used for answering RQ2. Since this question is explorative in nature, and the topic is rather new and quite unknown, expert semi-structured interviews have been decided upon as the most suitable way of doing this research. Since mobility is always an issue when it comes to interviews, phone and Skype interviews have been chosen. Experts have been identified mainly using informative publications since scientific literature and scientific research are still not available.

4.2.3 Case study

According to Schramm, the "essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (year, pg.).

Stake (1995), highlights that a case study is a research method for in-depth research of a particular individual, more individuals, an organisation, program or event. The case study is a multi-disciplinary research method, and a researcher can use different methods over a certain period to collect data.

The case study is widely used in contemporary science as a research method. It is used in psychology, sociology, political science, social work, business and community planning (Young, 2009). Usually, a case study is used when "a how or 'why' question is being asked about a contemporary set of events, over which the investigator has little or no control" (Young, 2009). It is used to attain a comprehensive picture of complex social phenomena. However, it remains "one of the most challenging of all social science endeavors" (Young, 2009).

Yin describes the case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (2009). According to Yin (2009), five components have to be part of every case study: research question(s); proposition or purpose of the study; unit analysis; logic that links the data to the propositions; and criteria for interpreting findings. This study follows Yin's components. In this case, the components of the study are defined:

The research question of this case study is what are drivers and barriers for polymer compounding manufacturing company. Moreover, this case studiy is interested in mechanism how polymer compounding manufacturing company is alligning its energy strategy with global goals.

The purpose of this case study is to understand what the important drivers and barriers for industrial energy efficiency in the rubber compounding industry are, and to explore what could be the potential effects of global societal goals on these drivers and barriers.

According to Yin (2009), the unit of analysis is the focus area of the case study. In this case study, the unit of analysis is twofold. On a more specific level, the unit of analysis is the specific, mid-size manufacturing factory that produces rubber compounds. Physically, this is the place where the case study has happened. In a more broad sense, the unit of analysis is the manufacturing corporation, which the aforementioned factory is part of, since data from the entire corporation is utilised. However, personal observations and most of the interviews has happened in this specific factory.

The logic for connecting the data to the propositions has emerged from a theoretical framework established in Chapter 1 of this thesis. Data collected in the case study is understood and processed using concepts of energy efficiency drivers and barriers. As it is already stated by Thollander and Palm, "a variety of perspectives, theories, methods, and models can be used to analyse energy systems" (2015, pg. 5).

There is no clear methodology for interpreting the data. Again, as with the logic for connecting data to propositions, the interpretation is based on findings on drivers and barriers from the literature review and the author's personal interpretations.

The case study has been conducted from the end of January until the end of February, 2016. The data collection was threefold. The most valuable data has been gathered from the author's own work on the development of energy performance indicators for a specific production line within the company. This information has been used and combined with insights from the literature review, and for interviews with the factory's management. Moreover, significant sources of information have also been also informal, such as everyday talks with the company's management and staff.

5. Case study findings and analysis

5.1. Background of the company

5.1.1 Brief description

HEXPOL AB is a Swedish manufacturing corporation that produces "advanced polymer compounds, gaskets for plate heat exchangers, wheels made of plastic and rubber materials for forklifts and castor wheel application. HEXPOL AB works in two business areas: Hexpol Compounding, producing polymer compounds, and Hexpol Engineered Products, producing gaskets, heat exchangers and wheels. Headquarters of the corporation are in Malmö, Sweden.

HEXPOL Compounding consists of 31 production facilities around the globe. These facilities are organised into four groups. Three groups, HEXPOL Asia, Europe and NAFTA, are created according to geographical location. The fourth group is created according to a specific type of product, TPE polymers. This group is located in China. Moreover, there is a "global unit" based in Belgium, with global responsibilities when it comes to R&D of new materials and products, agreements with strategic suppliers or strategic price negotiations, and engineering or "design of equipment to meet requirements" (HEXPOL, 2014a, p. 23).

The vast majority of the aforementioned 31 units work as separate companies, with complete structures of independent companies, including departments for sales, product development and production (HEXPOL, 2014a, p. 23). However, upper management requires all of them to work closely and cooperate with each other. HEXPOL Compounding has 2212 employees.

5.1.2 Products, operations and market

Customers of the HEXPOL compound products are "mainly system suppliers to the global automotive and engineering industry, the energy, oil and gas sector and medical equipment manufacturers. (HEXPOL, 2014, p. 23). HEXPOL is trying to keep its highly specialised niche market position by offering "innovative and specialized polymer products and solutions" (HEXPOL, 2014a, p. 24). The company focuses on three compounding areas: rubber compounding, thermoplastic elastomer compounding (TPE) and thermoplastic compounding (TP). In 2014, around 37 percent of all products was sold to the automotive industry (HEXPOL, 2014, p. 23). Hexpol Compounding sells its products under several brands: GoldKey, Burton Rubber, Chase Elastomer, Colonial Rubber, Robbins and Kardoes, Vigar, ELASTO and Müller Kuntstoffe (HEXPOL, 2014a, p. 26).

5.1.3. Vision and Business Strategy

The vision of the company is "to be a market leader, ranking number one or two in selected technological or geographical segments, in order to generate growth and shareholder value" (HEXPOL, 2014a, p. 5).

Hexpol's business strategy has the goal to "maintain its long-term profitability and sustainable competitiveness"; in order to do so, five operational strategies are applied (HEXPOL, 2014a, p. 26):

3 *Product development through in-depth and broad polymer and applications expertise*
4 *Most cost-effective company in the industry*
5 *Efficient supply management that generates volume and technological benefits*
6 *Superior management skills through skilled and experienced teams*
7 *Speed management through short and fast decision-making procedures*

Moreover, the company's growth is organic,, especially through acquisition. Since 2002, the entire Hexpol Group acquired eleven companies, and contributions to sales made by acquisitions rose from approximately 50 MEUR to approximately 900 MEUR (HEXPOL, 2014a, p. 14).

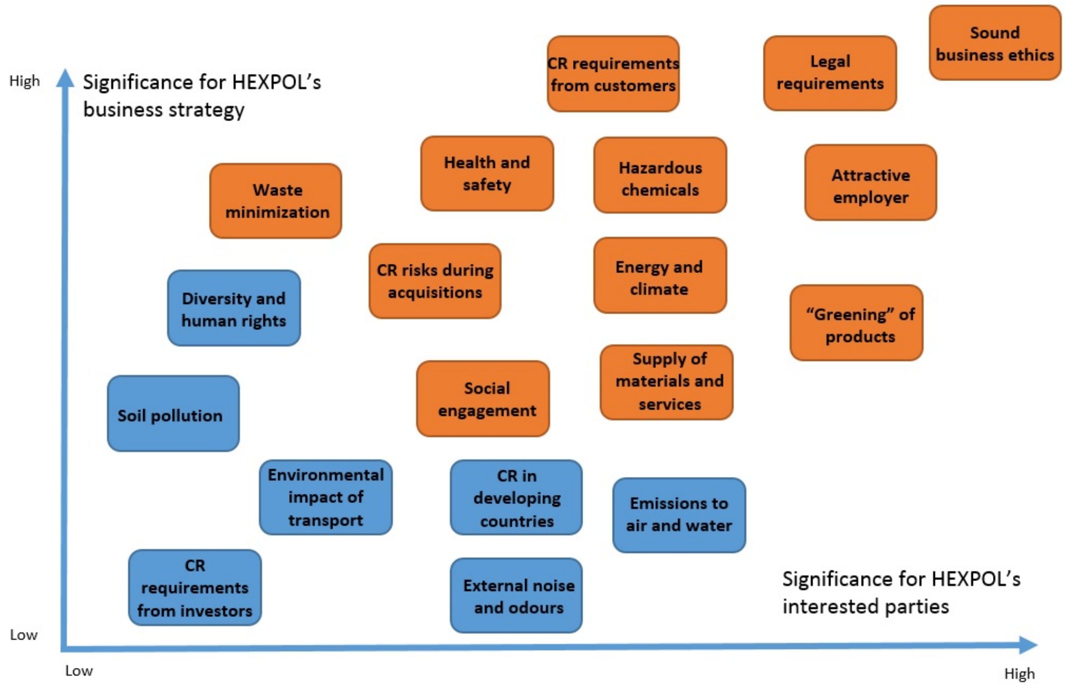
5.1.4 Sustainability Governance

HEXPOL's management has a strong determination to increase its overall sustainability. In order to do so, the company relies on environmental management systems, improved energy efficiency, reduced chemical product risks and transparent reporting on the company's performances in sustainability-related issues (HEXPOL, 2014b, 6). The responsibility for sustainability in the corporation is decentralised and has shifted to the legal entities. Executives at the level of the company and/or production facility are held responsible for taking care of environmental, work environment and social responsibility issues. The corporation is responsible for strategic issues, risk monitoring, sustainability accounting, as well as risks related to corporate acquisitions (HEXPOL, 2014b, p. 9)

Figure: 5-1 HEXPOL's materaility analysis according to GRI G4

Source: Based on HEXPOL AB Sustainability report (2014b, p. 6)

Sustainability-related work in HEXPOL is organised around six focus areas as shown in Picture 7-2.



Analyses of risks and opportunities "include the consequences of developments in terms of legislation, stakeholder requirements and expectations and scientific advance in sustainability" (HEXPOL, 2014b, p. 11). Since the company is expanding mainly through acquisition, environmental risks related to the acquisition of other companies are a priority. The company perceives opportunities in having the ability to develop more environmentally friendly products.

Figure 5-2 Environmental governance in Hexpol AB

Source: Based on HEXPOL (2014b)

The company has developed sustainability-related goals for energy, climate, environmental management systems, hazardous chemicals, work-place safety and suppliers. An energy-related target is a continuous reduction in energy consumption, measured as a proportion of GWh and net sales. When it comes to climate, a corporate goal is to cut emissions of carbon dioxide (tonnes/net sales) by 15 percent by the end of 2018, using the 2010-2011 year average as a baseline. The target for environmental management systems requires the ISO14001 management system certification for all facilities. After acquisition, there is a 2-year period for new facilities to be certified. In order to be a "frontrunner in the polymer industry as a supplier of environmentally compatible products" (HEXPOL, 2014b, p. 12), HEXPOL is working on the identification and phasing out of hazardous substances.

Certified management systems include the ISO140001, ISO9001, OHSAS 18001 and ISO50001. The ISO140001 and ISO9001 are implemented in all production plants within the company. The ISO50001, only in two.

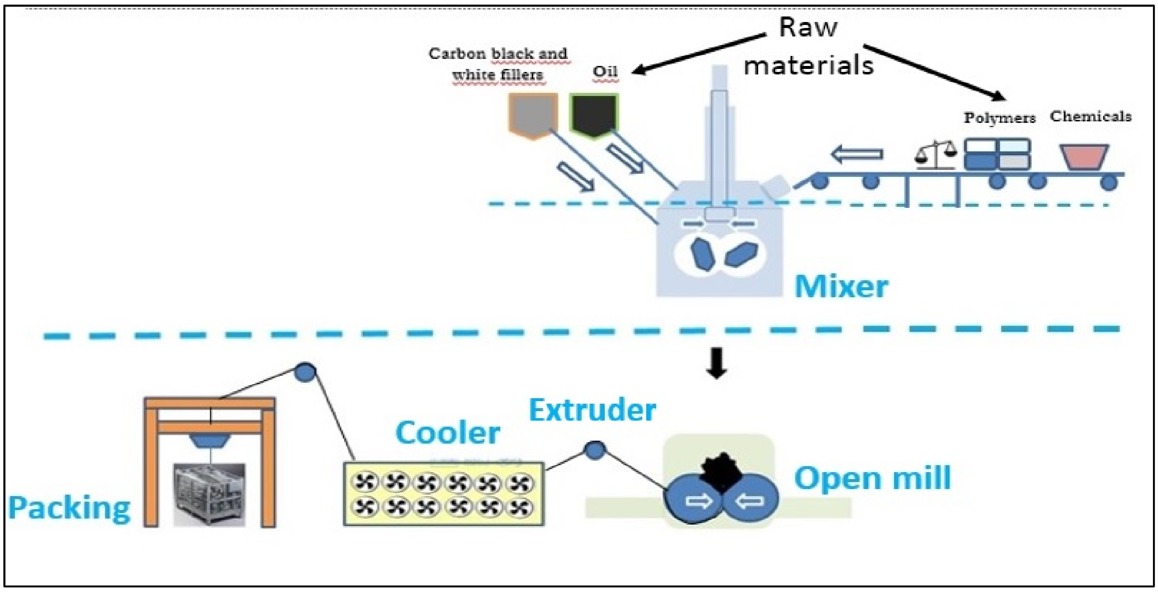
Environmental responsibility has a focus on material aspects. Key environmental aspects that affect HEXPOL's operations include "the use of resources in the form of polymer raw materials, chemical products, energy and water" (HEXPOL, 2014b, p.13). Moreover, other aspects relate to emissions, to the atmosphere and to waste generation. On top of these, there are "supplier activities, transportation of raw materials and complete products, as well as customer use of our products" as indirect impacts (HEXPOL, 2014b, p. 13).

When it comes to reporting, the company reports according to the Global Reporting Initiative (GRI) G4 reporting standard. The company also participates in the Carbon Disclosure Project (CDP).

5.2. Polymer compounding process and energy consumption

Rubber and polymer compounding's raw materials are artificial polymers and/or rubber, chemicals, oil and carbon black or white fillers. Artificial elastomers or natural rubbers represent a basis of raw material input. Besides elastomers, the most important ingredient are various chemicals, since they can influence physical and other characteristics of a compound. The most important ones are hardiness and viscosity.

As shown in picture 5-3, the process of compound production starts in a mixer, in which all of the aforementioned raw materials are mixed, and a compound formed. How long a certain compound will be in the mixer before it is fully mixed depends on several factors.



Temperature is the most important one. The longer the compound is in mixer, the higher the energy consumption per unit of an output. The higher the hardiness and viscosity of a compound, the more difficult it is to mix. Consequently, energy consumption is higher. The main mixer motor is the largest energy consumer in the production line. Energy consumption of a motor can be up to 70 percent of the total consumption of a single line (Personal communication, HEXPOL AB)

Figure 5-3: Scheme of a production line for polymer compounds

Source: personal drawing

After a compound reaches a certain temperature in the mixer it is released into the mill. The mill rolls it and forms it into sheet strips. Finally, the extruder forms a never-ending strip. The next two steps are cooling and packing.

The main source of energy in rubber compounding facilities is electricity. All the engines in the production line are electric engines. Besides the production lines, the largest electricity consumer is the system for cooling and ventilation. In HEXPOL Compounding, electricity represents 70 percent of the total energy consumption. Natural gas in in second place at 17 percent. Propane, light and heavy oil are in use to a lesser extent (personal communication, HEXPOL AB)

5.3. General characteristics of polymer and rubber compounding industry

5.3.1 Market size

The market for the rubber and polymer compounding industry is not very large. There are only a few global players in this industry. Besides Hexpol Compounding, there are, for instance, AirBoss, Teknor Apex, Dynamix, PTE, Multibase, GLS and Kraiburg. The overall trend is that small and middle-sized companies face difficulties due to high costs and rather complex processes. These companies are adjusting by outsourcing their production to larger companies (HEXPOL, 2014a). This kind of environment can discourage companies from investing in competitiveness and resource efficiency.

5.3.2. Highly diversified portfolio

One of the main characteristics of the industry is its highly diversified portfolio, even at the plant level. Polymer compounding production sites have dozens, or even hundreds of different products in their product portfolio (Personal communication, HEXPOL AB). Every compound has a specific set of factors that influence energy consumption during mixing. In most of the cases, the rule of thumb is that the harder the compound is, the more difficult to process, and so energy consumption is consequently, higher. It is the same case with viscosity. However, these two factors, although the most important ones, are not the only two factors influencing energy intensity.

This multitude of products and factors that influence energy intensity of these products results in difficulties in creating data repositories on energy intensity. Consequently, production facilities often do not have data on the energy performances of their products and they can rely only on an average intensity calculated using a ratio of total output and total energy consumption. Moreover, it is difficult to establish both internal and sector-specific benchmarks regarding energy consumption for a specific product. The lack of data makes it impossible for companies to track improvements in energy consumption regarding the production of specific compound.

5.4 Findings Specific for Hexpol Compounding

5.4.1 Diversity

As mentioned before, HEXPOL Compounding is a global corporation with more than 30 production facilities around the globe, the vast majority of the production facilities having been obtained through acquisition. Therefore, various equipment is used in the different production facilities, even for production of the same or similar products. The equipment might differ in age, size, level of energy efficiency, level of automation and sometimes even in operational procedures (Personal Communication, HEXPOL AB) The production facilities differ in physical size, total output and number of workers (HEXPOL, 2015a, p.). As a result, it is rather difficult to impose a one-fits-all solution from the upper management even though all production facilities are part of the same company.

All of the plants have emerged from specific socio-political backgrounds, and have more or less different organisational cultures and, probably, different positions on many topics, including energy efficiency. Besides values, different socio-political contexts provide different incentives for energy efficiency investments. For instance, energy prices might differ significantly. Alternatively, in some countries, there could be strong policies promoting industrial energy efficiency. There is a visible disparity in the knowledge on energy efficiency between different production facilities within the company (Personal communication, HEXPOL AB)

5.4.2. Characteristics of Energy Efficiency Investments

An example of a large capital investment is the purchase of new electric motors for compound mixing. The production facility in Eupen, Belgium changed their electric DC motors on a compound mixer with new AC motors. The main reason was for the reduction of energy-related costs, since AC motors, are, in general, more efficient than DC motors. Moreover, the rule of thumb is that newer equipment is more efficient than the older. However, one of the plant engineers mentioned that one of the crucial reasons, besides cost reduction, was also noise reduction. This facility has a rather small production line and quite a small factory building. Consequently, excess noise might present an issue.

5.4.3 Energy and carbon taxes

Fuel and energy taxes and regulations represent a strong driver for energy efficiency in Hexpol Compounding. The potential introduction of carbon taxes might represent a significant driver for the company as well. Although they are under consideration in several countries where the company is in production, currently carbon taxes are not yet in place in any of them. The company is not considering introducing internal carbon pricing (Personal communication, HEXPOL AB)

5.4.4 Reputation

As mentioned, 37 percent of the company's output is intended for the automotive industry. Much of it, especially parts producing luxury vehicles, have high requirements for the quality of a compound. Any kind of intervention in a compound recipe to, for instance, decrease energy consumption, might be a potential issue since it might compromise high quality standards. At the same time, the price of compounds intended for the automotive industry is above average. (Personal communication, HEXPOL AB) Reporting on the company's emissions is considered as a part of good reputation in the company.

5.5. Findings Specific for Hexpol Compounding Hückelhoven

5.5.1 Findings Related to Energy Management System

HEXPOL Compounding Hückelhoven got a certificate in 2014 according to the ISO50001 management standard. One of the key requirements in order to obtain the certificate is having a system for collection and analysis of data related to energy consumption within the company.

In the case that this kind of software does not exist, information regarding energy consumption is derived from monthly energy bills provided by the utility company. In the best case, information on monthly energy consumption can generate the average energy consumption per unit of output. However, this calculation might not be the best one for the rubber compounding industry, since energy consumption might vary significantly depending on a compound (Personal communicatin, HEXPOL AB.).

Companies with the software for collecting and analysing the data on energy consumption are able to make sophisticated analyses. The software collects and analyses data on energy consumption in real time. Moreover, it creates a data depository and allows thorough *ex-post* analysis. Besides energy consumption in kWh, the software collects data on various aspects of energy consumption and various characteristics of a company's equipment. For instance, it gives and overview of specific engine efficiency and information on power characteristics.

Picture 5-4 shows the window for energy consumption monitoring in real time for different segments of production line.

Figure: 5-4 Screenshot from Energy management system

Source: Hexpol Compounding Hückelhoven

5.5.2 Unsuitable Presentation of Data on Energy Consumption

Software for energy monitoring allows sophisticated analysis. However, it is important to keep in mind that this kind of software is made to be used by different departments with specific needs. For instance, in Hückelhoven this software is used by the plant manager and the technical department. Naturally, they are interested in different aspects of energy consumption.

From a managerial perspective, the most important information is related to various aspects of energy costs (Personal communication, HEXPOL AB). If the software is properly adjusted, the manager is able to see energy-related costs of running each specific piece of equipment, in real time. Moreover, is it possible to have a detailed analysis of consumption and consequent costs for any piece of equipment in the whole production line, even the whole factory, for any time period. However, it happens that, due to lack of time, personnel and previous experience, the software is not fully utilised. This might be especially important for the plant managers, since one of the key factors in their decision to invest or not is the cost of the running equipment (Personal communication, HEXPOL AB)

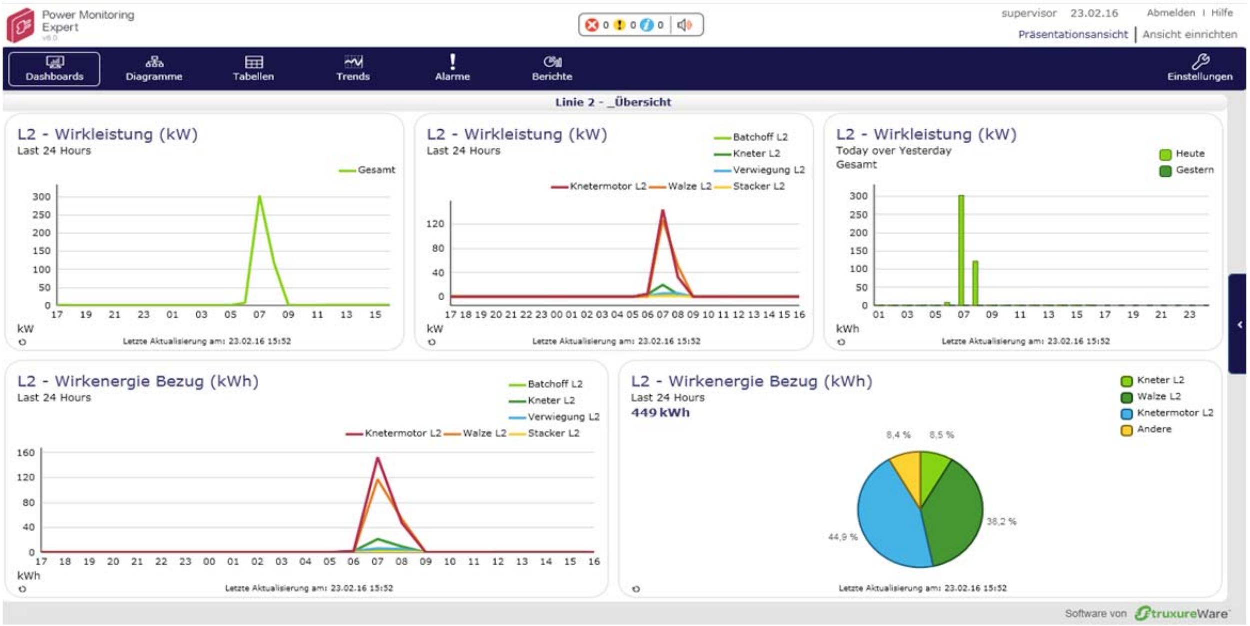


Figure 5-5: Power Monitoring Experts software for ccollection and anlysis of energy-related data

Source: Screenshot from Hexpol Compounding, Hückelhoven

Picture 5-5 shows a software window where the main interface is not optimal from a managerial perspective since it does not show anything related to costs of running equipment.

5.5.3 Advanced Utilisation of Collected Data

A vast amount of data collected by the aforementioned monitoring software can be used to calculate the energy intensity of produced compounds. However, this would require a merging of the data with data from the software for scheduling and organisation. Data on various other characteristics of produced compounds, such as hardness, viscosity, batch cycle and more, is also required. Since three separate and incompatible kinds of software gather these three types of data, an analysis of the energy intensity of specific compounds has to be done manually. Time constraints and lack of personnel discourage these kind of calculations.

5.6. Other Plant-Specific Findings

5.6.1 Share of Energy-Related Costs

The share of energy-related costs in total production costs is relatively low, not more than 3 percent (Personal communication, HEXPOL AB) However, the reduction of these costs still represents a chance for companies to obtain a competitive advantage, since there are not many opportunities to do so. Energy intensity represents one of the few factors a company might possibly influence. The solution would be to develop a compound with lower energy intensity and the same or similar performance. The interesting thing about the rubber compounding industry is the fact that new recipes are developed on an almost daily basis.

HEXPOL Compounding Hückelhoven has its own laboratory for developing recipes. However, the potential energy intensity of new compounds is not taken into consideration in the process (Personal communication, HEXPOL AB).

5.6.2 Lack of Personnel for Energy-Related Issues

A lack of personnel for energy-related issues is visible in two aspects. First, the plant does not have an energy manager. Tasks related to energy-related issues are divided between several departments. The plant manager is responsible for the overall monitoring of energy consumption, mainly in terms of costs, and for decision making regarding all kinds of investments, including energy-efficiency investments. The Environment, Health & Safety manager monitors overall consumption, prepares sustainability reports and assists the plant manager. The technical department at the plant level takes care that the equipment works properly. Moreover, the technical department is the only one familiar with the level of efficiency of the equipment, but only in technical terms, not related to their overall consumption, costs or energy intensity per unit of product. Consequently, no one has a full picture of all aspects of energy consumption.

5.6.3 Ambitious Management

Decision making about all sorts investments in HEXPOL Compounding is done at the plant level. Although the company's energy strategy is acknowledged as important (personal communication, HEXPOL AB), the ambition of the plant management is pointed out as equally important (personal communication, HEXPOL AB). Young and agile management are one of the reasons why the company has implemented the ISO50001 certification requirement.

5.6.4 The Price of Electricity

The price of kWh of electricity in Germany for companies that consume less than 10GWh per year is around 0,15 EUR per kWh. This is one of the highest rates in the European Union (Personal communication, HEXPOL AB). Out of this, only around 0,06 EUR per kWh is related to the costs of energy production. The rest of it is related to taxes. Only the renewable energy tax is around 0,05 EUR per kWh. In order to enhance energy efficiency and, at the same time protect its companies from high energy-related costs, the government is incentivising companies to implement the ISO50001 or EMAS energy management systems. An additional requirement is that annual electricity consumption has to be between 5 and 10 GWh per year. If the company meets both of these requirements, it qualifies for a partial renewable energy tax refund. In that case, the current 0,05 EUR/kWh is reduced by up to 85 percent. In Hexpol Compounding Hückelhoven, the tax refund was a crucial incentive to implement the ISO50001 (Personal communication, HEXPOL AB)

5.6.5. Complexity of the Tax-Back Scheme

One of the issues related to the aforementioned system of partial tax refund is its complexity. The renewable energy tax refund is tied not only to energy consumption, but also to several other factors. For instance, the number of workers is one of the factors. Therefore, there is no single formula, and the calculation will differ from one company to the next (Personal communication, HEXPOL AB) Moreover, taxes are refunded at the end of the year in a single payment. In Hexpol Hückelhoven, the amount of tax deduction has not been retroactively included in the calculations of the price of kWh of electricity (Personal communication, HEXPOL AB) As a consequence, the plant manager does not have a clear picture of electricity and energy costs.

5.7. Summary of Barriers to and Drivers for Energy Efficiency in the Compounding Industry

Using the classifications of energy efficiency barriers and drivers developed and explained in the literature review, this analysis seeks to identify energy efficiency barriers and drivers in the polymer compounding industry, and to explain them through theoretical concepts.

5.7.1. Barriers to the Polymer Compounding Industry

One specificity of the entire compounding industry is its highly diversified portfolio with a large number of different compounds. Each of these compounds is specific when it comes to energy consumption per unit of output. This multitude of factors makes it difficult for companies to obtain information on energy consumption for production of a specific compound. In order to do so, the company would have to invest time and other resources. In theory, this specific barrier is called “hidden costs”. These costs refer to costs of training, education and the employment of a staff member who would be in charge of designing and tracking energy performance indicators of polymer compounds.

Moreover, since the polymer compounding industry supplies highly selective customers, such as the automotive industry, it might be risky for the compounding companies to change their compound recipes or production processes. Any kind of change in compound characteristics could potentially lead to losses. The company perceives this as a risk that might inhibit investments in energy efficiency technologies and development of less energy-intensive compounds.

In addition, the global polymer compounding industry market has a rather limited number of large companies participating. This might potentially lead to a lack of a competitive environment that provides incentive for companies to invest in competitiveness. Consequently, resource efficiency and energy efficiency are not perceived as important.

One of the specific factors that inhibits energy efficiency uptake is the relatively low percent of energy-related costs in total production costs. Since the production processes raw materials that, used in production, are relatively similar for all the companies working in the industry, this might be understood as a barrier to industrial energy efficiency at the sectorial level.

5.7.2. Barriers Specific for Hexpol Compounding

An example, energy consumption monitoring software highlights inertia as one of the important barriers. This finding reveals that it takes time for organisations to adjust to management tools and practices. Moreover, this finding also reveals the existence of bounded rationality. Although it is beneficial for the company's management to make use of information provided by the software, time and other constraints prevent this. Moreover, findings related to the deduction of the tax refund also points out a bounded rationality in behaviour.

The plant management perceives as a barrier the way data on energy consumption is presented in the software. The lack of information on energy-related costs of running equipment might lead to perception of energy consumption as a peripheral issue. This finding corresponds with behavioural barriers related to form of information.

Moreover, diversity is one of the corporate characteristics that can pose a barrier, since companies with different backgrounds and different experiences are expected to have different values and organisational structures. This could inhibit efforts of upper management to increase energy efficiency. This is a organisational barrier related to power, culture and values in the production sites.

5.7.3. Drivers for Energy Efficiency in HEXPOL Compounding

Contrary to the sector-specific energy efficiency barriers, this inquiry is not able to identify energy efficiency drivers that could be perceived as applicable to the entire sector. Therefore, all the findings listed below are company-specific energy efficiency drivers.

Energy taxes are perceived as one of the most important drivers for energy efficiency, since they increase the price of energy consumption. Although carbon pricing has still not been introduced, the company perceives a potential introduction of carbon taxes as a major driver. This can be classified as one of the most important energy efficiency drivers and as is cost-reduction from lower energy use.

In addition, increasing energy tariffs, in the case of Hexpol, price of electricity, together with governmental incentives represent a major driver for implementing a certified energy management system.

Long-term energy goals, together with management ambitions, are also perceived as a driver. Lastly, concerns about the company's reputation, especially when it comes to emission related reporting, are perceived as a driver for investments in energy efficiency.

5.8 Assessment of HEXPOL's Energy and Climate Strategy Alignment with the Global Goals

This analysis seeks to understand how Hexpol Compounding can align its energy strategy with the global societal goals. The analysis has two steps, executed simultaneously. The first step is using the SDG compass, explained in detail in the sub-chpter 3.3 as a guide for incorporating global societal goals into business practices. The second step is a SWOT analysis. More precisely, the SWOT analysis is used to assess strengths, gaps, opportunities and threats in current business practices related to the incorporation of global societal goals. Findings of the SWOT analysis are listed in table:

Strengths	Weaknesses
• The existence of energy and climate strategy • Awareness regarding potential new markets	• GHG emission scope • Lack of quantitative targets for energy efficiency • The company did not recognize possible contributions to the network of SDGs
Opportunities	**Threats**
• Improve data on energy performances • Energy management systems • Carbon pricing	• Internal diversity

Table: 5-1 SWOT analysis Hexpols energy strategy alignmen with the global goals

5.8.1. Strengths

5.8.1.1 The Existence of Energy and Climate Strategy

The company has a long-term energy and climate strategy established. This long-term strategy provides an overall framework for all energy-related activities. As already pointed out, on the corporate level the energy-related target is to continually improve energy efficiency. When it comes to emissions, the company has a goal of cutting its emissions of carbon dioxide (tonnes/net sales) by 15 percent by the end of 2018, using the 2010-2011 year average as a baseline. The strategy shows two things. One is understanding that GHG emissions represent the highest amount of the company's negative environmental and sustainability impact. In addition, the existence of the strategy shows that the company is addressing its environmental and sustainability issues in a structured manner. In this way, global societal issues, mainly climate change mitigation, are already embedded in everyday activities of the company and "climate change issues are included in the strategic planning and budget processes" (Personal communication, HEXPOL AB)

5.8.1.2 Awareness of Potential Benefits

The company already understands the potential benefits of aligning with the global societal goals. These benefits are twofold according to the company's management.
One example might be the market for energy efficient equipment and materials. Energy efficiency is often stated as one of the crucial ways to attain global goals, especially when it comes to fighting climate change. It is likely that global goals will incentivise a stronger push towards overall energy efficiency improvements. The polymer and rubber compounding industry's products are used in manufacturing energy efficient equipment. Moreover, compounds are used in the building sector as an insulation material (Personal communication, HEXPOL AB)
In addition, rubber and polymer compounds are used in all kinds of pumping stations, pipe sealants and other installation materials, including wastewater treatment plans. Increased global efforts to ensure availability and sustainable management of water and sanitation for all, as outlined in SDG goal six, can help to increase overall demand for rubber and polymer compounds (Personal communication, HEXPOL AB)
Besides market-related benefits, the company perceives potential mandatory emission reporting as its comparative advantage. (Personal communication, HEXPOL AB)

5.8.2. Weaknesses

5.8.2.1. GHG Scope

GHG Corporate Protocol Standard scope 1 and scope 2 mean that only direct emissions and indirect emissions from, for instance, purchased electricity, are measured. The company does not measure scope 3 emissions. In this way, the company does not have a proper assessment of all the emissions caused by the company. The most important category of indirect emissions in the rubber and compounding industry is upstream emissions related or extraction, production and transportation of raw materials (Personal communication, HEXPOL AB)

5.8.2.2. The Type of the Energy-Efficiency Goal

When it comes to energy efficiency and energy performances, the target is framed as "continual improvement". There are two issues with this goal. The first issue is the fact that the goal is not time-framed. Tied to that, the goal does not have any baseline. Consequently, it is difficult or impossible to track and measure actual improvements. In addition, the goals do not have a clear, quantitative target. It is unknown what continual improvement means. The SDG Compass (GRI, 2015) recommends two type of goals. One is an absolute goal, and it takes only the KPI into account. For instance, the reduction of energy consumption in a certain period of time, by a certain percentage is the absolute goal. The relative goals show the correlation between KPI and a unit of output. HEXPOL's emissions reduction goal is an absolute or intensity goal.

5.8.2.3. Lack of Data on Energy Use of a Specific Compound

As stated, a specificity of the entire compounding industry is its highly diversified portfolio with a large number of different compounds. This makes it difficult for companies to calculate energy consumption and belonging related to the production of different compounds. The reason why is this considers as a weakness that the assessment of impacts related to emissions might not be accurate enough.

5.8.3. Opportunities

5.8.3.1. IT and Data Evolution

Although it is difficult to get data on the energy consumption of a specific compound, new technologies might make it possible, as already pointed out in 5.5.3 This would provide valuable data for production planning and energy efficiency investments. Moreover, the success of efforts regarding both goals of the Paris Agreement and SDGs might rely on the availability and accuracy of this data. Related to that, "many are predicting a data revolution to meet the demand" (PwC, 2015, pg. 27).

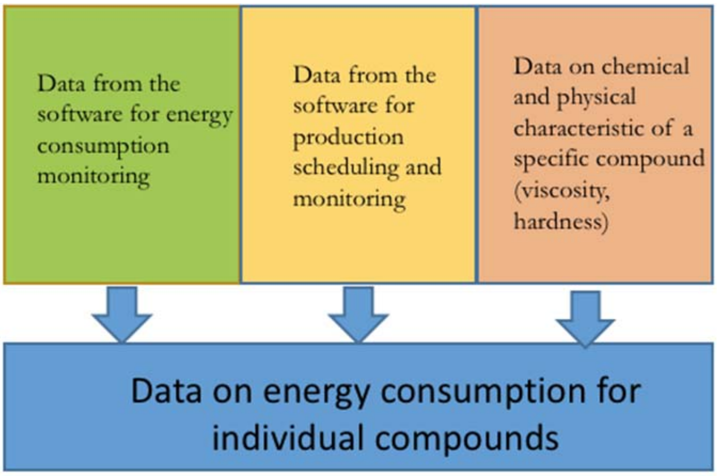


Figure 5-6: An idea for advanced data utilization

In addition, improved data would help the company to build better metrics for internal use. For instance, the company would be able to establish internal benchmarks for the energy consumption of certain compounds. This would incentivise production facilities within the company both to compete and to share knowledge.

5.8.3.2. Opportunities Regarding Energy Management System and Internal Carbon Pricing

The company already has two production sites with the ISO50001 implemented. Moreover, if experiences from these plants prove to be good, other production sites might become certified as well. Energy management systems are proven to cut energy consumption and energy-related emissions. Moreover, if the internal carbon pricing is introduced, resilience of the company for potential future legislations and carbon market pricing would strengthen.

5.8.4. Threats

5.8.4.1 Diversity

As explained in sub-chapter 8.2.1, the company is pushing business growth through acquisitions. As consequence, their production facilities are highly diversified in their characteristics. This could pose a threat to the efforts of the upper management to impose sustainability requirements. As mentioned, in this case a one-fits-all solution does not work and most of the work regarding implementation of susta

6. Discussion

This study has been conducted in a time when global changes are happening. Keystone sustainability-related agreements from 2015 might present a global game-changer for humanity. Inevitably, these changes will affect the business sector as well. Moreover, the business sector is expected to step in and take action in the areas of sustainability where it has the largest impact. One of the most evident sustainability-related impacts of businesses is energy consumption and consequent GHG emissions.

The idea of this study was to understand what the drivers of and barriers to industrial energy efficiency in the polymer compounding industry are, and how strategic work on industrial energy efficiency can be aligned better with global societal goals. The compounding industry has been chosen for three reasons. First, the research on energy efficiency drivers and barriers in this specific industry is literally nonexistent. Second, energy consumption, or, more specifically, electricity consumption in this industry is substantial. The third reason is more personal and related to the possibility of doing an internship in the company, working on energy-related issues while conducting the case study.

The methodology chosen for this study is interdisciplinary in nature. Since energy efficiency is a complex issue, a mix of various scientific disciplines is needed to understand all its aspects. Additional complexity is brought by an attempt to link work on corporate energy efficiency with global societal goals.
Interdisciplinarity is the usual approach for researching energy efficiency drivers and barriers. Most of the research is qualitative in nature and based on surveys, interviews and/or case studies.

There are several shortcomings to the methodology used in this thesis. For the research on energy efficiency drivers and barriers in industry, the applied methodology does not make a distinction between industrial sectors. Since there are no available studies on energy efficiency drivers and barriers specifically in the compounding industry, the approach has been to collect all the available studies without making distinctions. However, it is important to point out that there are differences regarding specific barriers and drivers, depending on the sector.

The second methodological shortcoming is related to the case study conducted and the findings from the case study. The case study is conducted in a single polymer compounding corporation. Single case studies are often criticised as not being representative enough.

The third shortcoming is related to the research on the impacts of global societal goals on businesses, and on how to align business strategy with global goals. The approach used here has been a mix of a literature review and expert interviews. However, questions posed in the interviews are rather broad and related to business in general. The literature used is not scientific literature. This topic is a rather new one and there are no scientific studies available.

The fourth shortcoming is related to an analysis if whether certain factors from the findings can be defined as energy efficiency drivers or barriers. There is no common and clear methodology for how to do so. One approach is to ask explicitly which factors are considered as drivers or barriers by the company. A second approach is to compare your

own research and theoretical findings from previous research, and to draw conclusions. Both of these approaches are in use in this kind of study, and both of them have been utilised here.
The fifth methodological shortcoming is related to the nonexistent distinction between energy efficiency and energy conservation. Energy efficiency means less energy consumed for the same amount of service. Energy conservation means the reduction in energy consumption through lowered energy needs. This study does not make a distinction between barriers and drivers for energy efficiency and barriers and drivers for energy conservation. However, most of the literature also does not make this differentiation.

Nonetheless, this study represents novel research in two fields. First, this study is the first attempt at outlining energy efficiency drivers and barriers specifically for the polymer compounding industry. Second, this study is one of the first attempts to establish links between business strategies and global societal goals. Moreover, this study outlines a way that manufacturing companies could assess the alignment of their strategy with global societal goals.

Parts of the research for this study have been used to provide a basis for recommendations to HEXPOL's Compounding Management for how to increase overall energy efficiency. These recommendations have been seen as valuable.

6.1. Discussion of Results

6.1.1. Energy Efficiency Drivers and Barriers in General

The results regarding industrial energy efficiency drivers and barriers have revealed a multitude of approaches for researching this topic. Theories for understanding energy efficiency barriers are more developed than those for understanding and interpreting energy efficiency drivers. A common starting point for understanding energy efficiency barriers is an understanding of the phenomenon called the energy efficiency gap. Barriers are usually classified into four distinct groups, based on the nature of the barrier: market failure related barriers, non-market failures, behavioural barriers and organisational barriers. However, this is not the only way to classify energy efficiency barriers. Research on energy efficiency drivers is less developed. There is no common theoretical approach, nor classification. Different researchers can define energy efficiency drivers in different ways. Moreover, classifications also differ. This study uses the classifications developed by Marchesani & Spallina (2012), which makes a distinction between internal, mixed and external drivers. The specific value of this taxonomy is the fact that it can help businesses to streamline their efforts for activating internal energy efficiency drivers. Energy efficiency barriers are summarized in the table 5-1.

Market failure	Non-market failures	Behavioral barriers	Organizational barriers
Imperfect information	Hidden costs	The form of information	Power
Adverse Selection	Access to Capital	Credibility of trust	Culture
The Agency Dilemma	Risk	Values	
Split incentives	Heterogeneity	Inertia	
		Bounded rationality	

Table 6-1 : Summary industrial of energy efficiency barriers

Internal drivers	Mixed drivers	External drivers
Long –term energy strategy	Voluntary agreements	Green image
People with real ambition	Education Programmes and Training	Increasing energy tarrifs
Management with real ambition and commitment	External cooperation	Public invesments
Willingness to compete	Knowledge of non-energy benefits	Management and technical support
Cost reduction from lower energy use		External energy audits/submetering
Existence of an energy management system		Awareness
Clearly defined KPIs		Technological appeal
		Availability, clarity, suitability and trustworthiness of information

Table 6-2: Summary of industrial energy efficiency drivers

6.1.2. Energy Efficiency Drivers and Barriers Specific to the Compounding Industry

An analysis on energy efficiency drivers and barriers that is specific for the compounding industry points out several important things on a corporate level. The specific nature of the industry, the highly diversified production portfolios, together with compound complexity, makes it difficult for companies to obtain information on energy use needed for the production of a single compound. As analysis has shown, the costs of obtaining information inhibit potential energy efficiency investments as well as energy conservation. The nature of the product might be one barrier as well. Since the polymer compounding industry supplies highly selective industries, such as automotive industries, any change in the equipment, compound recipe or process is perceived as risky. The reason for this is the compound complexity and the fact that small changes might influence physical characteristics of the product. Consequently, customers might complain or change suppliers. The relatively small number of global companies in the global market might not generate competition sufficient enough to incentivise companies to invest in their strategic advantages through resource efficiency, including energy efficiency. Finally, the relatively low percentage of energy-related costs in the total operational costs makes investments in energy efficiency less desirable.

Other results regarding energy efficiency barriers from the case study are more company-specific rather than sector specific. One part of these barriers is related to energy management monitoring software, which is a mandatory requirements of the ISO50001 certification. The specific barrier related to the software is how the information on energy consumption is presented. Moreover, bounded rationality is a relevant barrier that inhibits fully utilising this software. Finally, corporate diversity between the different production facilities can pose a barrier, since all of the facilities have different backgrounds, which could also mean different organisational cultures and different values regarding energy efficiency.

Drivers that could be relevant for the entire sector have not been not identified. The energy efficiency drivers are mainly based on the company's perception. The company sees energy taxes as one of the most important drivers. Moreover, increasing energy tariffs, together with governmental incentives, such as the tax refund of renewable energy tax in Germany, is also a major driver. In addition, a long-term strategy and ambitious management are drivers of energy efficiency. The potential introduction of carbon pricing is also seen as a driver for investing in energy consumption reduction. Finally, reputational risk, especially related to emissions reporting, is putting pressure on the company to increase energy efficiency.

6.1.3. Alignment of the Company's Energy Strategy with Global Societal Goals

Research on this question has shown that there is still no clear and sound methodology for how to align business activities with global societal goals. Currently available guidelines such as the Sustainable Development Global Compass can help companies to make its own path for aligning its activities with the global societal goals. The crucial finding is that there is no one-fits-all solution and every company has to make its own.

Companies should start with understanding the changes, their potential and opportunities for the company. The second step is assessing their own sustainability-related impacts, followed by measuring those impacts. It is important that the company has a clear picture on which issues are affected by its activities. The next step is setting right goals for improvement. Goals should be related to the area of the largest impact. Also, goals should be quantified and time-framed, and based on a clear baseline. Moreover, companies have to understand what the value is that they get from aligning with sustainability principles. Ideally, this value would also be quantified and communicated within the company. Last, companies communicate their commitment to all of the stakeholders and report regularly on their performance.

An analysis on how well HEXPOL's energy strategy is aligned with the global societal goals using SWOT analysis shows that the company's strengths are the existence of energy and climate strategies, as well as an awareness regarding potential new markets. The company's weaknesses are its narrow scope for GHG emission measurements, lack of quantitative targets for energy efficiency and non-recognition of the benefits energy efficiency can have for sustainability aside from GHG emission reduction. Opportunities for the company to strengthen its commitment to global sustainability goals are improving data on energy consumption per unit, implementing an energy management systems in its production facilities, and introducing internal carbon pricing. The main threat is the diversity of the company, since it may inhibit initiatives from upper management.

6.1.4. Concluding Discussion Remarks

The research questions from this study have proven to be relevant and legitimate. Moreover, findings from this has allowed fruitful analysis. However, this research could be improved through several steps, crucially, involving more companies from the compounding sector into research on energy efficiency drivers and barriers. Using multiple case studies seems to be a good methodological approach for that. Research on the global societal goals and businesses would have been more fruitful if the research was implemented several years from now.

The results of this study can be used in multiple ways. First, researchers interested in the research questions can use it for its methodological information, findings or even as inspiration for how to do their own research. Moreover, people working in the polymer compounding industry can use the findings from this research as a guide for how to align their energy and climate strategies with the global societal goals. Moreover, they could also use some findings from this thesis as inspiration for improving energy performance indicators in their own companies. Finally, the findings can be used as a guide for policy makers that are developing policies related to energy efficiency improvements, emission reductions or sustainability overall.

7. Conclusion

Industrial energy efficiency is becoming increasingly important. Industrial energy efficiency is a way to cut industry-related emissions and to mitigate climate change. Both the Sustainable Development Goals and the Paris Agreement from 2015 highlight the importance of energy efficiency in fighting climate change and in achieving other global societal goals. Industrial energy efficiency also brings a set of benefits to companies. The most obvious benefit is the reduction of energy consumption and subsequent costs. Other benefits include improvements in production to enhanced reputation. Although energy efficiency brings benefits to both companies and society, the uptake of energy efficiency measures is not at its optimal level. This is explained through the existence of a phenomenon called the "energy efficiency gap". There are many explanations as to why this gap exists. The common name for these factors is "barriers to energy efficiency". Research on industrial energy efficiency barriers is quite well developed, and many theoretical inquires and empirical studies on this topic have been done. However, almost all of them were sector-specific. Moreover, most of them had energy intensive industries as their research subject. There is also the concept of energy efficiency drivers, or factors that enable or enhance the uptake of energy efficiency in industry. The research on energy efficiency barriers is less developed than that of barriers. This study brings together topics of energy efficiency in industry and the effects new global goals might have on businesses. More specifically, this study has first sought to understand what energy efficiency drivers and barriers are known so far. Furthermore, what the energy efficiency drivers and barriers specific for the compounding industry are. Finally, how the single polymer compounding company can align its energy strategies with the global societal goals.

There are three reasons why this specific industry has been chosen. First, the literature on energy efficiency drivers and barriers in the polymer compounding industry is poorly developed or non-existent. Second, the polymer compounding industry is a significant consumer of energy, especially electricity. Third, the author of this study had a chance to work on energy-related issues while simultaneously performing the case-study in a polymer compounding company.

7.1 Key Results

Key results are listed in the dicussion parts, in sub-chapters 6.1.1, 6.1.2 and 6.1.3.

7.2 How this Study Contributes to the Body of Literature

This study contributes to the body of literature on industrial energy efficiency drivers and barriers by adding knowledge about energy efficiency drivers and barriers in the compounding industry. Moreover, this study contributes to the overall understanding of global societal goals and the effects they have on businesses. More specifically, this study adds to understanding how businesses can align their strategies with global goals.

7.3 Suggestions for Future Research

As a suggestion for a future related to industrial energy efficiency, it would be interesting to have research on the polymer compounding sector-specific energy efficiency drivers and barriers in the form of multiple case studies with several companies. Moreover, extensive research on sound methodology that make links between a company's performance and affected areas is needed. Finally, research on corporate practices for the alignment with global goals might be interesting in several years, when more companies take action on this issue.

Bibliography

Apeaning, R.W. and Thollander, P. 2013. Barriers to and driving forces for industrial energy efficiency improvements in African industries – a case study of Ghana's largest industrial area. *Journal of Cleaner Production, 53*, 204-213.

Backlund, S., Thollander, P., Ottosson, M. and Palm, J. 2012. Extending the Energy efficiency gap. *Energy Policy 51*, 392-396.

Bentzen, J. 2004. Estimating the rebound effect in US manufacturing energy consumption. *Energy Economic*s, *26*, 123-134.

Boyd, G. and Pang, J. 2000. Estimating the linkage between energy efficiency and productivity. *Energy Policy,* 28, 289-296.

Brunke, J-C., Johansson, M. and Thollander, P. 2014. Empirical investigation of barriers and drivers to the adoption of energy conservation measures, energy management practices and energy services in the Swedish iron and steel industry. *Journal of Cleaner production, 89,* 509-525.
Business Must Be More Transparent, Not Impede Climate Policy, Secretary-General Tells United Nations Global Compact Forum. (2015, December 8). Retrieved March 1, 2016, from http://www.un.org/press/en/2015/sgsm17401.doc.htm

De Groot, H.L.F., Verhoef, E.T., and Nijkamp, P. 2001. Energy saving by firms: Decision-making, barriers and policies. *Energy Economics,* 23, 717-740.
Fleiter, T., Worrel, E., Eichhammer W. 2011. Barriers to energy efficiency in industrial bottom-up energy demand models – a review. *Renewable and sustainable energy reviews, 15*, 3099-3111.
Gillingham, K., Rapson, D. and Wagner, G. 2015. The Rebound Effect and Energy Efficiency Policy. (Discussion paper No 14-39) Retrieved from: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-14-39.pdf

Greening, L, Greene D. and Difiglio C. Energy efficiency and consumption – the rebound effect – a survey. *Energy policy*, 28(2000), 389-401.

Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014. Impacts, Adaptation and Vulnerability.* Retrieved from: http://www.ipcc.ch/report/ar5/wg2/

International Energy Agency. 2014. *Energy Efficiency Indicators: Essentials for Policy Makers.* Retreived from: https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicators_EssentialsforPolicyMaking.pdf

International Energy Agency. 2015. *Capturing the Multiple Benefits of Energy Efficiency.* Retrieved from: https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicators_EssentialsforPolicyMaking.pdf

International Energy Agency. 2016. *International Energy Outlook 2016: Industrial sector energy consumption.* Retrieved from: http://www.eia.gov/forecasts/ieo/pdf/industrial.pdf

Irrek W. and Thomas S. 2008. *Defining Energy Efficiency*. Wuppertal Institute for Climate, Environment and Energy.
Retrieved from:
http://wupperinst.org/uploads/tx_wupperinst/energy_efficiency_definition.pdf

Jacob, T. (2015, July). *Means of Implementation and Follow-Up & Review.* Oral statement given at the United Nations Sustainable Development Summit 2015, New York, USA. Retrieved, March 5, 2016, from
https://sustainabledevelopment.un.org/content/documents/16255Business%20and%20Industry%20-%20Means%20of%20Implementation%20and%20Follow-Up%20&%20Review.pdf

Jeffe, A. and Stavins, R. 1994. The Energy-Efficienct Gap: What does it mean? *Energy Policy 22*, 804-810.

Lee, K.H. Drivers and barriers to energy efficiency management for sustainable development. 2014. *Sustainable development, 23(1*), 16-25.
Marchesani, F. and Spallina, G. 2012. *Drivers for industrial energy efficiency: an innovative framework*. (Doctoral thesis, University of Milano, Milano, Italy). Retrieved from: https://www.politesi.polimi.it/bitstream/10589/71904/3/Tesi%20Marchesani_Spallina.pdf

Mills E. and Rosenfeld A. 1994. Consumer non-energy benefits as a motivation for making energy-efficiency improvements. In: Proceedings ACEEE 1994 Summer Study on Energy Efficiency in Buildings. Washington DC: American Counciil for an Energy Efficient Economy. Retrieved from: http://evanmills.lbl.gov/pubs/pdf/nebs-mills-rosenfeld.pdf

O'Malley E., Scott S. and Sorrell S. 2003. *Barriers to Energy Efficiency: Evidence from Selected Sectors*. Policy Research Series 47. Retrieved from: http://www.esri.ie/pubs/PRS47.pdf

Okazaki T. and Yamaguchi M. 2011. Accelerating the transfer and diffusion of energy saving technologies. Steel sector experience – lessons learned. *Energy Policy, 39*, 1296-304.

Pye, M. and McKane A. 2000. Making a strongers case for industrial energy efficiency by quantifing non-energy benefits. *Resources, Conservation and Recycling*, 28(3-4), 171-183.

Rohdin, P. and Thollander, P. 2006. Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. *Energy, 31*, 1500-1508.

Rohdin, P., Thollander, P. and Solding, P. 2007. Barriers to and driving forces for energy efficiency in the Swedish foundry industry. *Energy policy, 35*, 672-677.

Sardianou, E. 2008. Barriers to industrial energy efficiency investments in Greece. *Journal of Cleaner Production, 16,* 1416-1423.

Sorrell S, Schleich J, Scott S, O'Malley E, Trace F, Boede E, Ostertag K, Radgen P (2000)
Thollander, P. and Ottoson, M. 2008. An energy efficient Swedish pulp and paper industry – Exploring barriers to and driving forces for cost-effective energy efficiency investments. *Energy Efficiency, 1*, 21-34.

Thollander, P. and Palm J (2013) *Improving Energy Efficiency in Industrial Energy Systems. An interdisciplinary Perspective on Barriers, Energy Audits, Energy Management, Policies, and Programs.* Springer-Verlag: London.

Trianni, A., Cagno, E., Thollander P. and Backlund S. 2013. Barriers to industrial energy efficiency in foundries: a European comparison. *Journal of Cleaner Production. 40*. 161-176.

Trianni, A., Cagno, E., Worrel, E. 2013. Innovation and adoption of energy efficient technologies: An exploratory analysis of Italian primary metal manufacturing SMEs. *Energy Policy, 61*, 430-440.

Trianni, A., Cagno, E., Worrel, E. and Pugliese, G. 2013. *Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs*. Energy, 49, 444-458.

International energy agency. 2007b. *Mind the gap. Quantifying principal-agent problems in energy efficiency.* Retrieved from: https://www.iea.org/publications/freepublications/publication/mind_the_gap.pdf

International Energy Agency. 2007. *Tracking Industrial Energy Efficiency and CO_2 emissions.* Retrieved from: https://www.iea.org/publications/freepublications/publication/tracking_emissions.pdf

United Nations Global Compact. (2015) *Impact. Transforming Businesses, Changing the World.* Reterieved from https://www.unglobalcompact.org/library/1331

US Department of Energy. 2015. *Barriers to Industrial Energy Efficiency. A Study Pursuant to Section 7 of the American Energy Manufacturing Technical Corrections Act.* Retrieved from: http://energy.gov/sites/prod/files/2015/06/f23/EXEC-2014-005846_5%20Study_.pdf

Venmans, F. 2014. Triggers and barriers to energy efficiency measures in the ceramic, cement and lime sector. *Journal of cleaner production, 69*, 133-142.
World Business Council for Sustainable Development. *Scaling up business actions on climate change & improving the business case.* [Flyer]. Retrieved from http://wbcsdpublications.org/project/flp-2015-scaling-up-business-actions-on-climate-change-improving-the-business-case/

World of business must play part in achieving new Sustainable Development Goals – UN chief. (2016, January 20). Retrieved March 1, 2016, from http://www.un.org/apps/news/story.asp?NewsID=53055#.VwZ5KHp8Fcw

Worrel E., Laitner A., Ruth M. and Finman H. 2003. *Productivity benefits of industrial energy efficiency measures.* Energy, 28(11), 1081-1098.

Maoz, Zeev. 2002. Case Study Methodology in International Studies: From Storytelling to Hypothesis Testing. In Michael Brecher and Frank Harvey (eds.) Millennium Reflections on International Studies. Ann Arbor, MI: University of Michigan Press, p. 455-475

HEXPOL AB. (2014a). 2014 annual report. Malmö: HEXPOL AB.

HEXPOL AB. (2014b). 2014 sustainability report. Retrieved from: http://investors.hexpol.com/afw/files/press/hexpol/201504229441-1.pdf

Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014: Mitigation of Climate Change.* Retrieved from: http://www.ipcc.ch/report/ar5/wg3/

Birnik, A. Developing Climate Change Strategy: A Framework for Managers. *Thunderbird International Business Review*, 55(6), 699-718.

Bennett, A. and Elman, C. (2010) Case Study Methods. In C. Reus-Smit and D. Snidal (eds) *The Oxford Handbook of International Relations*. Oxford University Press: Oxford. Ch. 29.

Yin, R. K. (2009) *Case Study Research: Design and Methods*. SAGE Publications Ltd: London.

Berg, B. and Lune, H. (2012) *Qualitative Research Methods for the Social Sciences*. Pearson: London.

Gillingham K., R., Newell, G. and Palmer, K. 2009. Energy Efficiency Economics and Policy. (Discussion paper No 09-13) Retrieved from: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-09-13.pdf

United Nations Industrial Development Organization. 2011a. Policy options to overcome barriers to industrial energy efficienc in developing countries. Retrieved from: https://www.unido.org/fileadmin/user_media/Services/Research_and_Statistics/WP132011_Ebook.pdf

United Nations Industrial Development Organization. 2011b. Barriers to industrial energy efficieny: a literature review. [White paper] Retrieved from: https://www.unido.org/fileadmin/user_media/Services/Research_and_Statistics/WP102011_Ebook.pdf

United Nations Industrial Development Organizaton. 2015. *Energy Management System Implementation in Industry* Retreived from: https://www.unido.org/fileadmin/user_media_upgrade/What_we_do/Topics/Energy_access/11._IEE_EnMS_Brochure.pdf

Hein, L. G., & Blok, K. (1995). Transaction costs of energy efficiency improvement. In European Council for an Energy Efficient Economy (Ed.), Proceedings of the ECEEE Summer Study, ADEME, Paris.

Jaffe, A., Newell G. and Stavins, R. (2004) Economics of Energy Efficiency. In *Encyclopedia of Energy* (2, pp. 79-90). Amsterdam: Elsevier

Pellegrini-Masini, G. and Leishman, C. 2011. The role of corporate reputation and employees' values in the uptake of energy efficiency in office buildings. *Energy policy, 39*(9), 5409-5419.

Jensen, O.M. Consumer inertia to energy saving. In: Proceedings ECEE 2005 Summer Study. Retrieved from:

http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2005c/Panel_6/6147jensen/paper

Yang, M. and Yu, Xin. (2015) Energy Efficiency: Benefits for Environment and Society. London: Springer-Verlag

Sanstad, A. H., & Howarth, R. B. (1994).' Normal' markets, market imperfections and energy efficiency. *Energy Policy*, *22*(10), 811–818.

Morgan, G. 1986. Images of organizations. California, Beverly Hills: Sage Publications.

O'Donnel, O. and Boyle, R. 2008. Understanding and managing organizational culture Retrieved from: http://www.cpmr.gov.ie/Documents/Understanding%20and%20Managing%20Organisational%20Culture.pdf

Choy, V. (2015) Improving Industrial Energy Efficiency by Changing the Energy Culture (Power Point slides). Retrieved from: https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2015/06/Valerie%20Choy_Improving%20Industrial%20Energy%20Efficiency%20by%20Changing%20the%20Energy%20Culture.pdf

Worrell, E., Laitner, J. a, Ruth, M., & Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. *Energy*, *28*(11), 1081–1098.

Zeng, S. X., Meng, X. H., Zeng, R. C., Tam, C. M., Tam, V. W. Y., & Jin, T. (2011). How environmental management driving forces affect environmental and economic performance of SMEs: a study in the Northern China district. *Journal of Cleaner Production*, *19*(13), 1426–1437.

Sorrell, S., Schleich, J., Scott, S., & O'Malley, E. (2000). *Reducing barriers to energy efficiency in public and private organizations. Retrieved* (pp. 1–232). Retrieved from http://www.sussex.ac.uk/Units/spru/publications/reports/barriers/finaltoc.pdf

Qi, G. Y., Shen, L. Y., Zeng, S. X., & Jorge, O. J. (2010). The drivers for contractors' green innovation: an industry perspective. *Journal of Cleaner Production*, *18*(14), 1358–1365.

Cooremans, C. (2011). Make it strategic! Financial investment logic is not enough. *Energy Efficiency*, *4*, 473–492.

Organization for Economic Co-operation and Development. 2015. *An introduction to energy management systems: Energy savings and increased industrial productivity for the iron and steel sector*. Retrieved from: https://www.oecd.org/sti/ind/DSTI-SU-SC(2014)14-FINAL-ENG.pdf

May, G., Taisch, M., Prabhu, V. and Barletta, I. 2015. Energy Related Key Performance Indicators - State of the Art, Gaps and Industrial Needs. *Applied Energy, 149*, 46-61.

Jasch, C. (2000). Environmental performance evaluation and indicators. Journal of Cleaner Production, 8(1), 79-88.

Matthews, J. R. (2011). Assessing Organizational Effectiveness: The Role of Performance Measures. The Library Quarterly, 81(1), 83-110.

Dillenburg, S., Greene, T., & Erekson, H. (2003). Approaching Socially Responsible Investment with a Comprehensive Ratings Scheme: Total Social Impact. Journal of Business Ethics, 43(3), 167-177.

Siemens. 2014. Managing Energy Using Key Performance Indicators. [White paper] Retrieved from: https://www.downloads.siemens.com/download-center/Download.aspx?pos=download&fct=getasset&id1=A6V10601358

Hasanbeigi, A., Menke, C., & Pont, P. (2010). Barriers to energy efficiency improvement and decision-making behavior in Thai industry. *Energy Efficiency*, *3*(1), 33–52.

Liu, X., Niu, D., Bao, C., Suk, S., & Shishime, T. (2012). A survey study of energy saving activities of industrial companies in Taicang , China. *Journal of Cleaner Production*, *26*, 79–89.

Möllersten, K., & Sandberg, P. (2004). Collaborative energy partnerships in relation to development of core business focus and competence– a study of Swedish pulp and paper companies and energy service companies. *Business Strategy and the Environment*, *13*(2), 78–95

Diabat, A., & Govindan, K. (2011). An analysis of the drivers affecting the implementation of green supply chain management. *Resources, Conservation and Recycling*, *55*(6), 659–667.

Qi, G. Y., Shen, L. Y., Zeng, S. X., & Jorge, O. J. (2010). The drivers for contractors' green innovation: an industry perspective. *Journal of Cleaner Production*, *18*(14), 1358–1365.

Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China: Drivers and practices. *Journal of Cleaner Production*, *14*(5), 472–486.

Aflaki, S., Kleindorfer, P. R., & Miera Polvorinos, V. S. (2012). Finding and Implementing Energy Efficiency Projects in Industrial Facilities. *Production and Operations Management*

Streimikiene, D., Ciegis, R., & Grundey, D. (2008). Promotion of energy efficiency in Lithuania. *Renewable and Sustainable Energy Reviews*, *12*(3), 772–789.

United States Department of Energy. 2010. *State Energy Efficiency Tax Incentives for Industry.* Retrieved from: https://www1.eere.energy.gov/manufacturing/states/pdfs/state_ee_tax_incentives_for_industry.pdf

Abdelaziz, E. a., Saidur, R., & Mekhilef, S. (2011). A review on energy saving strategies in industrial sector. *Renewable and Sustainable Energy Reviews*, *15*(1), 150–168.

World Energy Council. 2004. 2004 Survey of Energy Resources. Retrieved from: https://www.worldenergy.org/wp-content/uploads/2012/10/PUB_Survey-of-Energy-Resources_2004_WEC.pdf

Intergovernmental Panel on Climate Change. 2007. *Contribution of Working Group III to the Fourth Assesment Report of the Intergovernmental Panel on Climate Change.* Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter7.pdf

United Nations Industrial Development Organization. 2008. Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economics. Exectuive summary. Retrieved from: https://www.unido.org/fileadmin/media/documents/pdf/Energy_Environment/ind_energy_efficiencyEbookv2.pdf

International Energy Agency. 2006. Energy Technology Perspectives 2006: Scenarios and strategies to 2050. Retrieved from: https://www.iea.org/publications/freepublications/publication/etp2006.pdf

Global Reporting Initiative, United Nations Global Compact and World Business Council for Sustainable Development. 2015. *Sustainable Development Goals Compass: The guide for business action on the SDGs*. Retrieved from: https://www.globalreporting.org/resourcelibrary/gssb/Item%2029%20-%20SDG%20Compass.pdf

Center for Climate and Energy Solutions. 2015. *Outcomes of the U.N. climate change conference in Paris*. Retrieved from: http://www.c2es.org/docUploads/cop-21-paris-summary-02-2016-final.pdf

Environmental Resource Management. 2015. *What the COP21 Paris Agreement means for your business*. Retrieved from: http://www.erm.com/globalassets/documents/publications/2016/erm-post-cop21-briefing.pdf

KPMG. 2015. *COP21/Paris 2015 UN Climate Change Conference. What does it mean for business?* Retrieved from: https://www.kpmg.com/IN/en/Documents/KPMG-COP21-Briefing-WEB.pdf

PricewaterhouseCoopers. 2015. Make it your business. Engaging with the Sustainable Development Goals. Retrieved from: https://www.pwc.com/gx/en/sustainability/SDG/SDG%20Research_FINAL.pdf