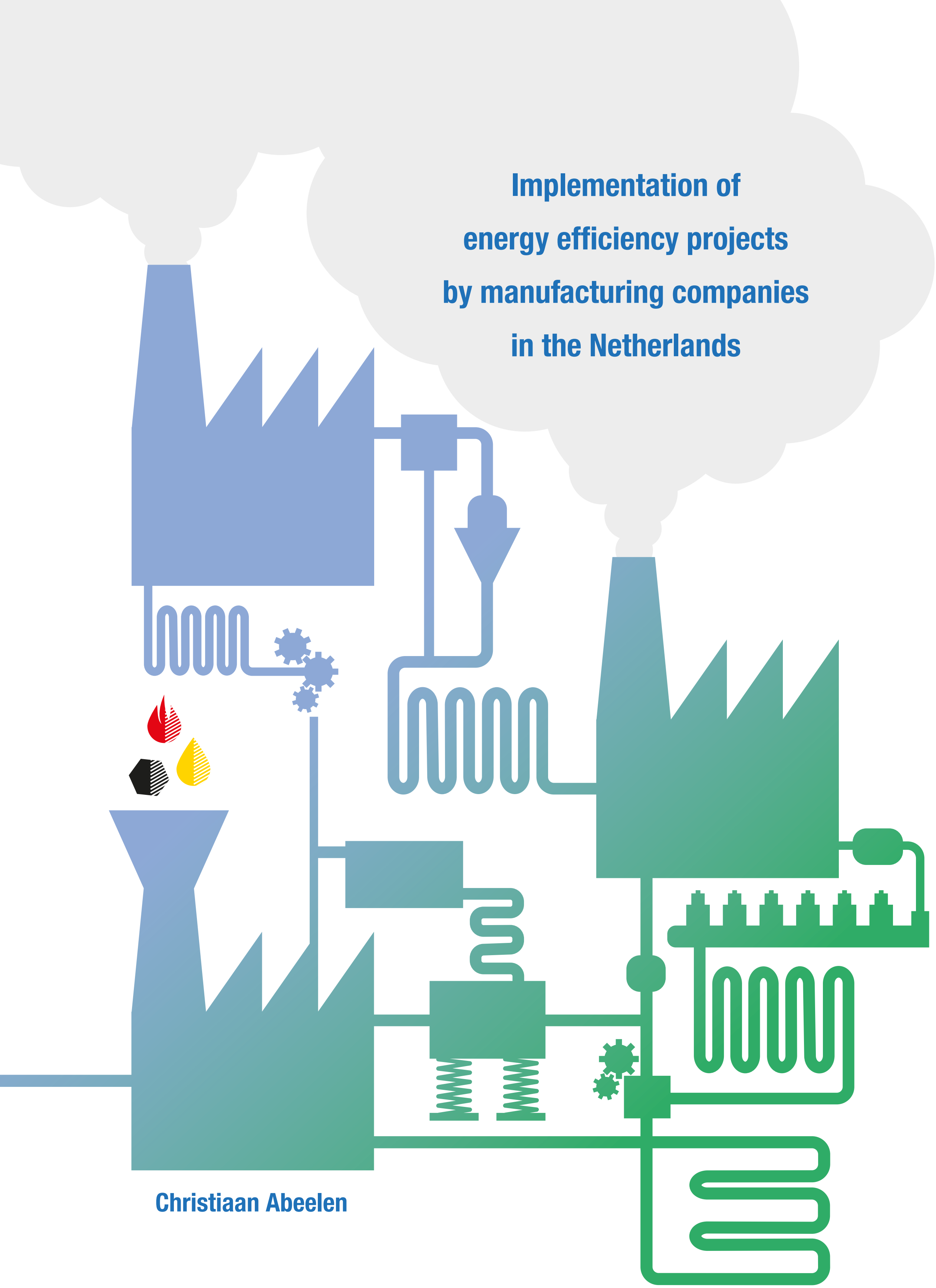
Implementation of energy efficiency projects by manufacturing companies in the Netherlands



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Implementation of energy efficiency projects by manufacturing companies in the Netherlands

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Implementation of energy efficiency projects by manufacturing companies in the Netherlands

Implementatie van energie-efficiëntie maatregelen
door industriële bedrijven in Nederland
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof. dr. H. Kummeling, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op 10 mei 2019 des middags te 12.45 uur.

door

Christiaan Johannes Abeelen

geboren op 3 februari 1973
te Breda

Promotor: Prof. dr. E. Worrell

Copromotor: Dr. R. Harmsen

Content

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Chapter 1

Introduction

1.1 Energy consumption and climate change: the role of industrial energy efficiency

In the 'Paris Agreement' the UNFCCC has agreed to implement actions to keep global average temperature well below 2 °C above pre-industrial levels (UNFCCC 2015). To reach this objective, reducing energy consumption or reducing carbon emissions from energy production is essential as carbon emissions from combustion of fuels for energy generation are a major contributor to global warming. Globally, energy consumption per capita has increased over the past 200 years, and this trend is unlikely to decline in the foreseeable future (Unido 2011), making energy efficiency, next to a decarbonisation of the fuel mix, an important means to combat growing energy demand.

The consumption of energy is related to population, income and technological change (Grubler, 2012). More people means increased energy consumption, as people need housing, food, clothing and transport. An increase in income also increases energy consumption per capita. Technological change can lead to both an increase or decrease in energy use. On the one hand, technological developments lead to an increase in energy demand as manual labour tends to be replaced by machines and new energy services are adopted by society. For example, the large increase in demand for digital data communication. Data centres and networks already account for about 2% of global electricity use, and this could increase as demand for their services rises (IEA, 2017). On the other hand, technological innovation can lead to a decrease in energy use, when machines become more efficient. For example Cagno et al. (2015) found that foundries that are more innovative are also more energy efficient.

The EU has set an objective to reduce greenhouse gas emissions by 80-95% by 2050 (Capros et al 2016). To reach this ambitious target, all sectors will have to reduce their emissions drastically. Industry is one of the major consumers of energy; the share of industry in EU final energy consumption was 25% in 2013 (Ademe 2015). Final energy demand in this sector is decreasing from 331 Mtoe in 2000 to 252 Mtoe in 2050, even though value added is expected to rise (Capros et al 2016). Decarbonisation of energy production through renewable energy will be an important means for the needed reductions of emissions. However, this will not be enough. Given the large reductions in greenhouse gas emissions and fossil energy consumption needed to reach the climate objectives, increasing industrial energy efficiency is crucial to reach these objectives and reduce emissions without blocking possibilities for industrial growth. Energy intensity gains are expected to contribute the largest part of the carbon efficiency in the EU industry (see figure 1-1).

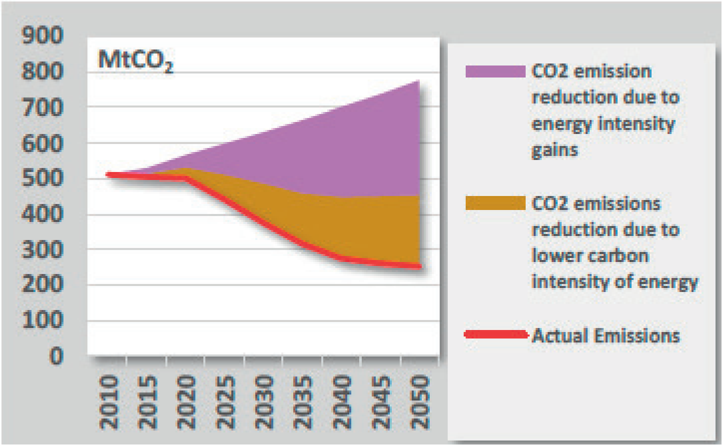


Figure 1-1. Energy-related CO_2 emissions of the industrial sector (Capros et al. 2016).

1.2 Industrial energy efficiency

Industry produces the goods that society needs. As population and income rise, energy consumption of industry inevitably will also rise, unless production becomes more efficient. Energy intensity in the EU is expected to decrease until 2050 (fig.1-2). Increased industrial energy efficiency is one of the most promising routes to sustainable industrial development worldwide (Unido 2011). For industry, the consumption of energy is related to the level of industrial activity, the structure of those activities and technological changes, including energy efficient technologies. Between 2000 and 2007, the stability of consumption in the EU was the result of the balance between the increase in industrial activity and energy savings. Since 2007, more than half of the reduction in consumption was linked to the decrease in industrial activity and only one fourth to energy savings (Bosseboeuf 2015). As the period since 2007 was characterised by economic crises, part of this decrease might be undone by a rise in energy consumption during economic recovery.

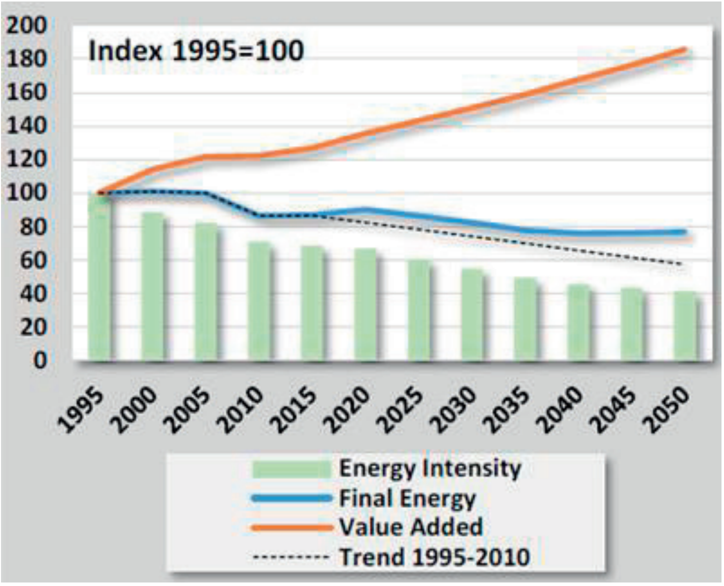


Figure 1-2. Industrial energy demand versus activity (Capros et al. 2016).

Energy is used in all parts of society for different purposes, be it to heat a house, fly a plane or operate a machine. Energy is needed to drive the economy. To achieve a reduction in energy consumption without hampering economic growth, a decoupling of energy consumption and economic growth is needed. This is where energy efficiency comes in. An efficiency gain can make a country less dependent on energy imports, or make a company more competitive. Energy efficiency is the art of doing the same with less energy. For example: drive a longer distance with the same amount of fuel or to produce the same amount of tons of cement but with less energy. As energy is used for so many purposes, measuring industrial energy efficiency poses difficulties. The challenge lies in comparing e.g. the energy needed to maintain a mobile data network to the energy used to produce a tonne of cement. The Energy Efficiency Directive defines energy efficiency as the ratio of output of performance, service, goods or energy, to input of energy (European Parliament and Council 2012). In other words: using less energy to produce a certain output (Blok 2007).

Although energy consumption and energy efficiency are related, this relation is not linear. Energy efficiency can help to achieve an actual reduction in energy consumption, but this is not necessarily the case. A strong increase in production can outweigh an increase in efficiency. The simultaneous impact of multiple factors poses a challenge to single out the effect of single factors. Several methods have been developed to decompose the effect of individual factors that affect energy efficiency (e.g. Cahill and Gallachoír 2010, Ang 2004, Boonekamp et al. 2001).

1.3 Industrial energy efficiency: Barriers, drivers and policies

In order for industry to maintain its long term competitiveness and realize a major increase in energy efficiency, far-reaching adoption of innovative techniques will be necessary. Especially the energy-intensive industry is presently still largely dependent on fossil energy for its main processes. There are numerous ways for companies to save energy, from turning off lights or machines when not in use, installing insulation, to replacing a complete production line. Some projects can be implemented without significant investments, other projects require large investments or an interruption of production. But actual implementation of new efficient technology is slow and even profitable technology is often not implemented. Many barriers hamper implementation or slow down their diffusion. Barriers are all factors that hamper the adoption of cost-effective energy-saving measures (Fleiter et al. 2011): access to capital, staff misses knowledge on new technology, other issues have more priority, etc..

Much has been written about the barriers that obstruct implementation of energy efficient techniques (Fleiter et al. 2011; OECD/IEA 2007; Johansson et al. 2007; Masselink 2008). Different authors use different classifications of barriers, depending on the scope of their topic (Sorrell, 2000; Cagno et al. 2013, Unido, 2011). Figure 1-3 gives an example of a system used by UNIDO in which 11 types of barriers are identified. Sorrell (2000) e.g. made the first classification scheme that classified barriers in 12 classes, drawn from economic, behavioural and organisation theory: heterogeneity, hidden costs, access to capital, risk, imperfect information, split incentive, adverse selection, principal-agent relationships, bounded rationality, form of information, power, culture.

While many policy instruments aim to overcome the effect of barriers, these instruments can also stimulate drivers; “factors that positively affect a firm’s intentions for innovation and therefore assist innovation activities” (Ren 2009). In other words: all factors that accelerate the uptake of energy efficiency measures: Internal motivation, cost reduction from energy savings or ‘a green image’ are all drivers that stimulate implementation of energy efficient technology. Organizational and economic drivers are, from the firms’ perspective, the most prominent stimulus for energy efficiency, e.g. commitment from the management or energy tariffs (Solnordal and Foss 2018). Strengthening these drivers might shift the balance between drivers and barriers in favour of the first. As drivers and barriers can be considered two sides of the same coin, Arens (2016) combines drivers and barriers as ‘diffusion factor’: all factors that have an positive or negative influence on diffusion of technology.

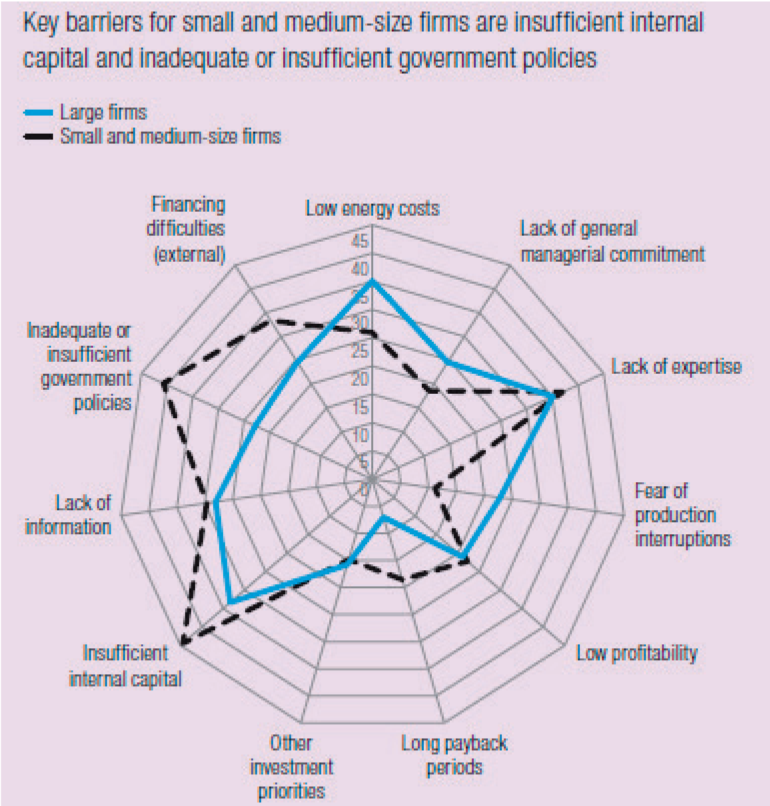


Figure 1-3. Barriers for implementation of energy efficient technology (Unido 2011).

Governments have designed energy efficiency policy instruments since the early 1970s, at first mainly as a reaction to the oil crises. In the 1990s climate change increasingly became a reason for energy efficiency policy. Strong energy efficiency policies are vital to achieve the key energy-policy goals of reducing energy bills, addressing climate change and local air pollution, improving energy security, and increasing energy access (OECD/IEA 2017). Several studies have concluded that energy efficiency is the most cost efficient way to reach climate targets (Gillingham 2007, European Parliament and Council 2012, IEA 2017) and that considerable potential exists for energy efficiency improvement (Boβmann et al. 2012, Solnordal and Foss 2018): a potential of 26% energy savings in 2030 compared to the EU 2009 baseline projection could be realized in industry, while final energy demand could be reduced by 57 percent in 2050 compared to the baseline development (Boβmann et al. 2012). Therefore, energy efficiency is part of the European Commissions' policy mix, as well as for most of its member states. The European Union has in 2007 agreed to a Climate and Energy Package, often referred to as the 20-20-20 target: a 20% reduction of greenhouse gas emissions compared to 1990, a 20% reduction of final energy consumption and a 20% increase in energy efficiency in 2020 compared to energy forecasts (European Parliament and Council

2012, Arens 2016). The European policy on energy efficiency is e.g. taken up in the Energy Efficiency Directive (EED) 1, which requires all member states to use energy more efficiently at all stages of the energy chain from production to final consumption. It is a set of binding measures including energy audits for large companies and incentives for small and medium-sized companies to undergo energy audits (European Parliament and Council 2012)

Energy policy instruments can be arranged according to their characteristics. Tanaka (2011) distinguishes three types of policies: prescriptive policies are regulations, mandates and obligations that directly compel specific actions by companies. Economic policies are taxes and tax reductions, direct financial support, tradable permits and price policies. Supportive policies are tools to identify opportunities for energy efficiency, cooperative measures, capacity building and information policies. Financial instruments dominate in industrial efficiency policy (Ademe 2012). The aim of these instruments is to act on the barriers and drivers in the decision making process of firms (figure 1-4).

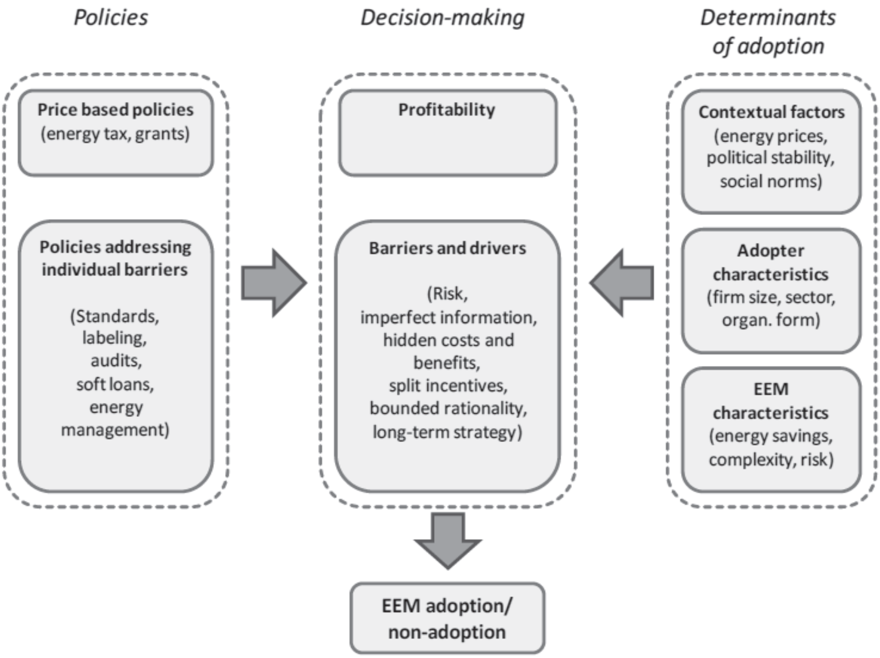


Figure 1-4. Framework for the determination of energy-efficient measures by firms (Fleiter 2012).

1 The EED replaces and strengthens two energy efficiency Directives (2004/8/EC on cogeneration and 2006/32/EC on energy services) and links with the obligations already set out in Directive 2009/125/EC on Ecodesign, Directive 2010/30/EU on energy labelling and Directive 2010/31/EU on the energy performance of buildings). Other relevant directives are the EU-ETS and the IPPC directive.

Policy makers will want to know if their policy is successful. The main question for an evaluation method is therefore to distinguish the effect of a policy instrument from that of other factors.

In the 1990s, the EU started the Odyssee -MURE project[2] to gather information on energy efficiency in its member states. The general objective of the project is to provide a comprehensive monitoring of energy consumption and efficiency trends as well as an evaluation of energy efficiency policy measures by sector for EU countries and Norway:

- Evaluate and compare energy efficiency progress by sector, and relate this progress to the observed trends in energy consumption.
- Contribute to the evaluation of national energy efficiency policy measures and analyze the dynamics of implementation over the National Energy Efficiency Action Plans.

Odyssee publishes country profiles with key figures and policies of EU countries regularly.

1.4 Energy policy in the Netherlands

The Netherlands have a long history of energy efficiency policy in industry. Voluntary agreements have been implemented since 1990, among other instruments. This provides an opportunity for researchers as the information collected during the implementation of these instruments provide a dataset that is consistent over a longer period. Several authors have used these voluntary agreements as subject for research, but the bulk of these studies dates from 2002 or earlier (Glasbergen 1998; Woerd 2002; Verdonk and Boonekamp 20009, Farla and Blok 1998, Farla and Blok 2002; Rietbergen et al. 2002). Since then the Dutch voluntary agreements have changed their monitoring method and new European policy on energy efficiency has been implemented. These developments highlight the need for new research in this field.

The energy policy in the Netherlands is a mix of instruments; prescriptive, economic as well as supportive instruments that address individual barriers. A long standing price-based measure is energy taxation, one of the highest in Europe (Odyssee 2015) although for large industry the taxation is a factor 3-5 lower than for small companies. The legislative basis is formed by the Environmental Management Act. These two measures are accompanied by programmes with supporting measures (information on saving options, pilot projects and subsidies) and various voluntary agreements for end-use sectors. The latest and broadest example of such agreements is the Energy Agreement (Odyssee 2015). The combination of these instruments influence different factors that drive investments in energy efficiency (IEA 2011). Figure 1-5 shows an overview of those instruments from 2000 onwards.

2 http://www.odyssee-mure.eu/

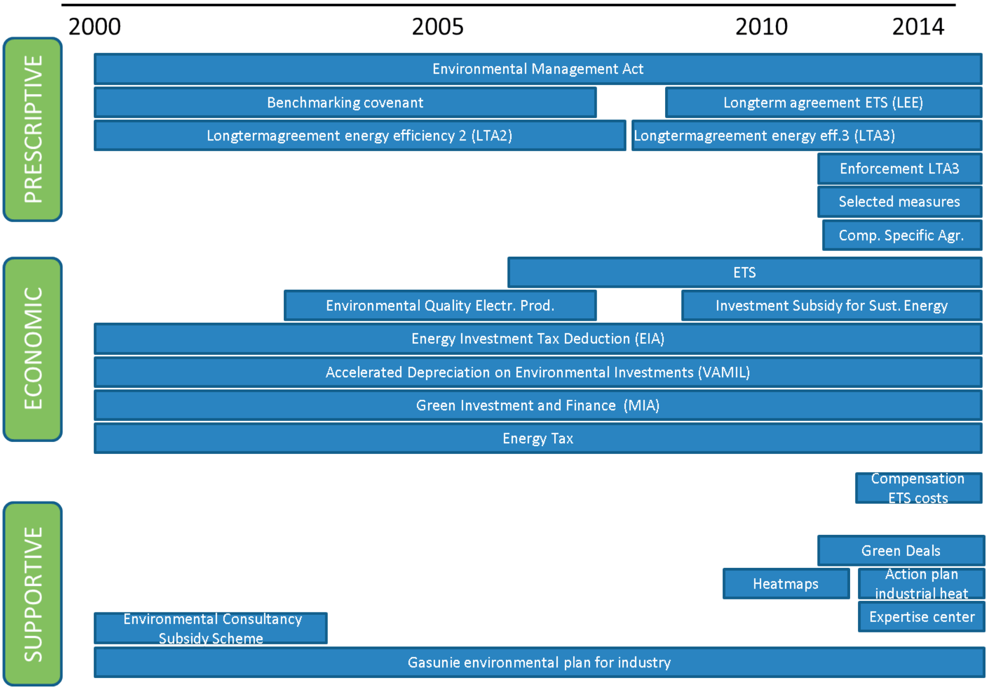


Figure 1-5. Overview of Dutch policy instruments on energy efficiency in industry from 2000 onwards. Source: Gerdes (2012), SER (2013).

Voluntary agreements (VA) have been part of the Netherlands' energy policy mix since 1990. In this period, five different agreements on industrial energy efficiency have been implemented, each with particular characteristics. In all cases, the VA was backed up by other policy instruments, mainly financial. A large part of Dutch industry, has joined these voluntary agreements. The most important obligation for companies within the VAs is to plan and implement energy efficiency measures based on an Energy Efficiency Plan (EEP) that has to be provided every four years, as well as an annual monitoring report. Measures with a Payback period of 5 years or less are obligatory. In return, companies can apply for tax returns or can get information on energy efficiency opportunities.

The Agreements' obligations require participants to provide information regarding their energy efficiency progress to an independent organization. This dataset offers a unique opportunity to analyse the way in which companies invest in energy efficiency techniques, the main subject of this thesis.

1.5 Research objectives & questions

This thesis describes how companies in the Netherlands implement energy saving projects, what drives them to implement these projects and the effect that these projects have on their energy use.

The main research question for this thesis is:
How are energy saving projects being implemented in industrial companies in the Netherlands?

To answer this question, we pose the following sub questions:
1-What is the impact of implemented projects on the actual energy use?
2-What kind of projects are being implemented?
3-What are drivers and barriers for the implementations of these projects?
4-How does the monitoring method affect the determination of realised energy savings?
5-How can energy efficiency results be compared?

1.6 Outline

Chapter 2 describes the context of the voluntary agreements in the Netherlands, a program that stimulates and monitors the implementation of energy saving projects. It describes the types of projects that are being implemented by what companies and the impact of these projects on the actual development of energy use. In other words, are the implemented projects a significant factor for the development of industrial energy use? By looking into the characteristics of companies, we try to discover the drivers behind the implementation of these projects.

Chapter 3 describes the planning process and the difference between planning and actual implementation of energy saving projects. Many projects undergo a long and sometimes elaborate process of preparation before they start and actually save energy. Companies participating in the Dutch voluntary agreements on energy efficiency are required to disclose the energy-saving projects that they have planned for a specified reporting period in an Energy Efficiency Plan (EEP). By comparing the characteristics of projects that have been implemented with those that were planned, insight is gained in the adjustments that companies make in their energy efficiency investments. We look at external circumstances that could explain these adjustments.

Chapter 4 analyses the mechanisms behind implementation. What are the drivers and barriers that determine if a project will start or not? Which actors play a role in this process and do they form a stimulus or a hindrance to implementation? Especially the role of the government is important as the government tries to shape conditions that stimulate implementation of energy saving projects and removes barriers. This chapter describes a model that relates drivers, barriers and actors in the process. In an exploratory study this model was applied to small- and medium sized companies in the Netherlands.

Chapter 5 discusses the differences between two methods to measure energy efficiency: an intensity methods and a projects-based method. In 2008, the Dutch voluntary agreements on industrial energy efficiency faced fundamental changes to their monitoring methodology. Where the old method was based on measuring the improvement of

energy use per unit of production, the new method focuses on the energy savings from projects implemented by participating companies. By applying the two methods on the same group of companies, the results can be compared and show to what extent the choice of monitoring method affects the realised energy savings.
Chapter 6 discusses methods on energy efficiency in a broader context. It describes the development of different methods and how these methods are used. It explains the differences between them. The central question in this chapter is how figures on energy efficiency, with a focus on industry in the Netherlands, can be compared and interpreted.
Finally, **chapter 7** summarizes all previous chapters and provides overall conclusions of this thesis. Here we return to the research questions that were posed in the introduction, to see whether these can be answered based on the results in this thesis.

2

Chapter 2

Implementation of energy efficiency projects by Dutch industry[3]

3 Christiaan Abeelen, Robert Harmsen, Ernst Worrell.
Published in: Energy Policy 63 (2013) 408–418

2.1 Introduction

As industry is responsible for 22% of final energy demand in the European Union (EU)[4] , it is essential that efficiency improvements also occur in this sector to make the economy as a whole more efficient. According to a study by Boßmann et al. (2012), realizing the potential of industrial energy savings would result in 26% energy savings in 2030 compared to the baseline projection. The European Commission recognises the importance of energy savings and has set an economy-wide policy target of achieving 20% energy savings by 2020 (European Parliament and Council, 2012). The urgency to strengthen energy savings policies at the European and Member State level is upfront as Europe is not on track in meeting its energy savings target (Harmsen et al. 2014; Wesselink et al. 2010). Actual implementation of new efficient technology is slow. Even technology that is profitable from an economic view is slowly implemented (DeCanio and Watkins 1998). Much has been written about the barriers that obstruct implementation of energy efficient techniques (Fleiter et al. 2011; OECD/IEA 2007; Johansson et al. 2007; Masselink 2008). Different authors use different classifications of barriers, depending on the scope of their topic. Cagno et al. (2013) developed a new taxonomy that includes all barriers and tries to reduce overlap between barriers. This taxonomy has categorized barriers in behavioural, technological, economic, organisational barriers and barriers related to competences, information and awareness.

The Netherlands Court of Audit (in Dutch: Algemene Rekenkamer), in an evaluation of Dutch energy policy, identifies the existence of other investment opportunities as the most important barrier for firms (Netherlands Court of Audit 2011). Especially if financial or other constraints play a role, investments in energy saving are likely to be pushed aside in favour of other investments. Other barriers are the resistance to replace existing machinery and the relatively small amount of money spent on energy (De Groot et al. 1999).

Financial instruments dominate in industrial energy efficiency policy (ADEME 2012). However, voluntary agreements (VA) have also been implemented[5], often in conjunction with financial instruments. Co-operative policy instruments like voluntary agreements are especially popular in countries with close relations between government and industry (ADEME 2012). The establishment of voluntary agreements are a common approach to get stakeholders involved in energy efficiency policies (Geiss et al. 2009). Some of the implemented agreements have a special focus on energy saving projects to be implemented by the participants. The VA-programs in Australia, Sweden and the Netherlands, as well as the Energy Efficiency Networks in Switzerland and Germany, are examples of programs that –each in their own way- ask participants to implement and

4 Source: IEA Statistics, 2009
5 e.g. in 13 EU-countries (ADEME, 2012)

report energy saving projects (Commonwealth of Australia 2011; Johansson 2007; NL Agency 2008, 2009; Koewener 2011).

The main purpose of the Dutch voluntary agreements is the speeding of implementation of energy saving techniques. This program is –as we know it- one of the few which has documented all types of projects that have been implemented by companies for more than 5 years and for a large share of industry. The aim of this paper is to analyse the actual implementation of energy saving technologies. We describe the savings reported by the companies participating in the Dutch voluntary agreements. We look at the properties of the projects that have been implemented and the savings as a result of these projects. The question is whether these savings actually show up in the energy use: do these projects make the difference, or are other effects more important? Are the savings as reported by companies an accurate estimate of real savings? Can we make a distinction between 'policy-induced' savings and autonomous savings?
Therefore our first research question is:
1) What is the impact of implemented energy efficiency projects on the actual development of energy use; in other words, are the implemented projects a significant driver of the development of industrial energy use?

As the results for different sectors and companies show rather great differences, we look at the characteristics of the companies that yield the highest results, in an attempt to identify the preconditions for higher results for the industry as a whole. This leads to the second research question:
2) Which characteristics (such as size of the company, energy price, participation in ETS or level of energy management) determine the energy savings effort of companies?

The set-up of our paper is as follows: Chapter 2 addresses our methodology. Chapter 3 provides description of the dataset, including a brief history of industrial voluntary agreements in the Netherlands. Chapter 4 shows the results of the analysis. Chapter 5 discusses the results and the various limitations regarding the input data. Finally, chapter 6 provides conclusions and recommendations.

2.2 Methodology

In order to answer our research questions, we analyse the data in the following way:

- We have assembled the necessary data from both the LTA and LEE covenant into a single dataset. Due to differences in reporting formats between LTA and LEE, it was necessary to adapt the data to make them comparable. These differences regard especially the level of detail in reporting.

- The total group of companies consists of a wide variety of sectors and fluctuates because of companies entering or leaving the agreement. In order to produce a dataset from a more uniform group of companies, without interference of changes in the covenant participants, we have singled out one distinctive sector for some analyses. The chemical industry was chosen as it is a large sector, both regarding the number of participating companies and energy use, and therefore important for the result of the total VA.

For analysing the first research question, we make a comparison of the different factors that influence the energy use: production changes, saving projects and other effects. If these effects together add up to the change in energy use, it is plausible that the reported effects are correct. Besides, we can arrange different effects by size, to define the main drivers for change in energy use.

For analysing the second research question we define the mean yearly savings per company and compare this to several characteristics of these companies: size, participation in ETS, energy management and energy prices.

2.3 Data set

2.3.1 History of voluntary agreements in the Netherlands

The Netherlands have a history of voluntary agreements of more than 20 years, covering almost the complete industry. In this period, five different agreements on industrial energy efficiency have been implemented, each with particular characteristics. Figure 2-1 gives an overview of the different VAs that were in force, with a rough indication of their total energy use. In all cases, the VA was backed up by other policy instruments, mainly financial. The combination of these policy instruments is sometimes complex, but also offer a large degree of flexibility for companies (Abeelen and Both 2012).

The first Long Term Agreement on energy efficiency started in 1991. The use of voluntary agreements became a quite common instrument in Dutch environmental policy of the nineties (de Bruijn et al. 2003). The first VA were considered very successful (Das et al. 1997) and therefore succeeded by new agreements. In 2000 the larger energy-intensive industry split off and joined the new Benchmarking covenant (Phylipsen et al., 2002). About 900 smaller companies joined the second generation VA (LTA2). Both target and method of the benchmark covenant and LTA2 differed. For LTA2 target and method were copied from LTA1: an annual 2% improvement in efficiency. This target was not deemed suitable for the large industries, as some of them had already reached large improvements in LTA1. Therefore, the target for the Benchmarking covenant was to reach the top 10% of most efficient installations in the world. However, the results of the Benchmarking covenant were disappointing. The progress report in 2007 revealed that the relative lead in the World Benchmark ranking on efficiency at the start of the Benchmarking covenant had dwindled: Energy efficiency improvement from 2000 to 2007 was little over 0.5% per year. Short pay back periods for investment in energy saving techniques were mentioned as a reason for the low results (Davidson et al. 2010; VBE 2008; Netherlands Court of Audit 2011). These results led to suspension of the Benchmarking covenant in 2008. Negotiations about a new agreement, more along the LTA approach, started and after lengthy negotiations two new voluntary agreements were signed. In 2008 LTA3 was signed, more or less with the same companies that participated in LTA2. In fact, LTA3 amends LTA2 and companies that joined LTA2 automatically joined LTA3, unless they chose to leave the agreement. A few large companies from the Benchmark covenant and two new sectors also joined LTA3. Most of the companies that formerly participated in the Benchmark covenant signed a separate agreement in 2009: the Long term agreement Energy efficiency for ETS-companies (LEE), which officially is an amendment to the Benchmarking Covenant, but has different targets and rules.

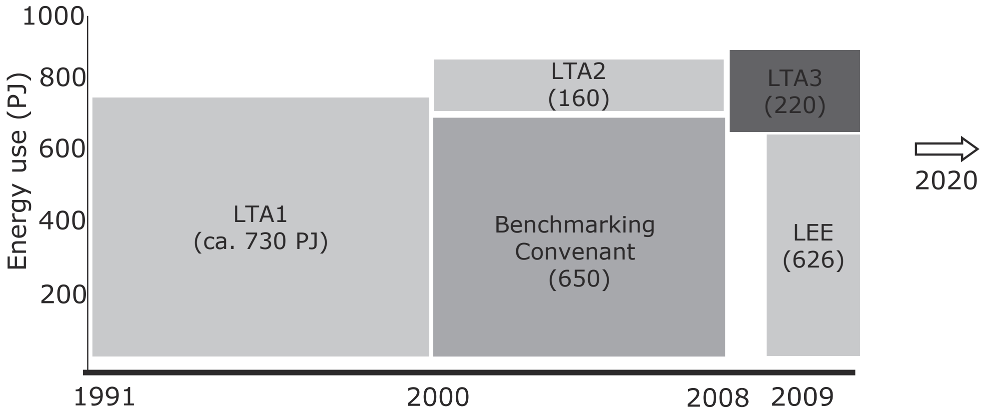


Figure 2-1. Overview of voluntary agreements in Dutch industry. (Shown in the figure is the approximate total primary energy use (excluding non-energy use) of the participating companies).

2.3.2 Companies joining the voluntary agreements

In 2013, two different agreements on energy efficiency are in force: LTA3 and LEE. LEE, the Long term agreement Energy efficiency for ETS-companies, was signed in 2009 as a continuation of the Benchmarking covenant and was signed by most of the companies that formerly participated in that covenant. Although LEE is meant in particular for companies that fall under the ETS-scheme, the distinction lines are not very sharp: Not all LEE-companies actually participate in ETS, while some companies in LTA3 also fall under the ETS-scheme. In total, 114 companies in 7 sectors joined the LEE-covenant, with an energy use of 602 PJ (2011), see table 2-1. The LTA3 (total energy use 237 PJ) is joined by over 900 companies in 32 sectors, mostly industrial sectors, but also some services and rail transport (table 2-2). Classification of sectors was mostly based on the processes or products within the companies, but also partly on the level of organisation within a sector, as the agreement was officially signed with the sector organisations.

Sectors without a representative organisation could join the sector 'non-branch related industry'. The share of the companies joining a VA compared to the energy use of total Dutch industry fluctuated between 80-95%.

Table 2-1. Sectors participating in LEE.

LEE	Companies	Energy use
Sector (NACE code)[6]	**#**	**PJ**
Breweries (11.05)	5	3
Chemical industry (20-21)	58	319
Glass industry (23.1)	9	13
Metallurgical industry (24)	5	74
Non-branch related industry (various)	13	18
Paper and cardboard industry (17)	19	23
Refineries (19.20)	5	152
TOTAL LEE	**114**	**602**

Table 2-2. Sectors participating in LTA3.

LTA3	Companies	Energy use	LTA3 (cont.)	Companies	Energy use
Sector (NACE code)	**#**	**PJ**	**Sector**	**#**	**PJ**
Asphalt industry (23.99)	41	3	Rubber and plastics industry (22)	98	9
Carpet industry (13.93)	13	1	Potato processing industry (10.31)	15	8
Chemical industry (20-21)	63	40	Rail sector (49.1-49.2)	2	14
Coarse ceramics industry (23.3 + 8.12)	40	8	Non-branch related industry (various)	39	14
Cocoa industry (10.82)	6	2	Oil and gas-producing industry (06)	10	43
Coffee roasting industry (10.83)	10	1	Refrigeration and cold storage industry (52.10)	85	3
Dairy industry (10.51)	49	18	Sand limestone and cellular concrete industry (23.5 + 8.12)	10	1
Financial service providers (64-65)	10	3	Soft drinks, waters and juices (11.07)	9	1
Fine ceramics industry (23.31)	7	1	Surface treatment industry (25.61)	61	2
Flour manufacturers (10.61)	6	1	Vegetable and fruit processing industry (10.3)	20	3
Foundries (24.5)	16	3	Tank storage companies (52.10)	16	2
Higher vocational education (85.4)	35	2	Textile industry (13)	24	1
ICT sector (63.1)	38	16	Textile service industry (96.01)	56	2
Margarine, fats and oil industry (10.4)	17	8	Universities (85.42)	14	6
Meat processing industry (10.1)	54	4	University medical centres (86.1)	9	5
Metallurgical industry (25)	19	4	Waste water treatment district boards (37.0)	25	8
			TOTAL LTA3	**917**	**237**

6 A NACE code in this table does not imply that all companies under that code are participating in LTA. In class 86.1 for instance, only the (bigger) academic hospitals are participating, but not the other (smaller) hospitals.

Companies joining a VA endorse both rights and duties stemming from the text of that agreement: (NL Agency 2009) for LEE, (NL Agency 2008) for LTA3. For different parts of the agreement separate guidelines have been formulated. The monitoring guidelines are described in (AgentschapNL 2012b).

The most important obligation for companies within the VAs is to plan and implement energy efficiency measures. Therefore, they have to deliver an Energy Efficiency Plan (EEP) every four years and a monitoring report on an annual base. The data used in this article is taken from the monitoring reports of the participating companies. The differences in population and reporting requirements between the two agreements pose some restrictions on the availability of comparable data. The most important restriction is the fact that hardly any data, other than publicly available reports, are available from the Benchmarking covenant, as this was supported by a special foundation under rule of confidentiality. At the start of LEE, companies have provided information from 2006, as this is the reference year for LEE. This means that for LEE companies, data on company level are available from 2006 onwards. Companies that joined LTA2 from the start have reported from 2001 onwards. However, not all companies joined from the start and not all companies have reported every year. The number of participating companies has risen from 500 in 2001 to almost 900 in 2011, with a comparable growth in energy use. A complete dataset from 2001 onwards exists for 500 companies, for 850 companies from 2005 onwards. For this article we have made choices regarding the selection of companies and time period. If a large time period is wanted, only LTA data are used. If LEE-companies have to be included, we must limit the time period to 2006-2011.

There are large differences in size of the participating companies (see figure 2-2). The smallest companies have an energy use of 0.001 PJ, the largest use more than 70 PJ. Smaller companies are overrepresented in the agreements: about half of the companies have an energy use of less than 0.1PJ. On the other side of the spectrum: the largest 10 companies use 51% of total energy. This skewed distribution means there is a large difference between the average and median of energy use and between weighted and non-weighted average. In this article, weighted average is used unless otherwise stated. In general it is true that the larger companies participate in the LEE-agreement. However, the distinction is not sharp and there is an overlap: The largest company in LTA has an energy use of 20 PJ, while the smallest LEE-companies have an energy use of 0.1 PJ.

All energy (both consumed and saved) is converted into primary energy using national default heating values. For fuels, these values are based on research on the most commonly used fuels (Vreuls and Zijlema 2012). For electricity a conversion factor of 9 MJ/kWh is used (40% conversion efficiency), based on calculations on the production mix in the Netherlands (Harmelink et al. 2012; AgentschapNL 2012b). Companies joining the

LEE are able to deviate from these default values, for instance when using exhaust gases with a specific composition. In these cases company-specific conversion factors are used.

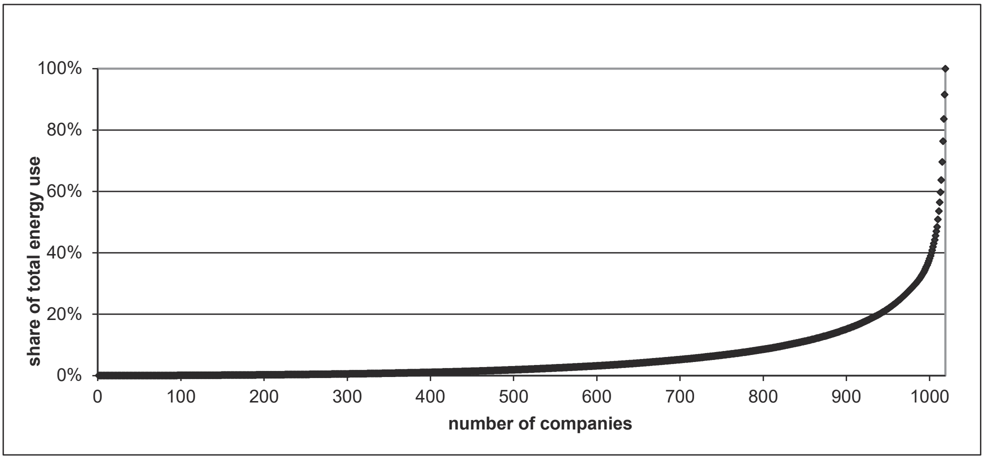


Figure 2-2. Distribution of total primary energy use of companies participating in LTA and LEE. (All fuels have been converted using default conversion factors. For electricity, a default efficiency of 40% has been assumed).

2.3.3 Implementation of measures

Participating companies must plan and implement all profitable measures, whereby profitable means measures with a positive net cash value at an internal discount rate of 15%. Alternatively, a payback period of five years can be used. Measures fall in two (LEE) or three (LTA) distinct categories: process efficiency and chain efficiency for LEE measures and renewable energy as the additional measure for LTA (NL Agency 2008, 2009). For this article, only measures in the category 'process efficiency' are assessed. This category is directly linked to the energy use of the company itself.[7] Process efficiency measures can be placed in four subcategories. Table 2-3 shows examples of the four subcategories.

7 The second category is chain efficiency. These measures improve energy efficiency not within the own company but elsewhere in the production chain from raw material to end use and the energy supply needed for that purpose. Chain efficiency can be improved by: improving performance, reducing the amount of materials needed, more efficient transport of goods and products, savings during the phase of product use (lower energy consumption or life cycle extension) or savings arising from efficient and effective disposal of products (reuse, recycling, the use of material for energy generation). For LTA companies, renewable energy is also an option as third category. These measures do not save energy use per se, but only fossil energy use and thereby 'green' the energy use of the company. Although all three categories contribute to the result of the VA, they cannot be added together.

Table 2-3. Subcategories of process efficiency measures.

Subcategory	Example
Energy management and good housekeeping	Awareness campaigns Monitoring system Improvement of maintenance programs
Adjustment in processes	New machines Different process-setting (temperature, pressure etc.) New process design
Utilities and buildings	Efficient lighting Insulation CHP (combined heat and power)
Strategic measures	New production plants Replacements Change in product mix

2.3.4 Efficiency plans and monitoring reports

Every four years, the participating companies must produce an energy efficiency plan. These plans contain a description of the processes in the company, an energy balance and a list of projects to be implemented in the next four years (NL Agency, 2008, 2009). For each project, the expected amount of energy savings is given. These deemed savings can be based on calculation, measurements in test setting, specifications of suppliers or an educated guess using assumptions for variables like e.g. output volume, production speed. The deemed savings are given as the saved amount of primary energy in Joules. To calculate the deemed saving percentage (SP), the absolute saving effect (S, in Joules) is divided by the total primary energy use (E, in Joules) in the most recent year available at the time of planning (AgentschapNL 2012b). So for the efficiency plan that is made in 2012, the energy use in 2011 is the reference energy use:

[1] $SP(\%)=S_{2011}/E_{2011}$

where SP is the saving percentage, S is absolute savings in Joule, E=energy use in Joule.

Each year, companies must produce a monitoring report. This report contains the following data:

- Use of energy carriers (electricity, heat, gas, and other fuels), in kWh, m^3, tonnes etc.
- Production (in physical units or an index for LEE-participants[8])
- Implemented saving projects
- Other factors influencing energy use
- Status of energy management (LTA only)

8 The production-index is the ratio of the production in the reporting year compared to the reference year, weighted by the specific energy use. The production level is based on one or more measures of production, in physical units. For reasons of confidentiality, only the resulting index is reported.

The most extensive part of the monitoring report is the part on energy saving projects. For each project, the following data are registered:

- Title of the project
- (Sub)category (see Table 2-3)
- Certainty level (certain, conditional, uncertain) at moment of planning.
- Year of implementation
- Expected saving (at the moment of planning) (in Joules)
- Realised saving, in units of avoided final energy use (in Joules)
- If necessary, an explanation is added

The monitoring reports are sent to NL Agency, the executive body of the Dutch VAs, by internet application or email. All reports are checked for completeness and correctness. These checks are in fact a probability check, as a more thorough control (for instance by a crosscheck with metering data) is not possible. Only in exceptional cases companies are visited to help them with their monitoring report.

Actual realised savings (AS) can differ from the savings as anticipated at the time of planning of the project. In the time between the planning and actual realisation of the project, which in some cases can take years, many project variables may have changed. After implementation of the project, companies have a better view on the variables to calculate the realised savings. Even then, it is often necessary to use assumptions. The realised savings are reported as absolute saved amount of primary energy, based on measurements or calculations. The relative effect is calculated as:

[2] $RS_x(\%)=AS_x/(E_x+AS_x)$

where RS=realised saving as a percentage of total energy use in year x, AS is Actual Savings in Joule and E is primary energy use in Joule.

The denominator (E_x+AS_x) is the energy used if the project would not have been implemented. The factor $+AS_x$ in the denominator is added because the energy use in the reporting year is the energy use *after* implementation of the project. For small projects this extra factor does not have a significant impact (being in order of 1-2%), but for large projects, or if many projects are combined, the effect can be significant.
The calculated saving percentage is the percentage in the reporting year. To calculate the realised saving after several years, the yearly realised percentages are multiplied:

[3] $SI=1-[(1-RS_1)*(1-RS_2)*\ldots(1-RS_x)]$

Where SI is the saving indicator, RS is the realised saving percentage in year x.

Projects are reported after realisation. An important assumption is that the savings will be in effect for the complete duration of the agreement (which runs to 2020). For building-related projects (insulation) and projects that have to do with replacement of installations, this is a relatively safe assumption. The duration of the agreement (12 years) is in the same range as the default project lifetimes (10-25 years) as assumed in Annex V of the Energy Efficiency Directive (EED) (European Parliament and Council 2012). For projects under the subcategory energy management, this assumption might not be true. The EED has classified these measures as 'short-term savings'. This uncertainty is discussed in chapter 5.

It is important to realise that the method in LTA3 and LEE - savings as a result of implemented projects- is quite different from the methods used under LTA2 and the Benchmarking covenant. In LTA2, the result was reported as an Energy Efficiency Indicator (EEI), defined as the quotient of the actual energy use and a 'frozen efficiency' energy use. The target of LTA2 was an annual 2% improvement of the EEI. The Benchmarking covenant also reported the EEI, although improvement of the EEI was no official target. As the EEI is dependent on factors not influenced by the companies themselves, the covenant partners decided on a new method with a stronger link to their own saving efforts (which is the method described with formulas 1-3). Therefore results from LTA2 and the benchmarking covenant cannot be easily compared with LTA3/ LEE.

2.4 Results

2.4.1 Savings

Figure 2-3 shows the relative savings of projects that have been implemented by LTA companies in the period 2001-2011 (as mentioned before; process efficiencies measures only). On average 1.9% per year was saved (weighted average). In total about 20.000 process efficiency measures have been implemented in the period 2001-2011. More than half of the process efficiency projects fall under the category 'Adjustment in processes', which makes sense as process installations account for the largest part of industrial energy use (Sorrell et al. 2011). About a quarter of the savings are measures in utilities or buildings. The contribution of energy management projects is smaller, but represents a larger number of small projects. Energy management is supposed to act as a driving force for other projects: it generates permanent attention towards energy use. Typically these projects require little to no investments. In some sectors, no or low-cost improvements in energy management can lead to significant savings even before any investment is needed (IEA 2011).There are not many strategic projects, but these projects are typically larger. Strategic projects are the most innovative, like the installation of a new plant or the introduction of a new product.

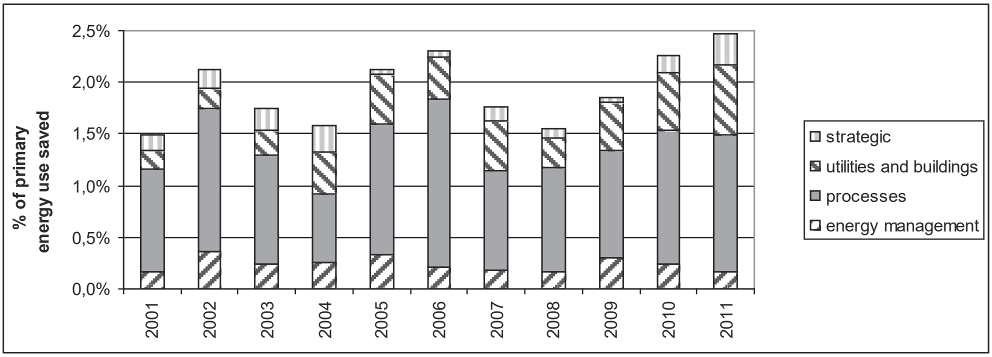


Figure 2-3. Yearly savings by LTA2 and LTA3 companies as a result of implemented projects.

As we can see, the resulting savings for the total LTA-population are between 1.5 and 2.5% per year (weighted average 1.9%). There are however large differences between the companies. Some companies have implemented measures that save up to 50% over the total period, meaning savings of more than 5% per year on average. These large savings typically come in large steps, when major installations are replaced. Therefore, there are also large variations from year to year savings, at least for individual companies. On the intermediate level, the differences between sectors are smaller, but still quite large. On average, the savings are twice as high as the autonomous effect which, according to a literature survey for an evaluation of Dutch climate policy, is supposed to be in the range of 0.8-1% (House of Representatives 2012, based on i.a. Rietbergen and Blok 1999). It should be noted that the reported savings are not isolated from the savings effects of other policy instruments, in other words, are not fully ‘additional’ to other energy policy instruments. Indeed, a sizeable part of the reported savings is also reported under the EIA-scheme, a tax deduction instrument for energy efficiency investments by firms (AgentschapNL 2012a).

2.4.2 Impact on energy use

One of our research questions is whether implemented projects do actually reduce energy use. To answer this question we visualise the impact of several influences on the development of actual energy use. To minimize the impact of population changes and structural changes, we do this exercise for a single sector (i.e. the chemical industry) and for a restricted period (2006-2011). Because new companies have entered the VA and some companies left, the energy use in 2011 was 3.7% higher than the energy use of the original population only, see Figure 2-4. Figure 2-4 also shows that during 2006-2011 the energy use (without population change) has decreased with almost 7%, but that the years in between show a large variation. The strong decrease in energy use in 2008-2009 is the direct result of the economic crisis.

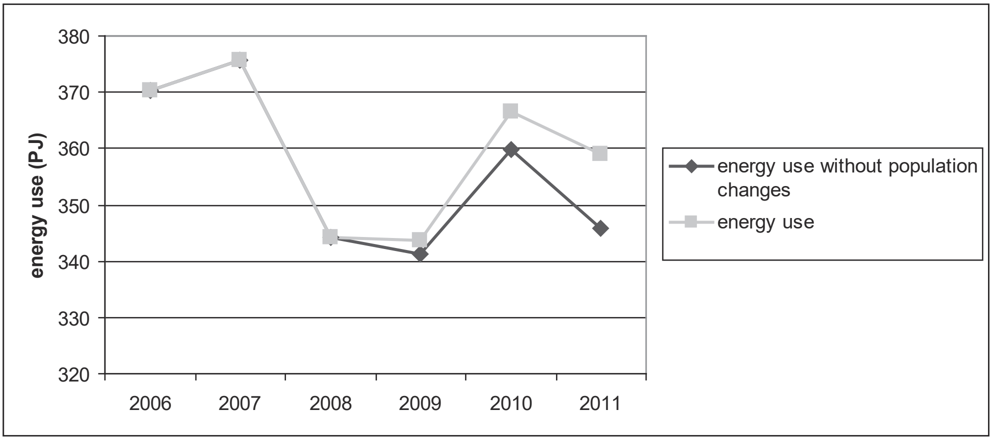


Figure 2-4. Development of energy use of companies in the chemical industry (127 companies in LTA and LEE).

Figure 2-5 shows the differences between the energy use at the start and end of this period and the effect of several factors that influenced the energy use. The change in energy use is decomposed in four separate effects:

- Saving projects;
- Changes in production volume;
- Companies joining or leaving the VA;
- Other influences.

This is not a formal decomposition method, but comprises elements of an additive structural decomposition method (Hoekstra and Van der Bergh 2003), as the addition of the sectoral effects together should match the change in energy use. The main difference with formal decomposition methods is that it is built up from individual company data. The effect of saving projects is the sum of the savings of reported projects. The volume effect is calculated on the basis of the reported production figures, assuming a linear dependency between production and energy use. Although this assumption is not entirely correct as it ignores the base load[9], in most cases it gives a good fit. A shift in production towards companies with a different specific energy use (a structure effect), will be visible as a volume effect in this figure, as production figures are weighted by specific energy consumption[10]. As this figure shows a relatively short period and only one sector, the assumption is that structural changes play a relatively small role. Lastly, other influences are reported by companies if special occasions have an impact on energy

9 In this context, base load is the energy consumption which is independent of the production level (e.g. lighting, space heating). In other words, a reduction of production level will not result in a reduction in base load demand. Therefore, the energy demand is likely to decrease less than the production.

10 For each product (or group of products) the specific energy consumption (SEC) in the reference year is determined (E_{t0}/P_{t0}). In the reporting year, for each product(group) the reference energy use (or frozen efficiency energy use) is calculated by multiplying this SEC by the production in the reporting year: $Eref_{t1}=SEC_{t0}xP_{t}$.

use, like weather conditions or incidents.

Shown in figure 2-5 is a relatively small decrease in energy use of 3%. As we can see in the figure, the effect of saving projects is quite large, compared to the total change in energy use. The net effect of production changes is almost zero, but there were large production changes in the intermediate years. Production increases in 2010 largely compensated for production decreases in 2008/2009 (see also figure 2-4). The effect of decreasing and increasing production is separated, showing that the gross volume-effect is larger than the effect of saving projects. Another large effect was the number of new companies entering the VA scheme. Other influences played a minor role. As not all changes could be accounted for, due to inaccuracies in energy and production figures and unaccounted other effects, a small residual remains, but together, the reported influences give a good fit to the change in energy use. This unaccounted part is an important criterion in determining the quality of the data. For large (LEE) companies, such an analysis is executed yearly, to explain the change in energy use. A large unaccounted part indicates a possible error in the reported data or omitted factors that could explain the resulting difference. Several of these possible errors are discussed in section 5.

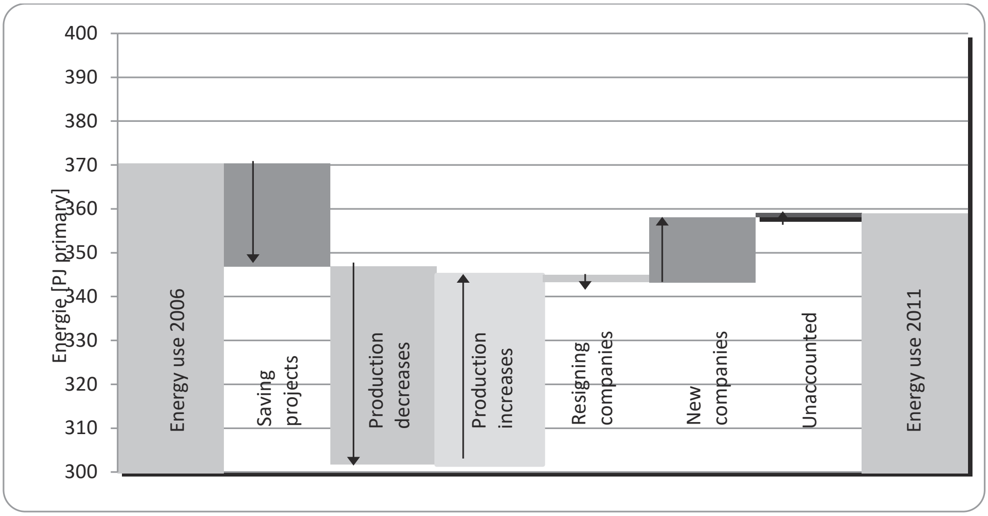


Figure 2-5. Decomposition of change in energy use between 2006 and 2011 in the chemical industry (127 companies in LTA and LEE).

In the next paragraphs, we will look at the savings of the covenant companies in more detail. By comparing realised savings on company level with characteristics of these companies, we try to establish the characteristics of companies that realize higher savings. If we can find the drivers behind energy saving projects, we might be able to establish if these savings are autonomous or policy-induced.

2.4.3 Savings in relation to energy use

Because of the large differences from year to year we have calculated the average yearly savings over the period 2006-2011. This period has been chosen because of availability of data for the LEE-companies.

In Figure 2-6 the relationship between the realized savings and the size of the company is shown. There are two reasons to expect larger companies to realize lower savings: first, the assumption that larger companies pay less for their energy, making investments in energy saving techniques relatively less profitable and second, the fact that larger companies are often also participating in the ETS, as ETS-companies that have a shortage of emission rights may opt to buy extra emission rights, which cannot be claimed under the voluntary agreement. However, although larger companies have realized slightly lower results, the difference is not significant. Most companies report savings in the range of 0-3% per year, but as we can see, even over a period of 6 year, several dozens of companies have reported savings in the range of 5-10% per year. This would mean that those companies have increased their energy efficiency over this period with about 50%. Most of these companies have implemented radical changes in their production plants, either by building new production lines or whole plants or by introducing totally new products with other energy characteristics.

About 26% of the primary energy savings are natural gas savings, 66% electricity savings, the remaining 8% are savings on other fuels. Electricity savings are somewhat higher than expected considering the share of electricity in total primary energy use (being 51%), whereas gas savings are somewhat lower than the share of gas in primary energy use (41%).

Hardly any differences have been found between companies that participate in the ETS and those that are not. Although there is a small tendency towards higher savings for non-ETS-companies, this difference is not significant. When looking at the chemical industry, the results are roughly the same. Apparently, participation in the ETS does not lead to higher investments in energy savings techniques, at least not in the observed period, which could be explained by modest carbon prices.

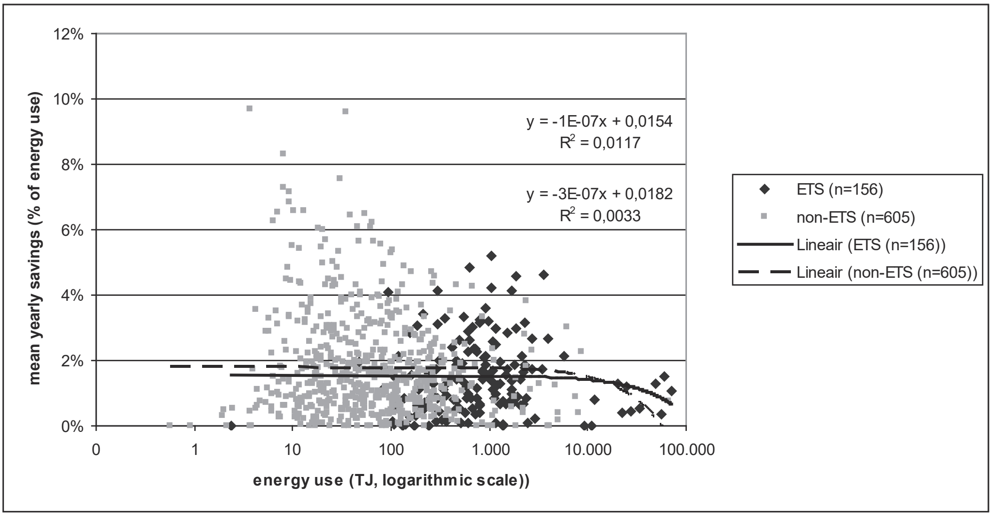


Figure 2-6. Relation between energy use and yearly saving percentage of companies participating in LTA and LEE (n=762, only companies that participated for the whole period).

2.4.4 Savings in relation to energy costs

Several authors claim a relation between savings and energy prices (i.a. Boonekamp 2011; IEA 1997; De Buck et al. 2010). To see if this relation is valid for the reported savings in the VA, we look at the Dutch chemical industry again.

There are two possible hypotheses regarding the relation between energy prices and energy savings behaviour. The first hypothesis is that the larger the share of energy costs in total production costs, the larger the incentive to save energy. The logic behind this hypothesis is that energy saving investments have to compete with other investments and even profitable energy savings investments will not be implemented when competing against other more profitable investments (Swigchem et al. 2002, De Buck et al. 2010). De Groot et al. (1999) even claim that this is the most important barrier for investments in energy saving techniques. If the share of energy costs in total costs is higher, energy saving investments will rank higher compared to other investments. Unfortunately, the LTA monitoring data do not contain data on total production costs, therefore it is not possible to investigate this hypothesis on a company level. Using the energy prices from the efficiency plans, we can calculate total costs for electricity for the participating companies at about 400M€, whereas the total costs for gas amount to 1300M€. Together, gas and electricity count for almost 60% of energy use in these companies, the rest is divided over a wide range of fuels (gas oil, coal, residual gases) and steam. If we assume the same price level for these fuels as for gas and electricity, total energy costs for the LTA companies in this sector are about 2800 M€. The Dutch Statistical Office (2012) estimates production costs for the sector at 90389M€. Calculated this way, total energy costs are 3.1% of total production costs. This is in line with Ramirez et al. (2005), who estimates the share of energy costs at 1.5-8% for different parts of the chemical industry. In comparison, labour costs are a factor 2-20 higher. We can therefore conclude that for the chemical sector in total, the share of energy costs is not very high and is unlikely to rank very high as a motivation for energy savings. This could be different for some very energy intensive companies or companies with a high share of non-energy use, as for these companies energy prices also determine the price of their raw materials.

The second hypothesis is 'the higher the price paid for energy, the larger the incentive to save energy'. The logic behind this hypothesis is that a higher energy price will yield higher benefits when applying energy saving investments, lowering the payback period for these investments. The same investment will therefore be more likely to be implemented in a period or a company with higher energy prices. Several authors claim an effect of energy prices on energy efficiency. Boonekamp (2011) states that higher energy prices will increase autonomous savings (in absence of additional policy). IEA (1997) mentions a clear relation between higher oil prices and national energy efficiency. In industrialised countries an increase in energy efficiency with 1.5% to 2.2% per year was seen after the oil crises in 1973-1985. Davidson et al.(2010) on the other hand suggest a relatively low price-elasticity for energy demand in Dutch industry of 0 to maximum -0.2 in the long term. This argument is supported by the fact that efficiency improvement lags behind price increases, as it takes time to replace machinery. If prices stay high for only a short period or if prices are expected to decrease again, motivation for investing in energy saving will probably decrease.

On average, larger companies pay less for their energy. Companies negotiate the price of electricity and gas with their energy supplier. This results in big differences, even within sectors. In general, the higher the energy use and the more constant the demand, the lower the price (Van Dril et al. 2012). However, within the companies in the chemical sector that have joined the LTA, this general trend is hardly visible. As part of their efficiency plans, companies have reported their 2011 prices that they use to calculate the payback period for investments. This might not be the same price as the price actually paid, as the latter price can vary within a year (some companies even operate on the spot market). However, the price used in payback calculations is better fitted for our purpose, as this figure indicates the 'value' of energy for a company. Because of confidentiality, a few companies did not declare their prices, but 95% did.

There are remarkable large differences between the prices different companies have to pay for their electricity and natural gas. The median price for natural gas is 0.26€/m^3 ranging from 0.17-0.45€/m^3. For electricity this is 0.07€/kWh, ranging from 0.05-0.12€/kWh. Earlier studies found large differences in energy prices between countries and also between different sectors within one country (UNIDO 2011). Apparently, the same holds for companies in the chemical industry in the Netherlands. One obvious reason for these large differences could be the large variation in energy use between companies: for gas the difference between the largest and smallest user in this sector is a factor 100 000, for electricity the difference is a factor 2 000. However, from the data in this sector we learn that the level of energy use is not the most important variable in defining the price: there is a small trend towards a lower energy price for large users, but not significant. For smaller users the trend is a bit stronger, but still not significant.[11] Apparently, above a certain level, prices are determined on other grounds than demand alone. Another possible reason for the large differences is that companies can choose from a large variety of contracts, with prices fixed for longer or shorter periods. Given the large variations in energy prices in the last years, the moment the contract is signed and the period for which prices are fixed in that contract can have a large effect. A third reason is fluctuation in demand profiles. Users with large variations in demand, or a high demand at peak moments usually pay higher prices (Van Dril et al. 2012).

Composing a consistent time series of energy prices for Dutch industry is difficult, as Statistics Netherlands introduced a new methodology in 2007 with a different classification of users and price components (Denneman 2012). In general, both electricity and gas prices rose very fast in the period 2000-2007 and stabilised or even decreased in the period 2007-2001 (Eurostat 2012; Statistics Netherlands 2012), see figure 2-7. For industry as a whole, energy costs rose much faster than value added (which grew 11% between 2000-2010). To a lesser extent, this is also the case for the chemical sector (value added +47%) Therefore, the relative importance of energy costs has grown.

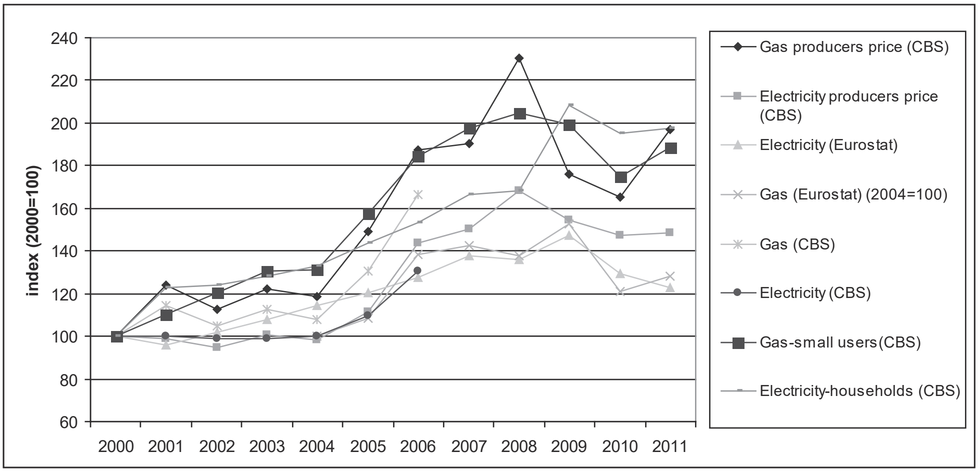


Figure 2-7. Development of energy prices in Dutch industry(index 2000=100).

11 y = -5E-07x + 0,2723, R^2 = 0,0015. A more in-depth analysis to further explore the relation between energy prices and investments would be interesting but is beyond the scope of this paper.

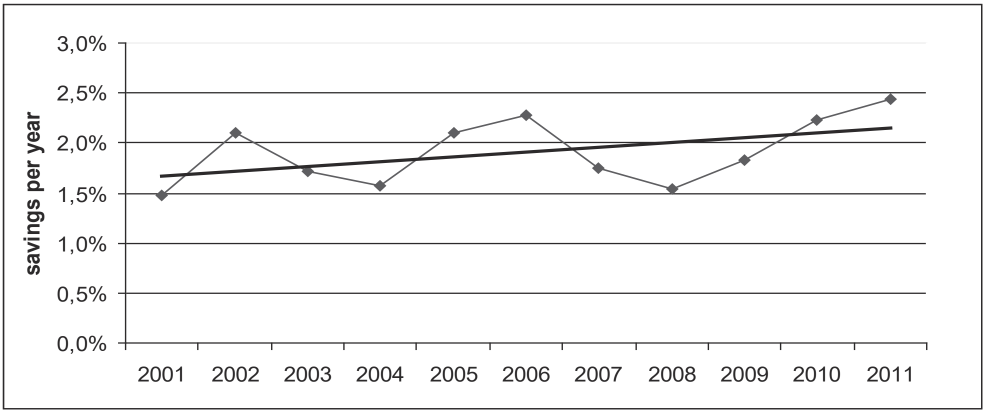


Figure 2-8. Savings per year of companies participating in the LTA covenant (n=600-900, total energy use 160-230 PJ).

Figure 2-8 shows the development of annual savings of LTA companies. By comparing this with the development of energy prices a relation can be found. Especially the period 2004-2008 shows a high increase in prices, but no increase in savings. The years 2008-2011 show relative constant prices, but an increase in savings. If these two are correlated, there is a lag of four years. This finding is in line with Saygin (2012), who compared energy efficiency improvements and energy prices over the period 1993-2008 for 6 industrial sectors in the Netherlands, but could not find a clear relation. Literature suggests three possible reasons why energy efficiency is not directly related to energy prices:

(i) The relative low share of energy costs in most sectors (Ramirez et al., 2005), as is the case in for instance the chemical industry in the Netherlands;

(ii) Unclear long-term development of energy prices (e.g. Boonekamp et al. 2002). The large changes in energy prices, especially in the period 2000-2006, could indeed add to the uncertainty of expected future price levels. This uncertainty in itself could pose a barrier to investments in energy efficiency (Sorrell et al. 2011);

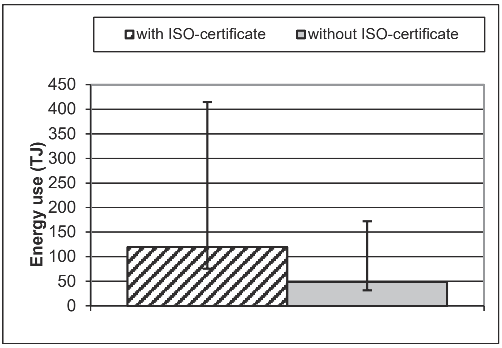
(iii) Possible delay between the increase in energy prices and investments in energy saving projects (Saygin 2012).

We conclude that for the studied period a relation between energy prices and investments does not exist in the case of the Dutch industry as a whole, but could be true in individual companies with a relatively high share of energy costs. Therefore it is not possible to establish if prices are the driving force behind part of the investments in energy efficiency. It is plausible that part of the investments is driven by energy prices and therefore autonomous, but which share of the investments is unknown.

2.4.5 Savings in relation to energy managements systems

In theory, an energy management system (EMS) is an incentive for energy savings. An EMS is meant to assure constant attention towards energy use and alert companies to new possible savings. Therefore, the Energy Efficiency Directive stimulates the adoption of management systems (European Parliament and Council 2012).

In LTA3, companies are obliged to have an EMS and are stimulated to certify their system with an ISO-certificate. If an ISO system is in place, energy management should be integrated in the energy paragraph. Figure 2-9 shows the difference in energy use between companies that have an EMS with an ISO certificate and those that have no certificate. As is to be expected, companies with an ISO-certificate are in general larger than those without a certificate. Companies with a certificate score somewhat better, but the difference is hardly significant. Within the two separate groups of companies with or without an ISO-certificate, there is no significant difference between larger or smaller companies. In a way this small difference is not surprising, because an EMS is a condition for an ISO-certificate, but not the other way round. In other words, companies without an ISO-certificate can have a perfectly well organised EMS. From the monitoring reports it is clear that almost all companies have at least some form of EMS, even given the fact that only 44% has an ISO-certificate. Therefore, the distinction between companies with or without an ISO-certificate is in practice not very meaningful.



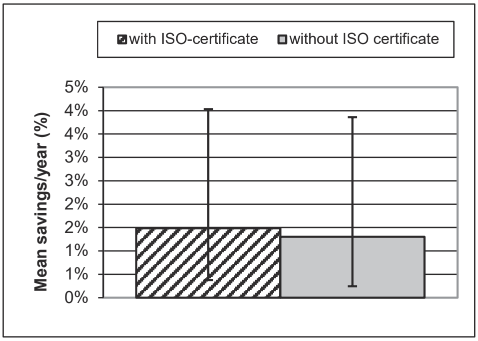


Figure 2-9. Comparison of median energy use and mean savings of LTA-companies with or without ISO-certificate + 90% percentile (n=654).

2.5 Discussion

Although the monitoring reports from the participating companies form a valuable source of information on implemented energy savings projects in the Dutch industry, this data source also has its limitations. The reporting format was drafted to satisfy the reporting requirements of a consensus agreement. There was no intention to use it for scientific analysis. Therefore the reported data does not always contain the information needed to answer all research questions. Another data complication is that not all companies participated in the agreements during the whole period. Therefore choices had to be made regarding the period and population under investigation. Finally, the data contains some uncertainty due to the fact that data were reported by companies themselves.

An obvious question regarding the new monitoring method is the **accuracy** of the reported data. On a company level, production and energy data will be easier to collect than data on realised projects. For many projects, it is only possible to *estimate* the realised savings. Therefore, the results obtained with the new method, which relies on project data, will probably have a lower level of accuracy than those obtained with the old LTA2 method that used only production and energy data. Still, there is no reason to expect that the level of inaccuracy is too high. Large mistakes are detected in the data audits that are structurally executed by the executive body. Smaller errors are likely, but because of the large number of implemented projects it is likely that positive errors in one project will be compensated by negative errors in another project, therefore ruling each other out on an aggregate level.
There are reasons to expect companies to over-report realised savings. Especially companies that score lower results might feel stimulated to report more savings than actually been realized. An evaluation study of the Danish energy efficiency obligation found a relatively small overestimation of projects reported by participants of 6% (Bundgaard et al. 2013) In our study we found very few examples of projects that have been reported but turned out not to be implemented. There are also many known cases of projects that have been implemented, but have not been reported. Sometimes companies forget to report projects, for instance in the case of smaller projects, sometimes companies report that a project has been implemented, but cannot quantify the savings and therefore report a zero saving. Knowing this, it seems reasonable to expect over- and underreporting to compensate each other, meaning that the inaccuracy on an aggregated level will be small. Bottom-up decomposition analysis of the changes in energy use for many companies and sectors show that the reported saving effect, volume effect and other influences together give a good fit for the change in reported energy use, making it likely that the saving effect is fairly accurate.

There is a large **time gap** between the planning and implementation of projects, sometimes years. Therefore, actual realised savings can differ from the savings as anticipated at the time of planning of the project. In the time between the planning and actual realisation of the project, many project variables may have changed. After implementation of the project companies have a better view on the variables with which to calculate the realised saving. Even then, it is often necessary to use assumptions. A possible error is introduced if companies just copy the planned savings from their energy efficiency plan without checking if project variables have changed. For companies this is the easiest way, not only because they do not need to recalculate, but also because it might raise questions if realised savings differ significantly from planned savings. In practice, this error seems small (<1%). Especially for bigger projects, companies tend to calculate the actual realised savings at the time of realisation.

How long will a project have an effect? Projects are reported only once, after implementation. An important assumption is that the implemented projects will have an effect during the total duration of the VA (2008-2020). For projects related to buildings or process installations this is a safe assumption, as it is unlikely that installed equipment is decommissioned. However, two important observations must be made. First, part of the reported projects fall under the category 'energy management and good housekeeping'. Part of these projects are behavioural measures (e.g. personnel training). Typically, these projects have only a temporary effect and a lifetime of 12 years is unlikely, unless well maintained by the company. Companies are requested to report these kind of measures only once, but this rule is difficult to uphold. Therefore, it is likely that the reported savings under this category are an overestimation. As this is the smallest category, the total effect is not big, but could be 0.1-0.2% annually. A second remark that could be made is whether it is justifiable to count the savings of all projects that have been implemented during this period. In case of replacement, one could argue that this replacement would have happened anyhow, only maybe some years later. Staniaszek and Lees (2012) argue that even with accelerated investment, savings should be counted only during the remaining lifetime of original equipment. But Worrell and Biermans (2005) claim that it is ambiguous to determine 'equipment lifetime'. To use a project-specific lifetime would be difficult and errors are likely, as one should make a distinction between replacement investments and other projects. It is easier to use the energy use before project implementation (this has the side benefit of making explanation of changes easier) and assume a certain share of 'autonomous' improvements.

A very important discussion point relates to the **additionality** of the presented results. Participating companies report implemented projects, but do not report the reason for implementation. Therefore, we cannot establish if a project is implemented because this was stimulated by participation in the VA or for another reason. In practice, several reasons will play a role. Therefore, the presented savings cannot be added to the results of other policy instruments. Also, part of the savings would have been realised without any policy at all, as some of the implemented projects are regular replacements. This part would therefore be autonomous. How large this part is, cannot be established. In a literature survey for an evaluation of Dutch climate policy, the autonomous saving is supposed to be in the range of 0.8-1% (House of Representatives, 2012), which would imply that about half of the reported savings are autonomous and the rest is a combined effect of several policy instruments. A special case is the additionality of the voluntary agreements to the EU ETS. ETS-companies consume 2/3 of total energy use covered by the agreements. As the ETS cap on emissions should ensure a 20% reduction at the EU level, one could argue that energy savings of these companies that avoid direct CO_2 emissions (from natural gas and other fuels) do not reduce emissions on a *net* base as these energy savings allow for increased emissions elsewhere in the scheme outside the Netherlands. Another special case of additionality is savings due to the implementation of new products which are more efficient than existing products. One could treat these as a structure effect instead of a savings effect. However, differentiation between incremental improvements of existing products and totally new products would be a research in itself, this discussion is beyond the scope of this paper.

2.6 Conclusions and recommendations

The Dutch voluntary agreements LTA and LEE have systematically promoted the implementation of energy saving projects. The LTA-program has monitored the implementation of these projects since 2001, the LEE-program since 2006. The character of these measures ranges from motivational campaigns to the replacement of complete production lines. On average, the projects in the LTA2-program have realised savings of 1.9% per year, but there are large variations between sectors and companies. Individual companies have realised average annual savings over 5%. It is not possible to establish the level of additionality of these savings, as part of these savings could be counted towards autonomous savings and part towards other policy instruments.

To establish the accuracy of the reported savings, we have made an analysis of the different factors that influence the use of energy: production, implemented savings projects and other influences, all based on data reported by the companies joining the VA. Together, these influences give a good fit for the change in energy use, making it likely that the savings effect calculated is fairly accurate. Although savings have a significant effect on energy use, in most cases other effects are larger.

Our findings show that there is no correlation between the size of the company (in terms of energy use) and realised savings. Besides, realised savings by firms do not match the development of energy prices, because of the large time gap between planning and implementation of projects, the large fluctuations in prices in the years 2008-2011 and the large uncertainty concerning future prices. As the share of energy costs in total production costs in most companies is quite low (<10%), the energy price is unlikely to rank very high as a driver for energy savings.

According to our research, participation in the ETS does not lead to higher investments in energy savings techniques, at least not in the observed period, which could be well explained by the modest carbon prices in this period.

For further research it is recommended to look closer into the reasons behind implementation of savings, in order to develop a better understanding of the contribution of autonomous savings. Related to this, is a more thorough exploration of the difference between energy savings and structure effects. Lastly, a study of the delay between planning and realisation of projects, could shed more light on a possible effect of energy prices.

3

Chapter 3

Implementation of energy efficiency projects by Dutch industry[12]

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3.1 Introduction

Energy savings can have multiple benefits. For individual energy users the main benefit is a lower energy bill, although other, non-energy benefits like better product quality or lower maintenance costs might be as important (Worrell et al. 2003). For a country, benefits are a lower dependency on fuel imports and a contribution to the reduction of carbon emissions. As there is still a large untapped potential in energy savings (Boßmann et al. 2012), there is increasing attention to implement policies to realise this potential (Harmsen et al. 2014). An overarching objective of energy efficiency policies is to realize or accelerate investments in energy saving technology. To achieve this, policy instruments need to be successful in influencing the investment decisions of companies. Different policy instruments apply different techniques to reach this objective. The Dutch industrial energy efficiency policy is an example of a mix of instruments influencing different factors that drive investments in energy efficiency (IEA 2011). For more than 20 years, long term agreements (LTAs) have formed an important part of the Dutch policy on energy efficiency for (industrial) companies (IEA 2008). The LTAs have always been linked to other instruments such as the Energy Investment Allowance (EIA; a tax deduction scheme for energy saving technologies) and the Environmental Management Act ("Wet Milieubeheer") (Tanaka 2011).

Two separate LTAs are currently in place in the Netherlands: LEE (Long term agreements Energy Efficiency) for companies participating in the EU Emissions Trading System (EU-ETS) and LTA3 for companies not participating in the EU-ETS. The ultimate goal of LTA3 is an improvement of energy efficiency with 30% in 15 years (2005-2020) (SenterNovem 2008a). For LEE the goal is a 'significant contribution' to improving energy efficiency for their facilities (NL Agency 2009). Almost 1100 companies currently participate in the two agreements. These companies are mostly industrial, but some non-industrial sectors like academic hospitals, universities and financial institutions are also included. There is no minimum threshold for participation for individual companies, but only sectors with an energy use of more than 1 PJ can join, when more than 80% of all companies in that sector join the voluntary agreement (NL Agency 2009). Together, the participating companies cover almost all industrial energy use (>80%). Most of the participating companies have an energy use of around 0.1 PJ, but the largest companies use over 50 PJ. In Abeelen et al. (2013) an extensive description of the Dutch LTA-scheme is provided.

Companies participating in one of the LTAs have to file an Energy Efficiency Plan (EEP) every four years. In these plans companies state which energy saving measures they intend to implement. EEPs form an important part of the agreements. The purpose of the EEP is comparable to an energy audit. They oblige companies to critically observe their own energy use and to look for energy saving opportunities. The Dutch Environmental Management Act directs this process and obliges companies to implement all projects with a payback period (PBP) of up to 5 years. Most economic studies claim industrial companies require a PBP less than 3 years to justify an investment decision, and even lower for energy efficiency projects (Swigchem et al. 2002; Fleiter et al. 2011; Sorrell et al. 2011). By setting the limit at 5 years, this law thus obliges companies to implement more projects than they would do autonomously.

Several industrial energy efficiency programs have methods comparable to the EEPs in the Dutch LTAs. In Australia, the Opportunities Program requires companies to perform an audit, in which projects with a PBP less than 4 years have to be identified. Implementation of identified opportunities is however a decision made by the companies (Commonwealth of Australia 2011). The Swedish Programme for improving energy efficiency in energy intensive industries (PFE) asks companies to perform an audit and identify profitable electricity saving measures. The list of identified measures is submitted to and approved by the Swedish Energy Agency. Measures with a PBP less than 3 years are obligatory to implement; other measures are pursued on a voluntary basis (Stenqvist and Nilsson 2012). The design of the Danish Energy Agreements contains some elements that are fairly similar to the Dutch LTAs: companies have to make an individual action plan based on energy audits, in which energy saving projects are identified. Some of those, subject to specific profitability criteria, are to be carried out (IPP 2012).

The aim of this paper is to provide insight in the differences in planning and implementation of energy efficiency investments by companies. In this article we compare the information in the EEPs (number and type of projects, expected energy savings) with actual implementation data and assess if the evaluation criteria used in the LTA fit to the evaluation criteria and decision making process used by industrial firms. In doing so we will answer the following research questions:
1-Are planned projects actually implemented? This question is especially relevant for projects with a PBP of less than 5 years, since these projects are supposed to be compulsory. Are companies deviating from this rule when projects with shorter PBP are not implemented?
2-What is the effect of changing circumstances during the time of planning and implementation of projects?
3-What is the payback period of planned projects?
4-Is there a relation between implemented projects and their payback period?
5a-Are projects with a short PBP also profitable according to criteria the companies use themselves?
5b-Are more sophisticated methods better suited for a voluntary agreement like LTA?

The structure of this article is as follows. Section 2 introduces the LTAs and describes the role of the EEPs in the instrument. It describes the dataset and the methodology. Section

3 shows the results of our analysis. Section 4 discusses the results and refers back to the research questions to draw conclusions and formulate policy implications.

3.2 Data and methodology

This paper used micro data from Energy Efficiency Plans (EEPs) of a large group of companies that participate in the Dutch LTAs. The data sample covered more than 80% of industrial energy use in the Netherlands. By comparing the EEPs with the monitoring reports of these companies, we were able to follow implementation of the projects, providing a unique insight in the applicability of EEPs to contribute to a policy instrument. In 2012, all companies have filed new plans for the period 2013-2016. At the same time, 2012 is the last year of the plan period 2009-2012.

Some of the obligatory elements of an EEP are:

- an energy balance of the company
- a description of the energy management system
- a process scheme of the most important processes of the company
- a list of energy saving projects

A full description of the format is provided in NL Agency (2012a, b).

RVO.nl[13] is the designated government agency for implementation of the agreements. All EEPs are reviewed by RVO.nl. This review comprises two elements: a check on completeness and a check on the level of ambition. If a company does not meet a certain minimum ambition, it has to provide an explanation for this lack of ambition. The reviewing process is closed with an advice from RVO.nl. If this advice is positive, the company can start implementation of its EEP. After completion of the reviewing process, all project information is uploaded to the monitoring database. In annual monitoring reports, companies report if and how the planned projects are implemented. If a company fails to implement the EEP, this is mentioned in the company reports, but until 2013, this had no consequence for the participation of individual companies.

The ultimate goal of an EEP is a list of energy savings projects that the company intends to implement in the next four years. This list should be the result of a careful consideration, being in line with company strategy, environmental context and legal requirements. The EEP should prove that the company has considered all possible options to improve energy efficiency. A description of this planning process, including the considerations of the company, are an obligatory part of the EEP (NL Agency 2012 a, b). There is no official definition of a 'project', but it should be a delimited activity being the result of actions of the company itself..

13 Rijksdienst voor Ondernemend Nederland (RVO.nl) or Netherlands Enterprise Agency is the name of a new merger organisation. The former NL Agency is part of this organisation. NL Agency is itself a merger of a.o. SenterNovem.

A 'project' can range from introducing a new metering system to the building of a completely new plant. This leaves some room for interpretation, as companies can define project boundaries themselves. A company might choose to merge all lighting projects (new lights in building A, B etc.) into one project. As each project must be monitored separately, companies (especially large ones) may be tempted to merge projects, to keep the number of projects manageable. On the other hand, it might be smart to keep projects in different buildings or business units separate if this is easier for the company's project administration or their implementation strategy.

For each energy savings project, inter alia the following data was available:

- category (*Process Efficiency*, *Supply Chain Efficiency* or *Renewable Energy*)
- subcategory
- certainty level ('certain', 'conditional' or 'uncertain')
- planned year of implementation & year of implementation
- deemed & realized primary energy saving (in Joules)
- payback period
- for 'conditional' projects, conditions that might block implementation
- for 'uncertain' projects, studies that need to be carried out before a project can start

A typical and important element of the project information is the so called 'certainty level'. For each project in the EEP, a company indicates how probable it is that this project will indeed be implemented. Projects with a payback period of 5 years or less have to be labelled 'certain' unless technical or other conditions exist which may hamper implementation. Companies face the threat of eviction from the covenant if they do not implement these projects, replace them for other projects or provide a valid explanation for why a project is not implemented.
If a specific condition has to be met before a project can be implemented, a project can be labelled 'conditional'. Such a condition might be a successful pilot project or a permit that has to be granted. Projects which might be possible but for which the company is not yet able to assess the deemed savings or the actual practicability, can be labelled 'uncertain'.
Under the covenant rules, a company is allowed to replace a planned project with another project, if this new project realizes at least the same amount of savings. When projects have been implemented that were not originally identified in the EEPs they are labelled 'additional'.
In order to analyse the research questions, we assembled two different datasets; one for the period 2009-2012 (LTA3 only) and one for 2013-2016 that also includes the companies of LEE. Table 3-1 indicates for which research questions the datasets are used.

Table 3-1. Characteristics of used datasets.

Nr.	Period	Covenant	Research questions
1	2009-2012	LTA3	1,2,3,4,5
2	2013-2016	LTA3+LEE	1,2

Data from LEE-companies are also available for the period 2010-2012, but could not be merged with LTA3 data because of differences in plan period and the used format. Analysis of the LEE-data over 2010-2012 show the same results as those of LTA3. Data from the EEPs for the 2013-2016 period cannot yet be used to assess implementation. The 2013-2016 plans do however give information on the conditions that might limit implementation of projects, information which is not readily available for the 2009-2012 period. Therefore, dataset 2 is used in section 3.3 to answer research question 2.

Only part of an EEP –the list of projects- was directly suitable for analysis as it was available in a uniform format. The rest of the EEP was available as qualitative descriptions that were not directly relevant to our analysis..

To analyse the research questions, only EEPs that were filed completely were used. To allow a comparison analysis, we excluded all companies that did not report for the complete monitoring period 2009-2012. This was the case for companies that entered the agreements after 2010, companies that left the agreement before 2012, or that did not file all monitoring reports for other reasons. All in all, 133 LTA3 were left out of the analysis for this reason, whereas data of 904 LTA3 were suitable for analysis. Because information on payback periods was not provided for all projects in the period 2009-2012, the analyses on this topic (section 3.4) were based on a lower number of companies: 798 for LTA3. To find a relation between PBP and implementation, a dummy variable for implementation was introduced and regressed against 12 classes of PBP.

3.3 Results

3.3.1 Planned projects

Table 3-2 shows the number of projects that have been planned by LTA3 companies for the period 2009-2012. In total, almost 12000 projects have been planned by 904 companies. On average, this is almost 13 projects per company, but considerable differences exist between companies: 99 companies have planned no projects at all, while 8 companies have planned more than a hundred projects (figure 3-1).

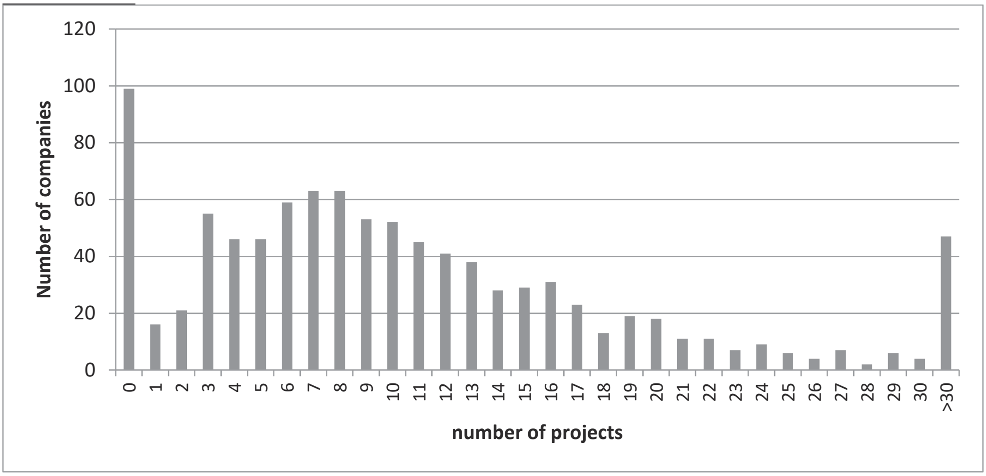

Figure 3-1. Distribution of projects per company planned in EEP 2009-2012 (LTA3, 904 companies).

By far the largest number of projects is found in the category *Process Efficiency*, especially in the subcategories *Adjustments in processes* and *Utilities and buildings*. Within the category *Supply Chain Efficiency*, most projects can be found in the subcategory *Reduction of raw materials* and *Optimisation of Distribution*. Within the category *Renewable Energy*, most projects are found in subcategories *Waste and Biomass* (mostly companies in the food- and drinks industry), *Ambient Heat* (heat pumps etc.) and *Purchase of Renewable Electricity*. The latter subcategory is under discussion within the covenant, as it is a relatively easy way for companies to reach significant covenant results against no or just limited extra costs, while the purchase of renewable energy mainly contributes to a decarbonisation of the energy supply and not to final energy savings.
As Table 3-2 shows, about half of the projects are qualified 'certain', which means that companies are certain these projects will be implemented.
Table 3-3 shows the deemed savings for the projects that are planned for the period 2009-2012. In this table *Process Efficiency* is the largest category as well, although the average savings per project in this category (2.1 TJ/project) is smaller than in *Supply Chain Efficiency* (6.4 TJ/project) and *Renewable Energy* (25.4 TJ/project). Within *Process Efficiency*, the largest subcategories are *Adjustments in Processes* and *Utilities and buildings*, as these subcategories had most projects and these projects are often larger. In the subcategory *Energy management*, projects are generally smaller (1.0 TJ/project). Projects labelled 'certain' are on average a little bit smaller in terms of energy savings than other projects.

Table 3-2. Number of planned projects in LTA3 period 2009-2012 (904 companies).

	Certainty level				
Category	Certain	Conditional	Uncertain	Total	Share
Process Efficiency	**5022**	**3129**	**.2048**	**10199**	**89%**
Energy management	1215	384	156	1755	*15%*
Utilities and buildings	1852	1492	884	4228	*37%*
Adjustments in processes	1808	1214	929	3951	*34%*
Strategic measures	92	39	60	191	*2%*
Other/unknown	55	0	19	74	*1%*
Supply Chain Efficiency	**367**	**180**	**181**	**728**	**6%**
Reduction of raw materials use	146	74	54	274	*2%*
Optimisation of distribution	105	39	47	191	*2%*
Improving product performance	32	14	21	67	*1%*
Lifetime extension	6	2	1	9	*0%*
Optimisation of disposal and re-use	37	31	21	89	*1%*
On site cooperation	16	7	29	52	*0%*
Energy performance of product	25	13	8	46	*0%*
Renewable Energy	**210**	**112**	**248**	**570**	**5%**
Waste and biomass	64	28	72	164	*1%*
Purchase of renewable electricity	84	55	19	158	*1%*
Ambient heat	44	12	50	106	*1%*
Water power	1	0	0	1	*0%*
Wind power	5	2	63	70	1%
Solar power	9	8	30	47	*0%*
Solar heat	3	7	14	24	*0%*
Total	**5599**	**3421**	**2477**	**11497**	**100%**
	49%	30%	22%	100%	

Table 3-3. Deemed savings (TJ) of planned projects LTA3 period 2009-2012 (904 companies).

	Certainty level				
Category	**Certain**	**Conditional**	**Uncertain**	**Total**	**Share**
Process Efficiency	**10801**	**6307**	**4931**	**22039**	**53%**
Energy management	1161	483	200	1845	*4%*
Utilities and buildings	3146	2352	1084	6582	*16%*
Adjustments in processes	4762	3384	3135	11282	*27%*
Strategic measures	1728	87	511	2326	*6%*
Other/unknown	4	0	0	4	*0%*
Supply Chain Efficiency	**1966**	**1190**	**1824**	**4980**	**12%**
Reduction of raw materials	1260	318	434	2011	*5%*
Optimisation of distribution	135	54	27	216	*1%*
Improving product performance	83	170	526	779	*2%*
Lifetime extension	5	12	0	16	*0%*
Optimisation of disposal and re-use	271	120	158	549	*1%*
On site cooperation	107	113	208	428	*1%*
Energy performance of product	106	403	471	980	*2%*
Renewable Energy	**5762**	**4106**	**5073**	**14941**	**36%**
Energy from waste and biomass	436	1169	2068	3673	*9%*
Purchase of renewable electricity	5185	2804	244	8233	*20%*
Ambient heat	130	121	26	378	*1%*
Water power	1	0	0	1	*0%*
Wind power	5	3	518	525	*1%*
Solar power	4	3	104	111	*0%*
Solar heat	1	5	2013	2020	*5%*
Total	**18529**	**11602**	**11828**	**41960**	**100%**
	44%	28%	28%	100%	

3.3.2 Implementation of projects

Table 3-4 shows the number of planned projects that has actually been implemented. For *Process Efficiency*, 80% of 'certain' projects have been implemented. Besides, not all of the implemented projects realised their deemed saving potential: only 73% of the originally planned saving potential is realised. Still, one can conclude that the largest part of 'certain' savings is realised. This is not the case for projects labelled 'conditional' or 'uncertain': Almost two thirds of 'conditional' projects are not implemented, while three quarters of 'uncertain' projects are not implemented. The realised saving potential of these projects is even lower.

About a quarter of implemented projects were not originally planned and are labelled 'additional' in table 3-4. The number of 'additional' projects is growing from 13% in 2009 to 38% in 2012, showing that most projects are planned for the first two years. Especially the number of 'certain' projects reduces drastically after two years: only 25% of the 'certain' projects are planned in the last two years of the plan period, see figure 3-2. There is a small portion of projects that were originally planned in the former plan period (2005-2008) but were delayed (labelled as 'delayed' in table 3-4). The overall ambition for LTA3-companies was to realise the saving potential of all 'certain' and 'conditional' projects (17.1 PJ). Of these projects, only 9.7 PJ (57%) has been realised. Of the total amount of planned savings for *Process Efficiency* (22.0 PJ), only 14.1 PJ (64%, including the 'additional' projects) was realised. When comparing these figures with the results of programs in other countries the following figures are found: just over half of the improvements suggested through the American IAC program have been adopted by industrial users (Shipley and Elliott 2006), whereas the Australian EEAP found an adoption rate of 80% (Harris et al. 2000). In the Belgian Auditing Covenant, which is highly comparable to the Dutch LTA, it was found that after two years 60% of the proposed measures were implemented or being implemented (Cornelis and Reunes 2012).

For projects under the category *Supply Chain Efficiency* and *Renewable Energy* the situation is very different, although we have to take into account the fact that the number of projects in these categories is much smaller than in *Process Efficiency*. For *Supply Chain Efficiency*, about half of planned 'certain' projects are implemented. The share of implemented 'conditional' and 'uncertain' projects is even lower than for *Process Efficiency*. The large amount of savings from projects that were not planned in the EEPs is notable: The savings from additional projects are even larger than the original saving potential. For *Renewable Energy*, these projects mainly consist of *Purchase of Renewable Electricity*. A possible reason for the high number of extra *Supply Chain Efficiency* projects could be that in many sectors special covenant projects were carried out to promote *Supply Chain Efficiency*. Another remark considering *Supply Chain Efficiency* projects is the fact that savings in this category are dominated by a few very large projects: 5 projects account for 30% of total savings.

Overall, LTA3 companies have reached the targets set in the EEPs mainly because of additional projects in *Supply Chain Efficiency* and *Renewable Energy*.

Table 3-4. Planning versus implementation of projects in 2009-2012 (LTA3, 904 companies).

	Number of projects			Savings (TJ)		
Certainty level	**Planned**	**Implemented**	**%**	**Planned**	**Implemented**	**%**
Process efficiency						
Certain	5022	4020	*80%*	10801	7891	73%
Conditional	3129	1164	*37%*	6307	1825	29%
Uncertain	2048	528	*26%*	4931	537	11%
Additional to EEP	0	1783	-	0	3685	-
Delayed*	0	334	-	0	196	
Total	**10199**	**7829**	**77%**	**22039**	**14135**	64%
Supply Chain efficiency						
Certain	366	179	*49%*	1966	1001	51%
Conditional	182	57	*31%*	1190	841	71%
Uncertain	180	28	*16%*	1824	128	7%
Additional to EEP	0	382	-	0	6100	-
Delayed*	0	106	-	0	1098	-
Total	**728**	**752**	**103%**	**4980**	**8071**	162%
Renewable Energy						
Certain	218	92	*42%*	5762	5253	91%
Conditional	114	13	*11%*	4106	182	4%
Uncertain	251	24	*10%*	5073	23	0%
Additional to EEP	0	298	-	0	31312	-
Delayed*	0	7	-	0	205	-
Total	**583**	**434**	74%	**14941**	**36770**	246%

*projects which were originally planned in the former planning period (2005-2008), but were delayed.

3.3.3 Conditions for implementation

If a project is labelled 'conditional', a company has to provide the condition which has to be fulfilled before the project can be implemented. There is a shortlist of default conditions to choose from (see table 3-5), or a company can provide an additional explanation.

Table 3-5. Conditions for implementation.

Condition	Explanation/example
1-Acceptance by market	Potential product changes must be accepted by clients.
2-Budget availability	Availability of project funding. Large overlap with 3.
3-Positive economic situation	Project profitability must be high enough, within company budget. A company's profitability must be sufficient. Large overlap with 2.
4-Product quality unaffected	potential product or process changes are not allowed to affect product quality, the robustness of the production process or labour conditions
5-Positive investment decision	Project must be profitable and costs must be small enough to take a positive investment decision. Overlap with 2 and 3
6-Management approval	Management/shareholders still have to take a decision on implementation. Large overlap with 5.
7-Company changes	Project implementation is dependent on implementation of other changes in the company, e.g. a large renovation or a new building.
8-Positive test outcome	Pilot test must show practicability of the project
9-Permit	Project implementation is dependent on a permit that has to be granted.

Table 3-6 shows the conditions that are linked to the planned 'conditional' projects for the period 2013-2016. About 3500 of the planned projects (out of a total of 12452), are labelled 'conditional'. For 2967 of these projects, one of the conditions listed in table 3-6 is actually registered. For 250 projects, more than one condition is stated. In our analysis, we use the first stated condition, assuming that this is considered the most important one.

About half of all stated conditions have to do with availability of resources (money or time). This is in line with Masselink (2008), who found that 'availability and allocation of capital' showed up as most important hurdle for investments.

For *Supply Chain Efficiency* financial conditions are less important than for other categories, although financial conditions are still mentioned most often. For *Supply Chain Efficiency*, conditions like 'positive test outcome' or 'acceptance by market' are stated often as well.

For *Process Efficiency* projects, financial conditions are stated most often too, except for *Energy Management projects*. This is not surprising as these projects often require small investments. For this category 'positive test outcome' is stated most often.

About one fifth of the conditions mentioned by the companies are technical in character: companies have to await positive outcome of experiments or pilot tests, before a final decision on implementation can be made.

Our results show that for projects with short PBP (2 years or less) financial conditions are relatively less important and technical conditions are more important.

Table 3-6. Conditions which could block 'conditional' projects 2013-2016 (LTA3 + LEE, 726 companies).

	Condition*									
Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Process Efficiency	**32**	**572**	**187**	**246**	**410**	**165**	**328**	**304**	**22**	**2337**
Energy management	10	37	11	40	15	18	28	43	1	215
Utilities and buildings	9	316	89	68	221	74	170	123	7	1101
Adjustments in processes	9	212	79	135	153	70	124	138	12	965
Strategic projects	4	7	8	3	21	3	6	0	2	56
Supply Chain Efficiency	**94**	**29**	**51**	**48**	**35**	**48**	**14**	**71**	**14**	**451**
Reduction of raw materials	40	12	20	29	12	9	6	28	3	177
Optimisation of distribution	17	6	12	5	7	25	3	18	4	112
Improving product performance	3	2	2	1	6	2	0	3	1	23
Lifetime extension	3	0	0	1	0	0	0	2	1	7
Optimisation of disposal and re-use	6	6	12	7	6	8	3	15	2	72
On site cooperation	9	2	0	0	2	3	0	2	2	22
Energy performance of products	16	1	5	5	2	1	2	3	1	38
Renewable Energy	**7**	**44**	**31**	**5**	**27**	**12**	**10**	**14**	**16**	**179**
Energy from waste and biomass	4	4	13	3	8	1	9	9	3	62
Purchase of renewable electricity	3	15	9	2	9	10	0	0	5	56
Ambient heat	0	6	2	0	3	0	1	2	2	16
Wind power	0	2	1	0	0	0	0	0	4	7
Solar power	0	13	6	0	5	1	0	2	2	31
Solar heat	0	4	0	0	2	0	0	1	0	7
Total	**133**	**645**	**269**	**299**	**472**	**225**	**352**	**389**	**52**	**2967**

*for explanation of the numbers, see table 3-6.

3.3.4 Use of payback periods

Dutch LTA companies can apply three possible methods to determine if a project is profitable: Net Present Value (NPV) and two versions of the Payback Period (PBP) . The 'simple' PBP accounts only for benefits from lower energy costs ('energy-only') whereas the 'variable' PBP includes all cash flows (i.e. also the ones not related to energy). Note that these definitions are different from the general definitions for PBP used in literature (i.e. simple and discounted payback, where simple payback does not account

for the time-value of money).The guidelines for the EEPs do not dictate a preferred method (SenterNovem 2008b), although in a separate instruction some basic guidance is provided when to apply which method: NPV for larger projects and projects with varying cash flows, and PBP for smaller projects (NL Agency 2011).
Almost all companies (>95%) have used the simple PBP method. This is in line with Russell and Young (2012) stating that simple payback is the most frequently cited investment metric. Despite the fact that it is obligatory to provide a PBP for every planned project, there are many projects for which no value is provided. In most of these cases, a PBP is not given since the company has insufficient data to calculate a PBP. The number of projects without a PBP is highest in 'uncertain' projects. Cornelis and Reunes (2012) also reported a high number of IRRs that were reported semi-quantitative (e.g. ">15%") instead of quantitative or not at all. In total, 3113 *Process efficiency* projects with a PBP were used for the analysis.

Figure 3-3 shows the result of an analysis of the payback periods of planned projects for the 2009-2012 period for the category *Process Efficiency* (LTA3). For *Supply Chain Efficiency* and *Renewable Energy*, this analysis is not meaningful, because of the smaller number of projects and the many projects for which no PBP is given.
Most projects (2045) have a PBP of less than 2 years, of which 63% are 'certain'. This is in line with other studies, like Anderson and Newell (2004) who observe that 79% of companies have payback thresholds less than 2 years. Bundgaard et al. (2013) found that many of the energy saving projects in industry use a PBP as short as 1-2 years, and 20% have PBP less than 1 year. Stenqvist and Nilsson (2012) report an average PBP of 1.5 years for measures reported under the Swedish PFE. Most recommended projects in the US Industrial Assessment Center program have simple PBPs of less than 1 year (Shipley and Elliott 2006). Considering these outcomes, it is notable that we find that 29.8% of planned projects have a PBP over 5 year, and 12.6% of projects with a PBP over 10 years and in some cases even more than 20 years, also for projects that are labelled 'certain'. These are projects that would never be implemented according to neoclassical investment decision theory. This observation is more in line with Martin et al. (2011) who find an average PBP of 4 years for investments in energy saving measures, and 10% of investments with a PBP of more than 7 years. Also Aalbers et al. (2004) observe a significant (5-15%) share of technologies with PBP of more than 20 years. These projects are likely to be implemented because of strategic reasons, not for profitability.

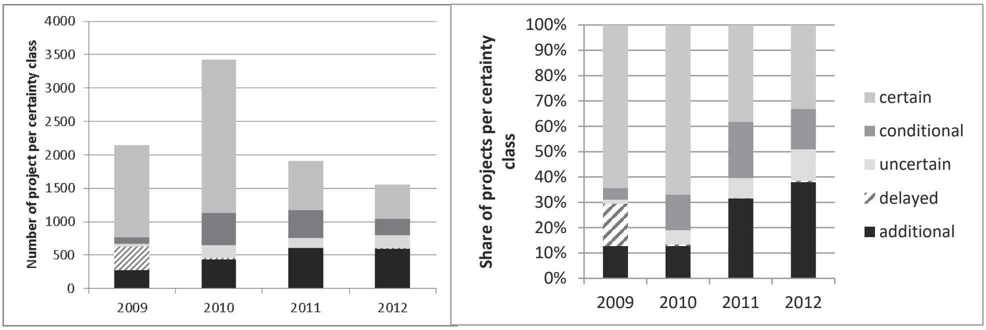

Figure 3-2. Distribution of projects per certainty class from 2009 to 2012 (LTA3, 904 companies).

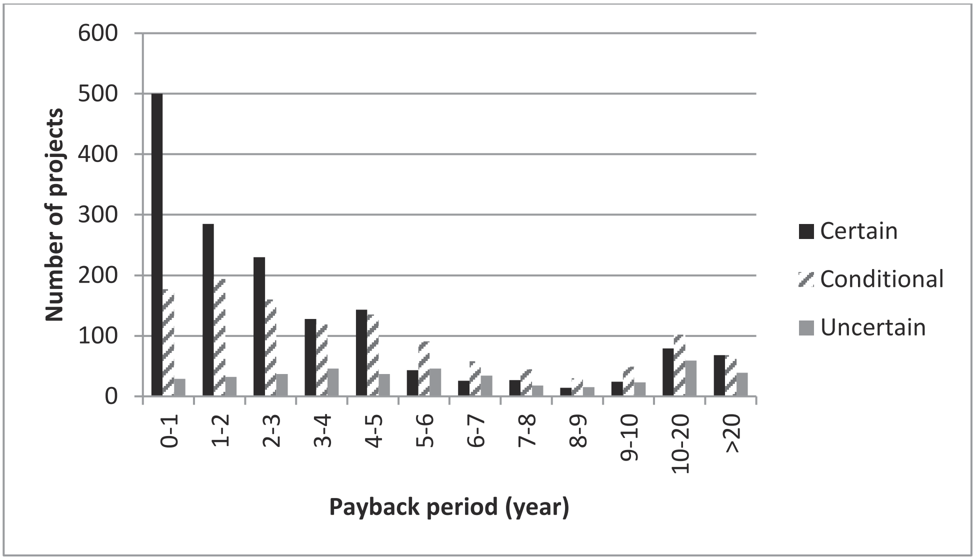

Figure 3-3. Used payback period of Process Efficiency projects planned for 2009-2012 (LTA3, 3113 projects, 798 companies).

The average PBP (not weighted for project size) for planned 'certain' *Process Efficiency* projects for 2009-2012 is 6.4 year, see table 3-7. The average PBP of 'certain' projects is lower than the PBPs of 'conditional' and 'uncertain' projects. As some projects have a very high PBP of over 50 years, a better indicator would be the median (2.1 year for planned 'certain' projects), as it is less sensitive to outliers. For projects with that high PBP-values, the simple PBP method does not lead to meaningful results. The average PBP of 'certain' projects is higher than found by Martin et al. (2011). This can be explained by:

1) The fact that projects with a PBP of 0 have not been taken into account, as no distinction could be made between projects with a PBP of 0 and those without a PBP (unknown or missing). Within the group of projects without a PBP, there are several hundred projects without an investment and hence a PBP of 0. If these projects would be counted, the average PBP would be much lower.
2) The use of an 'energy-only' PBP method. By taking into account only the benefits of energy savings, the resulting PBP will be higher than when other benefits are taken into account as well.

The average PBP of implemented projects is slightly lower than that of planned projects, but the difference is small, see table 3-7. Especially for 'conditional' and 'uncertain' one would expect companies to implement projects with the lowest PBP first. To delve deeper into the reasons for this small difference, we made a comparison of the share of implemented projects for different classes of PBP, which is shown in table 3-8. For both planned and implemented projects, there is a negative correlation between the frequency and PBP. However, once planned, projects with a low PBP are implemented just as often as projects with a higher PBP (>5 year). For all classes about 80% of the 'certain' projects are actually implemented. For 'conditional' and 'uncertain' projects the share of implemented projects is lower, but shows no significant difference between low and high PBP. On the one hand, our observations show that not all profitable projects are implemented. This phenomenon has been observed earlier and is called the efficiency gap (Hirst and Brown 1990). On the other hand, many projects are implemented that are not profitable, at least not at the time of planning. This can lead to two possible conclusions: at the time of planning it was not possible to make a correct calculation of PBP, because input parameters like energy prices were uncertain, or PBP is not that an important criterion for the actual decision to implement many of the projects. This issue is further discussed in section 4.

Table 3-7. Average PBP of planned and implemented Process Efficiency projects (based on the number of projects) [14].

	Certainty level			
Dataset	**Certain**	**Conditional**	**Uncertain**	**Total**
Planned LTA3 2009-2012 (904 companies)	6.4	6.8	10.6	7.1
Implemented LTA3 2009-2012	5.9	5.8	10.0	6.0

14 A weighted average would give very different results, but is not appropriate here, as there is no relation between certainty level and project size.

In the guidelines for the EEPs, a positive Net Present Value at a discount rate of 15% is presented as an alternative for a PBP of 5 years. Given the fact that virtually all companies use the PBP criterion in their EEPs, it is interesting to see if the alternative NPV method would lead to other results. The simple PBP method differs from the NPV method in that it does not take into account the time value of money and the lifetime of projects. This means that the same project could be considered 'profitable' according to one method, but not according to the other:

- PBP becomes irrelevant when the PBP exceeds the lifetime of a project. A project with a payback period of 4 years might be considered profitable according to the covenant rules, but if this project has a short lifetime of 3 years, it will not be profitable using the NPV method.
- PBP scores worse than NPV for projects with a much longer lifetime than the PBP, as PBP ignores cash inflows after the payback period: a project with a PBP of 8 years could have a positive NPV. In other words: this project is profitable (NPV>0) but is not obligatory (PBP>5 years) according to the covenant criteria. This phenomenon can be observed for projects with a long lifetime.

These examples are visualized in figure 3-4, which shows the relation between lifetime and the internal rate of return (IRR), with the dark line visualizing a project with a PBP of 5 year. All projects below this line are profitable according to the covenant criteria regarding PBP, whereas projects above this line are not. In 2 of the 4 segments in figure 3-4, the outcome of IRR and PBP calculation lead to the same conclusion (i.e. a project is profitable or a project is not profitable), but in the other 2 segments, the two methods lead to opposing conclusions.

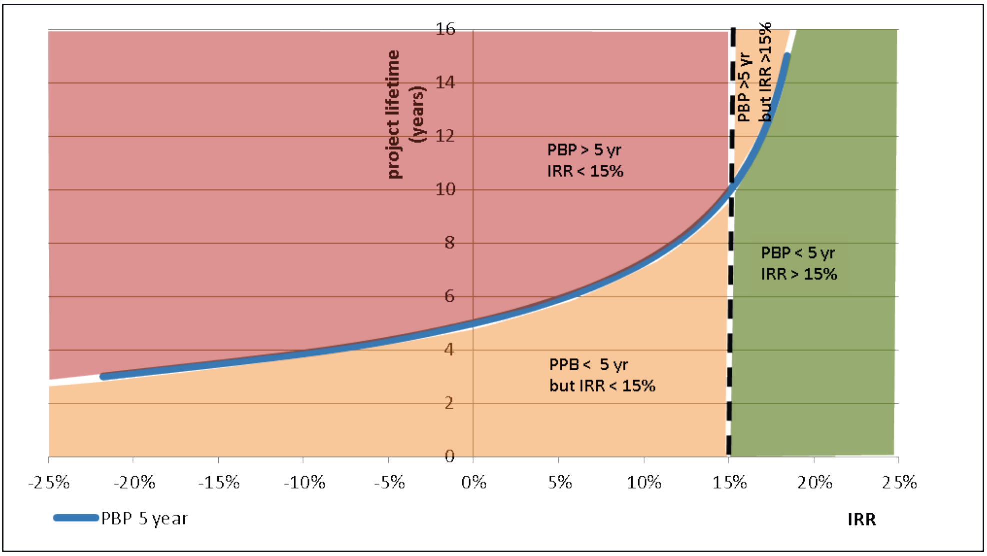

Figure 3-4. Relation between project lifetime and IRR.

An important, but unknown element of the planned projects is the lifetime, because this is not part of the obligatory EEP-format and is missing in the PBP calculation. Nevertheless, some general remarks are possible. Within the category of projects in "Energy Management and Good Housekeeping", part of the projects are behavioural, like awareness campaigns or audits, with an assumed short lifetime, often less than 3 year (CEN 2007). In the other categories (Utilities, Processes, Strategic) lifetimes will generally be longer (>10 years). Within the Dutch LTAs, the assumption is that projects will have an effect during the complete duration of the covenant (12 years). In Annex V of the Energy Efficiency Directive (European Parliament and Council 2012), default lifetimes of 10-25 years are proposed for several replacement projects.
Potentially, the difference between the two calculation methods might explain the high share of implemented projects with a PBP longer than 5 years and a lifetime longer than 10 years. Although we are not able to determine this difference with current data, an indication is that in the group of implemented projects with PBP>5 yr., a relatively large share of projects within the category "adjustments in processes" has a long lifetime (> 10 years).

3.4 Conclusion and discussion

1-Are planned projects actually implemented?

In section 3.2 we observed a large difference between planned and realised savings. A large part of 'conditional' and 'uncertain' projects has not been implemented, whereas a great share of 'certain' projects has been realized. Still about 20% of projects with a PBP less than 5 years has not been implemented. This suggests a deviation from the rule that all these projects should be implemented.
Overall, we can conclude that only the majority of 'certain' projects are actually implemented and that a large share of realised savings stems from projects that were not originally planned in the EEPs. A noticeable aspect of the covenant is the rule that a company can substitute a planned project for another project with the same amount of savings. Basically, this rule provides an escape for the obligation to implement all profitable projects, even though the outcome in terms of implemented savings is the same. Therefore, the obligations of participating companies –and their enforcement- become unclear: should they implement specific projects or achieve a specific amount of energy savings independent from the projects? This might imply that the Dutch policy makers should reconsider the distinction between 'certain' and other projects.

Considering the large amount of planned projects that are not implemented, we observed that the reason for not implementing a project is often formulated by companies in a very generic way. Better classification and monitoring of the reasons for non-implementation, especially for 'conditional' projects, would improve the way how governmental bodies can facilitate companies.

2-What is the effect of changing circumstances during the time of planning and implementation of projects?
The difference between planned and implemented projects can have three possible reasons: at the time the EEP was drafted companies were not aware of these saving possibilities, changing circumstances urged companies to change their plans or strategic behaviour by companies.

The first reason is probably true for most additional projects in the last 2 years of the planning period. This observation suggests that the planning period of 4 years is too long for reliable planning of projects, a conclusion that was also made in the evaluation of the LEE-covenant in 2013 (Hendriksen and van der Kolk 2013). A plan period of 1 or 2 years might be better suited to the investment planning of companies and lead to a better match between planning and realisation. However, the current EEP format is so extensive that a biennial plan would result in a too high administrative burden. Thus, for a better fit to companies' investment planning, the instrument should aim for a shorter plan period and a more concise plan format. Especially smaller companies have a shorter horizon and are faster and more flexible than larger companies, as they tend to be less sophisticated or deliberate in their approach to energy improvements (Russell and Young 2012). This is especially true in periods with uncertain economic conditions, such as experienced in the 2009-2014 period.

Due to lack of data, we cannot determine if changing circumstances between planning and implementation of projects have an influence on the realization of projects. The development of prices of energy, technology and work could have an impact on the outcome of PBP-calculations: rising energy prices will shorten the PBP, rising prices of technology and labour will increase PBP. In the 2009-2012 period, electricity prices for industrial consumers decreased on average with 20.6% according to Eurostat Statistics, after an increase from 2007. This would result in less projects being profitable, although the effect is not large. For projects that save gas, no effect is to be expected, as gas prices remained constant during the period analysed. As there is no detailed information on prices of technology and labour, we cannot establish if these might have a significant impact. It is probable that the economic crisis in the period 2009-2012 affected the investment plans of companies, but it cannot be established how large this effect is.

A third possible reason for the high number of additional projects is that companies are conservative in their planning: if they put more projects in their EEP, they might be forced to implement them. Stenqvist and Nilsson (2012, p.234) also found that "some companies are careful not to list measures they were not sure about" and found many additional projects being implemented. Although the design of the Dutch agreements tries to evade this phenomenon by providing the possibility of planning 'conditional'

and ‘uncertain’ projects (i.e. projects that are not obligatory), still companies may be hesitant in planning projects they are not absolutely sure about. Companies might also be tempted to report a too high PBP so that a project is not considered profitable –and obligatory. The fact that the minimum targets (consisting of only ‘certain’ projects) were easily reached suggest that these targets are fairly conservative and more savings are possible than originally planned This conclusion was shared in an evaluation of the LTA-covenant in 2013 (Volkerink et al 2013). This implies that an adjustment in the EEP-format regarding the distinction between projects of different certainty level should be considered.
The design of the ‘simple’ PBP-method which uses only energy benefits, could also provoke strategic behaviour: excluding the non-energy benefits from the PBP calculation leads to a higher PBP. Whether this indeed leads to strategic behaviour cannot be proven.

3-What is the payback period of planned projects?
The PBP of planned projects varies widely. The median of planned projects is only 2.1, but 30% of the projects have a PBP over 10 year. The average PBP of planned projects is 6.4, much higher than the median because some projects have a very high PBP of over 50 year. The fact that many companies plan projects with a PBP over 5 years, is in line with Cooremans (2009, 2012), who concludes that “financial factors play only a partial, or even secondary, role in investment decisions; the strategic character of an investment seems to have more influence on decision-making than profitability” (p.243). Howarth et al. (2000) claim “there is substantial evidence that the usual workings of the market mechanism fail to support the full adoption of cost-effective energy-efficient technologies” (p.479) and “the neoclassical theory of the firm constitutes an overly constrained approach to understanding the economics of voluntary participation programs” (p.485). DeCanio (1998, p.453) as well states that “organizational and institutional factors are important determinants of firms’ investment behaviour”.

4-Is there a relation between implemented projects and their payback period?
There is a negative correlation between PBP and the number of identified projects: the lower the PBP, the higher the number of identified projects. However, we do not observe a relation between implemented projects and their payback period: there is no difference in the share of implemented projects with a high or low PBP. This implies that either PBP was not assessed properly in the EEPs or that PBP for projects with a higher PBP is not the most important criterion for implementation. Both conclusions might question the use of and focus on PBPs in the Dutch voluntary agreements and Environmental Management Act. Other criteria are probably more important than PBP. Anderson and Newell (2004) observed that adoption rates are higher for projects with shorter payback periods, lower costs, greater annual savings, higher energy prices and greater energy conservation. If investments are crucial for continuity of production,

an investment will be made regardless of PBP; the energy savings are considered a co-benefit. If an energy saving project has negative consequences for production, it will not be implemented regardless of the PBP. In other words, non-energy benefits of a project such as its strategic character, productivity gains or lower maintenance costs are more important than PBP. If PBP is indeed not important for investment decisions, then the obligation to implement projects with a PBP less than 5 years might lead to suboptimal outcomes, for instance when a project with small savings and PBP less than 5 years is compared to a project with high savings and a PBP more than 5 years.
Therefore, comparable policy instruments should consider other criteria to use as leverage to stimulate companies to invest. Fleiter et al. (2012) categorize projects according to 12 characteristics and 3 attributes, arranged on the likelihood of implementation. This classification scheme provides a starting point for another design of such a policy instrument.

5a-Are projects with a short PBP also profitable according to criteria the companies use themselves?
We cannot determine whether projects with a short PBP are also profitable according to investment criteria used by the companies as we do not know if and what other criteria are used. The two methods to calculate PBP (energy-only vs all benefits) do not match with the methods generally used (simple and discounted payback). The use of a method that calculates PBP based only on benefits from energy savings will lead to a higher PBP. The analysis of conditions for implementation in table 3-5 shows that for projects with short PBP (2 years or less) financial conditions are relatively less important and technical conditions are more important. The fact that projects with a PBP less than 2 years are sometimes not implemented whereas projects with a PBP more than 20 years sometimes do get implemented, suggests that companies have included other –non-financial-criteria in their own evaluation.

5b-Should the covenants adopt more sophisticated methods?
Given our results and the results of other scholars, one might discuss the reliability of the simple PBP as evaluation method, especially for projects with longer lifetimes. The fact that the simple PBP does not take into account the time value of money or cash flows after the PBP makes PBP a worse indicator than IRR, especially for projects with longer lifetimes. Fleiter et al. (2012) claim “the payback period is actually a poor indicator for profitability“. So, in theory, other methods are better predictors of profitability. This issue offers a dilemma. On the one hand, the simple PBP method seems too simple to provide correct information, especially years before a project is implemented, when project variables are only partly known. The current lack of project information on investment and lifetime prevents good enforcement of the rules on investment criteria.

On the other hand, more sophisticated methods are not suitable for large amounts of projects -for governmental organisations with limited budgets it is not possible to check if the right input data is used. Here it should be noted that even more sophisticated methods still have to deal with the same uncertainties in project variables. If profitability is less important than the strategic character of an investment using a more sophisticated economic evaluation technique will not help in predicting which projects will be implemented. The PBP criterion should rather be seen as an indicator for profitability than as a stick for the government to force companies to invest.
One might try to avoid this dilemma by creating different rules for different type of projects, e.g. small and large projects, or projects with shorter or longer lifetimes. It is however doubtful if such a distinction helps to solve this problem or only make things more complicated. It is advisable to develop better guidelines to allow better judgement of profitability of projects.

4

Chapter 4

Barriers and drivers for energy efficiency: Different perspectives from an exploratory study in the Netherlands[15]

15 Enrico Cagno, Andrea Trianni, Christiaan Abeelen, Ernst Worrell, Federica Miggiano. Published in: Energy Conversion and Management 102 (2015) 26–38

4.1 Introduction

Large energy efficiency improvement potentials are found among European small and medium-sized enterprises (SMEs), where more than two thirds do not implement even simple rules to manage energy use (EC 2007). Despite policy-making efforts, policy makers and environmental associations do not seem to act effectively in promoting energy efficiency measures (EEMs), as they neither tackle the existing barriers nor are they able to address the relevant drivers. Therefore, it is necessary to find new and more effective ways to assess the importance of barriers and drivers on the firms' decision-making process for adopting EEMs and to understand the role of the actors responsible for drivers' promotion, highlighting the key mismatches between the companies' and external actors' perspectives. Based on a theoretical framework recently developed, we have carried out an exploratory investigation analyzing a set of metalworking SMEs participating in the Dutch voluntary agreements. To gain different perspectives, the study involved the major external actors, i.e. the national energy agency, the governmental and the industrial organizations, to map their views in the decision-making process.

In this paper we first present the approaches adopted to investigate barriers and drivers in the decision-making process (Section 2). In Section 3 we provide a brief overview of the Dutch policy instruments on energy efficiency and a discussion on the relation of policy instruments to the drivers and barriers. Section 4 describes the research framework and methods, while Section 5 presents and discusses the research findings. Conclusions and suggestions for further research are reported in Section 6.

4.2 Barriers and drivers for industrial energy efficiency

To analyse barriers, many different theoretical approaches can be found (e.g. Sorrell et al. 2004; Cagno et al. 2013), as well as empirical studies (see Cagno and Trianni 2014; Brunke et al. 2014) for recent reviews). On the contrary, scarce recent contributions on drivers exist, focused merely on highlighting which drivers should be fostered (e.g. Apeaning and Thollander 2013, Cagno and Trianni 2014, De Groot et al. 2001), without characterizing them in the decision- making process, and just a few taxonomies have emerged recently (Sudhakara et al. 2013). After a comprehensive and exhaustive literature review, we have chosen a recently developed framework for the analysis of both barriers and drivers, encompassing the latest taxonomies of barriers and drivers, as well as their effect on the decision-making process (Cagno et al. 2013, Trianni et al. 2013a). Cagno et al. (2013) identify 27 barriers categorized into 7 groups: economic, organisational, behavioural, technological, competences, informative and awareness (table 4-1). Trianni et al. (2013a) identify 23 specific drivers, divided into 4 groups according to the type of action, respectively: regulatory, economic, informative and vocational training (Table 4-2). Previous empirical research has not fully analysed the decision making process and the involved actors. A broader perspective can help to understand which barriers are experienced and how to overcome them. According to the framework developed by Trianni et al. (2013a), to achieve an improvement in energy efficiency, it is necessary to go through several steps constituting the decision-making process. If a decision-maker encounters a barrier during one or more of these steps, the progress of the investment assessment will be delayed or interrupted. In the first step of this process, awareness on energy efficiency issues must be achieved, followed by needs and opportunities identification, technology identification, and planning of the effective intervention. Financial analysis and financing represent the fifth phase, while the last step regards the effective installation, start-up and training. In each step, different drivers or barriers can be important. The model (Trianni et al. 2013a) identifies the major actors in the various stages of the decision-making process: government, financial institutions, industrial associations (IAGs), technology providers, manufacturers, installers, energy service companies (ESCOs), energy suppliers, competitors, allies, clients and also the individual enterprises.

Table 4-1. Synthesis of the taxonomy of barriers adopted for empirical investigation. Source: Cagno et al. (2013).

Barrier Groups	Specific Barriers
Technology-related	Technologies not adequate
	Technologies not available
Information-related	Lack of information on costs and benefits
	Information not clear by technology providers
	Trustworthiness of the information source
	Information issues on energy contracts
Economic	Low capital availability
	Investment costs
	External risks
	Intervention not sufficiently profitable
	Intervention-related risks
	Hidden costs
Behavioural	Other priorities
	Lack of sharing the objectives
	Lack of interest in energy-efficiency interventions
	Imperfect evaluation criteria
	Inertia
Organizational	Lack of time
	Divergent interests
	Lack of internal control
	Complex decision chain
	Low status of energy efficiency
Competence-related	Implementing the interventions
	Identifying the inefficiencies
	Identifying the opportunities
	Difficulty in gathering external skills
Awareness	Lack of awareness

Table 4-2. Synthesis of the taxonomy adopted for drivers for empirical investigation. Source: Trianni et al. (2013a).

Driver Groups	Specific Drivers
Regulatory	Long-term energy strategy
	Willingness to compete
	Efficiency due to legal restrictions
	Increasing energy tariffs
	External energy audit/submetering
	Technological appeal
	Clarity of information
	Trustworthiness of information
Economic	Cost reduction from lower energy use
	Information about real costs
	Public investment subsidies
	Private financing
	Management support
Informative	Voluntary agreements
	Green image
	Management with real ambition
	Staff with real ambitions
	Knowledge of non-energy benefits
	External cooperation
	Awareness
	Availability of information
Vocational training	Programs of education and training
	Technical support

4.3 Relation of drivers and barriers to policy instruments

4.3.1 Overview of Dutch energy policy instruments

The Netherlands has a long history of policy on energy savings and efficiency, starting in 1973 in the first oil crisis. Since 1990, voluntary agreements (VAs) form an important part of the Dutch policy mix on energy efficiency in industry. We focus on present instruments explicitly directed to industry. A more elaborate description can be found in Gerdes (2012). The instruments are arranged according to the typology introduced by Tanaka (2011) in three different types: prescriptive policies are regulations, mandates and obligations that directly compel specific actions by companies. Economic policies are taxes and tax reductions, direct financial support, tradable permits and price policies. Supportive policies are tools to identify opportunities for energy efficiency, cooperative measures, capacity building and information policies. This classification resembles that of the drivers in the framework described in the previous section. In Figure 4-1 an overview of Dutch policy instruments on energy efficiency in industry from 2000 onwards is presented. Table 4-3 provides a description of these instruments.

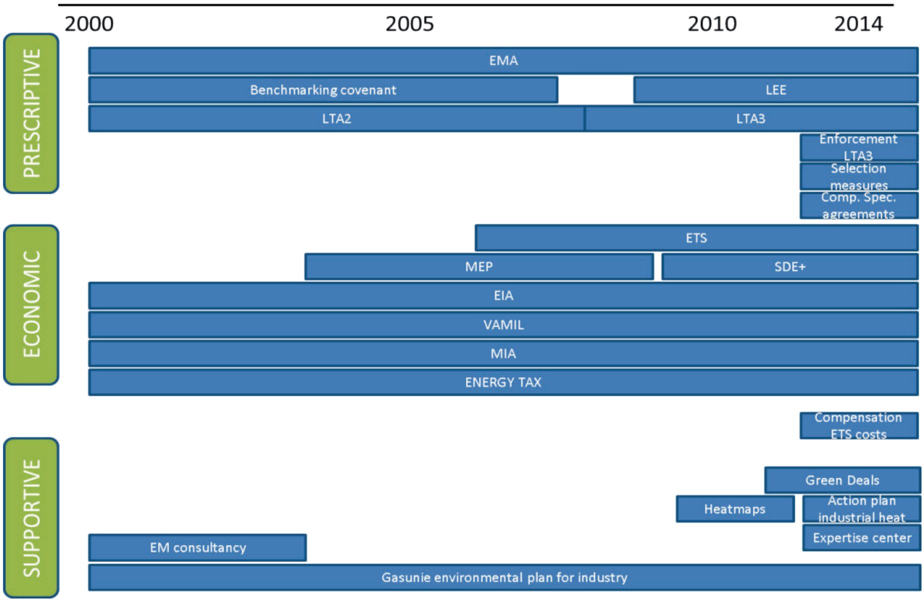

Figure 4-1. Overview of Dutch policy instruments on energy efficiency in industry from 2000 onwards. Source: Gerdes (2012), SER 2013.

Table 4-3. Overview and typology of current policy instruments on energy efficiency in the Netherlands.

Instrument	Description
Prescriptive	
Environmental Management Act (EMA)	This act sets out an integrated approach to environmental management in the Netherlands and provides the legal framework by defining the roles of national, provincial or regional, and municipal government. One of the obligations under this act is that companies are obliged to implement all energy saving measures with a payback period of up to 5 years.
LEE (Long term agreement on Energy efficiency for ETS-companies)	Signed by most of the companies that formerly participated in the Benchmarking covenant. Although LEE is meant in particular for companies that fall under the EU-ETS scheme, not all LEE companies actually participate in EU-ETS. In total, 114 companies in 7 sectors joined the LEE-covenant, with a combined energy use of 602 PJ (2011). Only a few of the LEE-companies fall under the definition of SME.
LTA3	The LTA3, combined energy use 237 PJ (2011), is joined by over 900 companies in 32 sectors, mostly industrial, but also some services and rail transport (Abeelen et al. 2013). Although there is a large diversity in terms of size, the majority of LTA3 companies fall under the definition of SME's.
Energy Agreement for sustainable growth	Signed by more than forty organizations – including central, regional and local government, employers' associations and unions, nature conservation and environmental organizations, and other non-governmental organizations and financial institutions. The overarching goal of the Energy Agreement is to achieve a completely sustainable energy supply system by 2050. The parties to the Energy Agreement will strive to achieve a.o. a saving in final energy consumption averaging 1.5% annually and a 100 petajoule (PJ) saving in the country's final energy consumption by 2020; In total, more than 100 actions have been identified in the Energy Agreement, of which 5 (mentioned in this table) are relevant to industry. The great diversity of the actions makes it difficult to characterize the agreement as a policy instrument. Part of the actions are prescriptive, part is economic or supportive.
Energy Agreement: Enforcement LTA3	An agreement with municipalities and regional government agencies to prioritize enforcement of the energy-saving obligation in the EMA.
Energy Agreement: Selection recognized measures	A list of specific approved measured that have proven to be profitable in other companies. Municipalities and regional government agencies could use this list in the enforcement of the EMA (http://www.infomil.nl/onderwerpen/duurzame/energie/erkende-maatregelen/).
Energy Agreement: Company specific agreements	Agreements with individual companies to implement certain projects, in exchange of specific support
Economic	
Regulating Energy Tax (REB)	A yearly set levy on the use of electricity, coal and natural gas. The height of the levy decreases with increasing energy use (tariffs on Belastingdienst.nl). Large industrial customers (>10 million kWh) can get a retribution of the tax on electricity when they are participating in the VAs.
EU-ETS	The largest industrial companies can trade emission certificates.
Compensation ETS-costs	A subsidy scheme for ETS companies to compensate for rising electicity prices. Budget 2015 is €50 million
SDE+	A € 3.5 billion subsidy scheme for production of renewable energy and combined heat and power (CHP).
EIA	Companies investing in energy-efficient technologies can deduct part of the investment costs from their profits. A list of possible energy investments is set yearly. There are five application areas, each with its own energy performance requirement: corporate buildings; processes; transport resources; sustainable energy; energy advice. Total 2013 budget for EIA was 151 Million euro (RVO.nl, 2014).
MIA/VAMIL[16]	Tax deduction schemes for investments in environmental friendly products or business resources. Total 2013 budget of €125 Million (website RVO.nl 2014).
Supportive	
Green Deals	In a Green Deal, central government signs a deal with market parties to overcome one or more problems that hamper progress towards a sustainable society. In fact, a Green Deal is a sort of mini-covenant, with a limited number of participants and a focused objective. Green Deals focus largely on non-financial barriers (Abeelen and Both, 2012).
Action Plan industrial heat	A plan to utilize industrial waste heat
Expertise centre energy efficiency	An independent centre of expertise to assist businesses and funding bodies in identifying the most effective measures
Gasunie environmental plan for industry	Free advice on energy saving possibilities

16 MIA (Environmental investment rebate) and VAMIL (Arbitrary depreciation of environmental investments)

4.3.2 The role of VAs in the Dutch policy mix

VAs have been part of the policy mix on energy efficiency since 1990. Since 1990, five different agreements on industrial energy efficiency have been implemented, each with particular characteristics. In 2014, two different agreements on energy efficiency are in force: LTA3 and LEE. Companies joining a VA endorse both rights and duties stemming from the text of that agreement: (NL Agency 2009) for LEE, (NL Agency 2008) for LTA3. The most important obligation for companies within the VAs is to plan and implement EEMs. Therefore, they have to deliver an Energy Efficiency Plan (EEP) every four years and an annual monitoring report. Participating companies must plan and implement all profitable measures, whereby profitable means measures with a positive net cash value at an internal discount rate of 15%. Alternatively, a payback period of five years can be used (NL Agency 2008, 2009). Figure 4-2 presents a schematic view of the interaction between the different actors in the LTA3. In 2013, both LTA3 and LEE have been evaluated. The LTA3 evaluation report concluded that the covenant partners had so far reached their objective to realise savings of 2% per year (including supply chain efficiency and renewable energy). The researchers encountered difficulties in establishing additionality, but concluded that the contribution of the LTA-program in these savings was limited; a large part of the savings would have been realized anyhow. They also concluded that the process within the agreements had helped raising awareness in covenant partners (Volkerink et al. 2013). The evaluation of LEE concluded that LEE contributed to the identification and planning of energy saving measures, including the long-term perspective for sectors and companies. Participants thought LEE contributed more to the implementation of measures than other policy instruments (EU-ETS, energy tax and Vamil (Hendriksen and van der Kolk 2013).

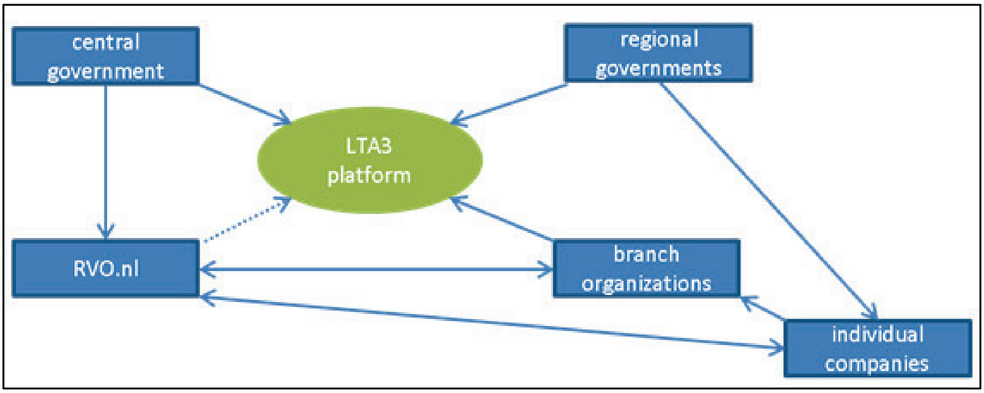

Figure 4-2. Overview of actors in LTA3.

<u>*4.3.3 Relation between policy instruments and drivers*</u>

The description in Section 3.1 gives an overview of the mix of different Dutch policy instruments. In this section we deal with the issue of defining which drivers are affected by such instruments (as summarised in Table 4-4).

The EU-ETS, as an economic instrument, affects only one driver: cost reduction of lower energy use, and that only indirectly (assuming a reduction of CO_2-emission is realized by lowering energy use, which is not always the case). The VAs LEE and LTA3 are aimed at several drivers: mostly informative, but also some of the drivers within the category regulatory. The driver 'cost reduction' is not directly affected, but is often used as a motivational argument to stimulate participants to invest in energy saving projects. The fiscal instruments EIA and VAMIL use the same mechanisms: as a public investment subsidy, they lower investments costs. Arguably, they could also use the 'technological appeal' driver; companies could show a higher acceptance of new technological equipment if information on this technology gives an impression of a modern, appealing and fashionable installation. The EMA is a purely regulatory instrument. By obligating profitable measures, it tries to speed up these investments. However, it also restricts freedom of choice for companies. Generally speaking, different instruments affect at least one driver in both regulatory, economic and informative driver types. Only the vocational type is not affected. Also on the level of individual drivers, most drivers are affected by one or more instruments.

The driver 'public investment subsidies' is affected by the fiscal instruments EIA and VAMIL. 'Management with real ambition' is a goal for the VAs. However, a recent evaluation concluded that targets in LTA3 were modestly ambitious (Volkerink et al. 2013). One could therefore doubt if this driver is successfully targeted. Two of the economic drivers and the vocational drivers, are not affected by any of the main instruments.

Table 4-4. Relation between instruments and drivers.

		EU ETS	LEE+LTA3	EIA	VAMIL	EMA
	Instrument type	**E**	**P**	**E**	**E**	**P**
Drivers	**Instrument subtype**	**TP**	**VA**	**IS**	**IS**	**OC**
Regulatory	Long-term energy strategy	-	+	-	-	-
	Willingness to compete	-	+	-	-	-
	Efficiency due to legal restrictions	-	-	-	-	+
	Increasing energy tariffs	+	-	-	-	-
	External energy audits/ sub metering	-	+	-	-	-
	Technological appeal	-	-	+	+	-
	Clarity of information	-	+	-	-	-
	Trustworthiness of information	-	+	-	-	-
Economic	Cost reduction from lower energy use	+	+	+	+	-
	Information about real costs	-	-	-	-	-
	Public Investment subsidies	-	-	+	+	-
	Private financing	-	-	-	-	-
	Management support	-	+	-	-	-
Informative	Voluntary agreements	-	+	-	-	-
	Green image	-	+	-	-	-
	Management with real ambitions	-	+	-	-	-
	Staff with real ambitions	-	+	-	-	-
	Knowledge of non-energy benefits	-	+	-	-	-
	External cooperation	-	+	-	-	-
	Awareness	-	+	-	-	-
	Availability of information	-	+	-	-	-
Vocational	Programs of education and training	-	-	-	-	-
	Technical support	-	-	-	-	-

Legend
Instrument types: E=Economic; P=Prescriptive
Instrument subtypes: TP=tradable permits; VA=Voluntary agreements; IS=Incentives and subsidies; OC=Obligations/commitments (see for explanation of drivers Table 4-2).
'+' means this driver is used as a mechanism by the instrument to achieve its goals,'-' means this is not the case.

4.3.4 Relation between policy instruments and barriers

ETS is predominantly meant to deal with economic barriers (see Table 4-5). By increasing the price of CO_2 (and hence energy), energy efficiency projects will become more profitable. One could argue that the 'awareness' barrier is relevant as well, as the price increase could increase attention as well. VAs can relate to a host of barriers, mainly behavioral and organizational. Which barriers are tackled depends on the design of the agreement. Tanaka (2011) categorizes VAs in 6 types, according to their design on two axes: incentives and the degree of certainty that rewards or penalties are exercised. Some VA's have strict obligations and tend towards a prescriptive instrument, others rely more on self-action, supported by networking and information sharing, appealing more to behavioral or organizational barriers. The Dutch agreements tend more towards the latter. However, as the agreements have stronger obligatory elements (EEP's, monitoring) than for instance subsidy schemes (Volkerink et al. 2013). It seems reasonable to categorize them as prescriptive policies. According to Tanaka (2011), they are categorized under types II (agreements with annulments/exceptions from existing measures) and IV (agreements with government support for actions). Covenants contribute to awareness, commitment of all parties and exchange of information, thereby making optimal use of the knowledge of other companies (Gerdes 2012).

The two fiscal instruments EIA and VAMIL appeal predominantly to economic barriers, by effectively lowering investment costs. By providing a list of possible profitable investments, the instruments are supposed to deal with the information barrier as well. The EMA is mainly focused on behavioral barriers: by making energy saving investments compulsory, the Act forces companies to change behavior.

Table 4-5. Relation between instruments and barriers according to policy design.

		Main instruments				
		EU ETS	**LEE / LTA3**	**EIA**	**VAMIL**	**EMA (Wm)**
Instrument (sub)type		E	P	E	E	P
Barriers		TP	VA	IS	IS	OC
Technology	Technologies not adequate	-	-	-	-	-
	Technologies not available	-	-	-	-	-
Information	Lack of information on costs and benefits	-	-	+	+	-
	Information not clear by technology providers	-	-	-	-	-
	Trustworthiness of the information source	-	+	-	-	-
	Information issues on energy contracts	-	-	-	-	-
Economic	Low capital availability	-	-	-	-	-
	Investment costs	+	-	+	+	-
	External risks	-	-	-	-	-
	Intervention not sufficiently profitable	-	-	-	-	-
	Intervention-related risks	-	-	-	-	-
	Hidden costs	+	-	+	+	-
Behavioral	Other priorities	-	+	-	-	+
	Lack of sharing the objectives	-	+	-	-	+
	Lack of interest in energy-efficiency interventions	-	+	-	-	+
	Imperfect evaluation criteria	-	+	-	-	-
	Inertia	-	+	-	-	-
Organizational	Lack of time	-	+	-	-	+
	Divergent interests	-	+	-	-	-
	Lack of internal control	-	+	-	-	-
	Complex decision chain	-	+	-	-	-
	Low status of energy efficiency	-	-	-	-	-
Competences	Implementing the interventions	-	+	-	-	-
	Identifying the inefficiencies	-	+	-	-	-
	Identifying the opportunities	-	+	-	-	+
	Difficulty in gathering external skills	-	+	-	-	-
Awareness	Lack of awareness	+	+	-	-	+

Legend

Instrument types: E=Economic; P=Prescriptive; S=Supportive

Instrument subtypes: TP=tradable permits; VA=Voluntary agreements; IS=Incentives and subsidies; OC=Obligations/commitments (see for explanation of barriers Table 4-1).

'+' means the instrument aims to lower this barrier, '-' means this is not the case.

Overall, the mix of policy instruments addresses most barriers. On an aggregated level, 6 of the 7 barriers are covered at least partially. Only the technology barrier does not seem to be covered. On a more detailed level however, some barriers are not covered by any instrument. Within the economic barriers for instance, 'low capital availability', 'intervention related risks' and 'external risks' are not covered by any instrument. Behavioural and organisational barriers are covered best, only 'lack of internal control' is not covered by any instrument.

4.4 Research methods

The research has adopted a novel approach to seek the mechanisms between policy instruments, drivers and barriers in the decision-making process of SMEs, focusing on the role different external major actors play in the various stages of the decision making process, based on the taxonomies of barriers and drivers for industrial energy efficiency. Figure 4-3 shows the main features of the model. At the bottom, the steps of the decision-making process are shown (following (Trianni et al. 2013a), they will be six). Each step is affected by different barriers (in the figure barriers are shown with bars placed on the respective step). The height of the barriers will show the importance attributed to the barrier by the respondents in the investigation. It is possible to represent the categories of barriers (following (Cagno et al. 2013), they will be seven) with reference to their impact on the decision-making steps. The width of the arrow from drivers to barriers shows how strongly a driver could affect one or more barriers in a decision-making step. Additionally, the top half of the figure shows the drivers (following (Trianni et al. 2013a), they will be twenty-three) and the actors most responsible for promoting such drivers. The investigation has been conducted interviewing the people knowledgeable and responsible for energy issues within a set of fifteen Dutch metalworking manufacturing SMEs in the province of Utrecht. Our study takes place in one of Europe's most competitive countries, with historical concern on industrial energy efficiency and environmental policies (Energy Research Centre of the Netherlands 2012). Furthermore, it is the Netherlands' most sustainable region with the most favourable expectations for economic growth of all the regions in Western Europe (EC 2013). Due to the exploratory nature of this study, firms have been randomly chosen within the metalworking sector. All firms participated on a voluntary basis. Semi-structured interviews, as described by Patton (1991) and taking inspiration from Yin (2003), were conducted during a visit to the production site. During the interview, a relatively detailed understanding of the firm has been acquired. We have collected general data about the enterprise (e.g. number of employees, annual average net turnover for the last five years, firm's organization), information regarding the characteristics of the production process, and information about how energy management activities are conducted (Table 4-6). Next, the interviewee was asked to complete a short, guided questionnaire regarding his/her view of the barriers, highlighting their roles in the decision-making process (step by step), as well as which drivers could act on the barriers on the single decision-making steps. Furthermore, the external actors that were able to influence the drivers were interviewed. As information on drivers, decision-making steps and external actors in literature are scarce, we decided to use the highest level of details given by the taxonomies; whilst for barriers we asked for type of barriers (i.e. group), always specifying which specific barriers were to consider within that group. The questions were scored on a 4-point Likert scale, which ranged from 1 ("not important/absent") to 4 ("very important/very strong"). Even though the sample size is limited due to the exploratory nature of this study, we still consider the findings to be of interest for their ability to help us form initial impressions, some of which may be expanded upon in future research.

To study the perceptions of firms and national external actors, five additional semi-structured interviews (with the same questions as for the firms) have been conducted with governmental institutions at a national (A1), regional (A4) and local (A5) level, as well as national (A2) and local (A3) metalworking IAGs (Table 4-7). In this way, different perspectives can be identified, not only between firms and other actors, but also between governmental and industrial organizations.

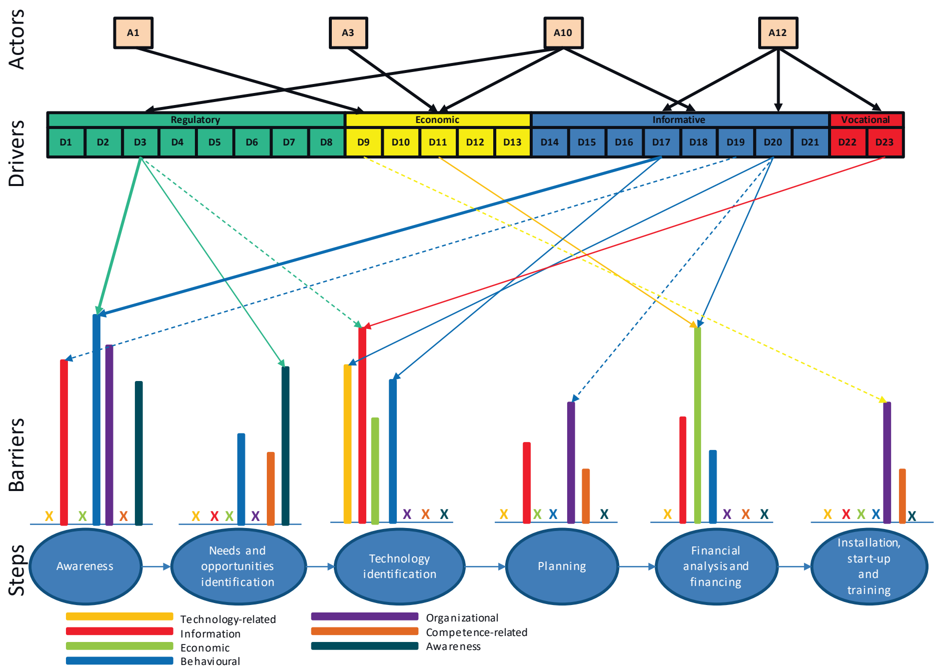

Figure 4-3. The framework to describe the mechanisms connecting barriers, drivers and actors in the decision-making processes to undertake an investment in an EEM.

Table 4-6. Firms' characteristics.

Firms	Size	Sector	Products/Activities
C1	ME	C25	Manufacture of metal components for the medical sector
C2	ME	C24	Production of customized steel castings
C3	SE	C24	Cast of non-ferrous alloys
C4	SE	C24	Design and manufacture of aluminium castings
C5	SE	C25	Manufacture of metal grills, hangers and plates
C6	ME	C25	Surface treatment of automotive, aviation and semiconductor components
C7	SE	C24	Anodizing of aluminium profiles and construction components
C8	SE	C24	Manufacture of castings in metal alloy
C9	ME	C25	Manufacture of locker systems
C10	SE	C25	Manufacture of metal components
C11	ME	C25	Production of zinc coils, strips and sheets
C12	SE	C25	Production of metal fences and screens
C13	SE	C24	Manufacture of aluminium castings
C14	SE	C25	Manufacture of metal components
C15	SE	C25	Production of stainless coils, strips and sheets

Size: ME = medium-sized enterprise; SE = small-sized enterprise.
Sector: C24 = manufacture of basic metals; C25 = manufacture of fabricated metal products.

Table 4-7. Governmental and industrial organizations' characteristics.

Organisation	Description	Role	Tasks
A1	National energy agency. Governmental institution belonging to the Ministry of Economic Affairs	Link between EU, the Dutch government and society	Implementing policies regarding sustainability, innovation and international business
A2	National metalworking IAG. Large industrial association group in the metal sector	Link between the government and metalworking companies; national network in the metal sector	Guaranteeing expertise and knowledge, advising on social, legal, economic and fiscal field, and providing information about changes in laws and polices
A3	Local metalworking IAG. Local industrial association group in the metal sector	Local network in the metal sector	Promoting new technical developments and spreading information about technical and regulations changes.
A4	Regional government. Environmental protection agency	Assessing success and failure of regional environmental policy; connection between EU directives and regional implementation	Releasing licenses and certifications, monitoring compliance standards
A5	Local government. Municipality	Governing the province	Favouring economic growth and developing processes for innovative and sustainable change in the province

4.5 Results

This section has been structured as follows: we analyse barriers, decision-making steps, drivers and most relevant actors from the perspective of the sampled SMEs and the other actors (i.e. governmental and industrial organisations) involved in the study. The final part of the section discusses the link of the Dutch VAs (LTA3) to the results of our investigation. Due to the limited number of responses, only the major and significant findings will be discussed.

4.5.1 Analysis of the involved SMEs

The studied SMEs agree on the priority of the main barriers expressed in general terms (see table 4-8). They put economic, organisational, behavioural barriers in first positions, in line with past studies (Trianni et al. 2013a, b, c ; Trianni and Cagno 2012; Sardianou 2008; Rohdin and Thollander 2006). Moreover, firms also agree on the most relevant barrier in each step of the decision-making process, as follows (Figure 4-4):

1st step: awareness and behavioural barriers;
2nd step: information-related barriers, followed by economic and organisational;
3rd step: technology-related followed by information-related;
4th step: organisational barriers;
5th step: economic barriers; and
6th step: behavioural barriers.

Moreover, firms also agree on the criticality of the decision-making step. As from figure 4-4, the needs and opportunities identification (step 2) and financial analysis (step 5) are deemed as the most critical steps. Interviewees seem to underestimate the very first step (awareness). Nonetheless, it is worth remarking that without proper awareness of the relevance of energy efficiency, the whole decision-making process of adopting an EEM could be stopped at its very beginning.

Table 4-8. Ranking of barriers. The ranking was built on the basis of the number of the firms that consider the barrier important or very important.

Barrier	Important or very important
Economic	12
Organizational	7
Behavioural	6
Information-related	5
Competence-related	5
Awareness	4
Technology-related	4

As most important drivers (table 4-9), confirming previous studies, we find long-term energy strategy (Rohdin and Thollander 2006; Rohdin et al, 2007; Thollander et al.2007; Thollander and Ottoson 2008; Cooremans 2012), clarity of information (Cagno and Trianni 2013), cost reduction from lower energy use (De Groot et al. 2001; Hasanbeigi et al., 2010; Thollander and Ottoson 2008; Thollander et al. 2013), public investment subsidies (De Groot et al. 2001; Cagno and Trianni 2013), technical support (Liu et al. 2012), and trustworthiness and availability of information (Cagno and Trianni 2013). Interestingly, the interviewees showed a strong alignment on some mechanisms (Figure 4-5), i.e. which driver, promoted by which external actor, acts on a main barrier of a given decision-making step. It is observed that, though a large number of actors could be responsible for stimulating a single driver (table 4-10), firms frequently cite just one of them. Other firms and technology suppliers are deemed as the most relevant, differing from other studies where the role of financial institutions was considered of primary importance (see e.g. (Cagno and Trianni 2013). Firstly, firms feel themselves to be responsible for promoting the following drivers: long-term energy strategy, having ambitious staff and management, management support, and promoting programs of education and training.

Secondly, technology suppliers are responsible not only for technical support, but also for information-related drivers such as availability, clarity, trustworthiness as well as knowledge of the non-energy benefits (NEBs). This is crucial, in line with recent literature highlighting that a greater knowledge of all benefits could effectively enhance the EEMs' adoption rate (Trianni et al. 2014; IEA, 2014b).

Thirdly, beside public investment subsidies, the authorities are considered as important for the promotion of VAs and regulations, thus pushing enterprises to improve energy efficiency.

Table 4-11 synthesizes the main mechanisms relating barriers and drivers in the decision-making steps. In detail, long-term energy strategy and clarity of information are the most relevant factors in the first stage. Understandable information is necessary in order to develop consciousness about energy efficiency, but having a long-term energy strategy is important to make the company aware of chances. There is a kind of causal link between them. In fact, any effective approach to energy efficiency must be first of all perceived as important Aflaki et al. 2013). Then, actions to be undertaken and expected results from implementing any EEM should be as clear and concrete as possible. Awareness could be the logical strongest driver in support of the first step. Nevertheless, interviewees have not placed it in first position, even though still considered as important, possibly reflecting their need to have something more tangible to incentivize their personnel to improve energy efficiency, as found by Aflaki et al. (2013). It is also possible to state which actors are responsible for the promotion of the drivers involved in the first stage: the technology suppliers and the firm. The existence of VAs is also recognized as driver, even if to a lesser extent.

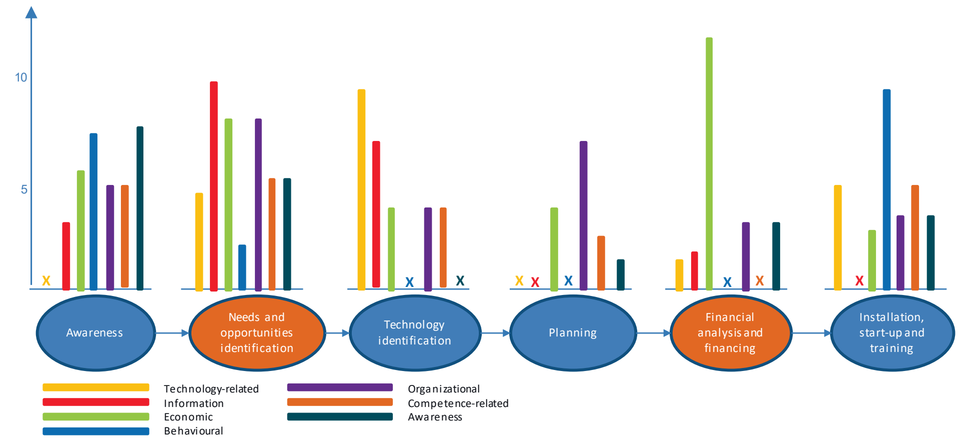

Figure 4-4. Barriers on the decision-making steps. The ranking was built on the basis of the number of the firms that consider the barrier important or very important on the particular decision-making step. Step 2 and step 5 were identified as the most troubled, even if step 1 and 2 were affected by more barriers.

Table 4-9. Ranking of drivers. The ranking was built on the basis of the number of the firms that consider this driver important or very important.

Driver	Important or very important
Long-term energy strategy	8
Clarity of information	8
Cost reduction from lower energy use	8
Public investment subsidies	7
Technical support	7
Trustworthiness of information	7
Availability of information	7
Increasing energy tariffs	6
Staff with real ambitions	5
Awareness	5
Voluntary agreements	4
Green image	4
Management with ambitions	4
Management support	4
Information about real costs	4
Efficiency due to legal restrictions	3
External energy audit/submetering	3
Private financing	3
Knowledge of non-energy benefits	3
External cooperation	3
Willingness to compete	2
Programs of education and training	1
Technological appeal	1

High information-related barriers mainly affect the second step, mostly tackled by having clear, available and trustworthy information. Technology and energy suppliers are the main actors involved in their promotion.
In step 3 the technology-related barrier is significant, and technical support is the strongest driver during technology identification. Other potential active driving forces are trustworthiness of the information source and clarity of information. Both technology suppliers and installers play a relevant role. Organizational barriers arise in the fourth step (planning). Technical support is still very relevant and also long-term energy strategy is crucial, as it can shorten the process and contribute to leaner, more efficient planning, thus also acting effectively on the economic barrier.
Additionally, organizational hurdles seem to be influenced by competent and ambitious management. Installers, technology suppliers, and the firm itself can act on this step, having the power to activate those drivers. Three of the 5 active drivers in step 5 belong to the economic group. Public investment subsidies may represent an important stimulus in making investments more appealing and economic, as well as cost reduction through reduced energy use. A long-term energy strategy, which was a significant factor in the previous step, may also be beneficial in this stage, improving the success of energy management, and taking long-term benefits into consideration when evaluating the profitability. Increasing energy tariffs and information about real costs of energy may stimulate considering the adoption of EEMs and to compare different investment opportunities once the decision of intervention has been made. Also, VAs may help in this step. Whilst the government has a major responsibility in fostering public subsidies and VAs, the energy suppliers and the company, together with technology suppliers and IAG are also relevant actors. In the installation phase (sixth step), behavioral issues emerged as major troubles. At the same time, committed staff and technical support are the highest ranked drivers. According to the respondents, staff with real ambition
is the main stimulating factor in the installation period, able to reduce the behavioral barriers. Whilst motivated staff may increase firm's efficiency, technical help provides support to the real implementation of the new EEM, aiding the staff with the start-up phase. Interestingly, while technical support is mainly related to installers and technology suppliers, the promotion of staff with real engagement is a firm responsibility. Of course drivers could also have a secondary effect on other barriers rather than the highest ones. For example, clarity of information is very effective on information-related barriers, but has also secondary impact on awareness, behavior, and technology related obstacles. Interviewees have also pointed out that some drivers have influence on almost every barrier, like energy auditing and sub-metering, knowledge on non-energy benefits, and collaboration with external actors, although not being listed within the highest ranked drivers.

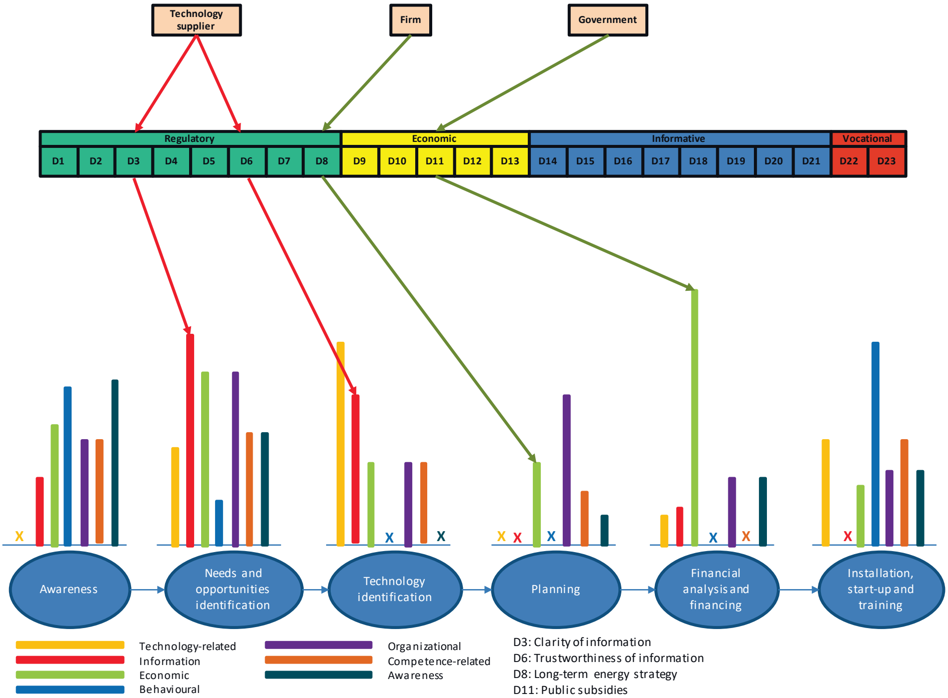

Figure 4-5. Different mechanisms of barriers, drivers, actors and decision-making process. In particular, same actor promoting different drivers to act on the same barrier on different decision-making steps (in red); and different actors promoting different drivers to act on the same barrier on different decision-making steps (in green). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 4-10. Main actors responsible for drivers according to firms.

Driver	Actors Firm	Tech. supplier	Govern.	Installer	Energy supplier	Client	IAG	Financial Instit.	Compet.	ESCO	Manuf.	Partner	Other
Long-term energy strategy	S		w		w								
Clarity of information		S		W	w								
Cost reduction from lower energy use		w	w		w								
Public investment subsidies			S										
Technical support		S		S									
Trustworthiness of information		S			w								
Availability of information		**S**	w		S		w						
Increasing energy tariffs			w		S								
Staff with real ambitions	S												
Awareness	S						w						
Voluntary agreements			S										
Green image						S							
Management with ambitions	S												
Management support	S												
Information about real costs			w		w		S						
Efficiency due to legal restrictions			S										
External energy audit/ submetering	w				w								
Private financing								S					
Knowledge of non-energy benefits		S					w						
External cooperation							S					w	
Willingness to compete									S				
Programs of education and training	S												
Technological appeal		w											

("S" = if the promotion is considered to be strong; "w" = if it is weak)

To summarize, the investigation allowed us to understand the relevance of firm itself, as well as external actors, which was evident in particular regarding the first (and most troubled) steps of the decision-making process. On the one hand, the firm itself has often the power to activate the drivers in several decision-making steps. On the other hand, regarding technology suppliers, they emerge in all the decision-making steps as main actor responsible for different drivers acting on the main barriers, sometimes in collaboration with other actors (installers, energy suppliers, and government).

4.5.2. Analysis of other actors

When we look at the other actors involved in the study (i.e. governmental and industrial organizations), results show a substantial agreement on the fact that the financial crisis is holding firms back from new investments in general, and even more if energy efficiency is not considered as an urgent matter. Beside this agreement, even a general common understanding of the barriers is disputed, and the ranking of barriers differs from what is indicated by the studied SMEs. As a first example, only the involved national IAG does not deem competence-related issues as relevant (similarly to SMEs). This could be explained by the fact that the IAG is in charge of guaranteeing skills and knowledge about the sectorial activities, therefore deeming its own activity as sufficient. The other investigated actors, nonetheless, evaluate competence related barriers of enterprises as a primary issue. Secondly, the national energy agency does agree with firms on the importance of 'lack of awareness', but this opinion is not shared by the IAGs. The position of the main barriers on the decision-making steps is clearly quite inconsistent with that of firms (see figure 4-6). As an example, the IAGs (either national or local) believe that the highest barriers are found in the last step, when real implementation happens. Nevertheless, they have completely opposite opinions on the most suffered barriers: the national IAG cites organizational, technology-related, economic, information-related barriers, whilst the local IAG highlights the others, i.e. behavioral, competence-related, awareness barriers. Additionally, we found a misalignment in the perception of the most critical decision-making steps. In fact, according to the external actors, technology identification (step 3) and installation (step 6) represent the most critical steps, while step 2 and 5 are most critical according to firms. This means that external actors just highlight where problems are seen, and not where the problems are generated. This misalignment might really affect the effectiveness of policies proposed. When dealing with drivers to energy efficiency and the interaction between barriers, drivers, decision-making steps and actors, misalignments between enterprises and other actors are even more evident, as shown by the following two examples considering the two most important drivers perceived by firms (long-term energy strategy and clarity of information). The local IAG does not see energy strategy as a relevant driver. For the national energy agency and local government this driver is important to tackle organizational and awareness

barriers. According to the regional government, it tackles economic, organizational and technology related barriers, whilst for the national IAG the information-related and behavioral barriers are important. The sampled SMEs believe this driver affects primarily economic barriers, followed by organizational and awareness barriers. Clarity of information is considered a strong factor among governmental institutions, whilst industrial associations deem it as marginal. Despite every actor being aware of its great potential in abating informative barriers, the effect on other barriers is disputed. Indeed, according to the national energy agency, also economic and technological issues could be tackled, whereas the local IAG and the regional government
extend its action also to behavioral and awareness barriers. Two additional comments regarding economic drivers are worth noting. First, the role of cost reduction from lowered energy use is deemed very important by the political institutions and less relevant by the industrial ones. Additionally, the role of public subsidies is disputed. In fact, according to IAGs, public subsidies have a marginal role, whilst for the governmental institutions they are quite important. Moreover, besides economic barriers, regional government and national energy agency believe that public subsidies are able to reduce technology-related barriers, whilst other actors strongly disagree on that.

Table 4-11. Main mechanisms (decision-making step – barrier(s) – driver(s) – actor(s)) identified by firms.

D-M step	Main barrier(s)	Main driver(s)	Main actor(s)
1st	Awareness & Behavioural	Long-term energy strategy Clarity of information Voluntary agreement	Firm Technology supplier Government
2nd	Information-related	Clarity of information Trustworthiness of information Availability of information	Technology supplier Technology supplier Energy suppliers
3rd	Technology-related	Technical support Trustworthiness of information Clarity of information	Installer + Technology supplier Technology supplier Technology supplier
4th	Organizational & Economic	Technical support Long-term energy strategy Management with real ambition	Installer + Technology supplier Firm Firm
5th	Economic	Public investment subsidies Cost reduction from lower energy Long-term energy strategy Increasing energy tariffs Information about real costs Voluntary agreements	Government (Technology supplier+ Energy supplier+ Government) Firm Energy supplier IAG Government
6th	Behavioural	Staff with real ambition Technical support	Firm Installer + Technology supplier

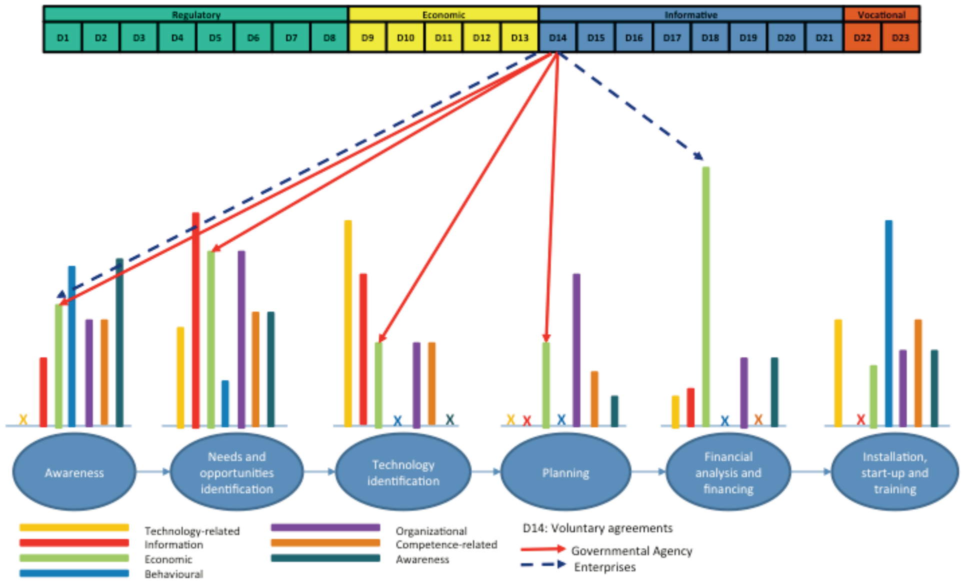

Figure 4-6. Comparison of mechanisms of barriers, drivers, actors and decision-making process between firms (in blue) and the national energy agency (in red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Finally, the analysis of drivers pointed out an additional interesting finding. External actors indicate as most relevant factors the ones that they can act on. For example, the national energy agency suggests VAs and subsidies as very important stimuli.

4.5.3 Alignment of voluntary agreements to drivers and barriers

If we take a closer look at the column for VAs (such as LTA3) in table 4-5, we see that the design of the LTA3 is such that a host of barriers is addressed. Focusing on behavioral barriers: 'Lack of interest in energy efficiency' and 'other priorities' are supposed to be addressed by keeping energy on the agenda for companies, through compulsory energy efficiency plans and monitoring reports. 'Inertia' is addressed by showing opportunities, best practices and benchmarking information. This also helps to tackle 'imperfect evaluation criteria' and 'lack of sharing the objectives'.

In theory, all behavioral barriers are covered. Organizational barriers are also incorporated in the original design of LTA3; 'Low status of energy efficiency' is addressed by keeping the subject on the agenda. 'Divergent interests' are prevented by sending information not only to energy coordinators, but also to management and use 'social pressure'. 'Complex decision chain' and 'lack of time' are addressed by providing information to energy coordinators.

Regarding competences, problems with 'identifying inefficiencies' are addressed by the obligatory energy balance in the EEP. The EEP also tackles the barrier of 'identifying opportunities' by an obligatory list of possible saving projects. Support for the barriers 'implementing interventions' and 'difficulty in gathering information' is provided by information on best practices. Awareness barrier is addressed by the same mechanism as behavioral barriers, namely by keeping energy on the agenda. One conclusion of the LTA3-evaluation was indeed that the LTA3-process has helped to raise awareness (Volkerink et al. 2013). However, findings here show that awareness was not the most important barrier. Moreover, the importance of economic barriers by all respondents raises the question if the existing financial instruments are appropriate and sufficient.

Most respondents in the LTA3-evaluation (Volkerink et al. 2013) claimed that cost savings are the most important reason to participate. A large majority of companies indicated that LTA-projects have been (very) profitable. However, about half of respondents indicate that they would have implemented those projects anyway, had LTA3 not existed (Volkerink et al. 2013). As it is, the existing financial instruments focus solely on lowering the investment costs, not on other economic barriers. It would be advisable to investigate how the adjustment of the present financial instruments could lower other economic barriers. According to Rezessy and Bertoldi (2011), five conditions for successful implementation of VAs are needed: (i), ambitious, but realistic and quantifiable targets; (ii) a proper institutional framework; (iii) an evaluation mechanism; (iv) a credible and enforceable mechanism to discourage non-compliance; and (v) support for participants.

According to Volkerink et al. (2013), the design of LTA3 matched many of those conditions: there is a quantifiable target, a qualified supportive institution, an evaluation mechanism, support for participants and discouragement of non-participation. However, for three of these conditions, successful implementation is threatened. In particular:

-the targets do not seem to be very ambitious. The Energy Agreement has agreed upon company-specific agreements – thus meant to increase ambition levels –, but these are specifically meant for ETS-companies, so will not be relevant for most LTA3-companies;

-It remains unclear whether the threat of enforcement of the EMA is seen as credible, as in practice enforcement is rare. For this issue, the Energy Agreement has introduced an agreement to increase enforcement SER 2013), but details still have to be agreed upon;

-Customer satisfaction studies by the energy agency show that participants value the provided support, but fear that budget cuts will threaten proper support of the agreements.

Such issues may be responsible for the misalignment between the investigated SMEs and the national energy agency on the role of VAs and the corresponding pattern of action (figure 4-6). According to the sampled SMEs, VAs are of medium importance, whilst the national energy agency ranks this driver among the strongest.

Moreover, the two patterns of action look pretty different. In conclusion, this kind of misalignment could give enterprises the perception of a minor relevance of the program (LTA3) promoted by the national energy agency.

4.6 Conclusions

Our exploratory study in the Netherlands among metalworking SMEs and the main governmental and industrial organizations aimed to analyze some mechanisms, i.e. which driver, promoted by which external actor, acts on a main barrier of a given decisional-step, and the different perceptions of the most relevant actors. Firm's responses reflected a very rational position. A structural alignment in views among enterprises could be observed, since they substantially agreed not only on the most relevant barrier in each step of the decision-making process, but also on the main drivers and the main actors responsible for them. The firm itself has often the power to activate important decision-making steps. Additionally, firm's suppliers, in particular those related to technologies and energy, sometimes together with other actors (installers, government) play a crucial role in all the decision-making steps as main actors responsible for different drivers acting on the main barriers. Nevertheless, when looking at the governmental and industrial organizations, results showed that a common understanding of the barriers is non-existent, as the interviewees only agree on the primary role of economic barriers. Mismatches appear when considering the mechanisms relating barriers, drivers, decision-making steps and actors. The most critical steps in the decision-making process according to governmental and industrial organizations do not correspond to those that emerged from enterprises' responses. This kind of misalignment may cause ineffectiveness of policies proposed by such actors. Although the Dutch LTA3 appears to fulfil the conditions for a successful VA, their successful implementation is questionable.

While companies agree on the high importance of a long-term energy strategy, they completely decouple the effect of a long-term energy strategy with the VAs impact on decision-making steps and barriers, even though the submission of an Energy Efficiency Plan in the medium-long term is included in the covenants. Although VAs represent the most popular energy policy on energy efficiency in the Netherlands, they do not seem to be considered by SMEs as a stimulus to improve energy efficiency. Despite the intention to address several barriers, the VAs seem to have little impact on the most important barrier (i.e. economic ones). Moreover, economic barriers are only partly addressed by other instruments. In conclusion, it is difficult to assess whether an energy efficiency project is implemented because of the agreements, or rather by autonomous initiatives. Even though this study was focused on a small sector in the Netherlands and on a voluntary basis, we believe that the method could be applied to other sectors and to other policy instruments.

Whenever a policy instrument uses a policy theory to impact specific barriers, our model could be used to test the policy theory. As this is just an exploratory investigation, more extensive empirical work should be performed to generate further insights. We believe that future research should further investigate such issues, investigating the drivers for increased competitiveness and sustainability, as only scarce contributions in the literature can be found. In doing so, the difference between the design of the policy instrument and the perception by participants should be analyzed. Such evidence could help external actors to fully understand the difficulties and needs of SMEs and thus develop the most appropriate policy instruments.

Furthermore, we believe that increased sample size – a limitation of this study – could provide more robust evidence of the various factors and mechanisms. Indeed, future efforts could be extended from Dutch metalworking SMEs other sectors, countries, regions, as well as firm size. Additionally, firm characteristics such as energy intensity, innovativeness, production complexity, market, supply chain position could affect enterprises' responses and therefore should be carefully considered by further research.

5

Chapter 5

Counting project savings – An alternative way to monitor the results of a voluntary agreement on industrial energy savings[17]

17 Christiaan Abeelen, Robert Harmsen, Ernst Worrell.
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5.1 Introduction

Industry is responsible for 28% of final energy demand in the world (IEA 2014a). Since the potential for energy savings in industry is significant (Saygin et al. 2011; Cahill and Ó Gallachoír 2012a; Boβman et al. 2012), an important contribution from industry is required in order to achieve ambitious economy-wide energy efficiency goals. A number of the EU Member States has introduced voluntary agreements (VAs) that aim to deliver energy savings and emission reductions via increased energy efficiency in different end-use sectors, mainly targeting industry (Rezessy and Bertoldi 2011). The VAs that have been implemented in the EU are heterogeneous. There are VAs with very specific actions that participants should undertake, whereas other VAs are more focused on targets and financial incentives (Tanaka 2011).

One of the first countries to embrace VAs as an instrument in the energy policy mix was the Netherlands, who implemented the first generation of the so-called Long Term Agreements[18] (LTA1) in 1990, later followed by LTA2 and 3. Although LTA1 was deemed a success (Das et al. 1997), there was also criticism. Farla and Blok (2001) for example disputed the transparency of the monitoring methodology, whereas Neelis et al. (2007) found substantial differences between the results of the Dutch LTA and national statistics. LTAs have been criticized "for deficiencies in compliance monitoring and self-reporting, and difficulty in demonstrating policy additionality" (Rezessy and Bertoldi 2011, p.7121). An analysis of two US[19] voluntary climate programs suggest that while voluntary programs can play some role in addressing climate change, they are unlikely to bring about the kinds of steep reductions called for in the current debate (Pizer et al. 2011). However, a study by OECD (2003) on voluntary approaches conclude that VAs are more efficient than command-and-control regulations, but not as efficient as market-based instruments such as emission trading. An evaluation of the LTA3 concluded that the monitoring could be improved (Volkerink et al. 2013). Another evaluation concluded that the covenant provided value for participants in formulating new energy saving opportunities, although the way in which results were presented could be improved (Hendriksen and van der Kolk 2013). As the LTAs are part of a mix of policy instruments, measuring and isolating their effect is challenging (Rietbergen et al. 2002).

In 2008 the Dutch voluntary agreements made fundamental changes to their monitoring methodology. Instead of measuring energy use per unit of production, the new method is based on the energy savings from projects that have been implemented by participating companies (AgentschapNL 2010a). The supposed advantage of this method is that it gives more insight in the companies' efforts to save energy as it provides a clear link between the investment in energy saving projects and the related energy

18 Here we use the term VA when referring to the instrument in general and LTA when referring to the LTA instrument in the Netherlands.

19 Differences between programs in different countries originate in part from differences in company culture and organization (Montgomery 2014). A study of the impact of these differences falls outside the scope of this article.

savings. However, opponents posit that the relation with 'real' energy efficiency is lost. Because the monitoring data provided by participating companies can be used for both the old and the new method, the results can be compared, showing to what extent the monitoring method affects the policy results. This article explains the new method and addresses its advantages and disadvantages compared to the old method. By comparing the effect of energy saving projects with the effect of production changes, changes in sector structure, product mix and other effects, it can be established if the implemented projects have made a significant contribution to energy efficiency.

Of special interest is the relation between energy and production in the period 2008-2012, a period with large fluctuations in the level of production and energy use, as a result of the economic crisis. As the capacity utilization of an industrial process has a significant impact on energy intensity (Boyd and Pang 2000), it is interesting to analyse how big this influence is.

This article aims to answer the following research questions:

1. What are the differences between the old and the new method?
2. How large is the effect of energy savings projects on energy use, compared to other influences as reported in the new method?
3. Can the results of the new LTA method be compared with the old method?
4. Which method is better suited for the monitoring of a voluntary agreement?

The outline of this article is as follows. Section 2 starts with a literature review providing some relevant definitions. Subsequently, it describes the two different approaches to measure energy efficiency: top-down (i.e. the old method) and project-based (i.e. the new method). Then, the dataset and methodology for this study is described in section 2.2. Section 3 presents the results of the analysis. Finally, conclusions and discussion are presented in section 4.

5.2 Data and methodology

5.2.1 Literature review

Definitions

In general, energy efficiency is defined as the amount of energy used for a unit of useful output. Sometimes the inverse (output/energy) is used as well (Farla and Blok 2000).

Frequently used energy efficiency indicators are specific energy consumption (SEC) and energy intensity. The SEC is a physical energy efficiency indicator, which is sometimes also called the Unit Energy Consumption (UEC) or Physical Energy Intensity (PEI) (Phylipsen et al. 1997). Several authors (Worrell et al. 1994; Phylipsen et al. 1997; Boonekamp 2006; Cahill and Ó Gallachoír 2012b) reserve the term SEC for the ratio between energy and physical production (J/kg) and define energy intensity as the ratio of energy and monetary values (J/€). Although energy intensity is sometimes used as a proxy for energy efficiency, they are not the same. Energy efficiency refers to how efficient energy is used for a given purpose. For example, providing a similar (or better) level of service with less energy consumption on a per-unit basis is considered an improvement in energy efficiency. This unit is always physical. Energy intensity is the amount of energy use per unit of activity. Examples of activity measures are households, floor space, passenger-kilometres, tonne-kilometres, physical units of production (e.g. tonnes of steel) and sectoral value added (SVA) or gross domestic product (GDP). Energy intensity is therefore a broader measure, capturing not only energy efficiency but also other impacts on energy consumption, such as changes in the structure of the economy (Natural Resources Canada 2012).

The main choice in defining the reference system is to measure the 'useful output' in physical (e.g. tons) or economic terms (€). The choice of the indicator for an activity can have a large effect on the energy intensity development (Worrell et al. 1997, Farla and Blok 2000). Freeman et al. (1997) showed a low correlation between physical and economic measures of output in industry. Physical indicators have a close relation with SEC and might improve the comparability of energy intensity indicators between countries. The use of economic indicators may serve to exaggerate year-to-year changes in efficiency. Boonekamp (2005) has produced an overview of different 'achievements' on different aggregation levels. Which unit is used best, depends on the aggregation level, the unit of analysis, the complexity of products and data availability. Indicators at a macro-level can contain many structural effects that can bias the indicators. As indicators are calculated at a more aggregated level, the influence of external factors increases. Generally, indicators measured in monetary units are applied at the macro-economic level, while physical units are applied to subsectoral level indicators (APERC 2000), obviously a consequence of data availability.

Apart from the term energy efficiency, 'energy savings' is used as well. In scientific literature, a clear distinction is made between energy efficiency and savings, but in daily language –and many policy documents as well- the terms are often used interchangeably. The fundamental difference between energy efficiency and energy savings is that energy efficiency is a relative, dimension free ratio, e.g. x% less energy consumption per unit of output or a conversion efficiency that has been raised from 80 to 90%. Energy savings on the other hand, are an absolute change in energy consumption. A change in energy efficiency says nothing about the change in energy consumption or savings and vice versa. In this article, the definition of Boonekamp (2005) is used to define energy savings: the difference of actual energy use and a reference energy use. The reference energy use is the amount of energy that would have been used in the absence of energy saving activities. In this definition, a lower energy use because of an economic recession is not defined as energy savings. Within the savings effect, one can make a distinction between autonomous savings (savings that would have been realised anyway) and policy induced savings, which is the amount that is of interest to policy makers.

Both energy efficiency and savings can be monitored in two ways: top-down or based on project savings. Top-down monitoring was used in LTA1 and LTA2, whereas project-based monitoring is used in LTA3. These are described in the following two subsections.

Old method - Top-down monitoring

Generally, top down monitoring boils down to measuring the change in energy use between two moments in time and subsequently, using a decomposition analysis, to disentangle the different causes for that change: volume effect, structure effect and efficiency effect. The ability of aggregated indicators to measure changes in energy efficiency may be seriously compromised by other influences, like inter-industrial structural changes, techno-economic and technological effects (Eichhammer and Mannsbart 1997). As an energy intensity effect is calculated using value added data, there remains a possibility that the energy intensity changes are influenced by changes in prices (Worrell et al. 1997, Cahill and Ó Gallachoír 2012b). Therefore, the outcome of the top-down monitoring depends on the ability to decompose the different effects.

The energy savings effect can be calculated by comparing the actual energy use with a reference use. Several methods exist to calculate this reference use, where choices have to be made on the selected reference system, the variable to construct reference energy consumption, the level of aggregation, interaction between saving effects, interaction with other effects and the chosen quantity to value energy consumption (Boonekamp 2006). These choices have a large impact on the outcome.

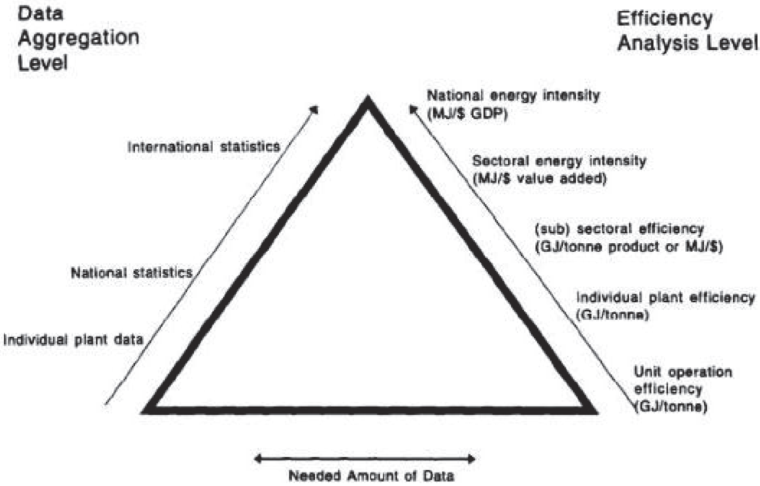

Figure 5-1. Aggregation levels in energy efficiency analysis, from national efficiency down to unit-operations or equipment in individual plants. From top to bottom the analysis is performed at an ever lower aggregation level. With a lower aggregation level the amount of data required for a comparative analysis increases (width of the pyramid). Source: Worrell et al. 1994.

Top-down indicators can be established at different levels of aggregation, visualized in figure 5-1. The lower the level of aggregation, the more structural effects influence the results (Boonekamp 2005). A low level of aggregation gives a better understanding, but requires a lot of data. Often, the chosen level of aggregation is guided by the availability of data (Farla and Blok 2000). Farla and Blok (2001) showed that many potential problems exist regarding the availability and quality of energy and production data when using physical indicators for analysing efficiency trends in the iron and steel industry. It turned out that quite some huge mistakes had been made in energy consumption data. The accuracy in the energy intensity indicators does not allow the measurement of developments between years that lie within a close range, only for a prolonged observation period of 5-10 years (Farla and Blok 2001). The Dutch LTA1 and 2 used top-down indicators that were established at company level and subsequently aggregated to a sectoral level (see section 2.2).

New method - Project-based monitoring

A totally different method to calculate the effect of an efficiency program is an approach that is based on the number of projects that have been implemented. Aggregating the savings per project provides the total effect. Especially subsidy programs use this method, as these often have detailed information regarding the projects being implemented. Examples are the Home Energy Programme in the UK (Bowie and Malvik 2005) or the Dutch EIA program (AgentschapNL 2012a), a tax deduction scheme. The difficulties with the project-based monitoring approach are:

- Determining the number of projects carried out by companies is labour intensive
- Determining the exact energy savings effect of a project is expensive and difficult to carry out without precise measurements
- Applying correction factors for temperature, free riders, rebound effects, additionality etc. is often debatable

The International Performance Measurement and Verification Protocol (IPMVP, EVO 2014) is a guidance document for measuring, computing and reporting savings on a project level. To properly document the impact of a savings measure, its energy effect must be separated from the energy effect of other conditions, like e.g. the production level (EVO 2014). Staniaszek and Lees (2012) have developed guidelines for the calculation of savings for companies participating in obligation schemes. For certain projects, standard values have been developed. For projects for which no standard values exist, specific calculations should be carried out. The guidelines treat various issues, i.e. rebound effect, normalisation factors and conversion factors. Also here applies the rule that the need for detailed data can lead to high costs.

The European Directive on energy end-use efficiency and energy services (European Parliament & Council 2006), the predecessor of the Energy Efficiency Directive, has made an attempt to standardise energy savings calculations. However it was confronted with considerable difficulties, mainly with respect to bottom-up calculations, leading to non-transparent, non-comparable results. Important sources for incomparability were: system boundaries, baseline definition, data quality and the application of corrections for climate factors (Leutgöb et al. 2011). The Policy and Action Standard of the World Resource Institute provides methods for estimating GHG reductions from interventions at sector or jurisdiction level (WRI 2014).

5.2.2 Measuring energy intensity trends in the Dutch LTAs

LTA1 – top-down monitoring

The first Dutch LTA (LTA1, from 1990 to 2000) used a method where the result was determined by the change in energy intensity, measured as the change in energy use per unit of production. For each individual participant, the improvement in the so-called Energy Efficiency Index (EEI) was established. The EEI was the ratio of actual energy use and a reference energy use, the latter being the energy use if the participant would have been as efficient as in the base year (Abeelen et al. 2013), also known as 'frozen efficiency'.

The formula for the EEI is:

[1] $$EEI = \frac{Ex}{\sum_{i} (P_{ix} \times SEC_{2005})}$$

Where Ex is the energy use (in Joule) in year x, Pix is the production (in physical units) of product i in year x and SEC2005 is the Specific Energy Consumption in 2005. The denominator Pix * SEC2005 is the reference energy use.

Although the EEI-method was essentially the same as the method used for calculating the national saving figures for Dutch industry, based on the so-called Protocol Monitoring Energy (PME) savings (Verdonk and Boonekamp 2009; Boonekamp et al. 2001), comparison of LTA-results with national data turned out to be difficult. Apart from the difference in population size (not all companies participate in the LTA, which means that a bias effect is probable), many differences existed:

- LTA does not take into account feedstock
- the national method uses a 3-year average
- differences in reference year and –systems

Both Neelis et al. (2007) and Verdonk and Boonekamp (2009) found that reported LTA-savings were much higher than PME-savings, even when methodological differences like the incorporation of feedstock energy were corrected: while LTA2 reported an average EEI-improvement of 1.5%/yr. over 2001-2007, PME calculated an improvement of 0.8%/yr. This difference could mainly be explained by the self-selection effect (companies with a small saving potential will not participate in LTA) and the fact that large energy-intensive companies did not participate in LTA2 (Verdonk and

Boonekamp 2009). Ramirez et al. (2005) calculated the energy intensity of the Dutch food industry (responsible for 9% of final energy use) using physical production data of National Statistics. Their results showed a difference of only 4% compared to the Dutch LTA. However, Neelis et al. (2007) found substantial differences between LTA1 data and national statistics in the paper, iron/steel and chemical industry. The critique echoed that of Farla and Blok (2002) who stated that 'LTA monitoring does not ensure a comparable and objective monitoring of the energy-intensity results. The monitoring is insufficiently transparent' (p.165); and 'differences with national statistics cannot be explained satisfactory' (p.173).

LTA2 – top-down monitoring

The monitoring method used in the Dutch LTA2 (2002-2008) applied a broader savings definition. Next to process-efficiency (based on the EEI approach) also savings in the production chain and fossil fuel savings from renewable energy production were counted as savings. The latter two were based on the effects of individual projects and expressed in two separate indices (AgentschapNL 2009a). In this way companies were rewarded for their other efforts as well. However, this led to a suboptimal, too complex presentation of results, which was not very transparent for participants (AgentschapNL 2010b). The main objection of participants to the EEI-method was that the change in EEI was heavily influenced by other factors than the actions of the companies alone, for instance by capacity utilization, temperature and product specifications and therefore did not give a good presentation of the efforts of covenant participants (AgentschapNL, 2010a).

When this was recognized, discussion started to improve the method (AgentschapNL 2009a). One option would have been to exclude structure effects and other effects that had nothing to do with the efforts of firms to save energy. Some sectors already tried to correct for some of these effects. This option was offered in the old monitoring method by using so-called 'correction factors'. A motivation to use these correction factors would be to exclude negative effects that were out of the sphere of influence of companies ('external' effects). Companies could only correct for external effects, not for effects they had caused themselves (e.g. an increase in energy use because of an extra process step to alter product specifications). The Dutch ceramics industry corrected for example for changes in the product mix and the potato processing industry corrected for changes in dry-matter content (AgentschapNL 2009b). Although the total effect of corrections remained small, this system created an imbalance between sectors, as not all sectors –or all companies within a sector- applied correction factors. Another problem was to determine which factors to correct for and to determine the level of corrections. Corrections tended towards better results, indicating a possible unfairness, as was already observed by Farla and Blok (2002). The applied corrections made it also more difficult to define the 'real' effect, creating even more of a 'black box'. Therefore, the method of corrections was discharged as being too complicated (Abeelen et al. 2013).

LTA3 – project-based

Instead, the partners in the LTA decided for a project based method which was assumed to better visualize the efforts of the participants, i.e. to count the effect of all energy saving projects implemented by the participants. An important part of the LTA is that participants make an energy efficiency plan (EEP) every four years. In this EEP they plan which energy saving projects to implement in the next four years. All projects with a payback period of less than five years should be implemented. The result of the agreement was formulated as the degree to which the planned projects have been implemented. In simple terms: has a company done what it promised to do? The method is described in AgentschapNL (2010a). Measures fall in three distinct categories: 1) process efficiency and 2) chain efficiency and 3) renewable energy (NL Agency 2008). For this article, only measures in the category 'process efficiency' are assessed. This category is directly linked to the energy use of the company itself. Process efficiency measures can be placed in four subcategories. Table 5-1 shows examples of the four subcategories. In Abeelen et al. (2013) the realised savings per subcategory are presented.

Table 5-1. Subcategories of process efficiency measures (Abeelen et al. 2013).

Subcategory	Example
Energy management and good housekeeping	Awareness campaigns Monitoring system Improvement of maintenance programs
Adjustment in processes	New machines Different process-setting (temperature, pressure etc.) New process design
Utilities and buildings	Efficient lighting Insulation CHP (combined heat and power)
Strategic measures	New production plants Replacements Change in product mix

In annual monitoring reports, companies report which projects they have actually implemented and how much energy these projects saved (in Joule). Guidelines for these calculations are given in the 'Handbook monitoring' (AgentschapNL, 2012b). The relative saving effect is calculated as:

[2] $$RS_x(\%) = \frac{AS_x}{(Ex+ASx)}$$

where RSx=realised saving as a percentage of total energy use in year x, ASx is Actual Savings in Joule in year x and E is primary energy use in Joule in year x. Final energy use was converted into primary energy using default conversion factors as defined by Vreuls

and Zijlema (2013); the most important factors being 31.65 MJ/m3 for natural gas and 9 MJ/kWh for electricity (assuming a 40% conversion efficiency).
The denominator (Ex+ASx) is the reference energy use in the definition of Boonekamp (2005): the energy used if the project would not have been implemented. The factor ASx in the denominator is added because the energy use in the reporting year is the energy use after implementation of the project (Abeelen et al. 2013).
All monitoring reports are checked for completeness and correctness by external consultants. This check is basically a probability check: by comparing the development of energy use with production and project data, they assess if the reported data are correct, using an analysis comparable to the one presented in section 3.5.

5.2.3 Data sources

All companies participating in the Dutch LTAs send annual monitoring reports to RVO.NL, which processes and analyses the data. Table 5-2 gives an overview of available data. For this article, only data from LTA3 are used, as this dataset is consistent over the longest period (2005-2013).

Table 5-2. Available monitoring data (annual base).

Theme	Available data
Energy	Purchase, production and sale of energy carriers (electricity, heat, gas, and other fuels) in kWh, m^3, tonnes etc.
Production	Production in physical units
Saving projects	Implemented saving projects Title of the project (Sub)category (see Table 5-1) Certainty level (certain, conditional, uncertain) at moment of planning. Year of implementation Expected saving (at the moment of planning) (in Joules) Realised saving, in units of avoided final energy use (in Joules) If necessary, an explanation is added
Influencing factors	Other factors influencing energy use that are not defined as saving projects, i.e. climate, changes in factory design, product specifications
Energy management	Status of energy management

To make a sound analysis of production and energy data, a comparison was made of the development of energy use and production on company level, to establish completeness and quality of these data. First, all companies without industrial processes were excluded: hospitals, universities and higher education, financial services and datacentres. For these companies 'production' has to be defined on other grounds than for industrial processes. Secondly, as will be explained in section 3.1, there is a very large influence of companies joining or leaving the LTA. To eliminate this influence, 245 companies that have only participated for part of the period 2006-2013, were excluded from the analysis. Thirdly, it was checked whether the unit of performance for the underlying production data was consistent for the whole period.

5.2.4 Analysis steps

For answering the first research question, the old and the new method, as described in section 2.2 is compared qualitatively, based on the general principles, the input data used, the calculation results.

The second research question required several steps.

- The first step was an analysis of the development of energy use, based on the energy consumption data reported by the participants in their monitoring reports. Final energy use was converted into primary energy using default conversion factors as defined by Vreuls and Zijlema (2013).
- The second step was an analysis of the development of production. Production was visualised in the form of a reference energy use. This reference energy use was calculated by multiplying the physical amount of production with the specific energy consumption in 2005:

  [3] $$E_{ref,x} = \sum(P_{ix} \times SEC_{2005})$$

  Where Pix is the production in physical unit (ton, m^2 etc.) of product i in year x and SEC is Specific Energy Consumption in 2005 (J/ton). Companies can define their own unit of production. About two third of the participating companies use one unit of production for their total production, the rest have different units for different products or product groups. A company could decide to merge several products in one product group. For instance a meat producing company could choose to use two product groups; one for all fresh meat products and one for all frozen products. The resulting reference energy use is the amount of energy that would have been used if production was as efficient as in the reference year. If the real energy use is lower than the reference energy use, production has become more efficient. The ratio of the reference use in two years is used to calculate the volume effect:

  [4] $$\mathrm{V} = Ex * \left(\frac{E_{ref,x}}{E_{ref,x-1}} - 1\right)$$

- Third, the effect of all implemented energy saving projects and other influencing factors that have been reported in the monitoring reports is counted.
- The last step is a combination of all above mentioned developments, to establish if the combined effects add up to the change in energy use. A too large gap between the added effects and the actual change in energy use is a sign of inaccuracy.

For the third research question, the EEI was calculated according to the old method and compared to the results of the new method (savings), in order to see the difference in outcome of the two methods.
For the last research question, a comparison was made between the original reasons for the change in methodology and the findings in the different evaluations that have been executed by the LTA-board.

5.3 Results and discussion

5.3.1 Energy use 2005-2013

Figure 5-2 shows the development of the energy use of the industrial companies participating in LTA3. Total primary energy use covered by LTA3 has risen from 147 PJ in 2005 to 199 PJ in 2013. However, the number of companies participating was not consistent over this period. In 2005, 762 companies participated, in 2013 847. In total 244 companies newly joined LTA3 in this period, notably 20 large chemical companies, 73 companies from the animal feed industry and 22 municipal waste companies. In the same period, 159 companies left. There are also 29 companies that joined but left after a few years. In most cases, the reason for leaving the agreement was a shutdown of the production plant, although some companies chose to leave for other reasons. Overall, the composition of the LTA3 population has changed considerably during this period. As new companies were on average larger than companies leaving the covenant, the net effect of population changes is an increase of the covered energy use by 45 PJ. This explains the largest part of the increase of the total energy use between 2005 and 2013 of 52.1 PJ in figure 5-2.

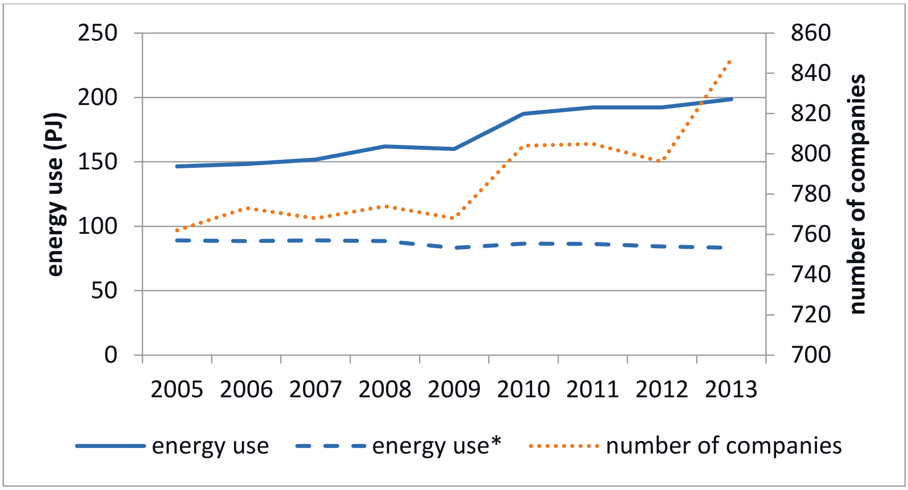

Figure 5-2. Development of primary energy use (without energy use for feedstock) and number of participants of LTA3 2005-2013. Energy use depicts all participating companies. Energy use* depicts only those companies that have participated and reported energy data for the complete period (n=559).

Figure 5-2 also shows the energy use of only those companies that have reported complete and consistent energy- and production data for the whole period 2005-2013. This accounts for about 60% of the energy use from all participants. Besides the large effect of companies that have reported only part of the period, a large effect is the exclusion of the oil and gas producing industry (37 PJ). As this sector has used a particular method for part of the period, it is not possible to provide a good comparison of energy use and production level. So, the effect of population changes and incomplete reporting is very substantial.

From figure 5-2 can be derived that the total energy use of the companies that participated and reported energy data for the full period (energy use* in figure 5-2) decreased from 89 PJ in 2005 to 83 PJ in 2013. The next paragraphs will explain the reasons behind this decrease.

5.3.2 Production 2005-2013

Figure 5-3 compares the energy use with a reference energy use; the theoretical energy use if production would have been as efficient as in 2005. The change in the reference energy use represents the volume effect: the effect of the change in production levels.

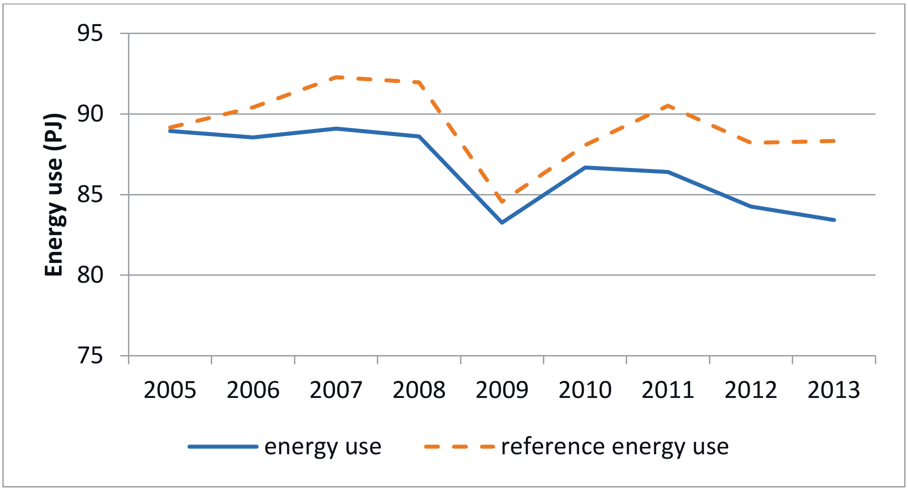

Figure 5-3. Development of energy and reference energy use 2006-2013 for industrial LTA-companies (n=559). Reference energy use is calculated using formula 3.[20]

As figure 5-3 shows, the actual energy use has decreased more than the reference energy use, indicating a decrease of the energy intensity. The larger the difference between actual and reference energy use, the larger the change in efficiency. The figure clearly shows the

20 National Statistics have a statistic on capacity use for industry (Conjunctuurenquete). Although it is based on a sample of companies, their trend gives a reasonable good match on our production figures: over the same period, they find capacity use decreased 3.0%.

large drop in energy – and production levels in 2009, a result of the economic crisis. Especially the sectors supplying to the automobile industry and building construction sector show large fluctuations in production. The years 2010 and 2011 show partial recovery, but 2012 shows another decrease in production levels. Usually, during a decrease in production, energy intensity increases. The reason for this effect is that part of the energy consumption (offices, cleaning, start-up energy use etc.) has no direct relation with production levels. As this 'basic energy use' is used for a smaller amount of products, energy intensity increases. The larger the share of basic energy use, the larger this effect. This effect is visible in figure 5-3 as the gap between the actual and reference energy use becomes smaller in 2009. Grobler (2010) has described this phenomenon and concludes that energy intensity should therefore not be used to determine savings. Normalizing for this phenomenon is possible, but requires detailed data, at least on company level, but preferably on installation level. This level of detail is not available in the LTA-data.
Overall, the production level in 2013 (calculated with formula 3) is 0.9% lower than in 2005. The net effect of the decrease of production is therefore relatively small: 0.24 PJ of the 6 PJ decrease in energy use can be explained by lowered production. It should however be noted that the gross effect of production changes is much larger than the net effect, because fluctuations between different years level out to a certain extent, and because growing production in one company in a specific year can be compensated by decreasing production in another company in the same year.

5.3.3 Energy saving projects 2006-2013 and other influencing factors

Companies participating in the LTA have to report all energy saving projects that they have implemented. By definition, these have a decreasing effect on energy use. From 2006-2013, the companies in the observed dataset have reported a total of 13.1 PJ savings. The new method calculates a savings index, an index based solely on the savings caused by energy saving projects. This index is 86.1 for 2013, showing savings of 13.9% or 1.9% per year.
As the results of a company are dependent on self-reporting, there might be reasons to expect companies to over-report realised savings. Especially companies who score badly will feel stimulated to report more savings than have actually been implemented, therefore making it probable that too many savings will be reported. Yet, there are very few examples of projects that have been reported but turned out not to be implemented, while there are known cases of projects that have been implemented, but not reported. Sometimes companies forget to report projects: for instance in the case of smaller projects, sometimes companies report that a project has been implemented, but cannot quantify the savings and therefore report zero savings. Therefore, it seems reasonable to expect over- and underreporting to compensate each other and the inaccuracy on an aggregated level will be small. On the one hand, production data are more accurate than project data, as production data are the centre of attention of all production plants

and information on production efficiency is key to profitability. Therefore, most plants have extensive systems monitoring key features of the production process. On the other hand, project data are more difficult to collect. For few projects actual savings can be measured, for most projects it is only possible to estimate the realised savings. A study on the accuracy of data in the Danish Energy Efficiency Obligation found a relatively small discrepancy of 6 % between the savings (kWh) reported by the obligated parties and the estimated actual savings (kWh) measured (Bundgaard et al. 2013). Still, to check if the savings effect is indeed accurate, it is necessary to perform a sample review of projects, or production data are needed to compare the saving effect with other effects and with a baseline. Such a consistency check is a systematic part of the check on monitoring data that is performed by external consultants.

Part of the reported projects would have been implemented regardless of the agreements but should be attributed to other policy instruments or autonomous savings. Quantitative evidence for additional effects of the agreements is limited. First of all, there is a lack of baselines against which to assess agreements. Secondly, it is difficult to disentangle the different instruments. In most cases, factors other than the voluntary approach seem to explain the major part of any environmental improvement. Based on estimates from other studies[21] , it is possible to conclude that less than half of the reported savings are additional.

5.3.4 Other influencing factors

Besides the effect of production and energy saving projects, other factors can have an effect on energy use as well. This can be yearly recurring effects like climate effects or special occasions like the introduction of new products, incidents in the production facility or deliberate changes in the facility. These factors can have either saving or dissaving effects on energy consumption. If applicable, LTA3 companies have to report these factors if production volume changes and/or energy saving projects alone do not explain the change in energy use. Overall, companies have reported influencing factors that have a net

21 An evaluation of the Danish Energy Efficiency Obligations in 2012 was able to determine that the net savings impact of the Danish Energy Efficiency Obligation is about a third of the reported savings. Additionality appeared to be 52–60 % for industry (Bundgaard et al. 2013). By comparing company-level savings in the Irish Large Industrial Energy Network (LIEN) to total industry savings (calculated using a top-down method), it could be estimated that 38 % of total savings could be attributed to participation in the program (Cahill 012a). An analysis of seven VAs by Vreuls et al. (2005) found that around 50 % of efficiency improvement could be credited to the program. Rietbergen et al. (2002) used two methods to isolate the impact of LTA1, the first Dutch agreements on energy efficiency. Through a combination of expert judgement and a survey, it was found that 27–44 or 29–44 % respectively could be attributed to the implementation of LTA1. The most recent evaluation of LTA3 concludes that the effect of the agreements as a separate instrument is difficult to establish, but several studies, based on surveys and interviews, mention an additionality of 50%(Volkerink et al. 2013). A large part of the reported savings could be attributed to other policy instruments, but it is very hard to attribute savings to a specific instrument when multiple instruments are in place simultaneously. A part of the reported savings could also be attributed to autonomous savings, savings that would have occurred anyway, and therefore should officially not be counted as saving effect in the definition of Boonekamp (2005).

It is difficult to determine exactly how large this autonomous savings are. A recent evaluation of the long-term agreements for ETS companies concluded that 86 % of respondents claimed that the agreements were ‘(very) important’ for implementation of energy-saving projects, but at the same time, 64 % of respondents stated that 80 % or more of those projects would have been implemented anyway (Hendriksen and van der Kolk 2013).

increasing effect of 10.5 PJ. As with the volume effect, the gross effect of these factors is much larger (31.9 PJ), as increasing and decreasing effects mitigate each other.

5.3.5 Decomposition analysis

If the results of sections 3.2-3.4 are combined, figure 5-4 can be drawn. This figure is not based on a formal decomposition method, but on a bottom-up inventory of the drivers of energy use, as reported by the LTA participants. The first bar shows the energy use in 2005, the last bar the energy use in 2013. The bars in between show the net effect of respectively energy saving projects, production changes, other influencing factors and an unexplained factor. The effect of saving projects is the total effect of all energy saving projects reported in this period. The effect of production changes is based on physical production data, using formulas 3 and 4 (see section 3.2). The effect of 'other influences' is the total of all other factors that have been reported by companies (i.e. climate, product specifications, etc.). The last 'unexplained' factor is the difference between the first six columns and the actual energy use in 2013. If this residual is too high, it is an indication of errors in the composition of the other factors: inaccuracies, missing factors, projects that have not been reported etc.

Figure 5-4 shows a large difference between gross and net effect of the volume effect and the effect of other influences. In both cases, saving and dissaving effects partly compensate each other. Although the net effect over this period is small, the total effect of production is several times larger than the effect of energy saving projects. This also holds for the effect of 'other influences'. Because this figure is based on a fixed population, the effect of population changes is filtered out. As was observed in section 3.1, the effect of increasing LTA-population in this period was 45 PJ, which is larger than any of the other effects.

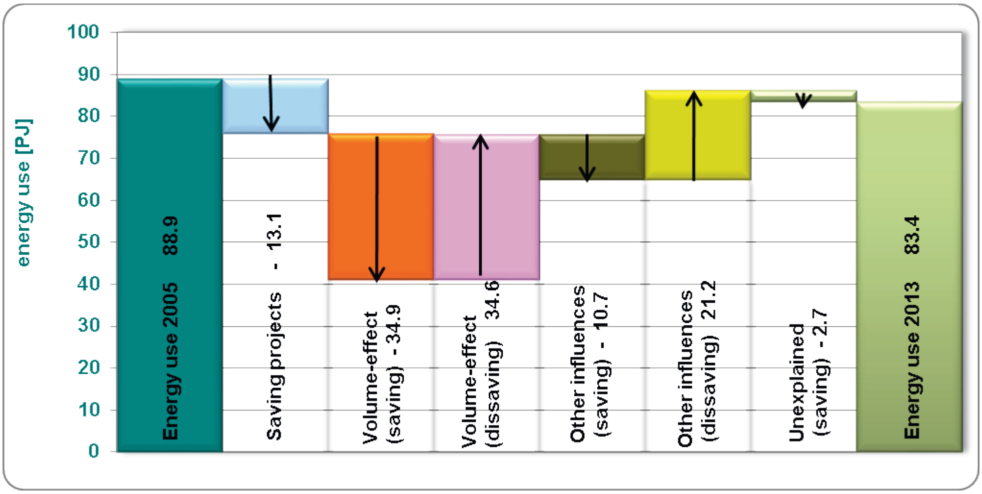

Figure 5-4. Explanation of the change in energy use between 2005 and 2013.

Chapter 5

5.3.6 Comparison of old and new method

By comparing the energy and production data, the Energy efficiency index (EEI) can be calculated, as was done in the old method. The development of this index is shown in figure 5-5. The EEI for 2013 is 94.4, which means a decrease in the amount of energy used per unit production of 5.6% (0.7% per year). It shows a gradual decrease in most years, but an increase in 2009 and 2012 (although much smaller in the latter). This increase corresponds with the decline in production in 2009 as a result of the economic crisis. Because of lower capacity utilization, the amount of energy used per unit of production rises. The savings index in the new method shows savings of 13.9% in 2013, or 1.9% per year.

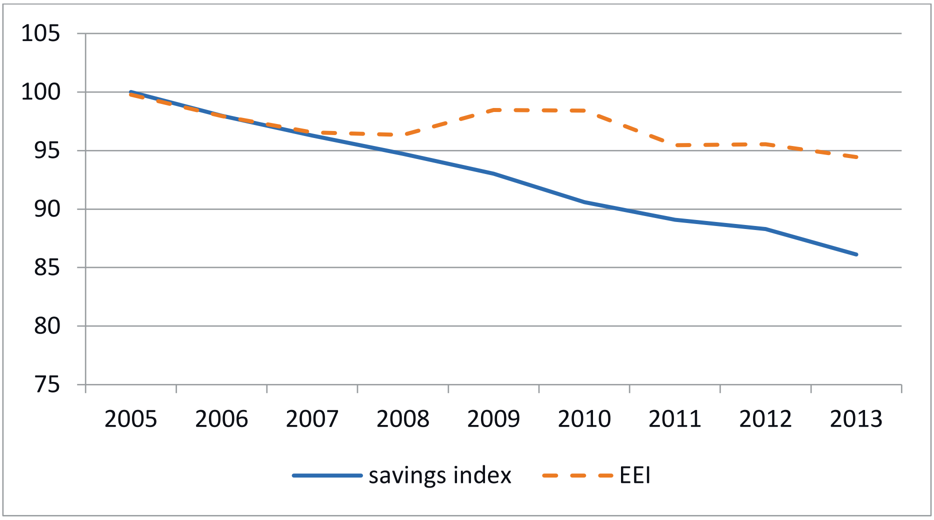

Figure 5-5. Development of Energy Efficiency Index (EEI) (old method) based on energy intensity versus savings index (new method) based on implemented saving projects for all industrial LTA companies.

When comparing the two indices, two differences can be observed. First, the savings index shows on average a higher result than the EEI, although in some years, the EEI decreases faster than the savings index. Second, the savings index shows a more gradual development than the EEI, at least at an aggregate level. At the level of individual companies there are large differences: some companies have implemented measures that save up to 50%, or more than 5% per year. These large savings typically come in large steps, when major installations are replaced. Therefore, there are also large variations from year to year savings, at least at company level. At sectoral level, the differences between sectors are smaller, but still quite large. Aggregated to the level of more than 500 companies as shown in figure 5-5, differences between years are levelled out. On the contrary, the EEI shows large fluctuations from year to year, even at an aggregated level. Year to year changes of the EEI range from -3.0% to +2.1%. This raises the question what conclusions can be drawn from this study period, but also offers an opportunity to visualize the effect of the economic crisis on the EEI.

The reason behind both differences is the high dependency of the EEI on production changes. This is shown most clearly in years of production decreases. However, also in years of fast growing production, the EEI usually shows a higher decrease. The development of the EEI clearly shows the effect of the economic crisis, with production decreases in 2009 and - to a smaller extent, 2012. The economic crisis also has an impact on implementation of energy saving projects, as investments go down. However, this effect is much smaller. In difficult economic periods, companies are more focused on efficiency than normal. Moreover, a forced temporary production stop can be an opportunity for maintenance on installations that would otherwise have to wait for planned maintenance, accelerating technological innovation.

A working group of the LTA board concluded that the new method provided a better indication of the efforts of participants to save energy. However, some sectors indicated that they wanted the old EEI-method presented next to the result of the new method, to keep track of the development of energy used per unit production and to be able to compare the results of the old and new method (AgentschapNL 2011a, b). As true as this might be, the new method still doesn't tell if these efforts are a result of a policy instrument or not.

A fundamental difference is that the result in the new method cannot be negative, as was sometimes the case in the old method. In the new method the minimum result is zero (in the situation that no company reports any implemented projects). Even when a previous saving is lost, this dissaving effect will be reported as an influencing factor and have no effect on the result.

5.4 Conclusions and policy implications

This section provides an answer to the research questions that were formulated in the introduction.

Q1: What are the differences between the old and the new methodology?

The main difference is the fact that the result in the new method is determined only by reported savings and not calculated on reported production and energy data. The new method therefore uses different input data. The reported savings in the new method are not influenced by volume or structure effects. Especially the effect of production changes had a large impact on the result of the old method, particularly in the period of the economic crisis. Although this effect represents an actual change in energy intensity, the effect does not represent structural savings, as the change in energy intensity is reversible. The new result, aggregated over all companies, shows much less variation from year to year, showing the independence to external influences. A fundamental difference in output is that the result in the new method cannot be negative, as was sometimes the case in the old method. In the new method the minimum result is zero.

Q2: How large is the effect of energy saving projects compared to structural change and volume developments and other influences?
Companies might be tempted to assign a decrease in their energy use to projects they have implemented, but in practice, other factors are more important. The analysis in section 3.5 demonstrates that energy saving projects play a significant role in the change in energy use, but their effect is smaller than the effect of other factors. Yet, because other factors can have both increasing as decreasing effect on energy use, the net effect of these factors is smaller. By definition, energy saving projects have only a saving effect. Still, the effect of implemented projects helps to explain the change in energy use: if the saving effect would not have been included, a larger residual would remain. Therefore, it is save to conclude that the implementation of energy saving projects does have an impact on energy use, as well as on energy intensity.
By far the largest driver for changes in energy use in individual companies is a change in production level. Only in special occasions other factors are more important. Because production levels can go up and down, the net effect of production changes is small in the period 2006-2013, while the effect in the intermediate years is several times larger than the other factors. A different study period would give different results.
A comparison of production and energy data (section 3.2) shows the importance of good design of the unit for production. The change in the reference year has introduced errors in a small share of companies. Changes in methodology distort the results for these companies, making long-term analysis of their specific energy consumption impossible.

Q3: Can the results of the new LTA method be compared with the old method?
The most essential question is whether the two methods provide comparable results. The answer is negative. In years of growing production, the EEI will often give higher results, in years of decreasing production a project based method will often give a higher result. This clearly shows the dependency of the old (EEI-)method on physical production levels. A possible solution would be to correct the EEI for the effect of capacity changes. To do so, one should have information on the relation between production level and specific energy consumption. This might give a better indication of the energy efficiency effect, but introducing corrections also affects the biggest advantage of the EEI-method: the fact that it shows the development of the actual specific energy consumption. Therefore, to give a good indication of the development of energy efficiency, one should include all drivers.
The two methods need different data to calculate the result. While energy data are used by both methods, energy efficiency index also uses production data, while the savings index uses project data to complete the calculation.

Q4: Which method is best for evaluating the results of a voluntary agreement?
It depends on the target of a policy instrument before one can conclude if a method based on project implementation is better than a method based on energy intensity. If one is interested in the actual development of the energy intensity, counting projects does not provide insight: Savings by the implementation of projects alone do not give an accurate view on the development of both energy use and energy intensity. Implementation of saving projects give only a partial explanation of development of energy use or intensity. A result based on projects alone therefore gives a too optimistic view. On the other hand, if one is interested in the impact of actions of participants, building a result on an energy efficiency index may lead to wrong conclusions as well. The dependency of the result on occupancy levels is better explained by the economic situation than the amount of energy saving investments.
Participants themselves concluded that the new method better indicated the efforts of participants even though some sectors still wanted the possibility to use both the old and the new method at the same time. The official goal of the Dutch LTA3 is an improvement of 30% energy efficiency improvement, defined as the ratio between the performance, service, goods or energy obtained and the energy supply for that purpose (NL Agency 2008). This goal is best represented by the (old) energy efficiency index. The (new) savings index represent a different development, as is shown in 3.5. Ergo, the new monitoring method based on project savings does not provide insight in the progress towards target achievement.
Policy implications
- In times of strong economic developments, the intensity approach has serious disadvantages, as it could conceal actual efforts on savings.
- The project approach has the drawback that it does not cover the (real) dis-saving effects of lower occupancy rates for industrial processes.
- Population changes are the most important factor in the change in energy use of the LTA population. This is an issue that should be considered when observing results that have not been corrected. A population change can be the result of actual change in the number of companies (as is the case for the datacentres) but also of existing companies deciding to join (or leave) the program. For reliable trends a correction should be made for population shifts
-Another drawback of the project approach is the large amount of data needed for a sound system for checking the real savings in the project approach. Despite the large amount of data in the project approach more could be done to provide more reliable data and withhold participants from presenting nicer saving figures than actually realized. For many programs, it is unlikely that participants are willing to provide all the necessary data.
-Policy makers are more interested in the policy effect rather than the total savings effect. In other words: what savings are additional to those that would have occurred anyway?

For both the old and new method, it is not possible with the available data to draw reliable conclusions on the additionality of the reported savings.
-For sound evaluation of a policy target, the monitoring result should be consistent with the set target. In LTA3, the consistency between set targets (intensity based) and the actual monitoring and evaluation (project based) is lost.

6

Chapter 6

Disentangling industrial energy efficiency policy results in the Netherlands[22]

22 Christiaan Abeelen, Robert Harmsen, Ernst Worrell.
Accepted for publication: Energy Efficiency (2018)

6.1 Introduction

A 20% reduction of primary energy consumption in 2020 is part of Europe's Climate and Energy package (European Parliament and Council 2012). To know whether this target will be achieved, it is necessary to measure progress towards the target and get insight in the effect of the implemented policy instruments. In 2013 the European Environmental Agency reported that some progress is made in reducing energy consumption (EEA 2013), but EEA (2015) reported a gap of 67.9 PJ (1621 ktoe) between energy use and the linear target path to 2020 if current trends would continue towards 2020.

Policy makers can use a range of instruments to realize energy efficiency: e.g. financial instruments, voluntary agreements, labelling. Together, these instruments should form a 'coherent policy package', i.e. a mix of instruments that strengthen each other (Coalition for energy saving 2013).

Tools such as decomposition analysis show the effect of production changes and structural changes in the economy. However, the results of such analysis do not distinguish between savings achieved as a result of policies and other factors. Instead, they reflect aggregate changes brought about by a variety of factors, such as price effects, autonomous effects, direct rebound effects, hidden structure effects as well as the effects of old and new policies (Cahill and Gallachoír 2010). Moreover, the result of a decomposition method depends on the chosen method. In some top-down decomposition methods the policy effect is a residual, which remains when all other possible explanations are removed (Boonekamp et al. 2001). In other words: an indirect measurement. In some cases, the difference between volume, structure, autonomous and policy effects is not obvious. In Smit et al. (2014) the difference in intensity effect between two scenarios is used as a proxy for the policy effect, even though this effect also includes the difference in autonomous intensity improvements in those scenarios. Different organizations use different methods, which is confusing for users of these data.

Theoretically top-down effects can be further explained by bottom-up analysis, although available bottom-up data often do not match with top-down national data. There have been multiple efforts to develop good methods to measure energy efficiency and a wide range of literature on this topic exists (e.g. Phylipsen et al. 1997; Boonekamp 2005; 2006; Cahill and Gallachoír 2012a; Farla and Blok 2001). However, users of this information have different requirements regarding the energy efficiency indicators that have to be produced. Some are interested in the development of energy efficiency regardless whether it is policy induced or not. Policy makers, on the other hand, are often more interested in the effect of policy intervention. This has led to a range of methods, each with their own characteristics. In the formulation of energy efficiency goals as well as in monitoring of the energy data, discussions arise concerning the definition and the measurement of energy efficiency (Schlomann et al. 2015). Many energy efficiency related concepts are still misunderstood, not only by laymen but even by specialists, e.g. the difference between efficacy and efficiency or the difference between intensity and efficiency. Therefore, methodological issues are still a subject of ongoing debate (Pérez-Lombard et al. 2013). The term 'energy efficiency' can have a totally different meaning in different studies.

In this paper we show how these issues occur in practice, using the Netherlands as a casus. Energy efficiency policy of the Netherlands consists of a mix of many instruments, each with different characteristics. There is a strong overlap between some of these instruments, e.g. between the voluntary agreements for improving industrial energy efficiency and subsidy schemes that support investments in energy saving equipment. The European 2020 energy target was translated in a reduction of 482 PJ of national final energy use for the Netherlands as a whole (Schoots and Hammingh 2015). Dutch progress on energy saving policy is reported in the 'Nationale Energieverkenning' (Schoots and Hammingh 2015), that describes general developments, progress in implementation of policy instruments and the expected amount of energy savings.

In the Netherlands, three national indicators on energy efficiency exist: 1) a national energy saving result (ECN 2012), 2) energy savings reported for art.7 of the European Energy Directive (Tweede Kamer der Staten-Generaal 2017), and 3) a saving result for the National Energy Agreement, all with a refinement towards industrial savings (Schoots and Hammingh 2015). In addition, results exist of individual policy instruments focusing on specific sectors. In the nineties, the EU started the Odyssee project (http://www.odyssee-mure.eu/) to gather information on energy efficiency in its member states. This project has developed the so-called ODEX indicator to compare energy efficiency in European countries (Enerdata 2010), including the Netherlands. Although one would expect the figures to be reasonably equal, large differences are observed. Especially for industry the results differ a lot. In the last official national report on energy savings (ECN 2012), a mean annual trend of 1% energy savings for the period 2000-2010 was reported for Dutch industry, while Odyssee reports a total efficiency gain of 27.5% over the period 2000-2012 (meaning 2.6%/yr) (Gerdes 2012). The differences between these numbers arise from differences in definitions and scope. The large differences between these reports are a cause for confusion among policy makers.

The aim of this paper is to investigate the reasons behind the differences between the methods used in the Netherlands. The main research question is therefore:
How can figures on energy efficiency, with a focus on industry in the Netherlands, be compared and interpreted?.

To answer this main question the following sub-questions are addressed:
- What are the differences between existing energy efficiency methods?
- What is the reason behind these differences?
- How are these methods applied in the Netherlands?
- What are the (dis)advantages of these methods?

In this article, section 2 provides the methods. Section 3 presents and discusses the results. After a description of the development of methods to calculate energy efficiency in section 3.1, we describe the impact of the choice of metrics on the outcome of the methods that are used to report on energy efficiency in section 3.2. In section 3.3 the Netherlands is used as a case to see how these methods are applied. The advantages and disadvantages of the different methods are discussed in section 3.4. Section 4 gives conclusions and recommendations.

6.2 Methods

To answer the research questions posed in the introduction we followed a four-step approach linked to the four sub-questions provided in section 1.

Step 1: What are the differences between existing energy efficiency methods?
The aim of this research step was to show the differences between existing energy efficiency methods. Therefore, step 1 included a review of literature on the methods to report on energy saving. We described definitions that have been developed for specific energy use and energy intensity, useful output and energy saving and the metrics that are needed for decomposition analysis. We focused on literature that described methods for energy efficiency in industry.

Step 2: What is the reason behind these differences?
In order to analyse these differences we visualized the differences between methods to calculate energy efficiency in step 2. We used a fictitious dataset that describes all factors that influence energy consumption. By using a fictitious dataset we can show the impact of changes in individual variables. This fictitious dataset stands model for the chemical industry in the Netherlands, which in the last decade featured a shift towards more specialized products, with a higher added value. Companies participating in the Dutch Long Term Agreement for Industrial Energy Efficiency are obliged to report all these factors (except for added value) in annual monitoring reports (Abeelen et al 2016). In a second analysis we use the same table , but now in more detail; where the sector is divided in two subsectors, one of which is growing, the other not.

For step 2 we used an additive Log Mean Divisia Index (LMDI) method to decompose the change in energy use, first with a two-factor decomposition (table 6-1), followed by

a three factor decomposition (table 6-2). The LMDI method was used as this method assures a perfect decomposition without a residual (Ang 2004). In other words: all changes in energy use are assigned to one of the factors.
Table 6-1 shows the formulas used for calculating the volume, structure and efficiency effect respectively. We used two- and three factor decomposition next to each other to show the change in the efficiency effect. The advantage of the two-factor decomposition was its limited need of data (being relatively easily available). The major disadvantage of two-factor decomposition is that structure effects are 'hidden' in the efficiency effect. This problem was partly solved by also decomposing in three-factors, although structure effects on a lower aggregation level were still hidden.

Table 6-1. Formulas for decomposition analysis

	Two-factor decomposition	Three-factor decomposition
Activity effect	$E_t^V = E_0 - E_t ln\left(\frac{E_0}{E_t}\right) ln\left(\frac{V_t}{V_0}\right)$	$E_t^V = \sum_i L(E_i^t, E_i^0) ln\left(\frac{V_t}{V_0}\right)$
Structure effect	n.a.	$E_t^S = \sum_i L(E_{i,t}, E_{i,0}) ln\left(\frac{S_{i,t}}{S_{i,0}}\right)$
Intensity effect	$E_t = \frac{E_0 - E_t}{ln\left(\frac{E_0}{E_t}\right)} ln\left(\frac{E/V_0}{E/V_t}\right)$	$E_t^I = \sum_i L(E_{i,t}, E_{i,0}) ln\left(\frac{I_{i,t}}{I_{i,0}}\right)$

Where E=Energy use (Joule), S=Structure=A/V, A=activity level (in ton or €) V=the total volume (in € or ton), I=Intensity in Joule/€ or Joule/ton

The formulas in table 6-1 were applied to four scenarios in which we combined different choices for the metrics used. The four scenarios are outlined in figure 6-1.

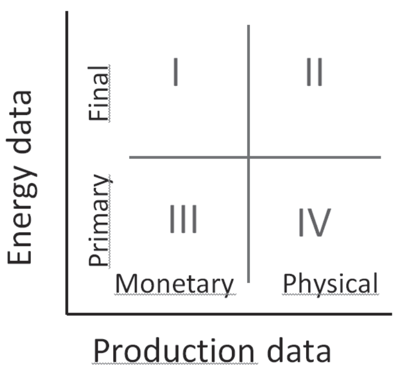

Figure 6-1. Data choices for 4 scenarios.

Step 3: How are these methods applied in the Netherlands?
In Step 3 we focused on the Netherlands. Based on the literature we made an inventory of the methods that are used in the Netherlands, both top-down and bottom-up methods based on the implementation of energy saving projects in industry. For each selected method, we describe the main features, scope and definition and the most relevant results. To compare these approaches, we adapted a table from Schoots and Hammingh (2015) in which the methods are compared on all the essential features that were identified in step 1, e.g. choice of energy and production metrics or the type of savings that are eligible under the selected method. From the original table, we deleted the line on inclusion of CHP-savings, as this distinction is already evident from the distinction between final and primary energy. We added the type of production data, the visibility of structural changes and other factors and a possible residual.

Step 4: What are the advantages and disadvantages of these methods?
This step builds on the outcome of step 1-3, using a more qualitative approach. As we will see in chapter 4, every method has its own context and this context defines the choices that are made in terms of scope, aim and target audience. These choices also define how the outcome of the method should be used and how they should not be used. This is done for each method from step 1-3, based on the literature review in step 1 and the finding of the analysis in step 2.

6.3 Results and discussion

6.3.1 What are the differences between existing methods for energy efficiency

Energy efficiency is generally defined as the amount of energy used for a unit of useful output. Frequently used energy efficiency indicators are specific
energy consumption (SEC) and energy intensity (EI). The SEC is a physical energy efficiency indicator, which is sometimes also called physical energy intensity (PEI) (Phylipsen et al. 1997; Farla and Blok 2000). Several authors (Worrell et al. 1994; Phylipsen et al. 1997; Boonekamp 2006; Cahill and Ó Gallachoír 2012b) reserve the term SEC for the ratio between energy and physical production (Joule/kg) and define energy intensity as the ratio of energy and monetary values (Joule/€).

The main choice in defining the reference energy use is to measure the 'useful output' in physical (e.g. tons) or economic (€) terms. The choice of the indicator for an activity can have a large effect on the estimate of the energy intensity development (Worrell et al. 1997; Farla and Blok 2000). Freeman et al. (1997) already showed a low correlation between physical and economic measures of output in industry. Trends in energy intensity based on the economic value of output can diverge quite sharply from trends in energy intensity based on physical volume of output. They suggest that economic indicators may serve to

exaggerate year-to-year changes in efficiency (Freeman et al. 1997). Therefore, economic indicators should not be compared to physical indicators.
Boonekamp (2005) has produced an overview of different 'achievements' on different aggregation levels. Which unit is used best depends on the aggregation level, unit of analysis, complexity of products, and data availability. Indicators at a macro level (both physical and monetary) can contain many structural effects that can bias the results. Therefore, as indicators are calculated at a more aggregated level, the influence of external factors increases. Generally, indicators measured in monetary units are applied at the macro-economic level, while physical units are applied to (sub-)sectoral level indicators (APERC 2000). The higher the level of industry aggregation, the more desirable is the use of market value of output relative to physical volume of output as measure of energy intensity. This is due to the difficulty of sensibly measuring the physical volume of output across very diverse products, like different chemicals with very different energy requirements (Freeman et al. 1997). Although physical indicators are preferred because of their closer relation to energy use, energy intensity is often used as a proxy for efficiency due to a lack of data.

Apart from the terms energy efficiency and intensity, the term energy savings is used as well. The fundamental difference between energy efficiency improvement and energy savings is that energy efficiency is a relative, dimension-free ratio, e.g. x% less energy consumption per unit of output or a conversion efficiency that has been raised from 80 to 90% (Abeelen et al. 2016). A change in energy intensity (or efficiency) can be a result of energy saving activities, but also of structural changes in the economy. Energy savings on the other hand are, by definition, a consequence of energy saving activities. Energy savings means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption (European Parliament and Council 2012). These are defined as the difference of actual energy use and a reference energy use. The reference energy use is the amount of energy that would have been used in the absence of energy-saving activities (Boonekamp 2005). The (theoretical) reference use is defined by calculating the impact of changes in volume- and structure and possibly other known factors, using a decomposition method. Ang (2004) and Boonekamp (2004) describe several decomposition methods. Despite the differences between these terms, in practice energy efficiency is used for all of them, which may lead to confusion.

To know why energy consumption has changed and what impact energy policy has had on this change, all factors influencing consumption have to be known. This is especially true in economies subject to large changes like strong economic growth or recession, population changes or economies in transition. The difficulty lies in disentangling the different drivers of energy efficiency development.

Not only the metrics itself, but also the level of detail of the source data can have a large effect on the size and distribution of the different decomposition factors. Generally, a greater level of disaggregation will give a more reliable set of results (Cahill 2010). For example, if there is only one number known for the production volume in a sector (e.g. tons of paper in the paper industry), a shift in production from low to high quality paper (a structure effect) will be hidden in the volume-effect. A shift in production between companies or subsectors with different energy characteristics will be hidden if energy and production data are only known on sectoral level. The resulting estimated energy savings effect can differ significantly in the two cases. The effect of aggregation level on saving results is shown in Fisher (2004).

A special aspect of the aggregation level is the choice between final or primary energy. This choice defines if developments in the efficiency of energy conversion will be observed or not. Looking at final energy alone, one gets a good view on efficiency developments on the level of the end user: in the case of industry, on the industrial process level. However, changes in energy conversion (in the electricity producing sector) will not be observed. A shift towards electrification might improve efficiency on the end use level, but when this electricity is generated by inefficient electricity generation plants, the efficiency of the total system might decrease. Moreover, savings by industrial CHP are not assigned to the energy producing sector, even when these savings are induced by actions from industrial companies. The choice for final or primary energy is often made deliberately, depending of the purpose of the analysis.

6.3.2 What are the reasons for the differences in methods

6.3.2.1 Main variables

For a decomposition analysis, one has to decide which source data to use. Important are the choices between final or primary energy and that between physical or monetary production data.

To illustrate the effect of this choice on decomposition results, we use the dataset in Table 6-2. The data in the set stand model for a sector like the chemical industry in the Netherlands, which in the last decade featured a shift towards more specialized products, with a higher added value. This means that added value grows faster than physical production. Both added value and physical production increase faster than energy use (both final and primary). As a result both 'physical' energy intensity and 'monetary' energy intensity decrease, with monetary intensity decreasing faster. A comparable scenario has been used by Cahill and Gallachoír (2010). Our dataset contains 5 PJ savings on primary energy as a result of more efficient energy conversion and 1 PJ of dissaving effects: e.g. an increase of energy use as a result of extra treatment of fume gases due to increased air pollution regulations. Such savings and other effects are reported by companies in annual monitoring reports (see also Abeelen et al. (2016) which contains a decomposition of the change in energy use of the chemical sector between 2006 and 2011).

Table 6-2. Basic data set sector A.

		Sector A		
Aspect	**unit**	**year 0**	**year t**	**Δ**
Production	Mton	2 000	2 100	5%
Added value	M€	7 000	7 700	10%
Consumption (final)	PJ	165.0	171.5	3.9%
Consumption (primary)	PJ	300. 0	306.0	2%
Unit consumption (f)	PJ/Mton	0.083	0.082	
Unit consumption (p)	PJ/Mton	0.150	0.146	
Unit consumption (f)	PJ/M€	0.0236	0.0223	
Unit consumption (p)	PJ/M€	0.043	0.040	
Project savings	PJ		5	saving
Other factors	PJ		1	dissaving

The following sections show the outcome for a two-factor and three-factor decomposition respectively.

__6.3.2.2 Two factor decomposition__

Figure 6-2 shows the outcome of a two factor decomposition where the change in energy use is decomposed in a volume and efficiency effect.

All four scenarios come to different efficiency effects, depending on choices of final or primary energy and physical or economic production data. In the scenarios I and II using final energy use, the efficiency effect is lower than in the scenarios using primary energy (III and IV). Methods focusing on final energy will not discern savings as a result of more efficient energy conversion, like CHP. Energy use in industrial CHP-installations is excluded from the industrial consumption and is considered as part of the energy conversion sector, even when those installations are situated on industrial sites. This means that those savings are not shown in the industrial sector, but are attributed to the energy sector. This might be understandable if one is only interested in the developments in end-use sectors. However, in many cases this is not logical from the point of view of the end user itself. Many CHP-installations are built, owned and operated by end-users. Since it is their decision to invest in a more efficient energy generation, it is debatable to attribute the results of their efforts to another sector.

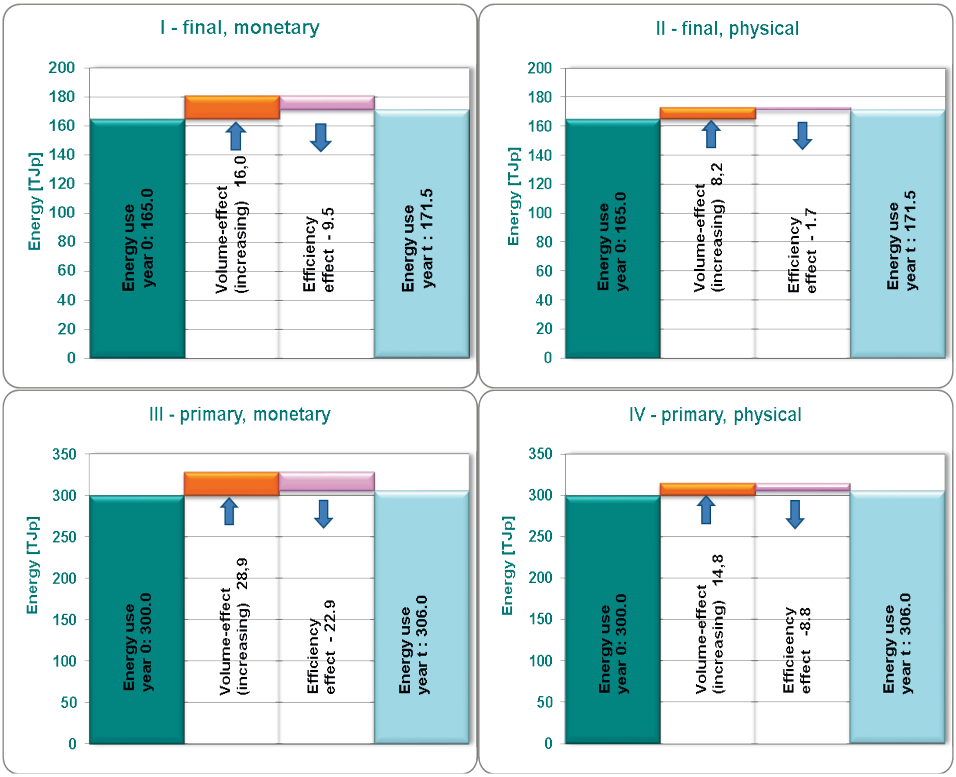

Figure 6-2. Two-factor decomposition for four scenarios applied to dataset table 6-2.

The second important choice is that between a physical or monetary activity indicator. In our example, the efficiency effect is higher in the monetary scenarios I and III, as value added grows faster than physical production. The efficiency effect is highest in the scenario III using both primary energy use and monetary production data, as this scenario captures both the CHP savings as the efficiency gain due to the growing value added. This difference between physical and monetary indicators confirms the conclusions of Freeman (1997).

The downside of the scenarios that use value added as a proxy for production is the influence of price effects. If value added increases while energy consumption remains stable, this will show up as a volume effect, but also as an efficiency effect of the same size. This is correct in the sense that Joule/€ has decreased. However, value added can be influenced by factors that have no direct relation to production, i.e. market prices or changes in other production factors. In other words, we do not know if production processes have become more energy efficient.

6.3.2.3 Three-factor decomposition

In a real economy, changes in the structure of the economy can have a significant impact on energy intensity as well. If a sector with a relatively low energy intensity grows, while a sector with high energy intensity remains stable, the energy intensity of the whole economy decreases, even though individual sectors remain at the same intensity level. This is visualized in the dataset in Table 6-3. In this dataset, Sector A, as treated in the former section, is divided in two subsectors (A1 and A2).

Table 6-3. Dataset for sector A divided in two subsectors.

		Sub Sector A1			Sub Sector A2		
Basic data	**unit**	**0**	**t**	**Δ**	**0**	**t**	**Δ**
Production	Mton	1 000	1 100	10.0%	1 000	1 000	0.0%
Added value	M€	5 000	5 700	14.0%	2 000	2 000	0.0%
Consumption (final)	PJ	55.0	61.5	11.8%	110.0	110.0	0.0%
Consumption (primary)	PJ	100.0	106.0	6.0%	200.0	200.0	0.0%
Unit consumption (f)	PJ/ton	0.055	0.056	1.7%	0.110	0.110	0.0%
Unit consumption (p)	PJ/ton	0.100	0.096	-3.6%	0.200	0.200	0.0%
Unit consumption (f)	PJ/€	0.011	0.0108	-1.9%	0.055	0.055	0.0%
Unit consumption (p)	PJ/€	0.020	0.019	-7.0%	0.100	0.100	0.0%
Project savings	PJ		5	saving		0	
Other factors	PJ		1	dissaving		0	

When we use these data to decompose the change in energy consumption in a volume-, structure- and efficiency effect, using the same four scenarios (Figure 6-1), we get the results as presented in Figure 6-3.

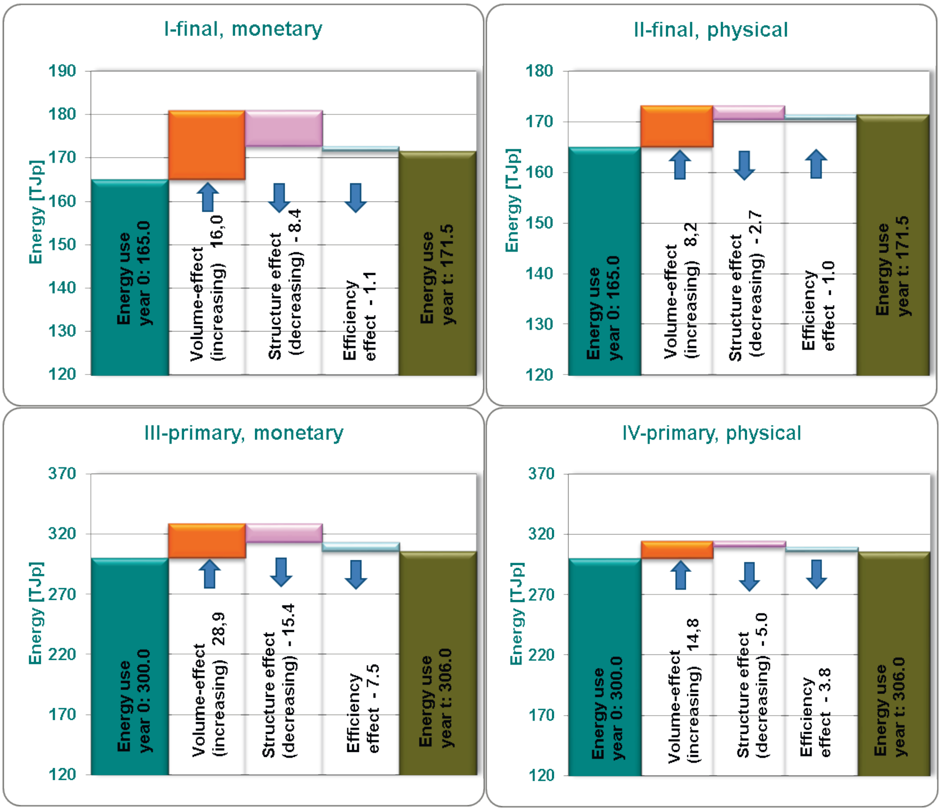

Figure 6-3. Three factor decomposition for four scenarios applied to dataset table 6-3.

In the combination of final energy use and physical production data (scenario II), the efficiency effect is the smallest, due to the dissaving 'other factors' and the fact that CHP-savings do not contribute to final energy savings. The efficiency effect is highest in scenario III, as this scenario captures both the industrial CHP savings and the "efficiency" gain due to the growing value added. In the scenarios using primary energy it should be noted that industrial companies do have control over the efficiency of their own industrial CHP-installations, but not on the efficiency of power plants in the energy sector. The difference of a factor 7 between the scenarios underlines the conclusions of Schlomann et al. (2015) who found that different meaningful definitions of energy efficiency can differ by a factor 10. This is in line with Cahill and Gallachoír (2010) who concluded that energy intensity results include changes brought about by a variety of factors, such as hidden structural changes.

The volume effect in these scenarios is the same as found in the two-factor decomposition analysis. However, in all scenarios the efficiency effect is smaller. This can be explained as part of the efficiency effect has now become a structure effect. In the combination

of final energy use and physical production data, the efficiency effect is even positive (dissaving), due to the fact that CHP-savings are not counted, while the dissaving of 'other factors' cause a higher energy use. In the first scenario (final/monetary) both volume- and structure effect are largest, as the two sectors show different developments. This shows the effect of the choice of metrics for production and energy use.
We can illustrate this with an example from the asphalt industry where more energy efficient but also more expensive lower temperature asphalt competes with hot temperature (normal) asphalt. Lower temperature asphalt uses considerably less energy during production than hot temperature asphalt (Thives and Ghisi 2017). If policy aims to decrease the energy use (and hence emissions) from asphalt production, a tax on hot temperature asphalt is a possible instrument. This instrument would increase the market share of lower temperature asphalt and contribute to the policy target. Let us first consider all lower temperature and hot temperature asphalt as the same product (ton asphalt). After all, the two products have the same basis characteristics. We would observe a decrease in average energy use, and therefore a savings effect. But if we consider lower temperature and hot temperature asphalt as different products, we would not see a savings effect, but a structure effect. If the tax would decrease the total asphalt production (as the price increases and therefore might lower total demand), it would be visible not as a saving, but as a volume effect.
This example shows that whether an effect is accounted as a volume, structure or a savings effect, depends on the level of detail of volume and structure data being used; when data are known on a more detailed, sub sectoral level, effects become visible that remain hidden when only data on a higher aggregation level are used. This has important consequences: detailed data lead to other results than aggregated data. If specific volume and structure information is not available full decomposition is not possible.

6.3.3 How are these methods applied in the Netherlands

6.3.3.1 Methods in use

Section 3.2 showed the impact of the use of different metrics to calculate progress in energy efficiency. In this section, we look how these choices were made in the different methods used in the Netherlands to calculate energy efficiency indicators for industry. Three of these are top down methods. Three methods are used nationally while a fourth is used for international comparison. Next to these methods, several policy instruments have their individual monitoring instruments using bottom up data of implemented projects. The voluntary agreements LTA and LEE in the Netherlands are used as an example of the latter methods, making it possible to compare bottom up with top down methods. We introduce these methods shortly below.

The oldest method is the Protocol Monitoring Energy Saving (PME), originating in 2001. The PME was developed on request of the Dutch Ministry of Economic Affairs to develop a uniform method to annually measure energy consumption and saving. An energy saving effect is calculated nationally and for every main sector, based on data by National Statistics. For industry, the average annual saving in the period 2000-2010 is 1.1% (see figure 6-4) (ECN 2012). The protocol defines energy savings as the difference between actual energy use and a frozen efficiency reference energy use. The saving effect is the residual after correction for volume and structure effects (Boonekamp et al. 2001). Several adaptations to the original method have been made to adapt the method to European reporting formats (ECN 2012).

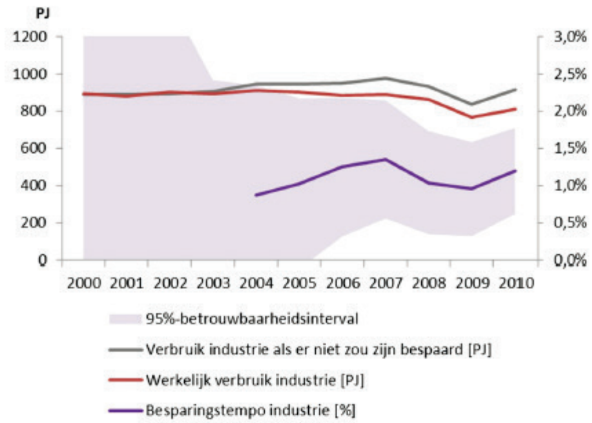

Figure 6-4. Final energy savings in industry (excluding chemistry) based on PME (ECN 2012).

The European Energy Efficiency Directive (EED) (European Parliament and Council 2012), in place since 2012, is a framework directive which sets overarching objectives and targets to be achieved by a coherent and mutually reinforcing set of measures covering virtually all aspects of the energy system (Coalition for Energy Saving 2013). It is the successor of the 2006 Energy Services Directive (ESD) (European Parliament & Council 2006). Following art.7, Member States must ensure that the required amount of energy savings is achieved through national energy efficiency obligation schemes or other "policy measures". These policy measures need to be designed to achieve 'end-use energy savings' which are 'among final customers' over the 2014-2020 period. Member States shall express the amount of energy savings required of each obligated party in terms of either final or primary energy consumption (EC 2012). Besides, following art. 3, Member states should define an indicative national energy efficiency target, based on either primary or final energy consumption, primary or final energy savings, or energy intensity (EC 2012).
Implementation of the EED in the Netherlands did not lead to one distinct new policy instrument, but rather a series of adaptations of existing instruments. Art. 7 of the

EED prescribes a method to calculate energy efficiency improvement. Policy measures that are primarily intended to support policy objectives other than energy efficiency or energy services as well as policies that trigger endues savings that are not achieved among final consumers are excluded only energy savings that are a result of real 'individual actions' that result from the implementation of these policy measures are to be taken into account. Member States may not count actions that would have happened anyway (EC 2012). For the Netherlands industry this means that an existing instrument like the Long Term Agreements can only partly be counted toward EED savings (under the exemption that savings can be counted against the target when they result from energy saving actions newly implemented between 31 December 2008 and the beginning of the obligation period and still have an impact in 2020), but adaptations to this instrument (extra demands on participants) can be counted as EED savings.

ODEX is the index used in the ODYSSEE-MURE project to measure the energy efficiency progress by main sector (industry, transport, households) and for the whole economy (all final consumers) for all 28 countries in the EU (Enerdata 2010). The ODYSSEE database contains detailed energy efficiency and CO2-indicators, i.e. about 180 indicators on energy consumption by sector and end-uses, activity drivers and related CO2-emissions, about 600 data series. The ODYSSEE database provides comprehensive monitoring of energy efficiency trends in all the sectors and priority areas addressed by EU policies. The database contributes to the development of a monitoring methodology based on top-down assessment of energy savings, through different types of indicators (Ademe 2015). There is no formal relation between the Directive and Odyssee, although the Odyssee reports were meant to monitor progress towards implementation of the EED targets of member states, The Energy Efficiency Directive itself does not mention ODEX or the Odyssee project;
Indices are calculated from variations of unit energy consumption indicators, measured in physical units. If no physical unit is available, an economic unit (Joule/value added euro) is provided.

Bottom-up methods are based on monitoring or evaluation of policy instruments, like the voluntary agreements LTA and LEE. These differ from the above mentioned methods in that they do not provide a figure on national level, but are limited to the effects of their own instrument. These methods are based on bottom up savings by individual projects implemented by companies, reported in yearly monitoring reports or subsidy request forms. These methods could help in providing explanations of developments.

A special case of a bottom up method is the monitoring of the Energy Agreement. It is special since it sets targets for the Netherlands as a whole and for individual sectors, but counts only those savings that can be attributed to one of 150 actions to reach 1.5%

efficiency improvement per year and 100 PJ final energy savings. As such, it is a bottom up method, although it also uses PME results to report on general progress in efficiency.

6.3.3.2 Comparison

Table 6-4 shows the differences between the methods described above. These criteria were selected based on an inventory of all possible differences and similarities between the numbers on energy efficiency in industry that were reported in the Netherlands. Important differences between the methods are the choice for final or primary energy use, the choice for a reference energy use, and the extent to which policy induced savings from different instruments are distinguished from autonomous developments. PME and ODEX are independent methods not coupled to a policy target, while the others are directly coupled to policy targets. The many aspects in which the methods differ make a comparison difficult. The only aspect on which the three national top down methods agree is that decrease of the final energy use and the effects of national policy counts as savings. In most other aspects the methods differ so much that comparison is impossible (Schoots and Hammingh 2015). The decomposition in section 3.2 provides a theoretical interpretation of the differences in results.

Table 6-4. Differences between methods used in the Netherlands.
Source: Adapted from Schoots and Hammingh (2015)

	PME	EED (art.7)	ODEX	LTA/LEE	EA
Target for Netherlands	No	482 PJ 2014-2020 (1.5%/yr)	No	30% in 2020, 2%/yr (LTA) No (LEE)	100 PJ in 2020, 1.5%/yr
Primary/final energy	Primary	Final	Final	Primary	Final
Reduction of energy use counted as savings	Yes	Yes	Yes	No	Yes
Renewables behind the meter counted as savings	No	Yes	Yes	No (counts as RE)	Yes
Reference energy use	Frozen efficiency*	Autonomous + EU-policy	Frozen efficiency*	Energy use + realized savings	Use without EA
Physical production data	Yes	Optional	Partly**	Yes	-
Monetary production data	No	Optional	Yes	No	-
Intersectoral structural changes visible?	Yes	No	Yes	No	-
Intrasectoral structural changes visible?	Partly	No	Partly	No	-
Autonomous savings counted as savings?	Yes	No	Yes	Yes	No
Savings due to existing and future EU-policy counted as savings?	Yes	No	Yes	Yes	Yes
Savings due to existing and future NL-policy counted as savings?	Yes	Yes	Yes	Yes	Yes
Based on bottom up project savings?	No	No	No	Yes	Partly***
Other company level factors visualized?	No	No	No	Yes	No
Residual in decomposition	No	No	Yes	Yes	-

*Reference energy use based on frozen efficiency is the energy used if one would be as efficient as in the base year
**Only for steel, cement and pulp & paper
***A combination of top down modelling results and bottom up reporting of individual policy instruments.

Policy makers do not only want to know if the policy target is reached but also if savings are induced by their policy instruments (effectiveness). Have their instruments brought about the desired effect? However, not all savings are induced by policy instruments and, the other way round: policy instruments will not only influence savings, but possibly also sector activity and structure.

The used methods differ in the way changes are assigned to a volume, structure or efficiency effect. For example, PME is stricter in its definition of savings than the EA. The EA is aimed towards lowering final energy use, regardless of the cause. Therefore, instruments that result in a decrease in the activity level or in a shift towards a less energy-intensive mix of activities, will be seen as a policy effect by the EA. The PME classifies these not as a savings effect, but as a volume or structure effect (Schoots and Hamming 2015). In other words, the same development will be assigned to a different effect dependent on the method applied.

Considering the fact that methods have been developed for different purposes and the differences mentioned in table 6-4, it is not surprising that the methods yield different results. Table 6-5 shows indicators on energy efficiency in the Dutch industry since 2000. The results differ by more than a factor 2. There are no data for EA and EED in this table, as there are no data for a comparable period; EED art. 7 specifically targets cumulative savings over the period 2014-2020, which are calculated according to EED Art. 7 requirements and are not comparable with normally used annual cumulative savings in another period. Schoots and Hammingh (2016) report 1 PJ final energy saving for industry in 2016 compared to 2000 that can be attributed to the EA, and 91 PJ energy savings for industry eligible under art. 7 of EED. The many different outcomes resemble the results of Voswinkel (2018), who was able to calculate 8 different but correct results from the same dataset.

Table 6-5. Different energy saving numbers in the Netherlands since 2000.

Method	Aspect	Result	Source
PME	Primary savings trend in industry 2000-2010	1.0 %/yr	ECN 2012*
ODEX	Energy efficiency progress industry 2000 – 2012	2.6%/yr	Odyssee**
Bottom up	LTA3-Savings by energy projects 2005-2014	2.0 %/yr	RVO.nl 2015
	LEE-Savings by energy projects 2010-2014	%/yr	RVO.nl 2015

*This is the last official publication of PME savings. Since then this publication is replaced by the NEV, which uses the PME method to publish a national saving figure, but not at the formerly used detailed level.
** http://www.odyssee-mure.eu, Ademe 2015

To better understand the reasons behind these differences, we evaluate developments in more detail. In Dutch industry, growth of value added is structurally higher than the increase in physical production (Schoots and Hammingh 2015), resulting in a decrease in energy intensity for the whole sector even while production of individual products is not becoming more efficient. The industrial subsectors have experienced a decrease in energy consumption (2000-2010), in line with a lower energy intensity within these sectors. This is a result of a structural change towards less energy intensive production

(Gerdes 2012). This decrease even compensates for an increase in the contribution of the (energy-intensive) chemical sector in the Netherlands between 2000 and 2008 (Ademe 2012). In the case of the Netherlands, the fact that in ODEX the production of the chemical industry (which covers half the total industrial energy use of the Netherlands) is measured in euros, results in a large efficiency effect (2.3%/yr) compared to PME (1.1%/yr). Added value in this sector has increased faster than physical production (Odyssee 2012). In the PME method, the reference energy use in the chemical sector is based on physical production of several products (via Prodcom) . In PME, a change in the product-mix will be visible as a structure effect or –if no data on subsectors are available- as a smaller volume-effect. This difference in outcome is visible in section 3.2.2 as the difference between figure 6-1 and 6-4.
LTA savings are higher than PME savings as the bottom up reporting of savings by implemented energy saving projects measures only savings and does not observe any developments that might have adverse effects on energy use or energy efficiency.

6.3.4 What are the advantages and disadvantages of the methods

Section 3.3 showed the differences that follow from the choices that have been made in terms of scope and used data. These choices also define the possible use of the outcome; the outcome of one method cannot be used for all possible purposes. This should always be kept in mind when interpreting results, especially when results are compared. What method is most suitable depends on the aim of the analysis; every method has its own (dis)advantages, which are summarized in table 6-6.

Table 6-6. (Dis)advantages of methods.

Method	Advantages	Disadvantages
PME	Enabling comparing historical with future trends	Some policy effects are shown as volume or structure effect
ODEX	Enabling comparing progress of energy efficiency of countries and trends from 2000	Structure effects are shown as savings
EED	Possibility to define the gap to national EED targets of member states	Not all policy efforts are eligible for EED art. 7 and therefore do not contribute to this policy target.
EA	Possibility to define the gap to the national target of 100 PJ final energy savings	Not all policy efforts are part of the EA and therefore do not contribute to this policy target
Bottom up	Gives the most detailed information on projects or policy instruments	Focuses only on positive savings. No distinction between autonomous and additional savings

The PME method has been in use since 2001 and can be used to compare historical and future trends in energy efficiency in the Netherlands. However, due to the differences with the European methods ODEX and EED, the results cannot be compared to other countries. Another disadvantage is that the PME results are sometimes confusing to policy makers: some policy effects are counted as volume or structure effects, hiding the policy effect. Only part of the efficiency effect that is measured in the PME, counts as savings for the EED, as PME also counts the effect of EU and older policy instruments. ODEX is designed to compare European countries, which makes it the best available method for this purpose. However, the method is largely dependent on availability of data. The choice between physical or economical production data can have a large effect on the outcome, especially in economies in transition. As countries make different choices regarding this issue, comparability between countries is doubtful.
Cahill and Gallachoír (2010) also showed that fluctuations in the data set used to calculate the indices can significantly influence the values yielded by the indices. Both ODEX (using unit consumption) as the LMDI approach (using energy intensity based on value added) overestimated the savings for Irish industry, with ODEX showing the greater overestimation of energy efficiency achievements of around 0.3 percentage points per year.
Another difference between ODEX and PME is the use of final or primary energy. This means a different allocation of energy consumption to sectors, but also a different observation of industrial CHP. Netherlands' industrial CHP surged in the nineties, but has been in decline since 2008 due to an unfavorable market situation. This means that CHP is replaced by less efficient power plants. PME, using primary energy, will therefore now see an increase in primary energy, while final energy use remains the same.

For most sectors ODEX is comparable with the PME method, but for reasons of comparison and lack of data between member states for some subsectors energy intensity is used as a measure for energy efficiency. Where the former method includes volume effects (services, physical productions units etc.), the latter does not, or at least to a lesser extent. This difference in approach needs to be kept in mind when looking at the ODEX figures. ODEX cannot discern structural changes within the chemical industry, as data on the (physical) amount of produced chemicals is not collected for ODEX. Compared to bottom-up evaluations, efficiency gains measured in Odyssee have a broader scope and include all sources of energy efficiency improvements: policy measures, price changes, autonomous technical progress, other market forces, etc. (Odyssee 2015). Horowitz and Bertoldi (2015) have disaggregated that part of the changes in ODEX that are due to the effects of EU and national energy policy. They also conclude that there is a statistical relationship between bottom up estimates of energy efficiency progress and actual energy consumption.

For the Energy Agreement, only those savings are eligible that are a result of the deals that are part of the EA. As the EA is a mix of new instruments and adaptation to existing European and national instruments, it is difficult to compare the results with other instruments or national saving figures. As such, the results are only useful to monitor the progress of the EA itself.

The main advantage of the EED method is that it defines the gap of a country towards its target as defined by the EED. However, member states can choose from a number of exemptions in the definition of their end-use target under art.7. For instance, member states can choose to exclude the transport sector and/or part of the ETS-sectors from their energy use. This makes targets from different countries incomparable and difficult to interpret. Not only target setting, but also the reported realized savings are difficult to interpret. This problem originates a.o. from (Coalition for Energy Saving 2013):

- A vague baseline, because of the many possible exemptions
- Possible double counting (e.g. subsidy schemes and LTA/LEE both reporting the same saving)
- Not all policy measures are eligible

In general the bottom up results of individual policy instruments based on implemented projects give a good insight in actual investments in energy efficiency projects and provide detailed insight in the implementation of new technologies, but cannot be aggregated to a national level, because of the overlap in savings of different instruments. Moreover, it is very difficult to make a distinction between autonomous and additional savings. Efforts have been made to establish additionality, but are associated with a high degree of uncertainty. The bottom-up methods also disregard other factors that influence energy consumption and therefore have no direct relation to actual development of energy consumption or energy efficiency. A company can install energy saving equipment, while at the same time implement changes in the production that lead to a higher energy consumption. Other choices that can have a large effect on the size of the savings effect are whether or not corrections are made e.g. for weather influences, capacity utilization, free riders, rebound effect or double counting.

6.4 Conclusions & recommendations

Conclusions

The most important difference between the methods described in section 3 lies in the choice of metrics used, which has a large effect on the outcome. The main choices for any energy efficiency method are the energy (final or primary energy) and the activity indicator (monetary or physical).

The choice of metrics is sometimes made deliberate, but is often a consequence of data availability. However, a choice made due to lack of data leads to misleading results. Whether an effect is shown as a volume, structure or an efficiency effect, depends on the selected indicator for production and on the aggregation level of information available and used in the particular method. The scenarios in section 3.2 showed that a different choice of metrics can lead to a difference of a factor 7 in the efficiency effect. Because of the large and fundamental differences between the methods it is not possible to compare the outcome. Up to a certain extent, it is possible to translate the results from one method to that of another. However, this is only possible with good understanding of the underlying method, definitions and data used. Therefore, one should not translate results of one method to that of another and always bear in mind the aim and background of the particular method before interpreting the result. This important conclusion holds for methods that are used within one country, but even more so when comparing results from different countries, when differences in structure add to the differences in methodology.

As we saw in section 3.3.1 the current Dutch Energy policy to reduce energy use is a mix of instruments, existing and new, targeting generic or specific groups, and steering to convince target groups to change their behaviour by enforcement, seduction and/or information. To follow this mix of policy measures the Netherlands use several methods to calculate energy savings. Importantly, the methods differ in aim, scope, the data used and the factors in which effects are decomposed in the calculations. It seems that every new policy instrument leads to a new evaluation method, resulting in a set of figures that cannot be compared, not only within the Netherlands but also the EU. One reason for different methods is also the diverging requirements in different legislative texts and their reporting. Therefore it is unlikely, at least at the short/medium term, that harmonized methods will be used in all countries

While comparing efficiency data within a country is difficult, comparing efficiency results of different countries is even more challenging. Art. 7 of the EED leaves countries many options to design their own method. Therefore it is not sensible to compare EED savings to other results.

An important finding from this paper is that it is not possible to nominate one of these methods as the 'methodologically most correct' method. It is only possible to tell which method is most suitable for a certain purpose. This depends on the aim of the analysis; every method has its own (dis)advantages (see table 6-6). In evaluating energy savings indicators one needs to keep in mind that indicators in some cases do not purely represent energy savings. It is important to have good insight in the method to know whether other effects, like volume or structure, are included as well. The used method should therefore be clearly reported with the results.

Recommendations

Our first recommendation is that scientists should not only look for that indicator that best represents progress in efficiency, but also the indicator that gives the best support for the policy makers. For an indicator to be useful for a policy maker it is necessary that the indicator has a close relation to the policy target and to the policy instruments that are used to reach that target. One might question whether it is useful to know if an effect should be considered an efficiency effect or a structure effect, as long as the effect is there. The first priority for a policy maker is to know if the policy target is reached. The second priority is to know if this effect was reached as a consequence of policy instruments. The monitoring system should be designed bearing in mind what is in practice possible with reasonable resources.

Our second recommendation is that in order to design a monitoring system that suits better to the needs of policy makers, one should design a system that is more simple and simple to communicate, focusing on either the development of easy to understand indicators or the effect of individual policy instruments, but not both.
Solutions thus far have tried to provide more detail, to decompose changes in energy consumption in ever more separate factors, trying to isolate the effect that one is searching for. But a more detailed monitoring instrument is more expensive and does not necessarily lead to better insight in the effect of policy instruments, as this study shows. Even a very detailed decomposition will not succeed in isolating the effect of a single policy instrument. Evaluation of individual instruments is more suited to this task.
Scientists have tried to design better monitoring systems. However, these efforts have not led to more comprehensive indicators. On the contrary, it has led to solutions with more degrees of freedom regarding the choices in metrics and applied corrections. The solutions provided thus far have focused too much on mathematical correctness, thereby forgetting the applicability for policy makers.

7

Chapter 7

Summary and conclusions

7.1 Introduction

Carbon emissions from combustion of fuels for energy generation are a major contributor to global warming. Industry is one of the major users of energy and remains among the most energy-intensive sectors. The share of industry in final energy consumption in the EU is 25% (Ademe, 2015), even though this share is expected to decrease until 2050.

To achieve a reduction in energy consumption without hampering economic growth, a decoupling of energy consumption and economic growth is needed. This is where energy efficiency comes in. Energy efficiency is the art of doing more with less. Energy efficiency is defined as decreasing the amount of energy used per unit of energy services, without affecting the level of those services.
Increased industrial energy efficiency is one of the most promising routes to sustainable industrial development worldwide (Unido, 2011). Several studies have concluded that energy efficiency is the most cost effective way to reach climate targets (Gillingham 2006; European Parliament and Council 2012, IEA 2017) and that considerable potential exists for energy efficiency (Boβmann et al. 2012; Solnordal and Foss 2018). Increasing industrial energy efficiency is crucial to reach climate objectives and reduce emissions without blocking possibilities for industrial growth.

Innovation through implementation of more efficient technology can increase efficiency, but this process is slow. Policy instruments have been implemented to stimulate energy efficiency in companies, by stimulating drivers of efficiency or overcome barriers that hamper efficiency. Some of these instruments use regulations to prescribe certain technology, financial instruments aim to improve the business case of efficient technology while supportive instruments help companies to identify and implement opportunities for efficiency. The energy policy in the Netherlands is a mix of those type of instruments. Among the longest standing instruments in this mix are the voluntary agreements. This thesis uses data from these agreements to test how energy efficiency is implemented in practice.

As energy is used for so many different purposes, measuring energy efficiency poses difficulties. The development of energy efficiency is a result of multiple factors, one of which is government policy to stimulate efficiency. To know whether those policy instruments are successful, a monitoring method should distinguish the effect of policy instruments from other effects. Multiple methods have been designed for this purpose. This thesis compares the outcome of these methods to the results of the voluntary agreements in the Netherlands.

The main research question for this thesis is:
How are energy saving projects being implemented in industrial companies in the Netherlands?

To answer this question, we pose the following sub questions:
1-What is the impact of implemented projects on the actual energy use?
2-What kind of projects are being implemented?
3-What are drivers and barriers for the implementations of these projects?
4-How does the monitoring method affect the determination of realised energy savings?
5-How can energy efficiency results be compared?

These sub questions are answered in section 7.2.

7.2 Key-findings and conclusions

1-What is the impact of implemented projects on the actual energy use?

This thesis focused on the energy savings realized under the Dutch voluntary agreements on industrial energy efficiency in the period from 2001 onwards. As there is a large potential for energy savings in industry, this sector can provide a major contribution to energy savings goals. Participants in the Dutch schemes are obliged to plan and implement all measures with a payback period of less than 5 years. As shown in chapter 2, companies in the Netherlands annually implement multiple projects to improve efficiency, even though energy savings are often not the main reason for implementing these projects. Between 2001 and 2011, 20.000 projects have been implemented which generated average savings of 1.9% per year. Our findings show that large differences exist in the realized savings between individual companies. Some companies have implemented projects that save up to 50% of their energy consumption over the total period, meaning savings of more than 5% per year. Savings of this size typically come in large steps, when major installations are replaced. There is however no significant difference in savings observed between companies that participate in the EU Emission Trading System (ETS) and companies that do not. Although it is impossible to disentangle the single effect of different drivers behind the implementation of these projects, the amount of savings suggest that at least part of it was implemented due to the voluntary agreements and the energy policy instruments supporting them, but that the ETS system may not have played a role in this period.

It is tempting to assign a decrease in energy consumption to the implementation of energy saving projects. As we saw in chapter 2, these projects have a significant role in the change in energy consumption, but their effect is smaller than the effect of other factors. Especially the impact of changes in production volume is important. However, because other factors can have both decreasing and increasing effects on energy consumption, partly compensating each other, the net effect of these other factors is smaller. For example, the period of the economic crisis (2006-2013), first witnessed a strong decrease in energy consumption as a result of decreasing output, but at the end of the period production and energy consumption recovered to pre-crisis levels. While the influence of production changes in intermittent years was very large, the net effect over the whole period was nearly zero.

2-What kind of projects are being implemented?
Participants of the voluntary agreements have to announce the energy-saving projects that they have planned for a specified reporting period in an Energy Efficiency Plan (EEP). All projects with a payback period less than 5 years should be implemented.

We have provided insight into the differences in planning and implementation of energy efficiency investments by companies, based on an analysis of the EEPs submitted in the period 2009–2012. By comparing the characteristics of projects that have been implemented with those that were planned, insight was gained in the adjustments that companies make in their energy efficiency investment plans and external circumstances that could explain these adjustments. Our results show that in the period 2009-2012 over 12,000 projects have been planned by the 904 long-term agreement (LTA) participants, about half of which were considered ‘certain’, which means that companies are certain that these projects will be implemented. However, we find a large difference between planned and realised savings of companies and a huge variation in the payback periods of both planned and implemented projects: although the majority of projects have a payback period around 2 years, about 30% of projects have PBP exceeding 5 years.

More than half (60%) of the implemented projects fall under the category ‘adjustments in processes’. This makes sense, as process installations account for the largest part of industrial energy use. About 20% of the savings are projects in utilities or buildings. The contribution of energy management projects is smaller (13%), although the number of projects in this category is large. Typically, these projects require little to no investments and can be implemented without interruption of production. Often, these savings are referred to as ‘low hanging fruit’.

The average Payback Period (PBP) of implemented projects is 6 years, while the median is 2, implying that relatively many projects have a short PBP. We did not find a correlation between implementation rate and payback period. Our observations have shown that not all profitable projects are being implemented. This phenomenon has been observed earlier and is called the efficiency gap. On the other hand, many projects are being implemented that are not profitable, at least not at the time of planning. The fact that many companies plan and implement projects with a PBP over 5 years can mean two possible things: the PBP was not assessed correctly (e.g. not all benefits were included in this calculation), or that other criteria than PBP were more important in the decision to implement the project. This makes sense as the costs saved on energy are small compared to other benefits from investments. Those other benefits can be financial, but non-financial benefits like better product quality occur often as well. This leads to the conclusion that a focus on payback period as a decisive criterion for investments without accounting for all benefits leads to suboptimal outcomes both for companies as for government agencies stimulate those investments. Policy instruments aiming to stimulate investments in energy efficiency projects should focus on other than financial benefits to trigger the drivers that coincide with the internal drivers of companies, for example productivity gains or higher product quality. Our results can be used to improve the effectiveness and efficiency of voluntary agreements.

3-What are drivers and barriers for the implementation of these projects?
Increased energy efficiency represents a crucial opportunity for industrial sustainability, yet barriers still need to be tackled to fully realize the potential. Thus, it is crucial to understand the existing mismatches between the perception of enterprises and what the major actors promoting energy efficiency believe enterprises suffer from and need within the decision-making process. To do so, we have performed an exploratory research analysing a set of small- and medium-sized manufacturing enterprises participating in the Dutch voluntary agreements. The study involved both the companies themselves as the major external actors, i.e. the national energy agency, governmental and industrial organizations, to map their views on the decision-making process within the companies. Results show that enterprises agree on the most important barriers and drivers and the mechanisms underlying them. However, external actors disagree on the working of all barriers except that of economic barriers. They disagree in their views on how drivers and barriers affect the decision-making process in a company, and what actors need to act to affect those drivers and barriers. Although voluntary agreements represent the most popular instrument for energy efficiency in the Netherlands, small and medium-sized enterprises do not seem to consider them as a stimulus for improving energy efficiency. Crucial for future success is the link with other policy instruments, and the degree to which the instruments trigger the right drivers and barriers at the right moment.

As we saw in chapter 3, energy costs were not the decisive criterion for implementation of energy efficiency projects. This might seem contradictory to the fact that most companies name cost savings as the most important reason to join the voluntary agreements and that economic barriers rank among the highest barriers named by firms (see section 4.5.3). The reason for this apparent inconsistency lies in the fact that energy costs are just one cost factor. Another reason lies in the complex organization of the decision-making process. Between the first awareness of a possible opportunity to save energy and the actual implementation of a project lies a long and winding process of different steps. At each step, different drivers or barriers are important. While economic arguments are most important at one step, in other steps technical aspects become more decisive. In the overall process, payback period is just one of many possible criteria. To be most effective, the mix of policy instruments should identify the decision steps that pose the most important barriers and address all of them. An instrument that removes one barrier, only to see the project blocked by another barrier, is ineffective.

Where many studies name the economic potential for cost savings as the most important driving force behind investment decisions, we draw a more nuanced conclusion. Economics remain an important driving force, but this economic advantage does not origin from energy costs savings alone, but rather from the total of all advantages.

4-How does the monitoring method affect the determination of realised energy savings? In 2008, the Dutch voluntary agreements faced fundamental changes to their monitoring methodology. Where the old method was an 'intensity' method based on measuring the improvement of energy use per unit of production, the new method focuses on the energy savings from projects implemented by participating companies. In this project-based method the results are determined by reported savings only, and not calculated on production and energy data.

The two methods therefore use different data; reported savings in the new method are not influenced by volume or structure effects. Especially, the effect of production changes had a large impact on the result of the old method, particularly in the period of the economic crisis. Although this effect represents an actual change in energy intensity, the effect does not represent structural savings, as the change in energy intensity is reversible (see section 5.4). A fundamental difference in output is that the result in the new project-based method cannot be negative, as was sometimes the case in the intensity method. In the new method, the minimum result is zero. This means that as long as at least one project is reported, the new method will always show a positive result, even when the energy used per ton increases as a result of e.g. a lower capacity utilization or other factors.

Our comparison of the intensity-method and the project-based method has shown that these methods do not provide comparable results. Both methods have their own advantages and disadvantages. While the intensity method provides an understanding of the amount of energy used per unit of product, it has only a cursory relation to efforts of firms to save energy. The project-based method on the other hand provides insight in the firms investments in energy saving projects, but does not have a relation with actual development of energy consumption or energy intensity. Even when a company has implemented energy saving projects, actual energy consumption can still increase and energy efficiency can deteriorate as a consequence of other factors. Every reported project is a claim saying 'energy use would be higher without this project'

Advocates of the new method claim that it gives a better view of the companies' efforts to save energy, as it shows their deliberate changes in production processes, whereas opponents emphasise that the relation with actual energy intensity is lost. By applying the two methods on the same group of companies, the results can be compared and show to what extent the choice of monitoring method affects the key message to policy makers. Of special interest is the relation between energy and production in the period 2008–2012, a period with large fluctuations in the levels of production and energy use as a result of the economic crisis. The data show that energy-saving projects made a significant impact on energy use in the analysis period, although their effect is smaller than that of other factors such as fluctuations in production. The old method shows a result for the period 2005–2013 that is less than half of that of the new method, mainly because of a decrease in efficiency during years of decreasing production in this period. Our analysis has clearly shown that the two methods do not show the same development of energy efficiency improvement and therefore should be presented as separate methods.

5-How can energy efficiency results be compared?
The European Commission has made strong efforts to harmonize methods to measure energy
efficiency and energy savings, to monitor the progress towards the goals of the Energy Efficiency Directive. However, in practice multiple methods are still used, which may lead to confusion. In this thesis we used the Netherlands as a case study to analyse this phenomenon. In the Netherlands, three national indicators on energy efficiency exist: a method based on the difference between actual energy use and a reference energy use based on energy intensity (PME); a method to report progress towards the EED target and a method to follow progress towards the National Energy Agreement. Besides these national methods there is also a method to compare energy efficiency in European countries (ODEX) and bottom up methods to monitor the impact of individual policy instruments. As shown in section 6.3, these methods yield results that differ a factor two where one would expect these to be more or less equal.

The large differences and sometimes contradictory results of the different indicators lead to questions about what is the ‘best’ method. We have studied the reasons behind the differences between the methods used for industrial energy efficiency improvement in the Netherlands. We compared detailed bottom up data from individual policy instruments with top-down national figures. We disentangled the impact of volume, efficiency and structure effects. In this way we visualised the differences between several methods and the impact of the choice of metrics used in those methods. This helps understanding why care should be taken when comparing industrial energy efficiency results from different countries. The differences follow from choices made in scope and used data, like the target group and reference year. The main choices for any energy efficiency method are the indicators for energy (primary or final) and activity (monetary or physical). These choices are sometimes made deliberate, but are often a consequence of data availability. Not only the choice, but also the level of detail of the used metrics define if an effect is shown as a volume, structure or efficiency effect and thus has a large effect in outcome. Therefore, one should not translate the results of one method to that of another and always bear in mind the aim and background of the particular method before interpreting the results. If the policy target changes, so does the right method to measure if that target is achieved. It is not possible to nominate one method as ‘better’ than other methods. One can only say that a method is better suited for a certain purpose. A bottom-up method will be better suited to evaluate the effect of an individual policy instrument, while a top-down intensity method will be more suited to measure the actual development of energy intensity.

7.3 Recommendations

- Monitoring reports should clearly present their result in absolute or relative terms. Efficiency improvement is part of the energy policy targets. The European Energy efficiency Directive gives member states the option to define a national efficiency target in terms of energy consumption, energy savings or energy intensity, as long as they contribute a fair share towards the EU 20% target. These targets are related, but not directly. An absolute reduction of energy use is not always coupled to an efficiency increase. An increase in energy efficiency can lead to a reduction in absolute energy use, but this is not necessarily the case as an increase in production volume can negate an increase in efficiency. As we saw in chapter 5 this has been the case in many of the monitoring reports of the voluntary agreements in the Netherlands during the years of strong economic recovery. These reports showed an improvement in energy efficiency, while energy consumption still increased. These voluntary agreements are an efficiency instrument: their target is an increase in efficiency, not an absolute reduction in energy consumption. This difference needs to be addressed in monitoring reports to safeguard good interpretation.

- Monitoring results should not be too easily compared to other results.

Following the first recommendation, the difference between energy savings and energy efficiency is a relevant issue as well. In scientific literature, a clear distinction is made between energy efficiency and savings, but in daily language—and many policy documents as well—the terms are often used interchangeably. The fundamental difference between energy efficiency and energy savings is that energy efficiency is a relative, dimension-free ratio, e.g. a conversion efficiency that has been raised from 80 to 90 %. Energy savings on the other hand are an absolute change in energy consumption (section 5.2.1). Efficiency can go both up and down, but savings are always pointing in the direction of less energy. If efficiency goes up, energy has been saved, but the other way is not necessarily true. Policy makers should mind this difference in their target setting. For sound evaluation of a policy target, the monitoring method should be consistent with the set goal (section 5.4). As discussed in the previous paragraph, absolute targets and efficiency targets are often confused.
As we have seen in section 6.3, existing methods to measure the effect of policy instruments differ fundamentally in terms of scope, used data and presentation of the results. Results of one policy instrument should not be translated to that of another instrument without good understanding of the used method.

- Policy instruments should not focus on payback period based on energy costs as a criterion for obligatory projects.

A calculation of a payback period based on saved energy costs alone is not a decisive criterion for companies when deciding to implement energy saving projects. Therefore, policy instruments should look for other criteria when obliging or promoting investment in certain projects. A government would not want to oblige or promote projects that would have been implemented anyway. The objective is to make companies implement more projects than they would have done by themselves. A possible idea is the classification scheme referred to in section 3.4, that categorizes projects according to 12 characteristics, divided into relative advantage, technical context and information context. Each characteristic is arranged on the likelihood of implementation. This classification scheme could provide a starting point for the design of policy instruments that would stimulate certain projects. As such a system is not dependent on just one variable, it has a higher chance of predicting whether a project will be implemented anyway, would never be implemented or might be susceptible to a nudge by a policy instrument.

Recommendations for future research

- Monitoring results should be easy to communicate

As we described in chapter 6, researchers have tried to design methods that provide more

detail by decomposing changes in energy consumption in ever more separate factors, in an effort to isolate the effect one is searching for with as little interference from other effects as possible. But a more detailed monitoring instrument is more expensive and does not necessarily provide better insight in the effect of policy instruments. Even a very detailed decomposition will not succeed in telling which part of the savings effect is autonomous and which part is policy induced. Moreover, it cannot isolate the effect of single policy instruments, as policy instruments usually work together in a mix of instruments that partly overlap. Bottom up evaluation of individual instruments is better suited to establish the effect of that particular instrument, even though evaluation of individual instruments tend to overestimate the effect of that particular instrument. Moreover, elaborate methods are not necessarily more accurate. The more detailed the decomposition, the more difficult it is to separate effects from each other. E.g. policy instruments will affect prices, thereby influencing price effects. In order to isolate effects, methods make use of correction factors, e.g. for climate influences, which are often based on assumptions. These correction factors cloud the result and make comparability with other monitoring instruments difficult.
Therefore we recommend that in order to design a monitoring system that suits the needs of policy makers, one should design a system that is more easy to communicate, focusing on either the development of easy to understand indicators or the effect of individual policy instruments, but not both. Such an instrument should provide indicators that are clearly presented in terms of efficiency, energy intensity or an absolute reduction in energy use.

- Better understand the reasons for implementation of saving projects

For further research it is recommended to look closer into the reasons behind implementation of energy saving projects, in order to develop a better understanding of the contribution of policy instruments versus autonomous savings. In the decision making process in companies some projects will be implemented as a result of a policy instrument; e.g. a subsidy that lowers the price of a more efficient motor. Other projects will be implemented for other reasons, that have no relationship with policy, e.g. an end-of-life replacement. In section 2.5 we saw that it is difficult to determine for what reasons projects are implemented. More insight into the drivers behind implementation, e.g. the value of other than financial benefits, or the corporate decision making process. This insight can reveal which projects are being implemented anyway (leading to autonomous savings) and which projects could be stimulated by a policy instrument. This would provide a starting point for a design of instruments that are better fitted to the drivers of companies. This knowledge is essential for policy instruments that are both effective and efficient.

8

Chapter 8

Samenvatting en conclusies

8.1 Introductie

CO_2-emissies door de verbranding van brandstoffen voor energie opwekking dragen in belangrijke mate bij aan het broeikaseffect. De industrie is een grote gebruiker van energie en is één van de meest energie-intensieve sectoren; in de EU bedraagt het aandeel van de industrie in het finaal energiegebruik 35% (Ademe 2015), hoewel dit aandeel tot 2050 waarschijnlijk afneemt.

Om het energieverbruik te beperken zonder economische groei te belemmeren, moet er een ontkoppeling komen tussen energieverbruik en economische groei. Energie-efficiëntie kan die ontkoppeling realiseren. Energie efficiëntie is meer doen met minder. Energie-efficiëntie is gedefinieerd als het verminderen van de hoeveelheid benodigde energie per eenheid van energiediensten, zonder het niveau van die diensten te verminderen. Energie-efficiëntie is wereldwijd één van de meest veelbelovende routes naar duurzame industriële ontwikkeling (Unido 2011). Meerdere studies hebben geconcludeerd dat energie-efficiëntie de meest kosteneffectieve manier is om de klimaatdoelen te bereiken (Gillingham 2006; European Parliament and Council 2012, IEA 2017) en dat energie-efficiëntie ook nog veel potentieel heeft (Boβmann et al. 2012; Solnordal and Foss 2018). Het verhogen van energie-efficiëntie is daarom cruciaal om klimaatdoelen te bereiken en emissies te beperken zonder groeimogelijkheden voor de industrie te blokkeren.

Innovatie door implementatie van efficiëntere technologie kan de efficiëntie verhogen, maar dit proces gaat langzaam. Daarom zijn beleidsinstrumenten geïmplementeerd om energie-efficiëntie bij bedrijven te stimuleren, door de drijfveren van efficiëntie te stimuleren of juist door barrières te doorbreken die efficiëntie tegenhouden. Sommige van deze instrumenten gebruiken voorschriften om bepaalde technologie te verplichten. Financiële instrumenten proberen de businesscase van efficiënte technologie te verbeteren, terwijl ondersteunende instrumenten bedrijven helpen mogelijkheden voor efficiëntie te identificeren en te implementeren. Het Nederlandse energiebeleid is een mix van die typen instrumenten. Onder de langst lopende instrumenten vallen ook de meerjarenafspraken. Dit proefschrift gebruikt data uit deze convenanten om te testen hoe energie-efficiëntie n de praktijk wordt geïmplementeerd.

Aangezien energie voor zoveel verschillende doeleinden gebruikt wordt, is het meten van energie-efficiëntie niet eenvoudig. De werkelijke verbetering van de efficiëntie is het gevolg van meerdere factoren, waarvan het energiebeleid er maar één is. De uitdaging bij het meten van energie-efficiëntie is om het effect van beleidsinstrumenten te onderscheiden van andere effecten. Hiervoor zijn meerdere methoden ontwikkeld. Dit proefschrift vergelijkt de uitkomsten van dergelijke methoden met de resultaten van de meerjarenafspraken in Nederland.

De belangrijkst onderzoeksvraag van dit proefschrift is:
Hoe worden energiebesparende projecten geïmplementeerd bij industriële bedrijven in Nederland?

Om deze hoofdvraag te beantwoorden, stellen we de volgende deelvragen:
1-Wat is het effect van geïmplementeerde energiebesparingsprojecten op het energiegebruik?
2-Wat voor soort projecten worden geïmplementeerd?
3-Wat zijn drijfveren en barrières voor besparingsprojecten?
4-Hoe bepaalt de monitormethode de uitkomst van de berekening van gerealiseerde energiebesparing?
5-Hoe kunnen we energiebesparingscijfers vergelijken?

Deze deelvragen zijn beantwoord in sectie 8.2

8.2 Belangrijkste resultaten en conclusies van deze thesis

1- Wat is het effect van geïmplementeerde energiebesparingsprojecten op het energiegebruik?
Dit proefschrift richt zich op de energiebesparingen die zijn gerealiseerd in de energieconvenanten in Nederland vanaf 2001. Gezien het grote potentieel voor energiebesparing in de industrie, kan deze sector een grote bijdrage leveren aan energiebesparingsdoelen. Deelnemers in de Nederlandse convenanten zijn verplicht om alle besparingsprojecten met een terugverdientijd van 5 jaar of minder uit te voeren. Zoals bleek in hoofdstuk 2, implementeren Nederlandse bedrijven jaarlijks meerdere besparingsprojecten om energie-efficiëntie te verbeteren, hoewel energiebesparing vaak niet de belangrijkste reden is om die projecten uit te voeren. Tussen 2001 en 2011 zijn 20000 projecten gerealiseerd, die gemiddeld 1.9% per jaar hebben bespaard. Onze resultaten laten zien dat er grote verschillen bestaan tussen individuele bedrijven. Sommige bedrijven hebben projecten gerealiseerd die samen meer dan 5% per jaar besparen. Dit soort grote besparingen komt vaak in grote stappen, als grote installaties vervangen worden. Wij zien geen significant verschil tussen bedrijven die wel of niet participeren in het Europese emissiehandelssysteem (ETS). Hoewel het niet mogelijk is om het effect van individuele effecten te isoleren, suggereert de omvang van de besparingen dat tenminste een gedeelte van de besparingen het gevolg zijn van de convenanten en ondersteunende beleidsinstrumenten, maar dat het ETS systeem daarbij in deze periode geen rol heeft gespeeld.

Het is verleidelijk om een daling in het energieverbruik toe te schrijven aan de realisatie van energiebesparende maatregelen. Zoals we zagen in hoofdstuk 2, hebben deze projecten een significante bijdrage aan de verandering in energieverbruik, maar is hun effect kleiner dan het effect van andere factoren. Vooral het effect van veranderingen in productievolume is belangrijk. Maar omdat andere factoren zowel een besparend als een ontsparend effect kunnen hebben op het energieverbruik, is het netto effect soms kleiner. De periode 2006-2013 bijvoorbeeld, de periode van een economische crisis, kent eerst een periode van dalend energieverbruik door de sterk dalende productie, maar aan het eind van deze periode stijgt het energieverbruik weer naar het niveau van voor de crisis. Terwijl het bruto effect van de productieverandering heel groot was, is het netto-effect over deze periode vrijwel nul.

2-Wat voor soort projecten worden geïmplementeerd?
Deelnemers aan de meerjarenafspraken energie-efficiëntie in Nederland moeten de energiebesparingsprojecten die ze in een rapportageperiode verwachten uit te gaan voeren, opnemen in een energie-efficiëntieplan (EEP). Alle maatregelen met een terugverdientijd van 5 jaar of minder moeten uitgevoerd worden.

We hebben inzicht geboden in de verschillen tussen planning en realisatie van investeringen in energie-efficiëntie door bedrijven, gebaseerd op een analyse van hun EEP's voor de periode 2009-2012. Door de karakteristieken van de gerealiseerde projecten te vergelijken met de projecten die waren gepland, hebben we inzicht gekregen in de aanpassingen die bedrijven maken in hun plannen en externe factoren die dat soort aanpassingen veroorzaken. Onze resultaten laten zien dat in de periode 2009-2012 meer dan 12000 projecten zijn gepland door de 904 deelnemers aan het convenant (MJA3). Ongeveer de helft van deze projecten was gekarakteriseerd als 'zeker', wat betekent dat bedrijven er zeker van zijn dat ze dat projecten gaan uitvoeren. We vinden echter een groot verschil tussen de geplande en gerealiseerde besparingen en ook een grote variatie in de terugverdientijd van zowel geplande als gerealiseerde projecten: hoewel de meerderheid van de projecten een terugverdientijd van ongeveer 2 jaar heeft, heeft 30% van de projecten een terugverdientijd van meer dan 5 jaar.

Meer dan de helft (60%) van de gerealiseerde projecten valt onder de categorie 'aanpassingen in processen'. Dat is logisch, aangezien procesinstallaties het grootste deel van het industrieel energieverbruik voor hun rekening nemen. Ongeveer een kwart van de besparingen zijn projecten in utilities of gebouwen. De bijdrage van energiemanagement projecten is kleiner (13%), maar deze categorie bestaat uit een groot aantal kleinere projecten. Over het algemeen vergen deze projecten weinig tot geen investeringen en kunnen ze worden geïmplementeerd zonder verstoring van het productieproces. Vaak worden dergelijke besparingen bestempeld als 'laaghangend fruit'.

De gemiddelde terugverdientijd (TVT) van gerealiseerde projecten is 6 jaar, terwijl de mediaan 2 is, wat impliceert dat relatief veel projecten een korte terugverdientijd hebben. We vinden geen correlatie tussen de mate van realisatie en de TVT. Onze resultaten laten zien dat niet alle rendabele projecten worden uitgevoerd. Dit fenomeen is eerder gevonden en heet de energie-efficiency gap'. Aan de andere kant worden er wel projecten gerealiseerd die niet rendabel zijn, tenminste niet op het moment dat deze projecten gepland werden. Dit kan twee dingen betekenen: of de TVT was niet correct berekend (bijvoorbeeld doordat voordelen van het project niet zijn meegenomen in de berekening) of dat andere criteria dan de TVT belangrijker waren. Het feit dat veel bedrijven maatregelen plannen en realiseren met een TVT van meer dan 5 jaar suggereert dat andere voordelen van deze projecten zwaarder wegen dan de financiële voordelen door energiebesparing. De kosten die bespaard worden op energie zijn klein vergeleken met andere voordelen van investeringen. Deze andere voordelen kunnen financieel zijn, maar ook niet-financiële voordelen spelen een rol. Dit leidt tot de conclusie dat de focus op TVT als beslissend criterium voor investeringsbeslissingen voor investeringen in energiebesparingsprojecten leidt tot een suboptimale uitkomst voor zowel bedrijven als de overheidsorganisaties die die investeringen stimuleren. Beleidsinstrumenten die dergelijke investeringen willen stimuleren zouden zich moeten richten op andere dan financiële voordelen om aan te sluiten op de interne drijfveren van bedrijven. Onze resultaten kunnen gebruikt worden om de effectiviteit en efficiency van convenanten te verbeteren.

3-Wat zijn drijfveren en barrières voor besparingsprojecten?
Toegenomen energie-efficiëntie biedt een uitgelezen kans voor industriële duurzaamheid, maar er moeten nog een aantal barrières geslecht worden. Deze barrières hinderen het besluitvormingsproces binnen bedrijven. Daarom is het belangrijk dat we begrijpen waarom er verschillen bestaan tussen de perceptie van bedrijven zelf en hoe de organisaties die energie-efficiëntie proberen te bevorderen denken dat bedrijven die barrières ervaren. We hebben een verkennende studie uitgevoerd bij kleine en middelgrote bedrijven die deelnemen aan de Nederlandse energieconvenanten. De studie omvat zowel de bedrijven zelf als de belangrijkste actoren in hun omgeving, bijvoorbeeld het nationaal energie-agentschap, overheids- en industriële organisaties, om hun visie op het besluitvormingsproces binnen bedrijven in kaart te brengen. De resultaten laten zien dat bedrijven het eens zijn over wat de belangrijkste barrières en drijfveren zijn en over de onderliggende mechanismen in het besluitvormingsproces. Echter, afgezien van economische barrières verschillen actoren van mening over de manier waarop barrières invloed hebben op bedrijven. Ze zijn het niet eens over de manier waarop barrières het besluitvormingsproces in bedrijven beïnvloeden en welke acties actoren uit kunnen voeren om die barrières te kunnen slechten. Hoewel convenanten een belangrijk instrument zijn om energie-efficiëntie te bevorderen in Nederland, beschouwen MKB-bedrijven dit instrument niet als een belangrijke stimulans voor energie-efficiëntie. Cruciaal voor toekomstig succes is de link tussen deze convenanten en andere instrumenten en de

wijze waarop deze instrumenten de juiste drijfveren en barrières op het juiste moment weten aan te pakken.

Zoals we zagen in hoofdstuk 3, vormen financiële besparingen op energiekosten geen beslissend criterium voor implementatie van energiebesparingsprojecten. Dit lijkt strijdig met het feit dat de meeste bedrijven kostenbesparing noemen als belangrijkste reden voor toetreding aan de convenanten en dat economische barrières door bedrijven als één van de belangrijkste barrières worden ervaren (sectie 5.4.3). De reden voor deze schijnbare tegenstelling ligt in de complexe organisatie van het besluitvormingsproces bij bedrijven. Tussen het eerste moment waarop een idee voor mogelijke energiebesparing opkomt en daadwerkelijke implementatie van dat idee ligt een lang en ingewikkeld proces dat uit meerdere stappen bestaat. Bij elke stap zijn andere drijfveren of barrières belangrijk. Terwijl economische argumenten het belangrijkst zijn bij de ene stap, zijn technische aspecten beslissend in een andere stap. In het proces als geheel, is terugverdientijd slechts één van de vele mogelijke criteria. Om effectief te zijn, moet de beleidsmix die stappen in het proces identificeren waar de grootste barrières optreden en op al die barrières aangrijpen. Wanneer een instrument één barrière opheft, maar het project strandt vervolgens op een andere barrière, is dat instrument ineffectief.

Terwijl veel studies het economisch voordeel van kostenbesparingen door lagere energiekosten zien als belangrijkste drijfveer achter investeringsbeslissingen, trekken wij een meer genuanceerde conclusie. Economisch voordeel blijft een belangrijke drijfveer, maar dit economische voordeel is niet het gevolg van besparingen op energiekosten alleen, maar vooral van andere financiële voordelen, bijvoorbeeld door minder productieverlies of betere productkwaliteit.

4- Hoe bepaalt de monitormethode de uitkomst van de berekening van gerealiseerde energiebesparing?

In 2008 hebben de Nederlandse energieconvenanten gekozen voor een fundamenteel andere monitormethode. Terwijl de oude methode was gebaseerd op energie-intensiteit -de verbetering van het energiegebruik per eenheid product- meet de nieuwe methode energiebesparing van maatregelen die deelnemende bedrijven implementeren. In deze project-methode worden de resultaten alleen bepaald door deze besparingen en niet berekend op basis van productie- en energiedata.

De twee methoden gebruiken dus verschillende data: gerapporteerde besparingen door projecten in de nieuwe methode worden niet beïnvloed door energie- en structuureffecten. Vooral het effect van volumeveranderingen had een grote invloed op de resultaten in de oude methode, met name tijdens de economische crisis. Hoewel de energie-intensiteit hierdoor werkelijk verandert, is dit geen structurele besparing, aangezien de verandering in energie-intensiteit reversibel is (sectie 5.4). Een fundamenteel verschil tussen de methoden is dat de nieuwe methode per definitie niet negatief kan zijn, waar dat in de oude methode soms wel het geval kon zijn. In de nieuwe methode is het resultaat minimaal nul. Zolang tenminste één project wordt gerapporteerd zal het resultaat altijd positief zijn ook wanneer het energiegebruik per ton stijgt, bijvoorbeeld als gevolg van een lagere bezettingsgraad of andere factoren.

Onze vergelijking van de intensiteit-methode en de project-methode laat zien dat deze methoden geen vergelijkbare resultaten opleveren. Beide methoden hebben hun eigen voor- en nadelen; terwijl de intensiteit-methode inzicht geeft in de hoeveelheid energie per eenheid product, geeft dit slechts beperkt zicht op de inspanningen die bedrijven plegen om energie te besparen. Aan de andere kant geeft de project-methode wel inzicht in de investeringen van bedrijven in energiebesparende technieken, maar heeft het resultaat geen relatie met de werkelijke ontwikkeling van het energieverbruik of de energie-intensiteit. Zelfs wanneer een bedrijf energiebesparende projecten heeft geïmplementeerd kan het energiegebruik toenemen en energie-efficiëntie verslechteren als gevolg van andere factoren. Elk gerapporteerd project is een claim die aangeeft dat het energiegebruik zonder dit project hoger was geweest.

Voorstanders van de nieuwe methode claimen dat deze een beter beeld geeft van de inspanningen van bedrijven om energie te besparen, omdat het laat zien welke aanpassingen bedrijven in hun eigen bedrijven uitvoeren met de intentie om energie te besparen. Tegenstanders van de methode benadrukken dat de relatie met de werkelijke energie-intensiteit verdwijnt. Door beide methoden toe te passen op dezelfde groep bedrijven, kunnen de resultaten worden vergeleken en kan getoond worden in hoeverre de keuze voor een monitormethode ook de boodschap voor beleidsmakers bepaald. Speciale aandacht gaat uit naar de relatie tussen energie en productie in de periode 2008-2012, een periode met grote veranderingen in het productieniveau en het energiegebruik, als gevolg van de economische crisis in die periode. De data laten zien dat energiebesparende projecten een significant effect hadden op het energieverbruik, maar dat hun effect kleiner is dan dat van andere factoren zoals productieveranderingen. Over de periode 2005-2013 laat de oude methode een resultaat zien dat half zo groot is als het resultaat van de nieuwe methode, vooral vanwege de daling van de efficiëntie in de jaren dat de productie sterk afnam. Onze analyse laat duidelijk zien dat de twee methoden niet dezelfde ontwikkeling van de efficiëntie verbetering tonen en zouden daarom ook als verschillende methoden gepresenteerd moeten worden.

5-Hoe kunnen we energiebesparingscijfers vergelijken?
De Europese Commissie heeft veel inspanningen gepleegd om methodes voor de monitoring van energie-efficiëntie en energiebesparing te harmoniseren, om de

voortgang naar de doelen van de Energie Efficiëntie Richtlijn (EER) te meten. In de praktijk worden echter nog meerdere methoden gebruikt, wat kan leiden tot verwarring. In dit proefschrift gebruiken we Nederland als casus om dit fenomeen te bestuderen. In Nederland bestaan drie nationale indicatoren voor energie-efficiëntie: één methode gebaseerd op het verschil tussen het werkelijk energieverbruik en een referentieverbruik berekend op basis van energie-intensiteit (PME), één methode die de voortgang naar het EER-doel meet en één methode die de voortgang van het Nationaal Energie Akkoord meet. Naast deze nationale methoden is er ook een methode om energie-efficiëntie in Europese landen te vergelijken (ODEX) en bottom-up methoden om individuele beleidsinstrumenten te monitoren. Zoals we lieten zien in sectie 6.3, leveren deze methoden resultaten op die een factor twee kunnen verschillen, waar men zou verwachten dat de resultaten ongeveer gelijk zouden zijn.

De grote verschillen en soms tegenstrijdige resultaten van de verschillende indicatoren leiden tot de vraag wat de beste methode is. We hebben de achtergronden bestudeerd van de verschillen tussen de methoden die in Nederland gebruikt worden om energie-efficiëntie in de industrie te bepalen. We vergeleken gedetailleerde bottom-up data van individuele beleidsinstrumenten met top-down nationale cijfers. We maakten een decompositie van het effect van volume, structuur en efficiëntie. Op deze manier konden we visualiseren wat de verschillen tussen de methoden waren en wat het effect is van de keuze van variabelen. De verschillen komen voort uit keuzes die gemaakt zijn in de scope en de gebruikte data van de betreffende methoden. Dit toont waarom we voorzichtig moeten zijn met het vergelijken van industriële efficiëntiecijfers uit verschillende landen. De belangrijkste keuzes voor elke methode zijn de keuze voor de indicator voor energie (finaal of primair) en activiteit (fysiek of monetair). Deze keuzes worden soms bewust gemaakt, maar zijn vaak ook het gevolg van de beschikbaarheid van data. Niet alleen de keuze, maar ook het detailniveau van de gebruikte variabelen bepalen of een effect wordt getoond als een volume-, structuur-, of efficiëntie-effect en heeft daarom een groot effect op de uitkomst. Daarom zouden resultaten van de ene methode niet zomaar vertaald mogen worden naar een andere en om de resultaten te interpreteren moeten altijd de achtergrond en het doel van de betreffende methode in aanmerking genomen worden. Als het beleidsdoel verandert, verandert ook de juiste methode om te meten of dat doel wordt bereikt. Het is niet mogelijk één van de methoden aan te wijzen als 'beste' methode, men kan alleen zeggen dat de ene methode beter geschikt is voor een bepaald doel dan een andere methode. Een bottom-up methode zal beter geschikt zijn om het effect van een individueel beleidsinstrument te evalueren, terwijl een top-down intensiteit methode beter geschikt is om de reële ontwikkeling van de energie-intensiteit te meten.

8.3 Aanbevelingen

8.3.1 Aanbevelingen voor beleid

-Monitorrapportages zouden duidelijk moeten presenteren of hun resultaten in absolute of relatieve termen zijn.

Energie-efficiëntie verbetering is onderdeel van energiebeleidsdoelen. De Europese Energie-efficiëntie Richtlijn geeft lidstaten de keus om een nationaal doel vast te stellen in termen van energieverbruik, energiebesparing of energie intensiteit, zolang dit bijdraagt aan het 20% doel van de EU. Deze doelen hangen met elkaar samen, maar niet direct. Een absolute reductie van het energiegebruik is niet altijd gekoppeld aan een efficiëntieverbetering. Een verbetering van de energie-efficiëntie kan leiden tot een reductie van het energieverbruik, maar dit hoeft niet altijd het geval te zijn; bijvoorbeeld een verhoging van de productie kan het effect van een verbeterde efficiëntie teniet doen. Zoals we zagen in hoofdstuk 5, was dit het geval in veel van de monitorrapportages van de energieconvenanten in Nederland in de jaren van economisch herstel. Deze rapporten lieten een verbetering van de energie-efficiëntie zien, terwijl het energieverbruik toenam. Deze energieconvenanten zijn een efficiëntie-instrument: hun doel is een verbetering van de energie-efficiëntie, geen absolute reductie van het energieverbruik. Dit verschil moet in monitorrapporten duidelijk vermeld worden om goede interpretatie van de resultaten te waarborgen.

-Monitorresultaten zouden niet te snel vergeleken mogen worden met andere monitorresultaten.

In vervolg op de eerste aanbeveling, is ook het verschil tussen energiebesparing en energie-efficiëntie relevant. In de wetenschappelijke literatuur wordt een strikt onderscheid gemaakt tussen deze twee begrippen, maar in het dagelijks gebruik – en veel beleidsdocumenten- worden deze termen vaak verwisseld. Het fundamentele verschil tussen energie-efficiëntie en energiebesparing is dat energie-efficiëntie een relatieve, dimensieloze ratio is, bijvoorbeeld een conversieverbetering van 80% naar 90%. Energiebesparing aan de andere kant, betreft een absolute verandering in energieverbruik (sectie 5.2.1). Efficiëntie kan omhoog of omlaag gaan, maar besparingen gaan altijd naar beneden, naar minder energieverbruik. Als de efficiëntie hoger wordt, wordt er energie bespaard, maar andersom geldt dit niet per definitie. Beleidsmakers zouden dit verschil moeten meenemen wanneer beleidsdoelen worden vastgesteld (sectie 5.4). Voor een goede evaluatie van een beleidsinstrument moet het monitorresultaat consistent zijn met het beleidsdoel. Zoals bediscussieerd in de vorige paragraaf, worden absolute doelen en efficiëntie doelen vaak verward. Zoals we zagen in sectie 6.3 verschillen gebruikte methoden in temen van scope, gebruikte data en presentatie van de resultaten. De resultaten van één beleidsinstrument zouden dan ook niet vertaald mogen worden naar die van een ander instrument zonder goed begrip van de gebruikte methoden.

-Beleidsinstrumenten moeten niet focussen op terugverdientijd als criterium voor verplichte projecten.
Een berekening van terugverdientijd die alleen is gebaseerd op bespaarde energiekosten is geen beslissend criterium voor bedrijven wanneer zij een investeringsbeslissing nemen over een energiebesparend project. Beleidsinstrumenten zouden daarom moeten zoeken naar andere criteria wanneer zij bepaalde projecten willen verplichten of stimuleren. Een overheidsorganisatie wil geen projecten verplichten of stimuleren die toch al uitgevoerd worden. Het doel van een instrument is om bedrijven net iets meer maatregelen te laten uitvoeren dan zij zelfstandig zouden doen. Een mogelijkheid is het classificatieschema waar in sectie 3.4 aan gerefereerd wordt, dat projecten indeelt naar 12 karakteristieken, verdeeld in relatieve voordeel, technische context en informatiecontext. Elke karakteristiek is gerangschikt op waarschijnlijkheid van implementatie. Dit schema zou een startpunt kunnen zijn om een beleidsinstrument te ontwerpen dat bepaalde projecten zou stimuleren. Aangezien zo'n instrument niet afhankelijk is van slechts één variabele, heeft het een grotere kans om goed te voorspellen welke projecten toch wel zouden worden uitgevoerd, welke projecten nooit zouden worden uitgevoerd en welke projecten gestimuleerd zou kunnen worden door een beleidsinstrument.

8.3.2 Aanbevelingen voor onderzoek

-Monitormethoden moeten eenvoudig te communiceren zijn
Zoals we beschreven in hoofdstuk 6, hebben onderzoekers geprobeerd methoden te ontwikkelen die meer detail zichtbaar maken door veranderingen in energieverbruik te deconstrueren in steeds meer verschillende factoren, in een poging om dat effect te isoleren waarin men geïnteresseerd is, met zomin mogelijk interferentie van andere factoren. Maar een meer gedetailleerde monitoring is duurder en levert niet per definitie meer inzicht in het effect van beleidsinstrumenten. Zelfs een zeer gedetailleerde decompositie zal er niet in slagen om te meten welke deel van besparingen autonoom is en welk deel het gevolg van beleid. Bovendien kan het niet het effect isoleren van individuele beleidsinstrumenten, omdat beleidsinstrumenten meestal onderdeel zijn van een mix van instrumenten die gedeeltelijk overlappen. Bottom up evaluatie van individuele instrumenten is meer geschikt om het effect van dat instrument te bepalen, ook al heeft evaluatie van individuele instrumenten de neiging het effect van dat betreffende instrument te overschatten.
Bovendien, uitgebreide monitorsystemen zijn niet per definitie meer accuraat. Hoe gedetailleerder de decompositie, hoe moeilijker het wordt effecten uit elkaar te houden. Bijvoorbeeld beleidsinstrumenten zijn van invloed op marktprijzen, waardoor er ook een prijseffect optreedt. Om individuele effecten te isoleren, maken monitormethoden gebruik van correctiefactoren, bijvoorbeeld voor klimaatinvloeden, die vaak op aannames zijn gestoeld. Deze correctiefactoren verhullen het resultaat en maken vergelijking met andere monitorinstrumenten lastig.

Daarom bevelen we aan dat om een monitorinstrument te ontwerpen dat beter aansluit op de wensen van beleidsmakers, men een systeem moet ontwerpen dat eenvoudiger is en eenvoudiger te communiceren, gericht op ofwel het ontwikkelen van makkelijk te begrijpen indicatoren ofwel het effect van individuele beleidsinstrumenten, maar niet allebei. Zo'n instrument moet indicatoren gebruiken die duidelijk gepresenteerd zijn in termen van efficiëntie, energie-intensiteit of een absolute reductie van het energiegebruik.

-Onderzoekers moeten zoeken naar de achterliggende redenen voor de implementatie van projecten.
Wij bevelen aan om nader onderzoek te doen naar de redenen waarom energiebesparende projecten worden geïmplementeerd, om zo beter te kunnen begrijpen wat de bijdrage is van beleidsinstrumenten ten opzichte van autonome besparingen. In het besluitvormingsproces binnen bedrijven zullen sommige projecten geïmplementeerd worden mede als gevolg van een beleidsinstrument, bijvoorbeeld een subsidie die de prijs van een efficiëntere motor verlaagt. Andere projecten zullen uitgevoerd worden om andere redenen die geen enkele relatie hebben met beleid, bijvoorbeeld de vervanging van een kapot apparaat. In sectie 2.5 zagen we dat het moeilijk is om te bepalen om welke reden projecten werden geïmplementeerd. Meer inzicht in de drijfveren achter implementatie van projecten kan inzicht bieden welke projecten hoe dan ook uitgevoerd zullen worden (en dus autonome besparing betekenen) en welke projecten gestimuleerd zouden kunnen worden door een beleidsinstrument. Dit biedt een startpunt voor het ontwerp van een beleidsinstrument dat beter aansluit bij de drijfveren van bedrijven. Deze kennis is cruciaal om een beleidsinstrument te maken dat zowel effectief als efficiënt is.

9

Chapter 9

References

References

- Aalbers, R.F.T., de Groot, H.L.F., Vollebergh, H.R.J. (2004). Effectiveness of subsidizing energy saving technologies: evidence from Dutch panel data. Rotterdam, Erasmus University Rotterdam.
- Abeelen, C., Harmsen, R., Worrell, E. (2013). Implementation of energy efficiency projects by Dutch industry. Energy Policy 63 (2013) 408–418.
- Abeelen, C.J. and Both, D. (2012). Energy efficiency measures: the next generation. ECEEE summer study paper 1-065-12. 11-14 September 2012, Arnhem.
- Abeelen, C.J., Harmsen, R., Worrell, E. (2016). Counting project savings—an alternative way to monitor the results of a voluntary agreement on industrial energy savings. Energy Efficiency [1570-646X] 2016 (9), 755 -770.
- Ademe (2012). Energy efficiency policies in industry. Lessons learned from the ODYSSEE-MURE project.
- Ademe (2015). Energy Efficiency Trends and Policies In Industry 2015. Ademe, France.
- Aflaki, S., Kleindorfer, P.R., De Miera Polvorinos, V.S. (2013). Finding and implementing energy efficiency projects in industrial facilities. Prod Oper Manage 2013;22(3):503–17.
- AgentschapNL (2009a). Verslag 17e Platformoverleg, d.d. 12 november 2009. Reference nr. 0919521/221/RvM/NW/156140.
- AgentschapNL (2009b). Deelvoorstel correcties in MJA3. AgentschapNL, 15 september 2009.
- AgentschapNL (2010a). Memo 'Voorstel wijzigingen methodiek energie-efficiëntie MJA3', prepared for the LTA board February 3, 2010. Reference nr. 1021828/221/AL/156140.
- AgentschapNL (2010b). Memo 'Evaluatie monitormethodiek', prepared for the LTA board November 25, 2010. Reference nr. 1029216/221/CA/NW/156140.
- AgentschapNL (2011a). Memo 'Stand van zaken vergelijking oude versus nieuwe methodiek', prepared for the LTA board November 1, 2011. Reference nr. 1133837/223/MK/NW/156140.
- AgentschapNL (2011b). Verslag Platform MJA3 overleg d.d. 1 november 2011. Reference nr. 1134584/221/RvM/NW/156140.
- AgentschapNL (2012a). Jaarverslag 2011 Energie Investerings Aftrek(EIA). July 2012. AgentschapNL, Zwolle.
- AgentschapNL (2012b). Handreiking Monitoring, Version 2.2, 4 January 2012. NL Agency, Utrecht.
- Anderson, S.T and Newell, R.G. (2004). Information programs for technology adoption: the case of energy-efficiency audits. Resource and Energy economics 26 (2004) 27-50.
- Ang, B.W. (2004). Decomposition analysis for policymaking in energy: which is the preferred method? Energy Policy 32, 1131–1139.
- 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. J Clean Prod 2013;53:204–13.
- APERC (2000). A study of energy efficiency indicators for industry in APEC economies. APERC, Japan.
- Arens, M. (2016). Technological change and industrial energy efficiency. Utrecht.

Chapter 9

- Blok, K. (2007). Introduction to energy analysis.
- Boonekamp, P.G.M., Harmsen, R., Kets, A., Menkveld, M. (2002). Besparingstrends 1990-2000: Besparing, instrumenten en effectiviteit. ECN, Petten.
- Boonekamp, P.G.M., Tinbergen, W., Vreuls, H.H.J., Wesselink, B. (2001). Protocol monitoring energy savings ECN, Petten. ECN-C-01-129; RIVM 408137005.
- Boonekamp, P.G.M. (2005). Improved methods to evaluate realized energy savings. PhD thesis. Utrecht University, the Netherlands.
- Boonekamp, P.G.M. (2006). Evaluation of methods used to determine realised energy savings. Energy policy 34, 3977-3922.
- Boonekamp, P.G.M. (2011). How much will the Energy Services Directive contribute to EU energy and emissions goal? Energy efficiency 4(2), 285-301.
- Boßmann, T. (2012). Policy Report: Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050. Report for the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).
- Bowie, R. and Malvik, H.V. (2005). Measuring savings target fulfilment in the proposed directive on energy end-use efficiency and energy services. COM(2003)0739. ECEEE summer study 2005.
- Boyd, G.A. and Pang, X.A. (2000). Estimating the linkage between energy efficiency and productivity. Energy Policy 28 (2000) 289-296.
- Brunke, J-C., Johansson, M,, 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. J Clean Prod 2014;84:509–25.
- Bundgaard, S.S., Mikkelsen, K.D., Hansen Kjærbye, V., Togeby, M., Sommer, T., Larsen, A.E., (2013). Spending to save: evaluation of the energy efficiency obligation in Denmark. ECEEE summer study paper 7-131-13. 3-8 June 2013, Toulon/Hyères, France.
- Cagno, E., Worrell, E., Trianni, A., Pugliese, G. (2013). A novel approach for barriers to industrial energy efficiency, Renewable and Sustainable Energy Reviews, Volume 19, March 2013 p290-308.
- Cagno, E. and Trianni, A. (2013). Exploring drivers for energy efficiency within small- and medium-sized enterprises: first evidences from Italian manufacturing enterprises. Appl Energy 2013;104:276–85.
- Cagno, E. and Trianni, A. (2014). Evaluating the barriers to specific industrial energy efficiency measures: an exploratory study in small and medium-sized enterprises. J Clean Prod 2014;82:70–83.
- Cagno, E. (2015). Barriers and drivers for energy efficiency: Different perspectives from an exploratory analysis in the Netherlands. Energy Conversion and Management, 26–38.
- Cagno, E. Ramirez-Portilla, A., Trianni, A. (2015). Linking energy efficiency and innovation practices: Empirical evidence from the foundry sector. Energy Policy 83 (2015) 240-256.
- Cahill, C. and Ó Gallachoír, B.P. (2010). Monitoring energy efficiency trends in European industry: which top-down method should be used? Energy Policy 38, 6910-6918.
- Cahill, C. and Ó Gallachoír, B.P. (2012a). Quantifying the savings of an industry energy efficiency programme. Energy efficiency 2012 (5) 211-224.

- Cahill, C. and Ó Gallachoír, B.P. (2012b). Combining physical and economic output data to analyse energy and CO2 emissions trends in industry. Energy Policy 2012 (10), Pages 422-429.
- Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., Evangelopoulou, S., Zampara. M., et al. (2016). EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050. European Commission Directorate - General for Energy, Directorate - General for Climate Action and Directorate - General for Mobility and Transport , Luxembourg.
- CEN (2007). Saving lifetimes of Energy Efficiency Improvement Measures in bottom-up Calculations. Final CWA draft (CEN WS 27). Comité Européen de Normalisation, Brussels.
- Coalition for energy saving (2013). EU Energy Efficiency Directive (2012/27/EU). Guidebook for Strong Implementation.
- Coalition for energy saving (2014). Implementing the EU Energy Efficiency Directive: Analysis of article 7 member states reports. April 2014.
- Commonwealth of Australia (2011). Energy efficiency opportunities—Continuing opportunities 2011. Results of EEO assessments reported by participating corporations. Commonwealth of Australia, Department of Resources, Energy and Tourism, Barton ACT, Australia.
- Cooremans, C. (2009). The role of formal capital budgeting analysis in corporate investment decision making: a literature review. ECEEE summer study 2009, paper no. 1393. 1–6 June 2009 La Colle sur Loup, France.
- Cooremans, C. (2012). Investments in energy efficiency: do the characteristics of investments matter? Energy efficiency (2012) 5: 497-518.
- Cornelis, E. and Reunes, G. (2012). Analysis of the differences of the energy saving measures proposed by medium-sized industrial companies in Flanders, Belgium, in 2006 and 2009. ECEEE 2012 summer study on energy efficiency in industry. 11–14 September 2012. Arnhem, the Netherlands.
- Das, M.C., Driessen, P.P.J., Glasbergen, P., Habermehl, N., Vermeulen, W.J.V., Blok, K., Farla, J.C.M., Korevaar, E.M. (1997). Evaluatie Meerjarenafspraken over energie-efficiency. Universiteit Utrecht, Utrecht.
- Davidson, M., De Buck, A., Blom, M., Korteland, M. (2010). Evaluatie energiebesparingsbeleid in de industrie. Kosten en baten in de periode 1995-2008. CE, Delft.
- De Bruijn, T., Bressers, H., Lulofs. K., Van der Veer, A. (2003). Evaluatie Milieuconvenanten. Eindrapportage. CSTM Universiteit Twente, Enschede.
- De Buck, A., Blom, M.J., Smit, M., Wielders, L.M.L. (2010). Convenant Benchmarking Energie-efficiency: resultaten en vrijstellingen energiebelasting. CE, Delft.
- De Groot, H.L.F., Verhoef, E.T., Nijkamp, P. (1999). Energy saving by firms: decision making, barriers and policies. Department of Spatial Economics, Vrije Universiteit, Amsterdam. Energy Econ 2001;23(6):717–40.
- DeCanio, S.J. (1998). The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. Energy Policy 26 (5) pp.441-454.
- DeCanio, S.J. and Watkins, W.E. (1998). Investment in Energy Efficiency: Do the Characteristics of Firms Matter? The Review of Economics and Statistics. Vol. 80, No. 1 (Feb., 1998), pp. 95-107.

- Denneman, A. (2012). Toelichting statlinetabel eindverbruikersprijzen aardgas en elektriciteit. Statistics Netherlands The Hague/Heerlen.
- EC (2007). Survey of the Observatory of European SMEs. Brussels, Belgium; 2007.
- EC (2013). EU regional competitiveness index – RCI 2013. Joint research centre report no. EUR 26060 EN; 2013.
- ECN (2012). Energiebesparing in Nederland 2000-2010. ECN, Petten.
- ECN (2017). Nederlandse Energieverkenning 2016. Petten: ECN.
- EEA (European Environmental Agency) (2013). Trends and projections in Europe 2013 – Tracking progress towards Europe's climate and energy targets until 2020. EEA Report No 10/2013.
- EEA (European Environmental Agency) (2015). Trends and projections in Europe 2015 – Tracking progress towards Europe's climate and energy targets until 2020. EEA Report No 4/2015.
- Eichhammer, W. and Mannsbart, W. (1997). Indicators for a European cross country comparison of energy efficiency in the manufacturing industry. Energy Policy Vol. 25, nos. 7-9, pp.759-772.
- Enerdata (2010). Definiton of ODEX indicators in Odyssee database.
- Energy Research Centre of the Netherlands. Energy efficiency policies and measures in the Netherlands (2012). Petten: ECN; 2012.
- European Parliament and Council (2006). Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. OJ L 114, 27.4.2006, p. 64–85.
- European Parliament and Council (2012). Directive 2012/27/EU of the European Parliament and of the council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. OJ L 315, 14.11.2012.
- Eurostat (2012). http://epp.eurostat.ec.europa.eu/ , accessed 07-12-2012.
- EVO (2014). International Performance measurement and verification protocol. Evaluation Valuation Organization, June 2014.
- Farla, J. and Blok, K. (2000). The use of physical indicators for monitoring of energy intensity developments in the Netherlands 1980-1995. Energy 25 (7) 609-638.
- Farla, J. and Blok, K. (2001). The quality of energy intensity indicators for international comparison in the iron and steel industry. Energy policy 29, 523-543.
- Farla J. and Blok K. (2002). Industrial long-term agreements on energy-efficiency in the Netherlands. A critical assessment of the monitoring methodologies and quantitative results. Journal of cleaner production 1, 165-182.
- Fisher-Vanden, K. Jefferson, G.H., Liu, H. Tao, Q. (2004). What is driving China's decline in energy intensity? Resource and Energy Economics 26 (1), 77-97.
- Fleiter, T., Worell, E., Eichhammer, W. (2011). Barriers to energy efficiency in industrial bottom-up energy demand models-A review. Renewable and Sustainable Energy Reviews 15 (2011) 3099– 3111
- Fleiter, T., Hirzel, S., Worrell, E. (2012). The characteristics of energy-efficiency measures–a neglected dimension. Energy Policy 51(2012)502–513.
- Freeman, S.L., Niefer, M.J., Roop, J.M. (1997). Measuring industrial energy efficiency: practical issues and problems. Energy policy 25; Nos. 7-9, p.703-714.

- Geiss, J., Müller, A., Schüle, R., Arens, C., Höfele, V., Becker, D., Boermans, T., Bettgenhäuser, K., Harnisch, J., Jaworski, P. (2009). Promoting energy efficiency in Europe. Insights, Experiences and Lessons learnt from the National Energy Efficiency Action Plans. Brochure Presented by the Energy Efficiency Watch Project. Wuppertal, Cologne, Berlin, Brussels, January 2009.
- Gerdes, J. (2012). Energy efficiency policies and measures in the Netherlands. Odyssee-MURE 2012 monitoring of EU and national energy efficiency targets. Petten: ECN; 2012.
- Gillingham, K., Newell, R., Palmer, K. (2007). Energy efficiency policies: A retrospective examination. Annual Review of Energy and the Environment, Pages 161-192.
- Grobler, L.J. (2010). Measurement and verification of energy efficiency savings in industrial facilities: the flaw of using energy intensities to determine savings. Energy engineering vol. 107, No.5, pp24-41.
- Grubler, A. et al. (2012). Chapter 1 - Energy Primer. In Global Energy Assessment - Toward a Sustainable Future. pp. 99-150.
- Harmelink, M., Bosselaar, L., Gerdes, J., Boonekamp, P., Segers, R., Pouwelse, H., Verdonk, M., (2012). Berekening van CO_2-emissies, het primair fossiel energiegebruik en het rendement van elektriciteit in Nederland. Report for NL Agency, Utrecht.
- Harmsen, R., Eichhammer, W., Wesselink, B. (2014). An exploration of possible design options for a binding energy savings target in Europe. Energy Efficiency Volume 7, Issue 1, February 2014, pages 97-113.
- Harris, J., Anderson, J., Shafron, W. (2000). Investment in energy efficiency: a survey of Australian firms. Energy Policy 2000; 28(12) 867-76.
- Hasanbeigi, A., Menke, C., du Pont, P. (2010). Barriers to energy efficiency improvement and decision-making behavior in Thai industry. Energy Efficiency 2010;3(1): 33–52.
- Hendriksen, B. and van der Kolk, J. (2013). Resultaten en vooruitzichten Energie-efficiëntie MEE bedrijven in Nederland. Evaluatie Meerjaren afspraken energie efficiëntie MEE. KPMG Sustainability, 24 september 2013.
- Hirst, E. and Brown, M. (1990). Closing the efficiency gap: barriers to the efficient use of energy. Resources, Conservation and Recycling 3 (1990) 267-281.
- Hoekstra, H. and Van der Bergh, J.C.J.M. (2003). Comparing structural and index decomposition analysis. Energy Economics 25 (2003) 39-64.
- House of Representatives (2012). Parlementair onderzoek Kosten en effecten klimaat- en energiebeleid. kst-33193-2. ISSN 0921 – 7371, The Hague.
- Howarth, R.B., Haddad, B.M., Paton, B. (2000). The economics of energy efficiency: insights from voluntary participation programs. Energy Policy 28 (2000) 477-486.
- IEA (1997). Indicators of Energy Use and Energy Efficiency. IEA/OEDC, Paris.
- IEA (2008). Energy policies of IEA countries. The Netherlands 2008 review. International Energy Agency, Paris.
- IEA (2011). The Boardroom Perspective: How Does Energy Efficiency Policy Influence Decision Making in Industry? International Energy Agency/Institute for Industrial Productivity, Paris.

- IEA (2014). Key world energy statistics. Paris: International Energy Agency.
  Making in Industry? Paris: Institute for Industrial productivity.
- IEA (2014). Capturing the multiple benefits of energy efficiency. International Energy Agency, Paris, France; 2014. p. 232 [ISBN 978-92-64-22072-0].
- IEA (2017). World Energy Outlook 2017. Paris: IEA.
- IPP (2012). Denmark's Agreement on Industrial Energy Efficiency (DAIEE).
- Johansson, B., Modig, G. , Nilsson, L.J. (2007). Policy instruments and industrial responses-experiences from Sweden. ECEEE summer study paper 7,048. 4 – 9 June 2007 La Colle sur Loup, France.
- Kesicki, Y. (2015). Modelling the potential for industrial energy efficiency. Energy Efficiency, 155-169.
- Koewener, D., Mielicke, U., Jochem E. (2011). Energy efficiency networks for companies-concept, achievements and prospects. ECEEE summer study paper 3-325. 6–11 June 2011, Presqu'île de Giens, France.
- Leutgöb, K., Reichl, J., Kollmann, A. (2011). Making the results of bottom-up energy savings calculations comparable. ECEEE 2011 summer study 6–11 June 2011. Belambra Presqu'île de Giens, France.
- Liu, X., Niu, D., Bao, C., Suk, S., Shishime, T. (2012). A survey study of energy saving activities of industrial companies in Taicang, China. J Clean Prod 2012;26:79–89.
- Martin, R., Muûls, M., Wagner, U. (2011). Climate change, investment and carbon markets and prices - Evidence from manager interviews. CPI and Climate Strategies.
- Masselink, D.J. (2008). Barriers to Investments in Energy Saving Technologies: Case Study for the Industry. ECN, Petten.
- Montgomery, W.D. (2014). Voluntary action in present and future climate policy. Presentation at the International symposium on voluntary approaches. Tokyo, Japan, 2 September 2014.
- Natural Resources Canada (2012). Improving Energy Performance in Canada. Office of Energy Efficiency Natural Resources Canada.
- Neelis, M., Ramirez, A., Patel, M., Blok, K., Farla, J., Boonekamp, P. (2007). Energy efficiency developments in the Dutch energy-intensive manufacturing industry, 1980–2003. Energy Policy 35 (12) p.6112–6131.
- Netherlands Court of Audit (2011). Energiebesparing: ambities en resultaten. kst-33016-1. ISSN 0921 – 7371. 5 October 2011, Den Haag.
- NL Agency (2008). Long-term agreement on energy efficiency 2001-2020. Final version. 13 June 2008, The Hague.
- NL Agency (2009). Long-term Agreement on Energy Efficiency for ETS enterprises (LEE). 2 October 2009 The Hague.
- NL Agency (2011). Factsheet Rendementberekening energie-efficiencymaatregelen. Publicatie-nr. 2MJAP1145. Utrecht.
- NL Agency (2012a). Handreiking EEP-format 2013-2016 MJA3. 31-01-2012, Sittard.
- NL Agency (2012b). Handreiking EEP-format 2013-2016 MEE. 31-01-2012, Sittard.
- Odyssee (2012). Profiel energie-efficiëntie: Nederland. Odyssee-MURE, August 2012.

- Odyssee (2015). Synthesis: Energy Efficiency Trends and Policies in the EU. An Analysis Based on the ODYSSEE and MURE Databases. Odyssee-MURE, September 2015.
- OECD (2003). Voluntary approaches for environmental policies, effectiveness, efficiency and use in policy mixes. OECD, Paris.
- OECD/IEA (2007). Tracking industrial energy efficiency and CO2 emissions. OECD/IEA, Paris.
- Patton, M.Q. (1991) Qualitative research & evaluation methods, 3rd ed. Saint Paul, MN, US: Sage Publication Inc; 1991.
- Pérez-Lombard, L. , Ortiz, J., Velázquez, D. (2013). Revisiting energy efficiency fundamentals. Energy Efficiency (2013) 6, 239–254.
- Phylipsen, G.J.M., Blok, K, Worrell, E. (1997). International comparisons of energy efficiency-Methodologies for the manufacturing industry. Energy policy Vol. 25, Nos. 7-9, pp. 715-725.
- Phylipsen, G.J.M., Blok, K., Worrell, E., de Beer, J. (2002). Benchmarking the energy efficiency of the Dutch industry: an assessment of the expected effect on energy consumption and CO2 emissions. Energy policy 30, 663-679.
- Pizer, W.A., Morgenstern, R., Shih, J. (2011). The performance of industrial sector voluntary climate programs: Climate Wise and 1605(b). Energy policy 39(2011)7907–7916.
- Ramirez, C.A., Patel, M., Blok, K. (2005). The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30 (5), 749–767.
- Rezessy, S, Bertoldi, P. (2011). Voluntary agreements in the field of energy efficiency and emission reduction: review and analysis of experiences in the European Union. Energy Policy 011;39(11):7121–9.
- Rietbergen, M. and Blok, K. (1999). The Environmental Performance of Voluntary Agreements on Industrial Energy Efficiency Improvement, NWS–99068. Utrecht University, Netherlands.
- Rietbergen, M.G., Farla, J.C.M., Blok, K. (2002). Do agreements enhance energy efficiency improvement? Analysing the actual outcome of long-term agreements on industrial energy efficiency improvement in the Netherlands. Journal of cleaner production 10, 155-163.
- Rohdin, P. and Thollander, P. (2006). Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. Energy 2006;31(12):1500–8. 2006;31(12):1500–8. 24]
- Rohdin P, Thollander P, Solding P. (2007). Barriers to and drivers for energy efficiency in the Swedish foundry industry. Energy Policy 2007;35(1):672–7.
- Russell, C. and Young, R. (2012). Understanding Industrial Investment Decision-making. ACEEE Research report IE124.
- RVO.nl (2014). Energieinvesteringsaftrek (EIA) Jaarverslag 2013. Rijksdienst voor Ondernemend Nederland (RVO.NL), Juni; 2014 [in Dutch].
- Sardianou, E. (2008). Barriers to industrial energy efficiency investments in Greece. J. Clean Prod 2008;16(13):1416–23.
- Saygin, D. (2012). Assessing Industrial Energy Use and CO2 Emissions; Opportunities for Energy Efficiency, Biomass and CCS. Ph.D. Thesis. Utrecht University, the Netherlands.

- Schlomann, B., Rohde, C., Plötz, P. (2015). Dimensions of energy efficiency in a political context. Energy Efficiency 8, 97-115.
- Schoots, K. and Hammingh, P. (2015). Nationale energieverkenning 2015. ECN-0—15-033. Petten: Energieonderzoek Centrum Nederland.
- Schoots, K. and Hammingh, P. (2016). Nationale energieverkenning 2016. ECN-0—16-035. Petten: Energieonderzoek Centrum Nederland.
- SenterNovem (2008a). Long-term Agreement on Energy Efficiency 2001–2020. Final Version. 13 June 2008, The Hague.
- SenterNovem (2008b). Handreiking EEP 2009 - 2012, d.d. 1 juli 2008.
- SER (2013). Energieakkoord voor duurzame groei. Sociaal Economische Raad, 6 September; 2013.
- Shipley, A.M. and Elliott, R.N. (2006). Ripe for the picking. Have we exhausted the low-hanging fruit in the industrial sector? ACEEE report number IE061.
- Smit, T.A.B., Hu, J., Harmsen, R. (2014). Unravelling projected energy savings in 2020 of EU member states using decomposition analyses. Energy Policy 74, 271–285.
- Solnordal, M.T. and Foss, L. (2018). Closing the Energy Efficiency Gap—A systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. Energies 2018, 11, 518.
- Sorrell, S., Schleich, J., Scott, S., O'Malley, E., Trace, F., Boede, U., Ostertag, K., Radgen, P. (2000). Reducing barriers to energy efficiency in public and private organisations. Final report. SPRU, JOS3CT970022.
- Sorrell, S., Mallett, A., Nye, S. (2011). Barriers to Industrial Energy Efficiency: A Literature Review. UNIDO Working Paper 10/2011.
- Sorrell, S., Malley,E.O., Schleich, J., Scott, S. (2004). The economics of energy efficiency. Cheltenham, UK: Edward Elgar Publishing; 2004. p. 349.
- Staniaszek, D. and Lees, E. (2012). Determining energy savings for energy efficiency obligation schemes. ECEEE, RAP.
- Statistics Netherlands (2012). Monitor Topsectoren. Statistics. The Hague/Heerlen, Netherlands.
- Stenqvist, C. and Nilsson, L.J. (2012). Energy efficiency in energy-intensive industries-an evaluation of the Swedish voluntary agreement PFE. Energy efficiency; 5:225-241.
- Sudhakara Reddy, B., Assenza, G.B., Assenza, D., Hasselmann, F. (2013). Barriers and drivers to energy efficiency – a new taxonomical approach. Energy Convers Manage 2013;74:403–16.
- Swigchem, J., Keizer, I., Roos, J., Rooijers, F., Klaver, M., Strating, S., Klein Teeselink, H. (2002). Energie-efficiency in de industrie, ratio achter investeringsbeslissingen. CE, Delft.
- Tanaka, K. (2011). Review of policies and measures for energy efficiency in industry sector. Energy policy 39 (2011) 6532-6550.
- Thives, L.P. and Ghisi, E. (2017). Asphalt mixtures emission and energy consumption: A review. Renewable and Sustainable Energy Reviews 72, 473–484.
- Thollander, P., Danestig, M., Rohdin, P. (2007). Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 2007;35(11):5774–83.
- Thollander, P., and Ottosson, M. (2008). An energy efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments. Energy Efficiency 2008;1(1):21–34.

- Thollander, P., Backlund, S., Trianni, A., Cagno, E. (2013). Beyond barriers – a case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. Appl Energy 2013;111:636–43.
- Trianni, A. and Cagno, E. (2012). Dealing with barriers to energy efficiency and SMEs: some empirical evidences. Energy 2012;37(1):494–504.
- Trianni, A., Cagno, E., Marchesani, F., Spallina, G. (2013). Drivers for industrial energy efficiency: an innovative approach. In: 5th International conference on applied energy (ICAE), Pretoria (South Africa); 2013.
- Trianni, A., Cagno, E., Worrell, E., Pugliese, G. (2013). Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs. Energy 2013;49:444–58.
- Trianni, A., Cagno, E., Thollander, P., Backlund, S. (2013). Barriers to industrial energy efficiency in foundries: a European comparison. J Clean Prod 2013;40:161–76.
- Trianni, A., Cagno, E., De Donatis, A. (2014). A framework to characterize energy efficiency measures. Appl Energy 2014;118:207–20.
- Tweede Kamer der Staten-Generaal (2017). Vierde Nationale Energie Efficiëntie Actie Plan voor Nederland. kst-31209-213.
- UNIDO (2011). Industrial Development Report 2011. Industrial Energy Efficiency for Sustainable Wealth Creation. United Nations Industrial Development Organization, Vienna Austria.
- Verdonk, M. and Boonekamp, P.G.M. (2009). Vergelijking methoden energiebesparing: PME en MJA. ECN, Petten.
- Volkerink, B. Meindert, L., van der Wagt, M., de Groot, H.L.F., Bolscher, H., Slingerland, S., Reynes, F., Jonkhof, W., Ivanova, O. Bulavskaya, T. (2013). Evaluatie Meerjarenafspraken Energie Efficiëntie 2008-2020. Ecorys, Rotterdam, 10 april 2013.
- Vreuls, H., De Groote, W., Bach, P., Schalburg, R., Dyhr-Mikkelsen, K., Bosseboeuf, D., Celi, O., Kim, J., Neij, L.,Roosenburg, M. (2005). Evaluating energy efficiency policy measures & DSM programmes – volume I: evaluation guidebook. Report for the IEA-DSM task IX, October
- Vreuls, H. and Zijlema, P. (2013). Nederlandse lijst van energiedragers en standaard CO2-emissiefactoren, version February 2013. AgentschapNL, Utrecht/Sittard.
- Worrell E., Cuelenaere, R.F.A., Blok, K., Turkenburg W.C. (1994). Energy consumption by industrial processes in the European Union. Energy 19; 11, 1113-1129.
- Worrell, E., Price, L., Martin, N., Farla, J., Schaeffer, R. (1997). Energy intensity in the iron and steel industry: a comparison of physical and economic indicators. Energy policy 25, 727-744.
- Worrell, E., Laitner, J., Ruth, M., Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. Energy 28(2003) 1081-1098.
- Worrell, E. and Biermans, G. (2005). Move over! Stock turnover, retrofit and industrial energy efficiency. Energy Policy 33, 949–962.
- WRI (2014). Greenhouse Gas Protocol. Policy and Action Standard. World Resources Institue, ISBN 978-1-56973-840-5.
- Yin, R.K. (2003). Case study research: design and methods. 3rd ed. Thousand Oaks: Sage Publication Inc; 2003.

Curriculum Vitae

Curriculum Vitae

Christiaan Abeelen studied Environmental Sciences at Wageningen University, where he finished his Master in 1997. He started work as a consultant, working at monitoring of emissions and environmental policy. In 2002 he joined Novem, a predecessor of RVO.nl. At Novem he worked a.o. on the monitoring of renewable energy and energy innovation. In 2008 he started working on the Long Term Agreements, first as a sector advisor, later as monitoring coordinator, responsible for implementation of monitoring methods and software. In order to make a more profound study of the results of the long term agreements, he started his doctorate thesis at Utrecht University under the guidance of Ernst Worrell in 2012, using the data gathered in these agreements.

Implementation of energy efficiency projects by manufacturing companies in the Netherlands

Increasing energy efficiency in industry is crucial to reach the climate objectives in the European Union. Many policy instruments have been implemented to increase the speed of implementation. But actual implementation of new efficient technology is slow and even profitable technology is often not implemented.

The Netherlands have a long history of energy efficiency policy in industry. Voluntary agreements have been implemented since 1990, among other instruments. The data gathered during these agreements offer a unique opportunity to analyse the way in which companies invest in energy efficiency techniques.

This thesis describes how companies in the Netherlands implement energy saving projects, what drives them to implement these projects and the effect that these projects have on their energy use.