

Design of Effective Energy Efficiency Policies

An analysis in the frame of target setting,
monitoring and evaluation

Barbara Schlomann



Innovationspotenziale



Fraunhofer Institute for
Systems and Innovation Research ISI

Book Series »Innovation Potentials«

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Zugl.: Utrecht, Univ., Diss., 2014

Bibliographic information published by Die Deutsche Bibliothek

Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at www.dnb.de.

ISSN: 1612-7455

ISBN: 978-3-8396-0773-2

Printing and Bindery:
Mediendienstleistungen des
Fraunhofer-Informationszentrum Raum und Bau IRB, Stuttgart

Printed on acid-free and chlorine-free bleached paper.

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DESIGN OF EFFECTIVE ENERGY EFFICIENCY POLICIES

An analysis in the frame of target setting, monitoring and evaluation

Ontwerp van effectief energie-efficiëntiebeleid

Een analyse in het kader van doelstelling, monitoring en evaluatie

(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. G.J. van der Zwaan, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op 5 november 2014 des middags te 12.45 uur

door

Barbara Schlomann

geboren op 2 maart 1962 te Recklinghausen, Duitsland

Promotor: Prof. Dr. K. Blok

Copromotor: Dr. W. Eichhammer

*“People have forgotten this truth”, the fox said. “But you mustn’t forget it.
You become responsible forever for what you’ve tamed.
You’re responsible for your rose.”*

Antoine de Saint-Exupéry, The Little Prince

Für meinen Vater

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1 Introduction

This chapter first of all introduces the two main pillars of this thesis which are

- the role of energy efficiency in the framework of energy efficiency potentials, targets and policies and
- the integration of monitoring and evaluation into this framework.

In the last part of this chapter we formulate our research questions addressing key issues in the frame of these two pillars.

1.1 The role of energy efficiency in the framework of energy and climate policy

Today, it is widely acknowledged that energy efficiency plays a decisive role within a global strategy to limit the long-term increase of global temperatures to within 2°C above pre-industrial levels. According to the IEA, energy efficiency, i.e. end-use efficiency related to fuels, power plant efficiency and electricity savings, accounts for more than 70% of the CO₂ emission savings in 2020 in a policy scenario targeted to achieve the 2°C goal (IEA, 2012a, p. 253). Although the importance of energy efficiency compared to the other CO₂ emission reduction strategies considered in the IEA scenario (renewable energies, carbon capture and storage, nuclear energy) falls to almost 42% by 2035, energy efficiency will continue to be the most important strategy for achieving global climate targets for decades. It is, accordingly, a corner stone of worldwide and European energy and climate policies.

In this thesis, we mainly focus on examples from the European Union (EU) and one of the Member States, Germany, in order to illustrate the important role of energy efficiency in policy making, and present drawbacks. But the key questions which we discuss with regard to target setting as well as monitoring and evaluation of energy efficiency policies are widely the same for all countries around the world. This is even more so for developing countries, as many of them are more exposed to high energy prices due to the larger share of the costs of their energy system in their economic output. This strengthens the need to develop policies and measures that promote energy efficiency. Though some of these countries show particularities such as subsidized energy prices, the major elements discussed in this thesis are relevant for all countries which put greater emphasis on the improvement of energy efficiency.

The European Union launched a system of climate and energy targets for 2020 with its 2008 climate and energy policy package (EC, 2008a). This included headline targets for greenhouse gas (GHG) emissions, renewable energy sources (RES) and energy

efficiency (EE). The aim is to reduce GHG emissions by 20% compared to 1990, increase the share of renewables in the total EU gross final energy consumption to 20% and reduce primary energy consumption by 20% compared to the trend up to 2020¹. Although the EU is on track to achieve its GHG and RES targets, there is evidence that it may not be fully on track to meet its 2020 energy savings target (EEA, 2013; Harmesen et al., 2014; Fraunhofer ISI et al. 2014). This is astonishing since it is well documented in several European and international studies that there is a huge potential for energy efficiency and reduced use of energy. Such a strategy is often cost-effective from a social perspective, and even that of an individual private investor, in both companies and households (Fraunhofer ISI et al., 2009; Ecofys and Fraunhofer ISI, 2010; IEA, 2012a; Fraunhofer ISI, 2012; Eichhammer, 2013).²

The cost-effectiveness of energy efficiency measures is further improved if taking into account the significant co-benefits of energy efficiency such as increases in GDP and employment, and an improvement in competitiveness (see e.g. IEA, 2012b, eceee, 2013, Cambridge Econometrics, 2013). In addition, the reduction of energy consumption through energy efficiency is one of the most effective means of reducing the dependence on imported energy and thus increasing energy security.

In reality, there is still a gap between the market potential for energy efficiency and the cost-effective potential from an individual or social point of view. Even the profitable potential is not fully exploited, primarily because of persistent barriers to the deployment of energy efficiency measures. Such barriers prevent private investors in households as well as companies and public organisations from realising energy savings potentials even though they are cost-effective under current economic conditions (e.g. Blok, 2007, pp. 241-242; Granade et al., 2009; IEA, 2012a, pp. 280-282; Fleiter et al., 2013, pp. 74-84). According to the classification by Sorrell et al. (2004), the barriers fall into the following broad categories (see Figure 1-1): imperfect information and other transaction costs (e.g. search costs) for identifying energy use of buildings, products and services; hidden costs, such as overhead costs for management or for staff training; technical risks of energy-efficient technologies; financial risks associated with irreversible investments and uncertainties in the returns of energy efficiency measures; lack of access to internal or external capital; split incentives, preventing the investor in energy efficiency measures fully benefiting from the savings (e.g. the well-known land-

1 The trend was set by the PRIMES 2007 projections (EC, 2008b) and does not include impacts of the financial and economic crisis from 2008 onwards.

2 Energy efficiency potentials are usually distinguished as follows (compilation based on Blok, 2007): theoretical, technical, economic, profitable and market potentials (see also the definition of these potentials in Figure 1-1).

lord-tenant problem); and bounded rationality, which means that constraints on time, attention, and the ability to process information prevent individuals from making “rational” choices in complex decision problems.

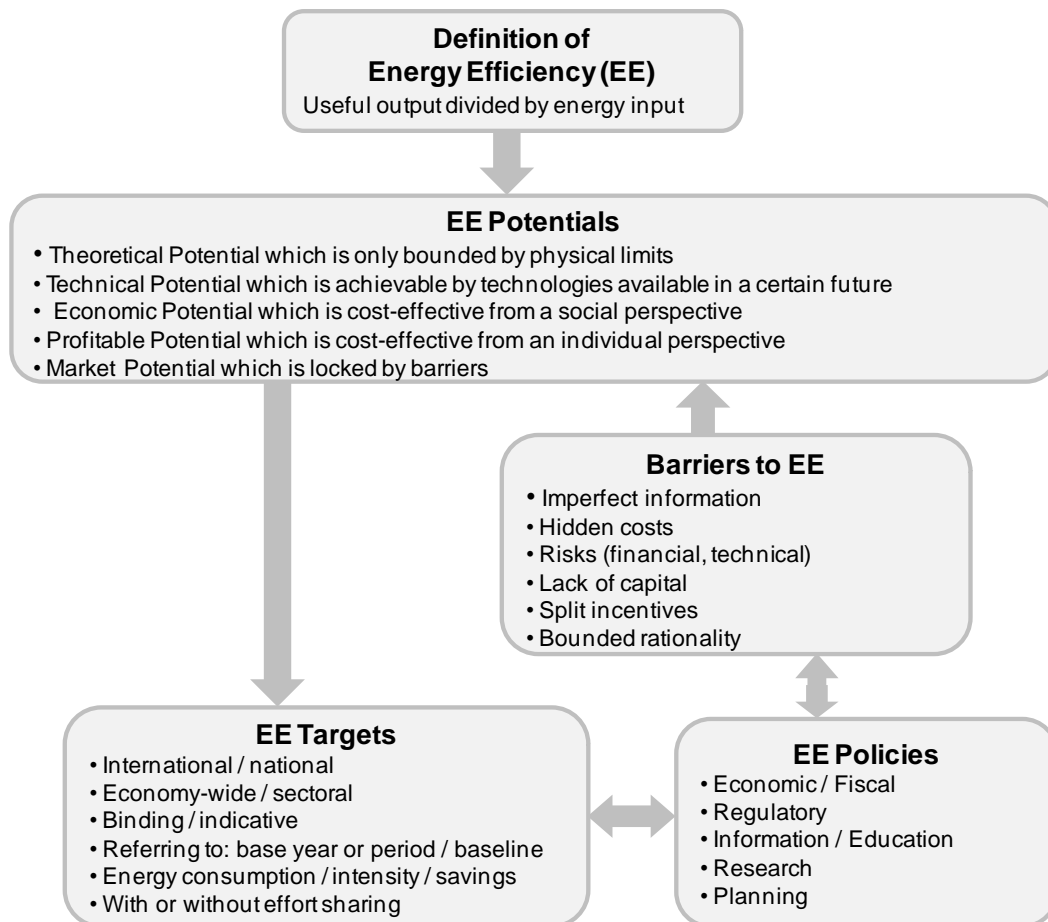


Figure 1-1: Energy efficiency (EE) in the framework of targets and policies

The persistent existence of these barriers is one important justification for the introduction of policy instruments³ in the field of energy efficiency, aiming at overcoming the barriers and thus fully exploiting the cost-effective potential. There are several types of

³ Policy instruments are concrete tools to achieve overarching policy objectives such as the removal of barriers. The term ‘instrument’, can also be described in studies as ‘implementing measures’, ‘programs’, ‘policies’, or ‘policies and measures’ (for a comprehensive overview see Rogge and Reichardt, 2013). In the following, we use the term ‘instrument’ or ‘policy instrument’ synonymously when referring to a specific tool. In a more general sense we only use the term (EE) “policy”. However, we try to avoid the term ‘measure’ with regard to policies since in the energy efficiency terminology, a ‘measure’ is usually defined as concrete technical, organisational or behavioural energy efficiency improvement action which can be triggered by a policy instrument (e.g. Thomas et al., 2012).

instruments that are in principle capable of removing these barriers. The UNFCCC (2000, p. 85) describes these as follows⁴:

- economic instruments such as investment programs, subsidies, feed-in tariffs, loans/grants, or trading schemes
- fiscal instruments affecting taxes
- voluntary/negotiated agreements
- regulatory instruments, i.e. binding standards and labels or building regulations
- information such as voluntary labels and standards or campaigns for raising awareness
- education, i.e. training programs, capacity building, or education of multipliers
- research programs and demonstration projects
- planning, which mainly comprises transport or urban planning.

However, each of these instruments usually only address parts of the barriers. Therefore, several policy studies in the field of environmental research have argued for the need to combine different policy instruments in so-called policy mixes (see Rogge and Reichardt, 2013, for an overview). A suitable policy mix in the field of energy efficiency should not only be able to break down the barriers, but also make use of the driving forces which facilitate the implementation of energy saving measures in private households, companies and organisations. These particularly include social and psychological factors, such as high environmental awareness, the desire for greater comfort, social “pressure” or a better image (see e.g. Eichhammer et al., 2012; Fleiter et al., 2013).

Targets for the reduction of energy consumption or GHG emissions play an increasing role in the field of energy and climate policy at the international, European, and national levels. The European Union, for example, launched a system of climate and energy targets for the period to 2020 (EC, 2008a) and a new framework to 2030 is currently being developed (EC, 2013). With its Low Carbon Roadmap from 2011 (EC, 2011), which demands a reduction of GHG emissions to 80-95% below 1990 levels by 2050, the EU has also set a long-term decarbonisation target. In Germany, a new energy concept for the transformation of the energy system, the so-called “Energiewende” (Energy transition), was launched by the Federal government (German government, 2010), and includes a set of energy and climate targets for the medium- and long-term up to 2050. These target systems may get fairly complex and raise questions with respect to target interaction.

⁴ For an overview of different typologies of instruments in the field of energy and climate policy see Blok, 2007, pp. 243-246, and Rogge and Reichardt, 2013.

There is an ongoing discussion in Europe into a new framework for energy and climate targets up to 2030. Within this, there is controversy over the possible role of a separate target for energy efficiency. At the national level, many European and other countries have already introduced such a target (for an overview see Wade et al., 2011; Enerdata, 2011) and it is part of the present EU target system up to 2020⁵. The current debate centres around both the principle requirement of a separate target for energy efficiency and some key design features for such a target. Figure 1-1 shows the design features debated as follows: (compilation based on Harmsen et al., 2014; Broc, 2014)

- the scope of the target, i.e. whether it should be set at the international, EU or national level and cover the whole economy⁶ or single energy consumption sectors
- the degree of commitment, i.e. whether the target should be legally binding or indicative
- the reference type of the target, i.e. whether it should refer to a base year or period, or to a (fixed) baseline development as was defined in the EU 2020 target system
- the reference level of the target, i.e. whether it should refer to the total energy consumption, the energy intensity (i.e. the energy consumption related to an economic activity such as GDP), or to energy savings, defined as a reduction in the use of energy (Pérez-Lombard et al., 2013, p 252)
- the sharing of the target, i.e. whether the target should be equally distributed across the participating countries or should individual country specifications be considered.

The supporters of an own target for energy efficiency argue particularly that such a target can contribute to a better exploitation of the cost-effective energy efficiency potentials both directly and by inducing additional EE policies to remove the barriers that still exist (see Figure 1-1). Further, a specific energy efficiency target corresponds to the importance of specific objectives such as supply security, a competitive energy system and resource efficiency. In addition, they also refer to the co-benefits of energy efficiency as described above. The opponents of a separate EE target highlight the greater flexibility of one single target for GHG emissions and the absence of overlaps between the targets. Another counter-argument is the difficulty of defining and monitor-

5 Though the energy efficiency target always had another “quality” within the 2020 framework; whereas the GHG emission and the renewable targets were mandatory and therefore binding for all Member States, the target for energy efficiency has never been translated into a legally binding text.

6 Sometimes, also one sector may be excluded from the overall economy, as e.g. transport or companies participating in the EU Emission Trading Scheme in the Energy Efficiency Directive target mentioned in Article 7 of Directive 2012/27/EU (EED). The reason may be avoiding putting a double burden on companies though this neglects synergy between instruments.

ing an EE target, which will be further discussed in Section 1.2 (for an overview of these pros and cons see e.g. Broc, 2014). There are also intermediate aggregations of targets possible, for example a common target for energy efficiency and renewable energies, called “resficiency”. This offers the possibility of trade-offs between both important pillars of a sustainable energy system, while maintaining some flexibility.

The role of energy efficiency in the framework of EE potentials, targets and policies, is summarised in Figure 1-1 which considers the different issues discussed in this section. The arrows indicate how the definitions of energy efficiency⁷ are taken up in the formulation of energy efficiency potentials which in turn are used in this thesis as a central element in the formulation of EE targets. The way how energy efficiency potentials are defined is, on the other hand, influenced by the manner how barriers are reflected in the definition of potentials. Barriers, similar to targets, have a strong impact on the formulation of EE policies. EE policies, on the other hand, do have themselves an important impact on barriers and targets as they need to be designed in a dedicated manner to overcome specific barriers and may lead to target readjustments depending on the success of implementation. This is reflected by the double arrows between the corresponding elements of Figure 1-1.

The role of energy efficiency in the framework of energy efficiency potentials, targets and policies is the first pillar of this thesis. We will address several research questions which arise within this framework and where we still see a gap in the present research (see Section 1.3). We particularly consider

- the possible role of an energy efficiency target within a new 2030 target architecture in the EU,
- possible design options for such a target and
- key design features for EE policy instruments and policy mixes designed to effectively remove barriers and better exploit the cost-effective EE potential.

1.2 Monitoring and evaluation of energy efficiency targets and policies

Both the setting of EE targets and the design of EE policies is closely connected to the issues of monitoring and evaluation. Against the backdrop of a growing number of energy and climate policy targets and the introduction of new policy instruments to meet

⁷ The definition of energy efficiency itself is equivocal. In Figure 1-1 we used a typical definition from Rosenfeld et al. (2004). In Section 2.2.1, the definition of energy efficiency is discussed more detailed.

these at national and international levels, it has become more important to regularly monitor the progress made towards these targets.

At EU level, for example, there are obligations for the Member States to regularly report their GHG emissions up to 2020, within the framework of the Kyoto protocol (Decision 280/2004/EC) and the development of renewable energies (Directive 2009/28/EC). The Effort Sharing Decision 406/2009/EC⁸ establishes binding annual greenhouse gas emission targets for Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport (except aviation and international maritime shipping), buildings, agriculture and waste. The Effort Sharing Decision sets national emission targets for 2020, expressed as percentage changes from 2005 levels. By 2020, the national targets will collectively deliver a reduction of around 10% in total EU emissions from the sectors covered compared with 2005 levels. The Commission Implementing Decision 2013/634/EU⁹ adjusts the annual emission allocations (AEAs), Article 6 of the decision requires annual reporting of the emissions concerned by the Decision.

The former EU directive on energy end-use efficiency and energy services (ESD; 2006/32/EC) also included regular reporting obligations within the frame of national energy-efficiency action plans (NEEAPs). In the present Energy Efficiency Directive (EED)¹⁰ these reporting obligations are further developed by demanding annual as well as more comprehensive reporting at three year intervals (Article 24). In Germany, the progress made towards the targets of the “Energiewende” is evaluated in yearly monitoring reports (BMW i and BMU, 2012; BMW i, 2014).

A regular monitoring process is also increasingly being established at the level of individual instruments. At the European level, new EE policy instruments such as energy efficiency funds or energy efficiency obligations (EEOs) require a system for the monitoring and evaluation of the achieved energy savings. EEOs are market-oriented systems to promote energy efficiency, which have already been introduced by several European countries and proposed by a larger number in their notifications in the frame

⁸ Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community’s greenhouse gas reduction commitments up to 2020.

⁹ 2013/634/EU: Commission Implementing Decision of 31 October 2013 on the adjustments to Member States’ annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC of the European Parliament and of the Council.

¹⁰ Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/123/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

of Article 7 of Directive 2012/27/EU (EC, 2014). Internationally, these schemes are already widespread in the some U.S. states and Australia (for comprehensive overviews of EEOs see Bertoldi and Rezessy, 2008; Bertoldi et al., 2010; Bertoldi, 2012; Lees 2012; Staniaszek and Lees, 2012; RAP, 2012). Since the late 1970s, the monitoring of energy savings has been a part of Demand Side Management (DSM), which aimed to change both the level and timing of electricity demand. Extensive programs have been running and various measurement methods have been developed, particularly in the U.S. (Loughran and Kulick, 2004; Koomey et al., 2010; Violette et al., 2012). Larger subsidy programmes such as the programmes by the German promotional bank KfW for energy efficient buildings also often require regular evaluations of its impacts.

A monitoring process is usually implemented in practice via a set of indicators, though the use of calibrated models, e.g. for monitoring building performance, is also possible (Held et al., 2010). The demands made of such indicators depend on the monitoring objective, and can vary considerably according to the following factors (Figure 1-2):

- *ex post* or *ex ante* evaluation of targets and policy instruments
- top-down monitoring based on aggregated statistical data or a bottom-up monitoring of individual EE policy instruments and/or EE improvement measures
- methods applied within the monitoring process.

Many of the above mentioned reporting obligations and monitoring processes actually combine more than one objective, for example they may include an evaluation of what has been achieved so far as well as an estimation of future developments, or they may incorporate the derivation of aggregated top-down indicators with the concrete assessment of individual policy instruments.

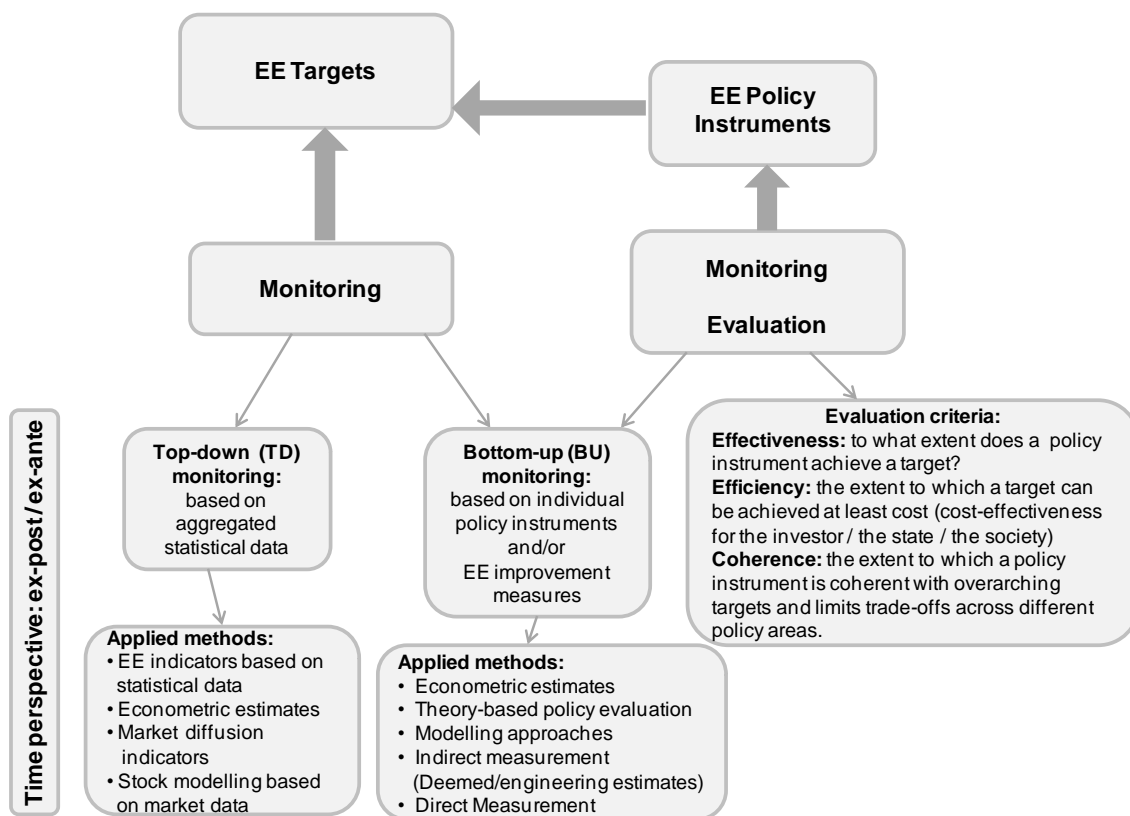


Figure 1-2: Monitoring and evaluation of EE targets and policies

Top-down indicators are generally calculated at a high level of aggregation, such as the economy as a whole or individual consumption sectors, and more rarely at the level of individual fields of application. In its pure form, this is a statistical approach which relies predominantly on official statistics. To map the actual development of energy efficiency more accurately, these raw data are often normalised or corrected for external influences which are not primarily attributable to changes in energy efficiency (e.g. weather fluctuations or structural changes within the economy). For more advanced corrections of price or economic influences as well as the influence of technological progress, econometric approaches are predominantly used which involve a regression analysis based on a (corrected) indicator (e.g. Schüle et al., 2011; Thomas et al. 2012). The range of top-down methods is supplemented by sectoral modelling which is mainly used for forecasts or scenarios, but in principle can also be used for *ex-post* evaluations if the models adequately portray the past (especially in case of stock modelling based on market data) and are calibrated to observable statistical data. Indicators measuring the share of energy-efficient technologies, equipment or practice in the market (as e.g. the share of highly efficiency electrical household appliances), - so-called “market diffusion indicators” - make up another group.

The policy impact at the level of individual instruments is usually measured using so-called “bottom-up indicators”. These usually address energy consumption at a lower level of aggregation than top-down indicators. But some of the methods shown in Figure 1-2, i.e. the econometric and modeling approaches as well as market diffusion indicators, are also characterized as intermediate methods in literature (Eichhammer et al., 2008; Seefeldt et al., 2010; Thomas et al., 2012), which both can be applied to top-down and bottom-up monitoring approaches. Another impact evaluation approach at the level of individual policy instruments is the so-called “theory-based” evaluation, which assumes that policy instruments are based on an underlying theory how they are expected to work (Blok, 2007, p. 248).

The most detailed method of impact analysis is the direct or indirect measurement of energy savings either at the level of individual applications or more often at the level of single objects or systems (Figure 1-2). These methods contain only two basic elements to start with: an activity variable (usually number of cases or objects) and a uniform saving per case (usually the consumption before carrying out an energy saving measure minus the consumption after the measure). This means, however, that data at the level of individual measures are necessary which can, however, be gathered at different levels of accuracy: by direct or indirect measurement of individual actions or by the use of more aggregate average data standard values based on theoretical considerations or estimates (see e.g. Thomas et al., 2012). Conducting direct measurements on the respective object or case represents the “ideal” bottom-up method; this is, however, also by far the most complex and costly and will therefore only be applied in a few cases. When using indirect measurement methods, which are e.g. based on engineering estimates, it is essential that the technically identified impact correlations are properly illustrated.

All these monitoring methods described above are applied to the impact assessment of policy instruments which is usually based on a set of evaluation criteria. The “effectiveness” and the “efficiency” are particularly well-established ex-ante and ex-post assessment criteria which are often applied in impact assessments and evaluations of single policy instruments (Blok, 2007, p. 247). With regard to policy mixes, additional criteria such as consistency and coherence need to be taken into account (Rogge and Reichardt, 2013, p. 5). These criteria are defined ambiguously in literature (for a comprehensive literature review see Rogge and Reichardt, 2013). In this thesis, we follow the choice and definition of criteria for evaluating a new policy instrument as they are recommended by the European Commission in their Impact Assessment Guidelines (EC, 2009, p. 48), i.e. its effectiveness, efficiency and coherence (for the definitions see Figure 1-2).

For practical purposes, these overall evaluation criteria can be further specified in order to get a more comprehensive assessment of an individual policy instruments or a bundle of policies. In a study comparing different types of EE policy instruments (Schlommann et al., 2012, 2013; also see Chapter 5), the following criteria have been applied:

- scope and quality of the energy savings induced with an instrument; this criterion assesses the suitability of a policy instruments or a bundle of policies to tap the existing EE potentials and thus to meet EE targets
- costs of the instruments, distinguishing between administrative costs for the set-up, operation and monitoring of the instrument(s), program costs, i.e. the costs of the programs actually performed, as well as the additional investment costs, i.e. the differential costs for the investment in an energy-efficiency technology as compared to standard technology
- market conformity and impacts on competitiveness and the market of energy services
- distributional and structural effects as well as effects on the energy price trends
- interaction of policy instruments within the overall energy-policy landscape
- political acceptance by the different groups affected by a policy; this criterion is especially important for the introduction of new EE policy instruments
- scope for refinancing; this criterion examines the extent to which policy instruments differ in terms of their funding.

The integration of monitoring and evaluation into the framework of EE targets and policies is the second pillar of this thesis (see Figure 1-2). In the following section, we formulate several research questions addressing some key issues where we still see a lack of clarification in spite of the previous research and the practical experience in this field. These particularly include:

- the measurement of energy efficiency, where recent discussions show that clear definitions and common rules are still missing and that some methodological problems are still unsolved
- the possibilities and limits of top-down indicators as tools for the monitoring of progress in energy efficiency
- discussion on how top-down indicators could be effectively complemented by bottom-up methods which directly relate to individual policy instruments or EE improvement measures.

1.3 Scope and outline of this thesis

The research questions for this thesis were derived directly from the framework of EE targets and policies developed in the two previous sections.

The central research question for this thesis is:

What is necessary for the design of effective energy efficiency policies?

We focus our research on the central issues identified in the previous sections. First of all, these are the setting of energy efficiency targets and the design of energy efficiency policies in order to achieve the targets. Secondly, both issues are closely connected to the monitoring and evaluation of their success. This provides important information on the functioning of policies and hence their improvement in view of target achievement. In Figure 1-3, the central research question is therefore set in the overall context of energy efficiency targets and policies and their monitoring and evaluation. The following chapters of the thesis are structured according to this scheme.

In order to answer the overall research question, we define several sub-questions. Each of these refer to part of the issues raised in Figure 1-3 and are dealt with in one or more of the following chapters.

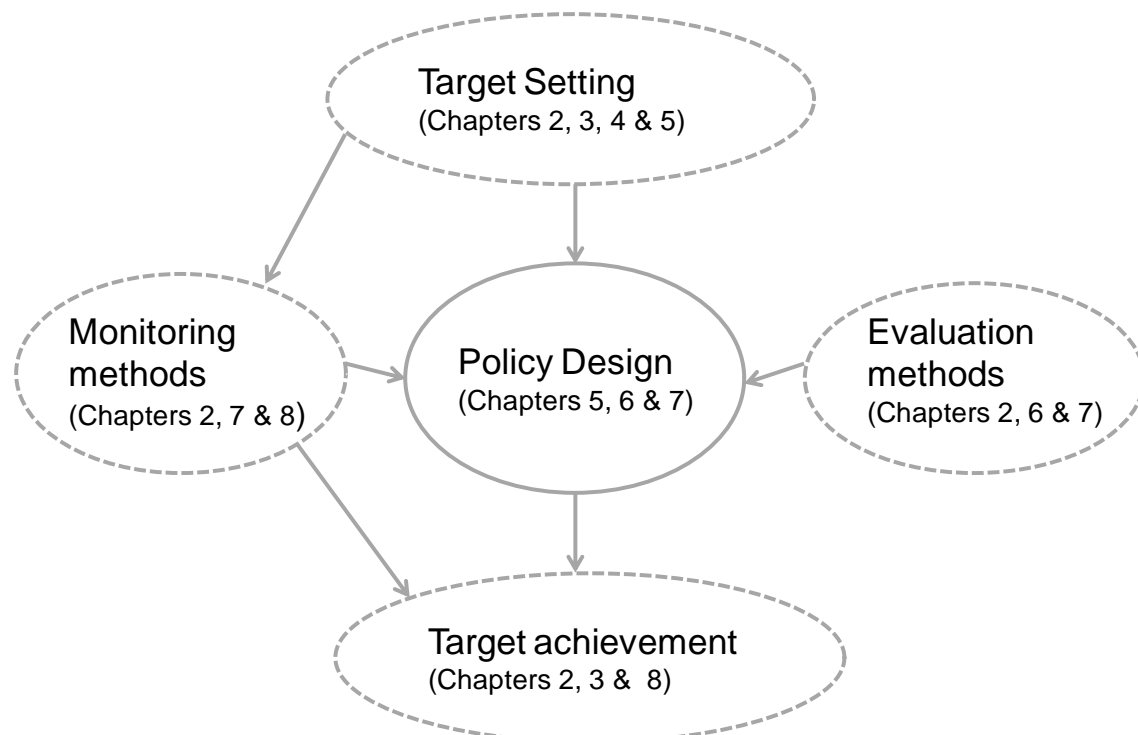


Figure 1-3: Conceptual framework of the thesis

The following sub questions are defined:

1. What are the fundamental aspects for measuring energy efficiency in a political context?
2. How does energy efficiency fit a target architecture aimed at multiple objectives for climate and energy?
3. What role can energy efficiency potentials play in the process of target setting and policy design?
4. Which key factors should be taken into account for the design of effective energy efficiency policies?
5. How can the perspective of specific actors and target groups be considered in the policy design?
6. What methods are appropriate to evaluate the effectiveness of EE policy instruments?
7. What methods are appropriate to measure the progress made towards EE targets and what factors should be taken into account?

Below we discuss the content of these research questions in more detail and link it to the respective chapters of this thesis where they are dealt with.

1. What are the fundamental aspects for measuring energy efficiency in a political context?

This question refers to several fundamental aspects with regard to the measurement of energy efficiency which have to be taken into account in a political context. Although energy efficiency is widely accepted as a simple and cost-effective way to reduce energy consumption and GHG emissions, there is controversy concerning both its concrete definition and its measurement in the context of the setting and monitoring of EE targets. This shows that clear definitions and common rules for the measuring of energy efficiency are still missing and that some methodological problems remain unsolved.

In **Chapter 2**, we therefore take up basic aspects of this discussion where we still see a lack of clarification. These are especially the formulation of a baseline and the accounting methods which are used for the measurement of energy efficiency. We will show that without a clear definition of these central elements, the setting and monitoring of energy efficiency targets in a political context is not well linked to a theoretical framework. In this sense, Chapter 2 also serves as a general methodological foundation for this thesis and is relevant for the whole conceptual framework.

2. How does energy efficiency fit a target architecture aimed at multiple objectives for climate and energy?

The European Union has set a system of climate and energy targets comprising target values for GHG emissions, energy efficiency and renewable energies up to 2020, and a new framework up to 2030 is currently being developed. In **Chapter 3** we analyse what lessons can be learned from the EU 2020 target system and how a new 2030 framework can be coherently designed. We base our new target system for 2030 on an ambitious EE target and discuss why energy efficiency should play a key role in a 2030 target architecture.

3. What role can energy efficiency potentials play in the process of target setting and policy design?

We have seen in Section 1.1 that energy efficiency potentials can be relevant for both the setting and monitoring of EE targets and for the design and evaluation of EE policies. The above research question is initially discussed in Chapter 3 and 4 with regard to the setting of EE targets. In **Chapter 3**, we derive a coherent target system for 2030 from a bottom-up assessment of energy efficiency potentials. In **Chapter 4**, we use a bottom-up stock modelling approach to calculate the technological improvement potentials to reduce electricity consumption for information and communication technologies (ICTs) in the medium and long-term. In **Chapter 5** we look at energy efficiency potentials with regard to the implementation of a new group of EE policy instruments, namely a possible introduction of market-oriented instruments such as EEOs in Germany. Such instruments are thought to be more in line with the generation of markets for energy efficiency than regulatory measures. For the discussion of the design of such market-oriented instruments, we make use of EE potentials for the main final energy consumption sectors. These are calculated with a bottom-up simulation model to derive an energy-saving target to be achieved by the new instruments. The EE potentials also enable the quantitative evaluation of the suitability of the new instruments to meet these targets.

4. Which key elements should be taken into account for the design of effective energy efficiency policies?

This research question refers to central issues with regard to the design of EE policy instruments and is therefore addressed in two chapters from different perspectives. In **Chapter 2**, we discuss key methodological issues which have to be taken into account when introducing new policy instruments such as an EEO. This focuses on the formulation of a baseline and the different accounting methods for energy savings in order to

clarify ongoing discussions. In **Chapter 5**, we apply these methodological thoughts to the concrete introduction of new market-based policy instruments for energy efficiency.

5. How can the perspective of specific actors and target groups be considered in the policy design?

The perspective of actors and target groups is a key feature for the design of effective energy policies in order to remove the existing barriers to energy efficiency deployment (see Section 1.1). This research question is explored in two of the following chapters. We choose the example of one specific actor (retailers) and one important target group (small and medium-sized companies) for EE policies in order to get more insight into the demands of these groups on policy design. For both analyses, we can rely on data from comprehensive surveys.

In **Chapter 6**, we have a deeper look at the retailers, who play an important role in the implementation of many product labeling regulations, yet sometimes fail to comply with these regulations. In order to understand retailers' (lack of) compliance with product label regulations and the impact of this failure on the effectiveness of the labels, we first develop a theoretical framework that encompasses instrumental and normative motives. We then test this framework in the energy label context through a large-scale empirical study covering 1,314 retail stores in all 27 European Union countries. In **Chapter 7**, we empirically explore factors driving the adoption of energy management procedures and of other low cost energy-saving measures in the so-called tertiary sector (mainly comprising public and private services, trade, commerce and some small industries). Our statistical analysis relies on more than 1500 observations from a recent representative survey in Germany, largely of small and medium enterprises (SMEs).

6. What methods are appropriate to evaluate the effectiveness of EE policy instruments?

In Figure 1-2 we show that there is a set of different bottom-up methods to evaluate the effectiveness of EE instruments or EE policy bundles. Each of these methods, however, has its drawbacks. In **Chapter 2**, we discuss the advantages and problems of these methods from a theoretical point of view. In **Chapters 6** and **7**, we apply these thoughts to two concrete EE policy instruments, i.e. the labelling of energy-using products and the introduction of energy management systems in companies.

7. What methods are appropriate to measure the progress made towards the targets and what factors should be taken into account?

Our last sub-question is similar to the previous one, but turns the focus from policy instruments back to the targets. The principle methodological approaches with regard to target monitoring are again discussed in **Chapter 2**. We refer to the different types of top-down and bottom-up monitoring methods and show that both contain a series of “adjustment settings” which can strongly influence the degree of energy efficiency target achievement. Finally, in **Chapter 8** we analyse the possibilities and limits of top-down methods as tools for the regular monitoring of EE targets. We refer to the respective targets of the German Energiewende and calculate and discuss several energy efficiency indicators for Germany both at the level of the overall economy and the main energy consumption sectors.

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2 Dimensions of energy efficiency in a political context*

Abstract

Energy efficiency is widely accepted as a simple and cost-effective way to reduce energy consumption and greenhouse gas emissions. It is accordingly a corner stone of European energy and climate policies. However, in formulation of explicit political energy efficiency goals as well as in monitoring these targets, discussions arise both concerning the concrete definition and the measurement. Accordingly, there is a lack of clarification and in-depth discussions of several fundamental aspects or dimensions of measuring energy efficiency, in particular in a political context. Here, we discuss and analyse two aspects of energy efficiency and ways to measure it, namely the formulation of a baseline and the accounting methods, in order to clarify ongoing discussions. We find that both top-down and bottom-up methods contain a series of “adjustment settings” which can strongly influence the degree of energy efficiency target achievement. Additionally, several baselines can be meaningfully defined and used in a political context. For a specific case defined in the paper, we find a factor of 10 or more between different meaningful definitions of energy efficiency easily achievable. Our results indicate that rigorous definitions should be used for formulating and monitoring energy efficiency targets in a political context if exactly the same understanding of target is to be achieved.

* Published in Energy Efficiency, 2014, (DOI) 10.1007/s12053-014-9280-8. Co-Authors are Clemens Rohde and Patrick Plötz. The final publication is available at <http://link.springer.com>

2.1 Introduction

Today, it is widely acknowledged that energy efficiency plays a decisive role within a global strategy to limit the long-term increase of global temperature to 2°C above pre-industrial levels. According to IEA (2012, p.253), energy efficiency, i.e. the better use of energy for the production and consumption of goods and services, accounts for 72% of the CO₂ emission savings in 2020 in a scenario targeted to achieve the 2 °C goal. Though the importance of energy efficiency compared to the other CO₂ reduction strategies considered in the IEA scenario (renewable energies, carbon capture and storage, nuclear energy) falls to almost 44% until 2035, energy efficiency will remain the most important strategy for achieving global climate targets for decades.

Against the backdrop of a growing number of energy efficiency targets, it has also become more important to regularly monitor the progress made towards these targets. Therefore, quantification becomes more and more important for policy design and evaluation also with regard to energy efficiency. At the EU level, for example, the Directive 2006/32/EC on energy end-use efficiency and energy services (ESD) demanded for a regular reporting on the progress achieved towards national energy efficiency targets by three national energy-efficiency action plans (NEEAPs). The Energy Efficiency Directive from October 2012 (European Commission, 2012) also provides for annual as well as more comprehensive reporting obligations at three year intervals in Article 24. A regular monitoring process is also increasingly being included at the level of individual policy instruments as for energy efficiency obligation schemes. These market-oriented systems to promote energy efficiency, which several European countries have already introduced (see e.g. Bertoldi and Rezessy, 2008; Bertoldi et al., 2010; Bertoldi, 2012; Giraudet et al., 2012; Lees, 2012; Staniaszek and Lees, 2012; Schlomann et al. 2013) are recommended for all Member States in Article 7 of Directive 2012/27/EU.

Furthermore, there are a lot of open questions with regard to the definition and the monitoring of energy efficiency, though a similar discussion was already led in the wake of Directive 2006/32/EC. This is astonishing for two reasons. Firstly, the general acceptance of energy efficiency as a useful strategy to reduce GHG and CO₂ emissions seems to be more pronounced than for any other strategy (IEA, 2012; European Commission, 2011). Secondly, there is a long history of profound research on the issue of the definition and measurement of energy efficiency already starting almost 40 years ago after the first oil crisis in 1973. This research mainly aimed at better understanding the link between energy use and economic growth based on indicators relating energy

consumption to some kind of economic activity.¹¹ Since that time we know that increasing growth is not inevitably linked with an increase in energy consumption due to the resource energy efficiency (also see Schipper et al., 1992).

The actual discussion, however, mainly focus on the setting of energy efficiency targets and its regular monitoring, which causes new challenges and the need for additional measurement methods. The deeper analysis of measurement issues during the implementation process of Directive 2006/32/EC brought some progress with regard to methodological problems and data constraints related to the measuring of energy efficiency (see e.g. Bowie and Malvic, 2005; Boonekamp, 2006; Eichhammer et al., 2008; Thomas et al., 2012). The main focus of these studies was on the development of a suitable framework for the measurement and verification of energy savings at the level of a country.¹² The authors addressed the key measurement problems and the tried to harmonise the so-called “top-down” and “bottom-up” measurement methods which were recommended in Directive 2006/32/EC for the Member States’ reporting of target achievement¹³.

In spite of the analytical progress which was already achieved, it seems that a similar discussion started again in the frame of Directive 2012/27/EU. Consequently, the topic of energy efficiency measurement aroused growing interest again. The revival of the discussion shows that clear definitions and common rules for the measuring of energy efficiency are still missing and that some methodological problems are still unsolved (see e.g. Bach, 2012; Pérez-Lombard et al., 2013; Bertoldi and Cahill, 2013).

11 The discussion started during the 2nd half of the 1970s in the U.S. (see e.g. Schipper and Lichtenberg, 1976; Darmstadter et al., 1977; Berndt, 1978 and Schipper, 1979). During the 1980s and 1990s, energy efficiency indicator projects started both at the country level (see e.g. EIA, 1995 for the U.S., Farla et al. 1998 and Farla and Blok, 2000 for the Netherlands, Natural Resources Canada, 2004) and for the IEA (2004) and the European Union (Morovic et al., 1989; Bosseboeuf et al., 1999). For a critical view of these approaches see Horowitz (2008).

12 Since the late 1970s, monitoring of energy savings has also been part of Demand Side Management (DSM) that aimed at changing both the level and timing of electricity demand. Especially in the U.S., extensive programs have been running and various measurement methods have been developed (Loughran and Kulick, 2004; Koomey et al., 2010; Violette et al., 2012). But these methods only aimed at a given energy efficiency program and not at the whole energy savings achieved in a country. This is the main difference to the present discussion in Europe which is in the focus of this paper.

13 In this context, „top down“ means a measurement at an aggregated level of the economy using statistical data whereas “bottom up” means an adding up of efficiency gains from individual energy efficiency improvement measures.

In this paper, we take up two basic aspects of this discussion where we still see a considerable lack of clarification in spite of the previous research in this field. These are firstly the formulation of a baseline and secondly the accounting methods which are used for the measurement of energy efficiency. We will show that without a clear definition of these central elements the formulating and monitoring of energy efficiency targets in a political context is more or less useless.

The paper is structured as follows. Section 2.2 introduces basic definitions of energy efficiency and discusses the issues “baseline” and “accounting method” from a theoretical point of view. In Section 2.2.2 and 2.4, we discuss these two fundamental aspects in connection with the setting and monitoring of energy efficiency targets and policies in detail. In the final Section 2.5 we summarize the main points of discussion and give an outlook of the future of energy efficiency measurement with regard to baselines and accounting methods.

2.2 Overview of the dimensions of energy efficiency

2.2.1 Definitions of energy efficiency

A typical definition of energy efficiency is the following:

Energy efficiency: useful output divided by energy input.
(Rosenfeld et al., 2004)

In this manner, energy efficiency is typically defined from a physical consumption of energy as input, which might be electricity, heat, or any other physical form of energy, which is compared to a certain use-value such as output, service, good, or energy. Thus, it is important to note, that all in-depth discussions of energy efficiency and energy efficiency goals start from a specific value of energy consumption in physical units.¹⁴ Both ratios, output per energy input and energy input per output, can serve as energy efficiency indicators. A simple example is provided by ‘miles per gallon’ and ‘litres per kilometre’, both indicating fuel efficiency in of vehicles. Similar ratios are likewise used as measures of energy efficiency in other fields.

For the ratio “energy required per output” the terms ‘specific energy consumption’ as well as ‘specific energy use’ or ‘unit energy consumption’ are used (Blok, 2007, p. 171).

¹⁴ The alternative approach to measure energy consumption in monetary units, i.e. to assess the energy quantities by energy prices, which was especially followed until the mid 1980s (see e.g. Turvey and Nobay, 1965 (pp. 787); Schmitt and G6rger, 1981 (pp. 275); Sweeney, 1984 (p. 34); Nguyen, 1984 (p. 103), did not gain general acceptance.

In some publications, these ratios are also called ‘intensity indicators’ (Perez-Lombard, 2013, p. 242), whereas in others the term “energy intensity” is limited to those cases where the output is measured in monetary units (Enerdata, 2008; IEA, 2014a, p.17). This short discussion shows that no general agreement on the definition of these terms exists. In the present paper, we will use the term ‘energy efficiency’ for discussing both ratios, i.e. output per energy input and its inverse.

Specific disciplines have, of course, more specialised definitions of energy efficiency.¹⁵

Using these and related definitions of energy efficiency, the ‘useful output’ and precise definition of ‘energy input’ can differ significantly depending on the application or context and different names for the specific ratios are also in use, such as “energy performance” or “energy usage”. Accordingly, many notions of efficiency and usefulness are met. In engineering, considering for example the efficiency of electric motors, energy conversion efficiency is quite common: $\text{efficiency} = \text{mechanical energy out} / \text{electric energy in}$ (Emadi, 2005). Similar to thermo-dynamics, the efficiency of a machine or process is a ratio of two energies and thus a dimensionless quantity.

Furthermore, it is important to note, that energy efficiency has to be distinguished from ‘energy savings’. Energy savings could, e.g., be defined to include reduced consumption due to behavioural changes, but the dividing line between energy saving and energy efficiency is of course ambiguous. A comprehensive discussion of the distinction between the two is beyond the scope of the present paper.¹⁶ For the following, we define energy efficiency as “the ratio between a useful output and energy input” closely connected to energy efficiency discussions in a political context. Energy savings, on the other hand, will be used as “a reduction in the use of energy” (Pérez-Lombard et al., 2013, p 252). This means that energy efficiency indicates a relative improvement in the use of energy, whereas energy savings mean an absolute amount of “not used”

¹⁵ For example, the thermo-dynamical definition of the (energy) efficiency of any heat engine is the ratio of mechanical work that engine performs to the needed input of heat the engine requires (Schwabl, 2006, p. 143). A comprehensive overview and discussion of the different concepts of energy efficiency from a thermodynamical and economical perspective also gives Patterson (1996). Similarly, the energy conversion efficiency of machines is given by the ratio between energy input and useful energy output. Clearly, all these formulations define energy efficiency as the ratio between an input and a useful output.

¹⁶ See, for example, Lebot et al. (2004), Moezzi (1998), Pérez-Lombard et al. (2013) and Boonekamp (2006).

energy (Pérez-Lombard et al., 2013, p 240).¹⁷ The main focus of this paper will be on energy efficiency as defined above.

2.2.2 The various dimensions of energy efficiency

Despite the various possible and useful definitions of energy efficiency, the focus of the present paper is on problems that arise when *comparing* energy consumptions or usage or intensity. The notion of ‘comparing’ immediately raises several questions that evoke different aspects or dimensions of energy efficiency: “Compare what?”, “Compare with respect to what?”, e.g. time, efficiency measure, usage patterns, and many questions alike. Taking together the various definitions of energy efficiency and problems in comparing energy efficiencies, we are led to discuss several aspects or *dimensions* of energy efficiency:

- The *reference evolution* or *baseline* to which the time evolution of an energy efficiency measure is to be compared
- The *output* and input analysed which are the energy services to be achieved with different physical energy inputs.
- The moment or period of *time* for which a level of energy efficiency is to be reached or the between two measures of energy efficiency shall be compared
- The specific *accounting method* for energy efficiency. Here, not the use-value is meant, but different technical variants possibly leading to very different results (more in following section)
- *Other* dimensions not discussed in detail here can also play a role.

We refer to these aspects as “dimensions of energy efficiency” in order to emphasise that their clarification or specification in dealing with energy efficiency in a political context is not a minor topic – as “aspect” or might suggest – but instead vital for fixing the actual meaning of or target for energy efficiency. These different dimensions will be discussed in more detail in the present and the following section.

Output and input dimension

As discussed above, different quantities for ‘useful output’ or ‘useful energy’ are applied in measures or indicators of energy efficiency. This can be confusing or misleading, but

¹⁷ This definition is also in line with Directive 2012/27/EU where “energy efficiency” is defined as the ratio of output of performance, service, goods or energy, to input of energy and energy savings (Art. 2(4)) and “energy savings” as an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure. (Art. 2(5)).

different applications or settings clearly have different goals and it is only natural to apply different indicators. Common denominators for an energy efficiency indicator are the gross domestic product (GDP – the corresponding indicator is usually called energy intensity), mass, mechanical energy (e.g. for electric motors), capita and many others alike.

To give an example, the energy input can be given as primary energy consumption or final energy consumption. This has important consequences: Since renewable energies are usually integrated into total primary energy consumption with an energy conversion efficiency of 100%, the change from fossil fuels or nuclear energy in electricity generation to renewable energies can lead to a significant reduction in primary energy consumption. By this ‘computational effect’ an economy can become ‘more energy efficient’ without reducing its final energy consumption at all.¹⁸

A further problem with energy input and system output lies in the notion of ‘system’. The system boundaries or precise definition of system can be rather involved and can complicate specific definitions of energy efficiency. For example, the energy efficiency of a household heating system will depend on the efficiency of the boiler and on the level of thermal insulation (Sorrell and Dimitropoulos, 2008, p. 638).

Time dimension

Time is an obvious dimension for comparisons. It is customary to study the time-evolution of energy efficiency indicators in order to identify trends or a general direction of change. However, a comparison in time is only useful under the common “*ceteris paribus*”, i.e. except for time and the parameters directly entering the energy efficiency indicators, all other parameters and circumstances should not change. To accomplish this exactly is virtually impossible. Thus, many additional normalisation procedures are required and performed when comparing in time. We will discuss different methodologies in the following chapter.

Reference evolution and baseline selection

In a political context the change in energy efficiency of a system is often compared to the potential evolution of energy efficiency in the same system under different conditions, e.g., without energy efficiency policies in place (sometimes denoted as “busi-

¹⁸ Also see the discussions on energy efficiency versus renewable energy sources in Perez-Lombard et al. (2013) and on the relationship between energy efficiency and renewable energy targets in Harmsen et al. (2014) or Schlomann and Eichhammer (2014).

ness-as-usual scenario”). This comparison to a reference evolution and different choices of references will be further discussed below.

Accounting and calculation method

A monitoring process for energy efficiency in a political context is usually implemented in practice via a set of indicators which are calculated using a defined accounting method based on a specific database. Depending on the monitoring objective, the demands made of such indicators can vary considerably according to whether this involves

- an ex post or ex ante evaluation of targets and of the policies implemented to achieve these targets
- a top-down calculation based on aggregated statistical data or a bottom-up calculation summarizing the impacts of individual energy efficiency improvement measures.

Many of the reporting obligations and monitoring processes mentioned above actually include more than one objective at the same time, i.e. they may include an evaluation of what has been achieved so far as well as an estimation of future developments or the derivation of aggregated top-down indicators and the concrete assessment of individual energy efficiency improvement measures. Directive 2006/32/EC e.g. explicitly demanded for “a harmonised calculation model which uses a combination of top-down and bottom-up calculation methods” (Annex IV, point 1.1) for the measurement and verification of target achievement. The methodological problems connected with such an approach will be further elaborated below. We will then show that all indicators usually applied to measure energy efficiency have associated problems which can strongly influence the result of the monitoring process.

2.3 The reference evolution and baseline dimension

2.3.1 Motivation: comparison in time

A comparison in time is most common to estimate energy efficiency changes. However, one has to account for the variations in many parameters that change over time. This includes normalisation with respect to weather fluctuations (cold winters certainly require more heating than warm winters, thus energy consumption indicators for heating need to take these ‘external’ conditions into account), economic fluctuations (the recent economic crisis led to a reduced demand for products and reduced production of goods resulting in a reduced energy consumption in industry, whereas the specific consumption per output increased in many countries; see Enerdata, 2012) and other system specific changes.

The changes and shifts within industry and between different industrial branches, the so-called structural changes, also lead to a shift in energy consumption and thus to a change in energy efficiency. Furthermore, the energy consumption of producing specific products changes not only due to more energy efficient production procedures but also due to changes in product itself, e.g. its quality and composition. E.g., glass bottles are being produced with thinner walls than 20 years ago and even the simple product 'glass bottle' cannot directly be compared. Likewise, there are endless methodological and technical issues involved in accounting for such "unwanted" external factors distorting the real change in energy efficiency, which are widely discussed from the early 1970s (see e.g. Berndt, 1978; Diekmann et al., 1999; Farla et al., 1998; Farla and Blok, 2000; Ang, 2004; Pérez-Lombard et al., 2013).¹⁹ How far a correction of energy efficiency indicators for these external factors is common in practice will be discussed in the next chapter.

2.3.2 Definition of reference evolution

Not only are energy efficiency indicators of a single system compared at different instances of time, but also two possible versions, one of these is fictitious, of one system at the same point in time. That is, one assumes that a certain time-evolution had taken place, and compares the actual time-evolution to this hypothetical one. The hypothetical evolution of the system under consideration is called reference evolution. Please note that this definition of reference evolution contains a comparison to a fixed point in time as well, as this point in time can be simply extended in time as constant. Other reference evolutions could be a 'baseline scenario' or 'business-as-usual'. This idea is schematically depicted in Figure 2-1.

¹⁹ Similar problems as for the time-dimension occur for cross-country or regional comparisons of energy efficiency (see e.g. Zhang and Ang, 2001).

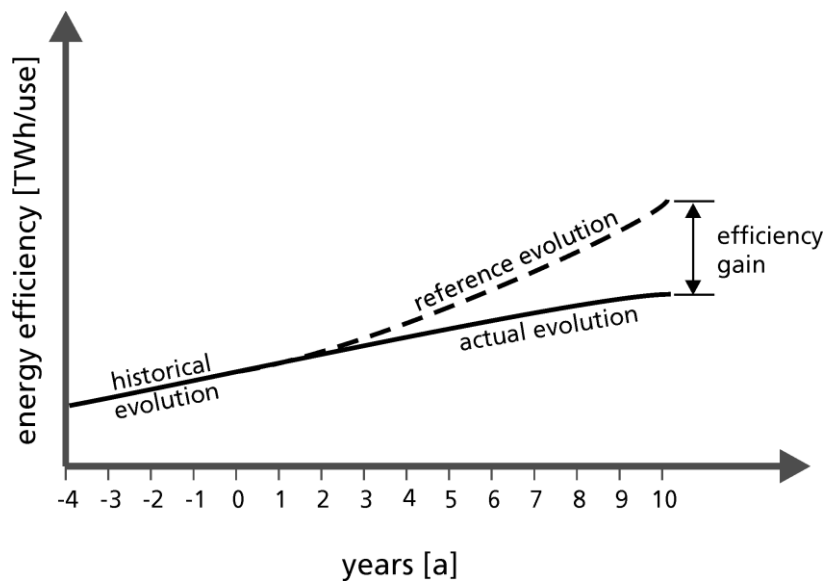


Figure 2-1: Schematic view of reference evolution for comparing energy efficiencies.

The use of reference evolutions can easily be identified by the formulation of conditional statements, i.e., if-clauses. These are counterfactual statements when comparing past evolution, e.g., “If we had not used that energy efficient fridge, our electricity bill would be higher.” But reference evolutions are also used for extrapolations into the future, such as “With continued economic growth and no increase in energy efficiency, the energy use in Europe will be xyz in 2020.” In political contexts the future reference evolutions can be particularly important when formulating energy efficiency goals. For example, the achieved savings compared to a reference evolution do strongly depend on the assumptions for the reference evolution.

2.3.3 Choosing a baseline

Depending on the field of study or the specific use-value for which a reference evolution is discussed, many ways of formulating reference evolutions are possible. Let us discuss one example in more detail. In many fields more and more efficient products are produced and offered to costumers, but only slowly enter the markets and corresponding stocks of appliances or machines. This diffusion of energy efficient products, its barriers and economical aspects are a field of its own (see Fleiter and Plötz, 2013 for an introduction). Within this context, different speeds of diffusion of the energy efficient products could be distinguished and could serve as reference evolutions, such as frozen efficiency, autonomous diffusion, near-economic diffusion, economic diffusion, technical diffusion. To each of these possible future evolutions belongs an energy sav-

ing potential. These possible evolutions and potentials are schematically depicted in Figure 2-2.

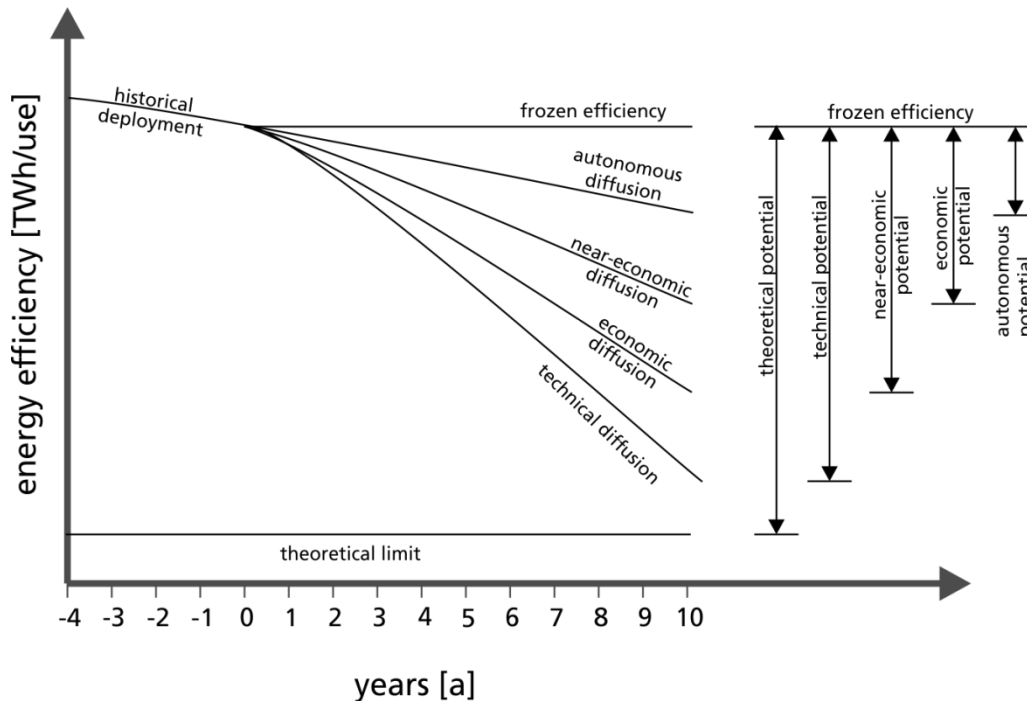


Figure 2-2: Schematic view of different possible reference evolutions

The 'frozen efficiency' evolution is the possible future evolution in which the technologies or products in stock or in the market maintain their current degree of energy efficiency. A second reference evolution with a future increase of energy efficiency of the technology or product under consideration is coined 'autonomous diffusion' referring to the speed of diffusion without any external stimulus or incentives. In this case, more efficient technologies automatically diffuse into stocks because older technologies are being replaced with newer, more efficient ones. Within diffusion of energy efficient technologies, the economical aspects and possible financial savings for users are an important group and different 'economic diffusions' are being discussed in the literature (see e.g. Jaffe and Stavins, 1994). Here, we chose to display 'economic diffusion' denoting the case of each consumer optimizing his total costs of ownership and buying more efficient technology in order to save running costs. However, not all consumers actually perform such an analysis and in practise one would observe a diffusion that is slightly slower diffusion which might be termed, somewhat vaguely, 'near-economic

diffusion'.²⁰ If all consumers acquired the most efficient technology available irrespective of their cost, one could speak of 'technical diffusion'. Whatever the speed of diffusion of efficient technologies into the stocks or markets might be, they cannot become more efficient than some technology-specific limit. However, this depends on the technological scope under consideration. For example, with regard to the efficiency of propulsion technologies of passenger cars, electric propulsion can reach much higher efficiency (in terms of MJ per kilometre) than internal combustion engines, such that the theoretical limit would depend on whether only combustion engines are being considered or more general propulsion technologies.

Overall, the different speeds of diffusion of energy efficient technologies provide a good example for different reference evolutions for comparing energy efficiency of a system.

Other factors, which are not directly related to energy efficiency, are the autonomous energy technology improvements or direct rebound effects, i.e. a negligent handling of energy following energy efficiency improvements (Lebot et al., 2004; Sorrell et al., 2009).

In summary, many different measures and indicators of energy efficiency exist and various aspects play an important role in determination of an actual energy efficiency and energy savings.

2.4 The accounting method dimension

2.4.1 Overview of applied methods to measure energy efficiency

As already described above, a monitoring process for energy efficiency in a political context is usually implemented in practice via a set of indicators which are calculated using a defined accounting method and is based on a specific database. A good example for such a monitoring process is Directive 2006/32/EC, which demanded for "a harmonised calculation model which uses a combination of top-down and bottom-up calculation methods" (Annex IV) for the reporting of the energy efficiency progress in the Member States. In the following, a top-down method means that the energy consumption is considered at a highly aggregated level of a country or an economic sector. As a rule, the consumption is related to a reference quantity such as the number of households or an activity quantity such as the economic performance of the area under

²⁰ The economic optimum itself is not uniquely defined but requires further discussion (which is not the scope of the present paper). Different near-economic diffusions could, e.g., be defined with different internal discount rates.

consideration. Bottom-up methods, on the other hand, start from calculating individual energy savings for one final consumer or one piece of equipment and add these up (Thomas et al., 2012).²¹ Directive 2006/32/EC was the starting point for an extensive discussion of measurement issues associated with energy efficiency in Europe. ²² The broad range of possible top-down and bottom-up methods and data sources for measuring energy efficiency and the resulting indicators, which was worked out during the implementation process of Directive 2006/32/EC, is indicated in Table 2-1.

Some of these methods are also part of the European standard “Energy efficiency savings calculation - top-down and bottom-up methods” (EN 16212), which became valid on 1 October 2012. Directive 2012/27/EU (Annex V, part 1) also recommends the bottom-up methods described in Table 2-1 for reporting obligations under Article 7 and 20 of the Directive.

Regardless of the broader use of these methods in official European standards and Directives, all accounting methods mentioned in Table 2-1 contain a series of “adjustment settings” which can strongly influence the degree of energy efficiency target achievement. These methodological problems and its implications for the monitoring of energy efficiency targets are discussed in the following paragraphs.

²¹ In Annex IV, point 1.1. of Directive 2006/32/EC, these methods were defined in a similar way: “Top-down calculation method means that the amount of energy savings is calculated using the national or larger-scale aggregated sectoral levels of energy savings as the starting point”. And “bottom-up calculation method means that energy savings obtained through the implementation of a specific energy efficiency improvement measure are measured in kilowatt-hours (kWh), in Joules (J) or in kilogram oil equivalent (kgoe) and added to energy savings results from other specific energy efficiency improvement measures”.

²² Important methodological issues were especially tackled within the project “Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services” (EMEEES) (see Eichhammer et al., 2008; Wuppertal Institute, 2009; Thomas et al., 2012).

Table 2-1: Spectrum of methods measuring energy efficiency

Method type	Calculation method /indicator	Origin of the database
Top-down	Aggregated energy consumption	Aggregated information from statistics (energy balances)
Top-down	Simple ratios relating energy consumption and an activity	Aggregated information from statistics (energy balances, national accounts etc.)
Top-down	Normalised and/or corrected indicator	Detailed information from statistics
Top-down	Methods for re-aggregation of indicators (e.g. chain index)	Detailed information from statistics
Top-down	Econometric methods (e.g. regression analysis)	Long-term time series from statistics (e.g. national accounts, energy price statistics)
Top-down/ bottom-up	Market diffusion indicator	Market statistics (share of specific equipment or practice in the market)
Top-down/ bottom-up	Stock modelling of products / equipment	Market statistics / partly market surveys
Bottom-up	Deemed estimates	Use of standard or default values
Bottom-up	Engineering estimates	Use of technical relations
Bottom-up	Aggregated measurement	Billing analysis
Bottom-up	Individual measurement	Direct measurement

Source: Own compilation based on Eichhammer et al., 2008; Seefeldt et al., 2010

2.4.2 The problem of normalization and correction

One major practical problem of an accurate measurement of energy efficiency are the *normalizations* and *corrections* for external influences which are not primarily attributable to changes in energy efficiency in a technical sense or to specific energy-efficiency policy measures. Though there is a long-lasting theoretical discussion on this issue, as it was shown in the previous section, the use of correction factors when measuring energy efficiency over time is not as widespread as imagined against this backdrop. Whereas a normalization for weather fluctuations is relatively undisputed, even corrections for structural effects are not natural despite the long history of methodological discussions. The same applies to the impact of short-term economic fluctuations, autonomous technical changes or rebound effects, where mainly the unavailability of suitable data often prevents from taking into account these external factors. This is summarized in Table 2-2 for the most relevant normalization and correction factors. A distinction is made between the relevance of these factors for top-down and / or bottom-up accounting methods.

Table 2-2: Normalization and correction for external influences in the case of top-down and bottom-up indicators

External influence	Methods for correction	Problems
<i>Normalization – case of top-down and bottom-up indicators</i>		
<i>Temperature variations</i>	Yearly deviation from average temperature	Climate-independent part of energy consumption uncertain
<i>Stock variations</i>	Yearly stock of storable energy sources	Limited data availability
<i>Occupancy levels, opening hours etc.</i>	Normalisation factors	Partly lack of suitable data to derive the normalisation factors
<i>Correction – case of top-down indicators</i>		
<i>Quantity influences: influence of economic or other drivers on energy consumption (e.g. value added in industry, no. of population or households)</i>	Use of energy intensities / specific consumption values	Choice of suitable driver for respective sector/end-use/object
<i>Structural effects (e.g. sector or product structure in the industrial and tertiary sectors)</i>	Disaggregation of energy consumption, factor decomposition methods	Limited data availability at disaggregated levels; suitable decomposition method
<i>Business cycle: influence of short-term changes in capacity utilization</i>	Econometric approach	
<i>Autonomous technological progress: energy efficiency improvement independent from policies</i>	Econometric approach; derivation of a baseline without autonomous development	Limited availability of long-term time series and esp. of longer time periods without policy influence
<i>Impact of energy prices (not policy-induced)</i>	Econometric approach; use of price elasticities	Limited availability of long-term time series
<i>Economic rebound effect: additional quantity effects, mainly depending on income (e.g. larger living area or appliances, higher room temperature)</i>	Correction factor	Suitable data for the derivation of correction factor are missing
<i>Early Action: influence of policies from earlier periods</i>	Baseline without impact of earlier policies	Restricted information on impact of earlier policies

External influence	Methods for correction	Problems
<i>Correction – case of bottom-up indicators</i>		
<i>Double-counting</i> : due to interaction of policies	Correction factor	
<i>Non-compliance</i> : stipulations are not fulfilled (esp. in case of regulatory instruments)	Correction factor	
<i>Multiplier effect</i> : enhances the initial impact of a energy saving measure	Correction factor	Suitable database for the derivation of plausible correction factors (e.g. by surveys or ex-post evaluations of policies) is often missing.
<i>Free-rider effect</i> : energy saving would have occurred without saving policy	Correction factor	
<i>Direct rebound effect</i> : behavioural changes due to saving measure (e.g. increased lighting or room temperature)	Correction factor	

Source: Own compilation based on Eichhammer et al., 2008; Thomas et al., 2012

Normalization factors are in principle similar for top-down and bottom-up indicators, whereas correction factors are different. The main difference between bottom-up and top-down evaluation methods with regard to corrections is that the first are applied to all participants of an energy efficiency policy measure, or a particular sample of the participants, while in the case of a top-down evaluation, the scheme also includes non-participants in the policy measure (“autonomous progress”) who have to be corrected for as well if “additional” energy savings are desired which are induced by a policy measure (Eichhammer et al., 2008).

In how far normalizations and corrections are taken into account, can have a considerable influence on the amount of energy savings. This is both true for top-down and bottom-up indicators, though the impact will be more pronounced in the case of top-down due to fact that also non-participants in the policy measure are included, as stated above. Depending on the external influence, the impact on energy savings can be in both directions. Two of the most critical factors in case of top-down measurement, i.e. the impact of the autonomous technological progress and the impact of earlier policies, however, increase the amount of energy savings and thereby reduce the efforts necessary to gain additional energy savings.

2.4.3 The problem of data availability

As shown in the previous section, missing data is one major problem for a widespread use of methods for correction (Table 2-2). But the problem of data availability also occurs with regard to the different methods measuring energy efficiency (Table 2-1). This

both applies for top-down and bottom-up methods, though the kind of necessary data is different.

For statistic-based top-down indicators, especially detailed, complete, timely and reliable statistics are essential to monitor the energy situation at a country level as well as at an international level (see e.g. IEA, 2005, 2014b). The data gaps generally grow with a higher degree of disaggregation. As the ODYSSEE database on energy efficiency indicators²³ shows, there are data gaps in many EU countries especially at the level of final end-uses (as e.g. energy consumption for heating and cooling), on energy consumption for building types and for the tertiary sector. Especially the latter is characterized by a very heterogeneous structure of energy consumption. Another problem of top-down indicators, which makes a regular and current monitoring difficult, is the often long delay involved in supplying the statistical data for a specific year. Depending on the data, the time delay can amount up to 2 years or even more. In order to bridge the data gap until the current year, there are first attempts to develop short-term indicators based on energy intensities as a proxy for energy savings (Boonekamp, 2012).

For model-based top-down indicators, the problems here primarily concern the methodology. Stock models, which are mainly used for forecasts, frequently only contain historical data for a reference year, or are only brought in line with the statistics for isolated years and then extrapolated. Moreover, the models illustrating energy consumption structures in great detail also frequently make extensive use of estimates which, in turn, have been obtained with different methods (e.g. surveys, measurement, expert interviews, literature searches).

All the bottom-up methods of determining savings shown in Table 2-2 contain only two basic elements to start with (European Commission, 2010): an activity variable (usually number of cases or objects) and a uniform saving per case (usually the consumption before carrying out an energy saving measure minus the consumption after the measure). This means that data at the level of individual measures are necessary which can, however, be gathered at different levels of accuracy depending on the method used: by direct or indirect measurement of individual actions or by the use of more aggregate average data standard values based on theoretical considerations or estimates (see Table 2-1). Conducting direct measurements on the respective object or case represents the “ideal” bottom-up method; this is, however, also by far the most complex and costly and will therefore only be applied in a few cases. The data collection cost in the other bottom-up methods is successively reduced by using already existing measure-

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ment data, especially from energy consumption invoices as well as by relying on technical impact assessments and the use of standardized key figures. But the cost reduction is gained at the expense of the accuracy of the energy saving assessment. Here it is essential that the technically identified impact correlations are properly illustrated. This may involve a certain effort when generating deemed estimates, but this only has to be done once, unlike the approaches based on continuous measurements and seems justified from the viewpoint of the accuracy of the evaluation. Using already existing data collected at case level in another context (e.g. building energy performance certificates, production statistics, energy management systems in companies) can also help to reduce the cost of data collection at a relatively high level of data accuracy.

To sum up, a sufficient amount of data availability is a prerequisite for all monitoring approaches and must be taken into account for each decision on a specific monitoring process in good time.

2.4.4 Importance of the accounting method

The method of accounting of efficiency measures over time is another important characteristic especially of bottom-up methods.

When efficiency measures are evaluated, the generated savings have to be accounted in some way to reflect the temporal development of the measures impact. Accounting energy savings has always a temporal dimension as it is the integral of power savings over time. The second dimension of accounting is whether a single measure is accounted or a variety of different measures is cumulatively accounted.

Depending on the approach, the calculated efficiency gains can differ significantly.

To illustrate these differences, an illustrative example is chosen to enhance the transparency of the considerations. As an example, the replacement of a refrigerator based on fictitious figures is chosen. Several assumptions are made to define this example:

The baseline definition is not considered in this illustration to enhance transparency by leaving out another variable. Instead the energy use of the refrigerator is used.

The same kind of efficiency measure, the purchase of a refrigerator, is conducted each year over 10 years (indicated by a red dot in Figure 2-3). This results in a total installation of 10 refrigerators. After ten years lifetime each refrigerator has reached its end-of-life and will be disposed of (indicated by a blue dot in Figure 2-3).

Let us assume the **annual energy use** of each refrigerator amounts to 1 kWh (per unit). The energy use over its lifetime (**cumulated lifetime energy use**) is 10 kWh (per unit).

The total energy use of all 10 refrigerators over their lifetimes amounts to 100 kWh (per 10 units). In the 10th year, the **cumulated annual energy use** of all ten refrigerators equals 10 kWh (per ten units).

These different methods are illustrated in Figure 2-3. Each refrigerator is represented by a bar, showing its cumulated lifetime energy use. Within the graph, the different annual energy uses are indicated by arrows, the cumulated lifetime energy uses are represented by the area filled by the bars.

In addition, the three sample calculations are given in Table 2-3. As a result, the energy uses assigned to the refrigerators vary considerably with the calculation methods though all of them are correct and accountable savings.

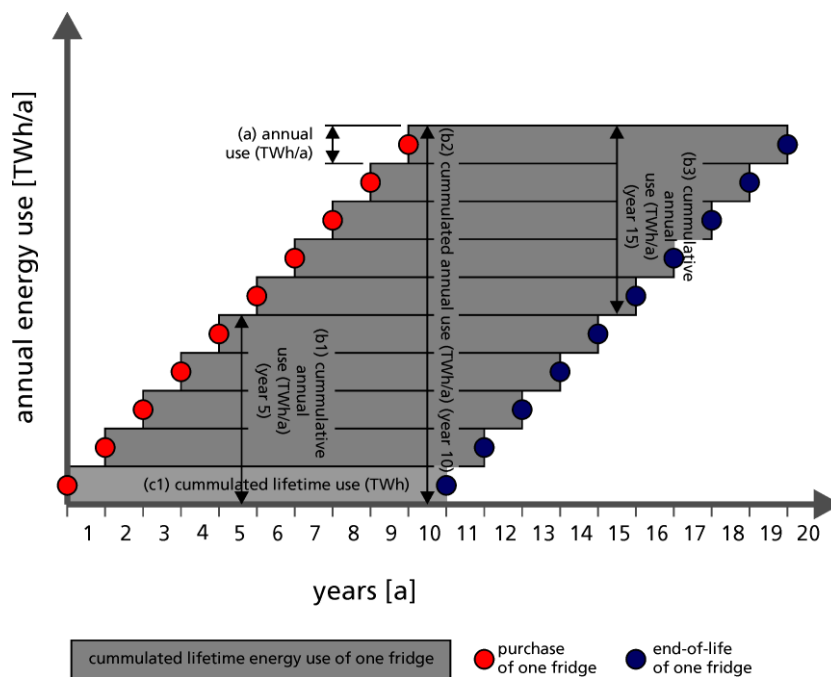


Figure 2-3: Possible accounting methods for energy use

Table 2-3: Exemplary energy use for different accounting methods

Accounting method	Unit	Accounted efficiency gains
(a) Annual use	kWh/a	1 kWh/a
(b1) Cumulated annual use (year 5)	kWh/a	5 kWh/a
(b2) Cumulated annual savings (year 10)	kWh/a	10 kWh/a
(b3) Cumulated annual savings (year 15)	kWh/a	5 kWh/a
(c1) Cumulated lifetime savings (measures of year 1)	kWh/a	10 kWh/a
(c2) Cumulated lifetime savings (measures of year 1-10)	kWh/a	100 kWh/a

The already existing EEO schemes in Denmark, Italy, France and UK show that the reflections above are not only theoretically, but that these accounting methods are actually in use, resulting in very different accounted energy savings for the same efficiency measure. As the example above does not only apply to energy use, but as a consequence also for energy savings (and thus for efficiency improvements), it may be used to illustrate this issue.

The following considerations are based on the accounting methodologies which are applied in the already existing EEO schemes in the countries mentioned above, but do not reproduce them in any detail. For example, UK does not account energy savings in their EEO, but the reduction of CO₂ emissions. All other factors not directly linked to the accounting methodology as described above are neglected.

The four countries' accounting methodologies can be summarized as follows:

- Denmark accounts the first year savings of the implemented measure
- UK accounts the cumulated lifetime savings (using an average lifetime)
- France accounts discounted cumulated lifetime savings (using an average lifetime)
- Italy accounts cumulated savings over the accounting period.

Taking up the same fictitious figures as above, Denmark has therefore decided to account for an annual saving of only 1 kWh from the first year of the measure, whereas the UK scheme accounts for 10 kWh for the exact same efficiency measure, since the cumulated lifetime savings of the refrigerator are accounted for in the first year (see Table 2-4). They represent the extreme approaches, the Italian and French mechanisms account for 5 and 8 kWh respectively. The differences between the least and the largest imputed savings in this example comprise a range with factor ten. In practice, with longer lifetimes of saving measures, this range can even become a lot larger. The other way round, the different accounting modes lead to completely different amounts

of induced saving measures, assuming a numerically identical accounting of energy savings. The idea behind this consideration is to show, that numerically identical targets may lead to quite different savings, when different accounting methodologies are used. This is shown in the last column of Table 2-5. The required extent of saving measures would amount to 100 refrigerators in Denmark and only 10 in UK in order to obtain the same accounted savings. France and Italy are somewhere in between with 12.5 and 20 units. However, the realized savings in Denmark would be, in fact, 10 times higher than the ones in the UK.

Table 2-4: Role of the lifetime of an energy saving measure in different EEOs

Country	Accounted savings in the different EEOs assuming the same size of real savings	Volume of induced saving measures assuming a numerically identical accounting of energy savings (here: 10 kWh/a)
Denmark	1 kWh/a (only energy saving in the 1 st year)	100 refrigerators (since each year only the energy savings of the "new" refrigerators of the respective year are accounted for)
Italy	1 kWh/a in the 1 st year up to a maximum of 5 kWh/a in the 5 th year	20 refrigerators (since the energy savings from the first year are also accounted for in the following years; after 5 years, the savings from the refrigerators bought in the first year cannot be credited, so that another 10 refrigerators have to be supported)
France	8 kWh cumac ^{1)/a}	12.5 refrigerators (since each year the savings during the lifetime of 1.25 refrigerators are accounted for; cumulative and discounted)
UK	10 kWh/a (energy savings over the whole lifetime)	10 refrigerators (since each year the total lifetime savings of 1 refrigerator are accounted for)

Description of the energy saving measure: Replacement of a refrigerator (lifetime: 10 years) each year over 10 years with annual savings of the new refrigerator of 1 kWh.

1) Cumac („cumulé actualisé“): specific energy unit in the French EEO expressing the energy savings during the whole lifetime of an energy saving measure.

Source: Schlomann et al., 2012

This implies that for a similar energy saving target and a free choice of accounting method, different savings can be reached that vary by factor 10 and more. This means that the same target can be very ambitious or not at all ambitious, only depending on the accounting mode chosen. These examples show the need for a precise definition of the accounting methodology, which is lacking sometimes when targets are set or measures are evaluated.

2.4.5 Importance of the baseline

As pointed out in the previous section, the choice of baseline is yet another issue which can further spread the different amount of energy savings which are achieved by a certain saving measure. As it was elaborated in the previous chapter, the role of the reference evolution is of particular importance when measuring energy savings.

Most simple, the status-quo ante can be used as the baseline for the achieved energy savings. To reflect legal or technological boundary conditions, normally only energy savings that exceed a standard defined by the baseline should be legitimated for the generation of savings. Nevertheless there is a broad variety of baseline definitions in relation to which the energy savings can be calculated.²⁴ Again, an example with a refrigerator is chosen in order to illustrate the crucial issue of the selection of the baseline. Figure 2-4 and Figure 2-5 show the cumulated lifetime savings as well as the annual savings of a single product. Three exemplary baselines are shown in the example:

- The stock in the base year
- The minimum standards in the base year
- The actual minimum standards for each year

Not shown are baselines like the actual stock in each year, the market average etc, but the highlighted problems will also apply to them.

Four scenarios are shown in Figure 2-4 and Figure 2-5:

- The purchase of an A+ refrigerator in year 1 (the base year)
- The purchase of an A+ refrigerator in year 11
- The purchase of an A+++ refrigerator in year 1 (the base year)
- The purchase of an A+++ refrigerator in year 11

²⁴ The principles for baseline setting are discussed generally in Vine (2008) or Staniaszek and Lees (2012). Concrete examples for the setting of the baseline for specific products or energy uses were developed in several case studies which were carried out within the EMEEES project (Wuppertal Institute, 2009; Thomas et al., 2012) and partly used in the recommendations for the measurement and verification of energy savings in the framework of the ESD (European Commission, 2010).

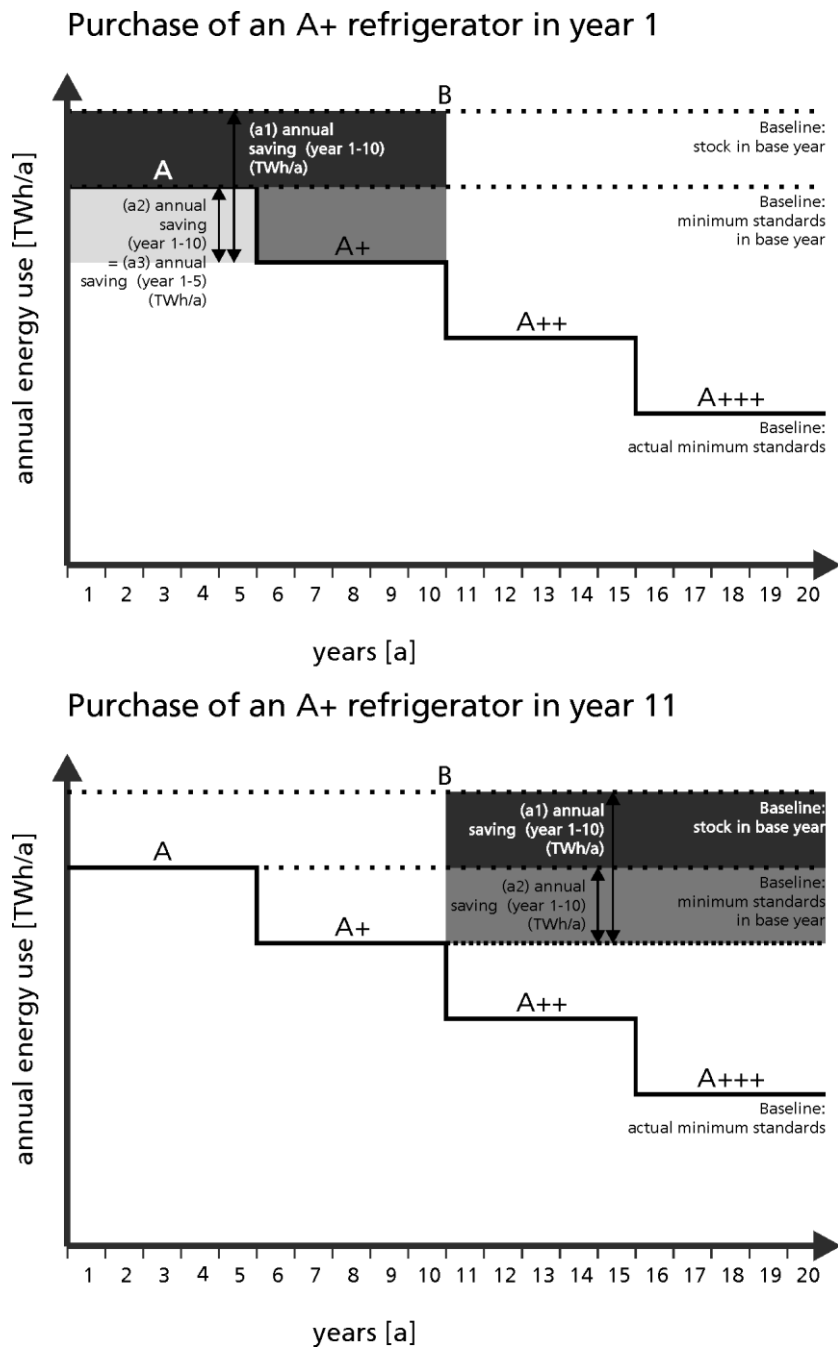


Figure 2-4: Baseline definitions for energy savings (example: purchase of an “A+” refrigerator)

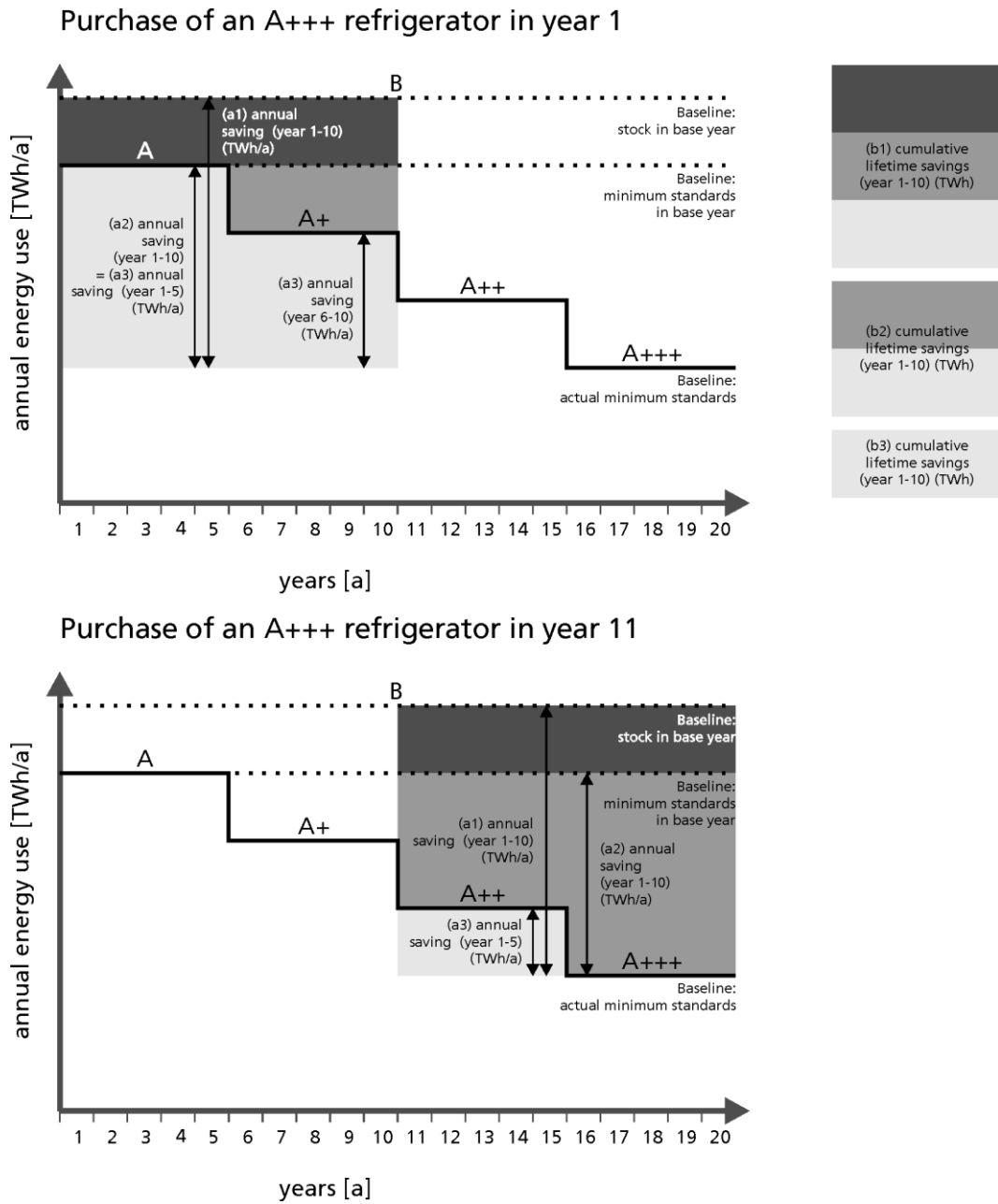


Figure 2-5: Baseline definitions for energy savings (example: purchase of a “A+++” refrigerator)

For these four scenarios, several kinds of savings (and therefore efficiency gains) can be derived from the graphs, when combining different baselines and accounting methods. They are all summarized in Table 2-5. As in the example before, the efficiency measure is the same for each of the two column sets. Thus the realized savings are of course the same, too. Nevertheless the accounted values differ from 5 kWh/a to 40 kWh/a for the “A+++”-example considering the cumulative lifetime savings. All figures

are “right”, nevertheless without the detailed information about the baseline, the figures (but not the savings) may differ by a magnitude.

Table 2-5: Exemplary accounted savings for different baseline methodologies for energy savings

Accounting methodology	A+ refrigerator in year 1	A+ refrigerator in year 11	A+++ refrigerator in year 1	A+++ refrigerator in year 11
Baseline: Stock in base year				
(a1) annual saving (year 1-10)	2 kWh/a	2 kWh/a	4 kWh/a	4 kWh/a
(b1) cumulative lifetime savings (year 10)	20 kWh	20 kWh	40 kWh	40 kWh
Baseline: Minimum standards in base year				
(a2) annual saving (year 1-10)	1 kWh/a	1 kWh/a	3 kWh/a	3 kWh/a
(b2) cumulative lifetime savings (year 10)	10 kWh	10 kWh	30 kWh	30 kWh
Baseline: Actual minimum standards				
(a3) annual saving (year 1-5)	1 kWh/a	0 kWh/a	3 kWh/a	1 kWh/a
(a3) annual saving (year 6-10)	0 kWh/a	0 kWh/a	2 kWh/a	0 kWh/a
(b3) cumulative lifetime savings (year 10)	5 kWh	0 kWh	25 kWh	5 kWh

Source: Own calculations

Looking at these substantial differences in the calculation of energy savings, the clear definition of the baseline is, besides the accounting method, one of the most important issues in the framework of the measurement and verification of energy savings as the basis for the calculation of efficiency gains.

2.4.6 Role of the lifetime

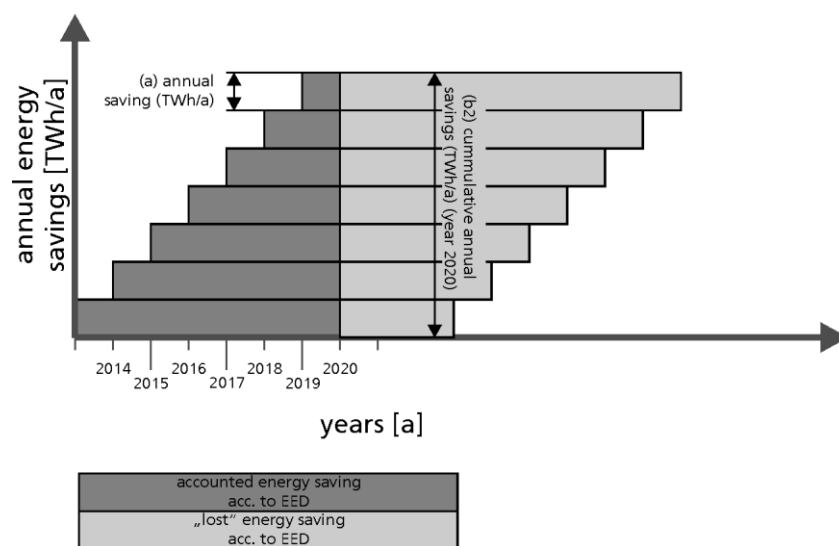
The accounting of the lifetime of an efficiency measure is another feature which can considerably influence the amount of energy savings undertaken in order to achieve a specific energy saving target. As shown above, the consideration of lifetime in the different existing EEO schemes is quite different and ranges from no consideration of the lifetime at all to a full consideration of an (estimated) lifetime.

In the following, the role of different lifetime accounting methodologies will be illustrated by an example from the new EED.

Annex Va (3e) of the EED states that “calculation of energy savings shall take into account the lifetime of savings. This may be done by counting the savings each individual action will achieve between its implementation date and 31 December 2020.” If read

literally, savings from a measure with a lifetime > 7 years in the year 2014 may be accounted 7 times, for all annual savings could contribute to a lifetime cumulated saving. If this lifetime cumulated saving is compared to the annual savings target of Article 7 EED, some strange implications may occur: the accountable lifetime savings decrease in time; this means that measures implemented in 2014 may be credited with a lifetime of 7 years, measures from 2020 only with a single year. This may make sense if only the achievement of the 2020 savings target is the purpose of Article 7. With regard to future saving from the year 2021 onwards, such a design of lifetime accounting seems a bit short-sighted.

In an interpretative note on Article 7 of the EED (European Commission, 2013a), the methodology considers a cumulative target increasing over time. So, for the first year 2014, the saving target is equal to the annual saving target of 1.5%, in the second year 2015 3% and so on. The following graph (Figure 2-6) shows this issue more clearly, assuming measures with an equal technical lifetime are implemented over the years to fulfil the requirements of the EED.



Source: Own calculations based on European Commission, 2013a

Figure 2-6: Accounting methodology of energy savings in the new EED

It is quite obvious, that measures taken in 2014 account more than the ones taken in 2020, as a result of the chosen accounting of the lifetime (see Table 2-6). In fact, if a country is bound to miss its saving target in 2020, the target could be reached by implementing a short-living (fiscal) measure, leading to the required savings, as the lifetime is of no relevance in this year. Whether it is in the intention of the directive to incentivize measures with lower lifetime in later years may be doubted.

Table 2-6: Accounting methodology of energy savings in the new EED

	Accountable years acc. to Annex V (3e)	Annual target acc. to Article 7 (=effective annual target)	Cumulative savings target
2014	7	1.5%	1.5%
2015	6	1.5%	3.0%
2016	5	1.5%	4.5%
2017	4	1.5%	6.0%
2018	3	1.5%	7.5%
2019	2	1.5%	9.0%
2020	1	1.5%	10.5%

Source: Own calculations based on European Commission, 2013a

Without the consideration of the interpretative note, the directive allows even other interpretations of the target. Another accounting mechanism leading to the same result is shown in the following (see Table 2-7). The actual numerical value of the target for 2014 could reflect the lifetime issue and should be set to 10.5%, which would lead to an effective annual target in accordance with the EED target. The accounting would then reflect the lifetime in such a way, that all the “lifetime” (always keeping in mind that the “lifetime” is limited to 7 years) savings are accounted in the year of measure implementation as it is e.g. done in the British obligation scheme CERT (see Table 2-4). Such a lifetime adjusted target would reflect the lifetime, but on the other hand, the sheer numbers would lead to a much more complicated communication, for we would face a numerically declining target over the years. Nevertheless such a target setting (which leads to equal savings that the proposed one) makes the effect of declining importance of lifetime quite obvious, whereas the proposed mechanism suggests an increasing effort.

Table 2-7: Alternative accounting mechanism for the EED target

	Max. accountable years acc. to Annex V (3e)	Annual target acc. to Article 7 (=effective annual target)	Life time adjusted savings target
2014	7	1.5%	10.5%
2015	6	1.5%	9.0%
2016	5	1.5%	7.5%
2017	4	1.5%	6.0%
2018	3	1.5%	4.5%
2019	2	1.5%	3.0%
2020	1	1.5%	1.5%

Source: Own calculations

2.5 Summary and outlook

In this paper, we discussed different ways to define and measure energy efficiency in order to clarify ongoing discussions concerning the formulation of explicit political energy efficiency goals as well as its monitoring. We showed that there are many definitions and measuring approaches, each in its own right and usefulness. We found that the accounting methods usually used for the measuring of energy efficiency in a political context contain a series of “adjustment settings” which can strongly influence the degree of energy efficiency target achievement. Additionally, several baselines can be meaningfully defined and used in a political context. We find a factor of 10 or more between different meaningful definitions of baselines and accounting methods easily achievable.

Our results indicate that rigorous definitions should be used for formulating and monitoring energy efficiency targets in a political context if exactly the same understanding of target is to be achieved. I.e., without a precise and rigorous definition of the relevant dimensions of energy efficiency such as baseline and accounting method, the setting and monitoring of energy efficiency targets in a political context is not meaningful at all.

So far, these clarifications are still outstanding with regard to energy efficiency measurement in the political context. The CEN standard "Energy efficiency savings calculation. Top-down and Bottom-up methods" (EN 16212) could offer the chance to rely on an agreed methodological basis at least. But this kind of standard only offers a defined framework within which the monitoring demands have to be determined for each process again. Guidelines, as they have only recently been prepared for the interpretation of Directive 2012/27/EU by the European Commission (2013b) itself, the Coalition for Energy Savings (Scheuer, 2013) and by eceee (2013) can bring some clarification, too. Nevertheless, all these documents are not binding and may not hinder to make use of existing loopholes due to unclear definitions and measurement approaches.

What is necessary is a common and widely accepted understanding of some basic rules which should at least cover central issues as the choice of the baseline and the accounting method which is crucial to evaluate impacts. This also requires to be as precise as possible about the energy efficiency measure under consideration. Comparability of the approaches is necessary in order to ensure similar efforts or at least to make different efforts transparent. Otherwise, a target which seems to be ambitious at first sight can turn out to be a paper tiger which will not contribute to the priority targets in the field of energy and climate policy. Without rigorous definitions at least on baselines and accounting methods, similar discussions as described here are to be expected in the near future with regard to the design of targets within a 2030 framework for climate and energy policies.

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3 Interaction between climate, emissions trading and energy efficiency targets*

Abstract

The European Union has set a system of climate and energy targets comprising target values for greenhouse gas emissions (GHG), for Emission Trading Sectors ETS and non-ETS sectors, and for energy efficiency and renewable energies until 2020. A new framework up to 2030 is just being developed. We analyse what lessons can be learned from the EU 2020 target system and how a new 2030 framework could be designed coherently. We derive a coherent target system for 2030 from a bottom-up assessment of energy efficiency potentials. Thus we show that ambitious energy efficiency and renewable energy targets also guarantee significant reductions in greenhouse gas emissions of 47-60% compared to 1990. ETS sectors can contribute significantly to the GHG reduction, provided that a stabilisation of the carbon price can be reached. An alternative design with a 40% GHG emission reduction as the only headline target, as currently debated, will not exploit all cost-effective energy saving potentials and so not take advantage of the macro-economic co-benefits of energy efficiency either.

* Published in *Energy & Environment*, Vol. 25 (2014) No. 3&4, pp.709-732. Co-author is Wolfgang Eichhammer. DOI 10.1260/0958-305X.25.3-4.709

3.1 Introduction

With its climate and energy policy package from 2008 (European Commission, 2008a), the European Union launched a system of climate and energy targets up to 2020 including three headline targets for greenhouse gas emissions (GHG), renewable energy sources (RES) and energy efficiency (EE). The EU aims at a reduction in GHG emissions by 20% compared to 1990 (30% under certain conditions, i.e. if other non-EU countries adopt comparable targets), the increase of the share of renewables in the total EU gross final energy consumption to 20% and the reduction of primary energy consumption by 20% compared to the trend up to 2020. The latter, which is usually referred to as an “energy saving” or “energy efficiency” target, has not been translated into a legally binding text. Nevertheless, the European Union has included the 20% EE target – together with the two other climate and energy policy targets – as one important key target in the general “Europe 2020” strategy for intelligent, sustainable and integrated growth (European Commission, 2010a).

The overall 20% GHG emissions reduction target for 2020 (compared to 1990 levels) consists of two main components. On the one hand, the EU Emissions Trading Scheme (ETS) needs to deliver a 21% reduction in 2020 compared to 2005 levels, which is based on the revised ETS Directive from 2009 (European Parliament and European Council, 2009a). On the other hand, the sectors not covered by the ETS such as transport (except aviation), agriculture, buildings, waste and industry outside the ETS have a reduction target of 10% for the same period according to the Effort Sharing Decision from 2009 (European Parliament and European Council, 2009b).

Soon after this target system was established, a discussion started on the suitability both of the GHG target and its two components, and on the energy efficiency target. At a general level, the discussion referred to problems in the process of setting and negotiating climate targets, see e.g. Lester and Neuhoff (2009) and Cust (2009). One main outcome of this discussion was the importance of the appropriate choice and clear definition of indicators both in the process of target setting and monitoring. More specifically, the ambitiousness of the GHG target and its components, the ETS and non-ETS targets, was doubted for two reasons. Firstly, the long-term decarbonisation objective of the Low Carbon Roadmap from 2011 (European Commission, 2011a) demands a reduction of GHG emissions to 80-95% below 1990 levels by 2050. There are doubts if a 20% GHG emissions reduction target by 2020 is sufficient to stimulate the necessary amount of progress, especially in the field of energy efficiency in order to achieve this long-term target. Secondly, due to the financial and economic crises the EU is already much closer to its target than assumed during the decision process on the target system, see e.g. Harmsen et al. (2009; 2014). The economic crisis especially led to an

oversupply of emission allowances on the market²⁵. Since the ETS fixes an absolute emission amount, which was not revised after the crisis, the allowance price collapsed, which considerably reduced the effectiveness of the system. The following discussion mainly focused on options to ensure the effectiveness of the ETS if prices are lower than expected.²⁶ In the political discussion, various parties specifically require a significant amount of emission allowances to be temporarily (e.g. by back-loading in the auctions²⁷) or permanently set aside. Since these adjustments may affect ETS's credibility and lead to uncertainty in the market, minimum and maximum allowance prices or an independent body to manage the supply of allowances to provide more price stability are proposed as alternative options in the scientific discussion, see e.g. Burtraw et al. (2010), Wood and Jotzo (2011).

At the same time, a debate has also started on the EU's energy efficiency target, which had another quality from the beginning due to its non-legally binding character. In a study for the European Climate Foundation, it was already reported in 2010 that Europe is not on track in meeting its 2020 energy savings target but that without intensified policies a gap of around 208 Mtoe will remain (Harmsen et al., 2014; Ecofys, Fraunhofer ISI, 2010). This was confirmed by the European Commission in its Energy Efficiency Plan 2011 (European Commission, 2011b) which stated that the EU is only on track to achieve half of the target. In the following discussion on a new Energy Efficiency Directive (EED) of the EU, which was finally passed in October 2012 (European Parliament and Council, 2012), especially the issues of a binding or non-binding energy efficiency target for the EU and the definition and monitoring of such a target were controversially debated, see Harmsen et al. (2014), Bosseboeuf and Broc (2011), Schlomann et al. (2012), Jolland (2012), Bertoldi and Cahill (2013).

The discussion on the appropriateness of the EU target system was reinforced after the European Commission published the Green Paper "A 2030 framework for climate and energy policies" in March 2013 (European Commission, 2013a). This raised a debate on the appropriate greenhouse gas reduction target for the EU in 2030 which is com-

25 Other factors of influence on the oversupply of allowances were the comparatively large amounts of certificates from the Clean Development Mechanism CDM, a stronger penetration from renewable energy sources than originally expected in the projections to 2020 and an overestimate of activities in the projections forming the basis for the cap setting, even before the economic crisis.

26 For a comprehensive overview of the various adaptation options and their discussion from an economic perspective see Diekmann (2012).

27 The EU Commission is about to postpone the auctioning of 900 million allowances for several years. This 'back-loading' of auctions is done by amending the EU ETS Auctioning Regulation (European Commission, 2014a).

patible with the global goal of limiting the long-term increase of global temperature to 2°C above pre-industrial levels. Some recent studies (Höhne et al., 2013, 2014) come to the conclusion that a GHG reduction target for the EU in 2030 would have to be in the order of 50% or more (with a large range) below 1990 in order to be in line with the 2°C limit. This is considerably more than the recent proposal in the EU's White Paper on energy and climate policy for the period from 2020 to 2030 from January 2014 (European Commission, 2014b). Here, the European Commission proposed a binding GHG emission reduction target of 40% compared to 1990, to be shared between the ETS and non-ETS sector, for 2030. This should be accompanied by a target at European level for renewable energy of at least 27% with flexibility for Member States to set national objectives. A proposal for a new energy efficiency target for 2030 was postponed until the impact assessment of the 2020 target for energy efficiency is available later in 2014.

This analytical paper aims at contributing to some of the key questions of the still ongoing discussion on a new 2030 framework for EU energy and climate policy. These include the lessons from the 2020 framework, the suitable design of the targets, the coherence of the targets, the appropriateness of sectoral targets and the influence of economic viability and technological progress on the targets. To start with we analyse what main lessons can be learned from the EU 2020 target system with regard to the ambitiousness of the targets and its coherence. With regard to a new target system for 2030, we argue that a target system that is built around an ambitious energy efficiency target opens up pathways for a much more drastic reduction in GHG emissions than the value of -40% (compared to 1990) as proposed by the European Commission in the White Paper of January 2014 (European Commission, 2014b). We argue that only when energy efficiency is taken as a starting point for the design of such a target system the multiple co-benefits of energy efficiency such as increases in GDP, and employment, or an improvement of competitiveness (IEA, 2012; eceee, 2013) can be fully exploited. Our analysis especially focuses on the coherency of the different targets for energy efficiency, renewable energies and GHG emissions within the target system. We think that this is a key factor for the success of a new target system up to 2030 which, however, has been under-represented in the scientific literature so far. As shown above, the main focus of the discussion was on single targets especially for GHG emissions, ETS and energy efficiency. There were, however, only a few analyses

of target interaction²⁸. The report “Analysis of a European Reference Target System for 2030” for the Coalition for Energy Savings (Eichhammer, 2013) serves as the main background document for our paper.

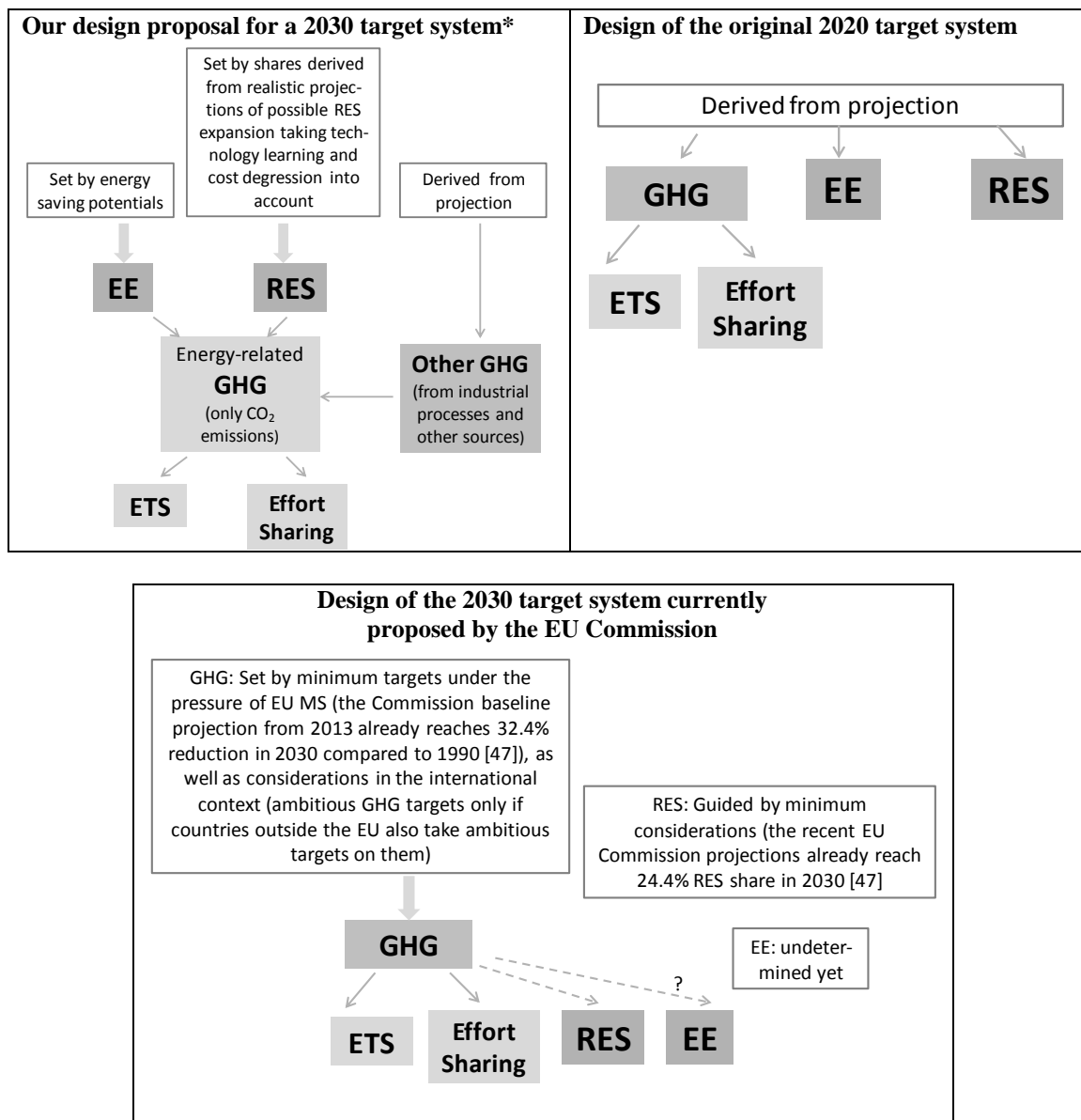
The paper is structured as follows: Section 3.2 introduces the methodological approach and in Section 3.3 we analyze the 2020 target system of the EU and show the main reasons for the failure of this system. In Section 3.4 we present our results on the development of an effective and coherent target system for 2030. Section 3.5 is devoted to a critical discussion of these results. In the final section we draw conclusions for the current energy and climate policy in Europe.

3.2 Methodology

3.2.1 Definition of the reference target system

Our analysis is based on the construction of a so-called “Reference Target System” for 2020 and 2030. By this we understand the combined set of targets covering the two areas of energy efficiency (EE) improvement and renewable energy sources (RES) which may be called the “Resiciency target”. The reduction of GHG emissions and sub-targets for the ETS- and non-ETS-sectors are then derived from the implementation of the EE and the RES target. This is also the fundamental difference between our approach and the “20-20-20” headline target system of the EU. In that target system GHG emissions are subject to a third independent headline target which interacts with the EE and RES targets at the same level (see Figure 3-1). Such target systems are usually derived from a projection of developments in the energy system. Typical examples are the EU target system for 2020, which was calculated based on the PRIMES 2007 projections (European Commission, 2008b), or the German target system for the transformation of the energy system up to 2050 (BMW and BMU, 2010a), which was also based on an energy scenario (Prognos et al., 2010).

²⁸ See Harmsen et al. (2014) and Ecofys, Fraunhofer ISI (2010) on the interaction of a binding EE target with the ETS, the effort sharing and the RES targets, Harmsen et al. (2011) on the interaction of the RES and EE target, LBST et al. (2013) on the interaction between ETS and EE, or Berghmans (2012) on the interaction between RES, EE and ETS.



* In our design proposal, we make a distinction between energy-related CO₂ emissions and GHG emissions from other sources (for example non-energy-related CO₂ as well as other GHG emissions from industrial processes, N₂O emissions from agriculture or transport and methane emissions from waste management or mining activities). We only calculate the impacts of EE and RES on energy-related CO₂ emissions in the target system. Concerning CO₂ emissions from industrial processes and non-CO₂ GHG (Methane CH₄, nitrous oxide N₂O, hydrofluorocarbons HFC, perfluorocarbons PFC and sulphur hexafluoride SF₆) we do not assume reductions beyond the reference development provided in PRIMES 2009 (which is based on calculations with the GAINS model) (European Commission, 2010b).

Figure 3-1: Methodological approach for the design of the reference target system, the 2020 target system and proposed design of the 2030 target system

Our starting point for the development of the reference target system is the EE target, which we define for 2020 and 2030 based on the calculation of energy saving potentials. For the first time, these potentials were calculated by Fraunhofer ISI and partners in the ‘Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries’ from 2009 (Fraunhofer ISI et al., 2009). This study took a detailed bottom-up approach to assess energy savings potentials for end-use sectors (residential sector, services sector, transport and industry), differentiated across EU Member States. In order to ensure compatibility with projections from the European Commission, the calculation of the potentials was based upon the economic drivers as defined in the PRIMES 2007 baseline scenario (European Commission, 2008b). The main drivers refer to the overall economic growth (which is assumed in PRIMES 2007 to 2.2%/a on average between 1990 and 2020), energy prices and to sectoral developments such as the growth of the buildings stock, the number of private households, transport volumes, and the development of industry’s value added and production. However, the actual development of these drivers deviated more and more from the initial assumptions, above all because of the financial and economic crisis. The PRIMES 2009 baseline scenario of the EU (European Commission, 2010b) at least partly reflected the impact of the crisis and assumed an average growth of GDP by 1.9% per year up to 2020. In a study for the German Environmental Ministry, the saving potentials calculated in Fraunhofer ISI et al. (2009) were adapted to the economic drivers from the PRIMES 2009 baseline scenario (Fraunhofer ISI, 2012).²⁹

In both studies, the cost-effective energy savings potential was defined as the savings that can be realized through energy efficiency improvement measures that over their lifetime deliver net financial benefits for the individual actor making the investment.³⁰ These saving potentials represent “realistic technical potentials” rather than theoretical potentials, since their method of calculation followed a scenario approach that considers dynamic aspects in the uptake of technologies as well as the time horizon during which a technology may reasonably be available. Realistic technical energy-saving potentials depend on the future development of drivers such as the economic or social development (e.g. the stock of existing buildings or appliances may increase or decrease over time etc.). This takes into account that there are reinvestment cycles which depend on factors other than energy efficiency. Hence the usual investment cycles

²⁹ The potentials were also corrected for the additional policy impact of PRIMES 2009, leading to a realization of some untapped potential compared to PRIMES 2007. But this impact was rather small due to the small time difference between the two scenarios.

³⁰ The macro-economic co-benefits of energy efficiency mentioned in Section 3.1 could not be taken into account in these model-based calculations, but they further improve the cost-effectiveness of energy saving potentials from a macro-economic perspective.

were not substantially modified with few exceptions. Non-economic barriers have not been translated into high discount rates as for example in the PRIMES projections (European Commission, 2010b); it was assumed instead that non-economic barriers to energy efficiency, e.g. lack of access to information and split-incentives³¹, will be removed by specific policies. This means that the saving potentials we used here reflect cost-effectiveness for the whole country. They show what savings can be achieved with the best technologies available, which are economic on a country-wide basis (typically a discount rate of 4% could be used for energy saving investments for this case) (Fraunhofer ISI et al., 2009).

In this paper, we base the derivation of the EE target on these saving potentials, which were adapted to the lower economic growth of the PRIMES 2009 projection.³²

The second pillar for the construction of the reference target system for 2020 and 2030 is the definition of the RES target. Renewable targets are typically formulated in terms of a percentage of gross final energy demand. We follow this formulation and set a renewable energy share as an overall RES target, which is further distributed on the RES subsectors for renewable electricity (RES-E), renewable heating/cooling (RES-H) and renewable in transport (RES-T). The assumed shares for RES are based on the projections in PRIMES (European Commission, 2008b, 2010b) and other recent studies for the European Union (Fraunhofer ISI, 2011; EREC, 2011; Resch et al., 2013). These studies investigate in detail the available renewable energy potentials in the EU Member States and assume a certain policy ambition to realize the potentials.

Figure 3-1 summarizes our methodological approach for the construction of a reference target system which is derived from an ambitious but realistic setting of targets for EE and RES, and compares it to the present target system of the EU. In addition, we will analyse a third design option in this paper which is based on a single GHG headline target in the form as currently proposed by the European Commission. The three target system constructions differ in the flexibility they offer to EU Member States to make tradeoffs between GHG, RES and EE targets, the degree of interaction between the

³¹ See for the discussion on non-economic barriers e.g. European Commission, 2013; EEA, 2013; Schleich and Gruber, 2008; Schleich, 2009.

³² An alternative approach could be to formulate the 2030 reference target system once again on the basis of the PRIMES 2007 projections to keep transparency with the formulation of the 2020 target system. In that case, the targets must be higher in percentage points, as the projections on energy consumption of PRIMES 2009 are lower than the PRIMES 2007 projections due to the lower economic growth which is assumed in PRIMES 2009. It must also be taken into account that in the new PRIMES 2013 baseline projections, published recently (Fraunhofer ISI, 2012), an even lower economic growth of almost 1.5% up to 2020 was assumed.

targets, as well as the emphasis which is put on targets other than climate protection (in particular resource efficiency, security of supply and competitiveness):

- though the target system we propose here offers less flexibility for the Member States than a single GHG target, it maintains the emphasis on targets other than GHG reduction and reduces the interaction between targets
- a unique GHG targets offers most flexibility and reduces complexity but puts the accent only on one target thus endangering other objectives
- three equal targets keep the emphasis on different objectives but may create problems of interaction between policies and targets if not handled properly.

3.2.2 Definition of the targets

Generally, we define the targets as they are defined in the climate and energy policy package of the EU for the target year 2020 (see Section 3.1). With regard to the energy efficiency (EE) target, we also distinguish between final and primary energy. We will use the energy saving potentials as a basis for the design of a 2030 target system (see Section 3.4), which are initially calculated on the basis of final energy, whereas the EU target itself is related to primary energy (see Table 3-1). There are arguments for both a final and primary energy efficiency target. The main arguments for primary energy are that there are also energy efficiency gains in the transformation sector (i.e. penetration of highly efficient fossil power generation or of combined heat and power generation CHP, improvement in transmission and distribution losses, and possible trade-offs with renewables which are accounted for with 100% conversion efficiency, in particular electricity from wind energy and photovoltaics). The arguments for final energy targets are that most energy efficiency potentials are on the demand side (final energy sectors) and may best be promoted by a dedicated target. Renewables could better be promoted by their own RES target rather than a primary energy target.

Table 3-1: Definition of the targets

Target related to:	Formulation of the target	Description
EE (final energy)	Energy consumption	Final energy consumption compared to a reference development
	Energy intensity	Final energy consumption per GDP compared to a reference development
	Energy saving	Amount of energy savings to be realized compared to a reference development
EE (primary energy)	Energy consumption	Primary energy consumption compared to a reference
	Energy intensity	Primary energy consumption per GDP compared to a reference development
	Energy saving	Energy savings compared to a reference
RES	Production	Production of RES / Share of RES production in gross final energy demand
GHG	Absolute emissions	Absolute GHG emissions compared to 1990
ETS sectors	Absolute emissions	Absolute emissions of ETS sector compared to 2005
Effort sharing sectors	Absolute emissions	Absolute emission of effort-sharing sectors compared to 2005

We also formulate three variants of the EE target, which are, however, all defined compared to a reference development to be in line with the definition of the EE target for 2020 in the EU:

- a target based on energy consumption; even in the case of an absolute energy consumption the reference development serves to derive the absolute level of consumption in order to take economic growth into account.³³
- a target based on energy intensity, i.e. the energy consumption is related to GDP (which is a proxy for energy efficiency but still includes the impact of structural changes), and

³³ In principle there are different variants possible in the formulation of energy consumption targets. First such a target could be formulated as an absolute reduction from the energy consumption level of a base year. This is the logic which was used for the reduction of GHG emissions in the Kyoto process. For energy consumption this has not been used so far as it was thought that economic growth would be limited by such a target. For a few years, however, primary and final energy consumption seem to have been levelling off in the EU, opening up the possibility to formulate reduction targets even compared to a historic base year. The approach which was chosen in the EED was to derive an energy consumption level to be achieved in the target year, which was derived from a reference energy consumption (supposed to increase still considerably). In order to distinguish this from an absolute energy consumption target in the upper sense, we use the term energy consumption target here.

- an energy saving target which measures the amount of energy savings to be realized³⁴.

This is done because we want to discuss all possibilities of target formulation which are currently under discussion for EE³⁵. For the energy efficiency target, there is the broadest range of choices whereas GHG and RES targets are usually formulated in one specific manner. In order to be compatible with the formulations in the EU target system, we relate the EE target to a projected energy use in a target year, which we call here “reference development”. The RES target is formulated as a percentage share and the GHG and its sub-targets for ETS and non-ETS sectors for the target year are formulated relative to a base year (which is 1990 for GHG and 2005 for the ETS and effort sharing sectors).

3.2.3 Calculation of the distance to the target

A reference target system as described above, which is derived from projections, is usually defined in a static manner and rarely contains dynamic elements, i.e. the system is not necessarily robust if the economy does not develop according to the assumed projection. To examine these dynamics we introduce the “distance to a target”. The distance to a target is a measure for the (policy) effort that is required to bridge the gap between a reference development (e.g. business-as-usual) and the target. The distance to target will change if the real economic development deviates from what was assumed in the projections. In order to grasp this dynamic component, we assume that the targets are fixed by a reference development and that the distance to the target is the distance from the reference development to the achievement of the targets. For analytical reasons, the targets are fixed either at the PRIMES 2007 baseline (European Commission, 2008b) or at the PRIMES 2009 baseline (European Commission, 2010b). The second is characterized by a lower economic development following the economic

³⁴ Also here two different ways of defining are possible: the first was the one developed under the Energy Service Directive ESD from 2006 (European Commission, 2006), which defines the amount of energy to be saved based on a historic period (in that case the average of a 5-year period, for most countries 2001-2005). However, when energy consumption is supposed to increase, the savings volume to be achieved does not keep pace with the growing energy consumption volume. We therefore define here an energy saving target with respect to a reference development, hence a certain percentage of the supposed (primary or final) energy consumption in the target year 2030.

³⁵ A detailed discussion of the possible formulations of an energy efficiency target can be found in Harmsen et al. (2014), Ecofys and Fraunhofer ISI (2010) and Rietbergen and Blok (2010).

crisis from 2008 onward.³⁶ With regard to the distance to the target, two cases are possible:

- if the economic development does not deviate from the development assumed in the reference development, the distance to the target would be the one expected (i.e. the original target would be achieved);
- if the economic development deviates from the assumptions, the distance to the target will more or less differ from the original expectation (i.e. the original target will be missed).

For the economic development, we calculate three variants:

- A “high growth” variant based on the economic growth projections from the PRIMES 2007 baseline (European Commission, 2008b), which expected an increase in GDP by 2.22%/year from 1990 to 2020.
- A “medium growth” variant taken from the PRIMES 2009 baseline (European Commission, 2010b) which assumed a GDP growth rate of 1.86%/year for the same period.
- A “low growth” variant assuming a GDP increase by 1.49%/year up to 2020; this development is very similar to the economic development as presented in the recent PRIMES 2013 baseline (European Commission, 2013b) which amounts to 1.43%/year for the period 2000 to 2020.

3.3 Lessons from the 2020 target system of the EU

In this section, we will apply the methodology described above first of all to an analysis of the existing 2020 target system of the EU.

The original European 2020 target system (see Section 3.1) was calculated based on the PRIMES 2007 projections (European Commission, 2008b). This system was coherent in itself, that is a 20% renewable share and a 20% reduction in energy consumption (as compared to the PRIMES 2007 baseline) indeed provided for a 20% reduction of GHG emissions in 2020 (as compared to 1990). Additionally, the sub-targets for ETS and for the effort-sharing sectors were coherent with the three main targets. This is shown in the third and fourth column of Table 3-2. There are slight deviations from the original target for GHG emissions (-21% instead of -20%) and for the effort-sharing sectors (-9% instead of -10%), but in general the system is coherent in the whole framework of the PRIMES 2007 projections.

³⁶ Our design proposal for a target system for 2030 (see Section 3.4.1) is then formulated based on the PRIMES 2009 projections (also see Footnote 32).

Table 3-2: Analysis of the original target system for 2020

Target formulation to:	Unit	Reference target system 2020 (target fixed at PRIMES 2007 baseline)					Reference target system 2020 (target fixed at PRIMES 2009 baseline) Target 2020
		Target 2020	Distance to the target (negative value = target exceeded)		Low growth		
		% comp. to ref.	High growth	Medium growth	% points	% points	% comp. to ref.
EE Final	Mtoe	-20%	270	151	23	983	-20%
Consumption	toe/M€ ⁰⁵	-20%	17	18	18	69	-20%
Intensity	Mtoe	-20%	270	270	270	246	-20%
Saving*							
EE Primary	Mtoe	% comp. to ref.	368	231	54	1322	% comp. to ref.
Consumption	toe/M€ ⁰⁵	-20%	23	26	26	93	-22%
Intensity	Mtoe	-20%	368	368	368	383	-22%
Saving*							
RES		% share in gross final energy					% share in gross final energy
Production	Mtoe	20%	60	15	14	204	20%
GHG Emis- sions		% comp. to 1990					% comp. to 1990
Total GHG	MtCO ₂ eq	-21%	871	310	-179	4047	-27%
only energy- related CO ₂	MtCO ₂ eq	-14%				3041	-23%
<i>Distribution on ETS and non-ETS sectors:</i>		% comp. to 2005					% comp. to 2005
ETS sectors	MtCO ₂ eq	-21%	476	99	-100	1805	-21% **
Effort sharing	MtCO ₂ eq	-9%	395	211	-79	2242	-21% **

* In the case of lower economic growth, potentials for energy efficiency may get smaller because the investment cycles get longer. However, we did not assume that lower economic growth should lead to a lowering of the energy saving target. This is consistent with the view that energy efficiency may be an answer to low economic growth by spurring GDP growth and by lowering the import bill rather than a luxury which cannot be pursued in the case of an economic crisis. Nevertheless, the availability of upfront investment capital may be a problem in the case of an economic crisis, which may need to be handled with specific instruments by the EU Member States (such as specific energy efficiency requests on subsidy programmes supposed to spur the economic growth).

** In case that the EU ETS would be "repaired" by removing one annual inventory, which corresponds to the actual surplus of allowances, the corresponding percentage for the ETS sectors would be -34% and for the effort sharing sectors -11%. The present approach by the EU Commission of "Backloading" does, however, merely postpone allowances to a later time in the period up to 2020, rather than definitely removing those allowances.

Source: Own calculations based on (European Commission, 2008b, 2010b)

In the next three columns of Table 3-2, the distance to the target is calculated for the three variants of economic growth (a negative value means that the target is exceeded). The high growth variant is compatible with the baseline assumptions of PRIMES 2007, but even here the distance to the RES and GHG targets is smaller than expected. This is due to the higher than expected share of renewables in the gross final energy demand as compared to the original reference development. The high impact of the lower than expected economic growth on target achievement becomes obvious in the medium and especially in the low growth variant. For all targets which are defined in absolute terms (i.e. the final and primary energy consumption targets and the GHG targets, the distance to target decreases considerably. Though this change in the distance to the target was the combined effect of the economic crises, some energy intensity improvements realized in the meantime and the higher than expected growth of renewables, the major contribution came from the considerably lower economic growth as assumed in the reference development as well as from some other corrections in the drivers for energy consumption not directly related to the economic crisis. It is also obvious that targets defined as intensity or saving targets are considerably less sensitive to such changes. We will come back to this observation later in the discussion section.

The change in the distance to target was, however, not the main consequence resulting from the dynamic development of the baseline in a static reference target system. The major change arose from the fact that the target system consisting of the three headline targets and two sub-targets was not coherent anymore. This effect is shown in the last two columns of Table 3-2. Here we have recalculated the target system so that it would have been consistent with the assumptions in the PRIMES 2009 projections (European Commission, 2010b). Based on this, a 20% renewable share and a 20% energy efficiency improvement expressed as a consumption target in final energy terms were coherent with a 27% reduction in greenhouse gas emissions in 2020 and a 22% reduction in primary energy.³⁷ This also shows that the EU could have relatively easily moved to a 30% GHG target (as proposed for the international levels if ambitious targets had been taken up by other countries) or at least a 25% GHG target (as was discussed to cope with the low CO₂ allowance prices). A similar result was presented in the latest trends and projections report from the European Environment Agency EEA (EEA, 2013). It found that with national domestic policies currently in place, the EU is likely to end up at 21% GHG emissions reductions in 2020 (compared to 1990), and

³⁷ A recalculation based on the new PRIMES 2013 projections (European Commission, 2013b) with its even lower economic growth would further enlarge the difference to the original 20% GHG emissions reduction target.

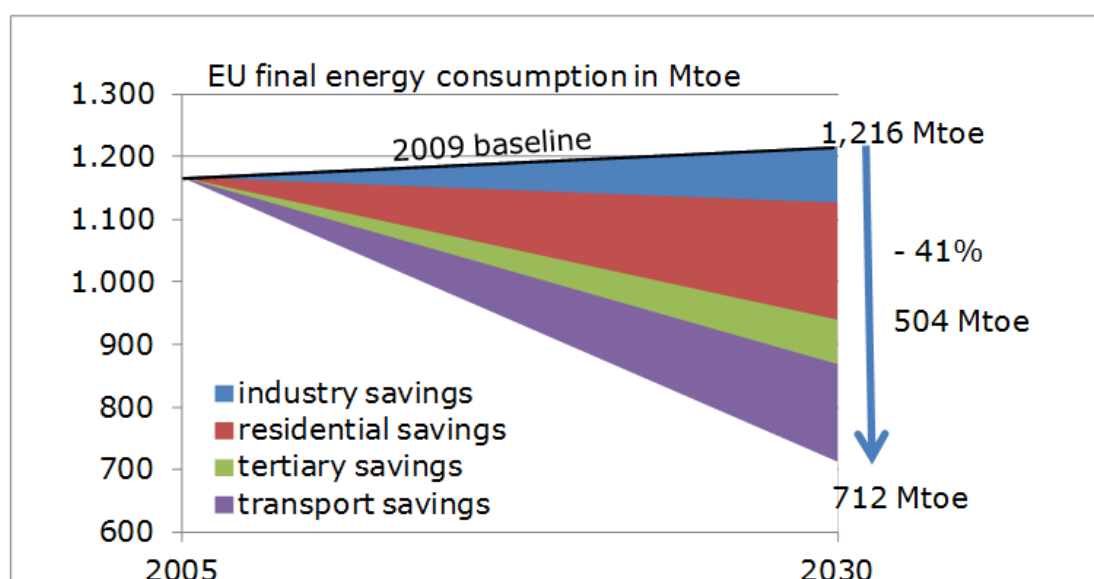
with the implementation of policies that are planned, the EU is already heading for 24%.

This has also an impact on the sub-targets for ETS and the effort-sharing sectors which depend on the GHG target. If the -21% target were maintained for the ETS, the effort-sharing targets would have to be enhanced from -9% to -21% in order to keep coherency (see Table 3-2).

3.4 Design of a reference target system for 2030 - Results

3.4.1 Design proposal based on an EE and a RES target

We now will design a coherent reference target system which we originally calculated based on the Primes 2009 baseline projections, i.e. on the medium growth variant. As described in Section 3.2.1, we take the final EE target in absolute terms as a starting point and fix it at the overall value of cost-effective energy savings potentials. The energy efficiency improvement at the demand side is thus set at -41%, which corresponds to a full realization of all cost-effective sectoral potentials as calculated for 2030 (see Figure 3-2).



Source: Fraunhofer ISI et al. (2009) and Fraunhofer ISI (2012)

Figure 3-2: Results of bottom-up modelling of cost-effective saving potentials in the final energy consumption sectors

The second pillar of the system is the RES target. The share of RES production in gross final energy consumption is set at 35% under the given growth in the reference development (see Table 3-3). This is equivalent to a distribution on the RES subsectors

Electricity, Heating and Transport as follows: RES-E 47%, RES-H 36% and RES-T 15%. All other targets are derived from these settings in a way that ensures the coherency of the whole target system if based on the Primes 2009 baseline projections. Primary energy is to be reduced by about 46% compared to the reference development (Table 3-3), which is the result of two opposite effects: on the one hand, the strong penetration of renewables and other supply side efficiency improvements induces a greater decrease in primary energy compared to final energy; on the other hand, the increasing penetration of electricity in final energy, which will still partly be generated with fossil fuels in 2030, counteracts this development. GHG emissions are reduced by 49% (as compared to 1990) in this reference case.³⁸

As a result, the targets for the ETS and effortsharing sectors have to be adapted, too. We assume a reduction for both targets in the same order of magnitude (-45%; see Table 3-3).

³⁸ The impact of the EE and RES settings on the GHG target is only calculated for energy-related CO₂ emissions. For non-CO₂ GHG and process-related CO₂ emissions we do not assume reductions beyond the baseline projections provided in PRIMES 2009 (European Commission, 2010b).

Table 3-3: Design proposal for a reference target system for 2030 based on an EE and a RES target

Target formulation	Reference target system 2030 (fixed at PRIMES 2009 baseline + full realization of EE potentials)				Calculation of sensitivities (fixed at PRIMES 2009 baseline)		
	Target 2030	Distance to the target (negative value = target exceeded) (in %points)			Target 2030		
		Medium growth	High growth	Low growth	Partial realization of EE potential	High RES share	Structural change
EE Final							
Consumption ¹	-41%	41%	57%	28%	-35%	-41%	-33%
Intensity	-41%	41%	41%	41%	-35%	-41%	-33%
Saving	-41%	41%	36%	48%	-35%	-41%	-41%
EE Primary							
Consumption	-46%	46%	62%	38%	-42%	-49%	-37%
Intensity	-46%	46%	46%	46%	-42%	-49%	-37%
Saving	-46%	46%	40%	54%	-42%	-49%	-46%
RES	35%	4%	4%	4%	35%	48%	35%
GHG	-49%	24%	36%	14%	-47%	-55%	-51%
ETS	-45%	11%	21%	2%	-45%	-45% ²	-45%
Effort sharing	-45%	38%	53%	26%	-41%	-57%	-49%

¹ Since the target is derived from sectoral energy saving potentials (see Figure 3-2), it is possible to distribute the target to the final consumption sectors with the highest target for the residential sector (61%), the lowest for industry (-26%), and the other sectors in between (tertiary: -38%, transport: -41%). A flat distribution is possible, too.

² The ETS target may have become stricter under the assumption of higher shares of renewables, especially in the power mix. However, we do not take that stake here. The cap was left the same, hence the ETS cap is more fulfilled by renewables while the pressure on other GHG reduction in the ETS is lower.

Source: Own calculations based on European Commission (2010b) and Fraunhofer ISI (2012)

The values calculated in this reference target system for 2030 can be considered as coherent under the given GDP development (which is the medium-growth variant), the given penetration of energy efficiency options, renewable energies and the assumed structural changes in the economy. The system reacts, however, to changing frame conditions. We show this by calculating the following sensitivities (see Table 3-3):

- As in the case of the 2020 target system (see Section 3.3), the impact of deviations of economic growth is measured by the distance to the target in the low and high growth variant; here again, the absolute EE target reacts considerably more on a higher or lower level than the expected growth of GDP as the intensity and the saving target.
- Additionally, we analyse the case of a lower realization of the EE potentials of 85% instead of 100% in the reference system (third-last column in Table 3-3). Here, the final energy target would only amount to 35% while the RES target is maintained at 35%. Correspondingly, the primary EE target and the resulting GHG emissions, as well as the ETS/Effort sharing emissions are lower.
- In another sensitivity, we calculate the effect of a higher penetration of RES as in the reference system. In case of a 48% RES share in gross final energy demand (corresponding to the “advanced RES scenario” in EREC (2011)), the primary EE targets and the resulting GHG target as well as the ETS/Effort sharing emissions are more ambitious than in the reference system. The final EE target is not affected.
- Finally, we show the impact of a more pronounced structural change towards less energy-intensive economic sectors as compared to PRIMES 2009 (last column in Table 3-3). We assumed a scenario in which the share of energy-intensive industrial branches in energy consumption is reduced in favour of the less energy-intensive service sector. Overall GDP growth is the same as in the reference system, but the total energy consumption in the target year is lower. This lowers the EE target both in absolute and in intensity terms, whereas the EE saving target is not affected. This shows that the intensity target which appeared as rather stable in the previous sensitivity runs may also be strongly affected if structural change in the economy is important.

3.4.2 Alternative design based on a GHG headline target

In principle, there are several alternatives concerning how to design a target system for 2030. It could also be accessed from the primary energy or the GHG side. However, in order to keep the coherency of the system, either the RES target or the EE target (or both) need to be adapted in case of change. In the following, we analyse an alternative design with GHG as the only headline target. In this variant, we assume a 40% reduction of GHG emissions by 2030, as recently proposed by the European Commission (2014c), and make sure that the necessary adaptations concern both the EE and the RES target about equally.

Results are shown in Table 3-4. In case of medium economic growth (i.e. the PRIMES 2009 economic development), energy efficiency needs to be improved by 25% in terms of final energy and 27% in terms of primary energy in 2030. This is only a very moderate additional improvement compared to the present 20% target for 2020. The same happens with renewables where the RES share in Gross Final Energy Consumption

would just reach 28% in 2030. The ETS target (-45% compared to 2005) is assumed to be the same as in the design proposal based on energy-saving potentials, resulting in a 28% emission reduction for effort-sharing sectors in case of a 40% GHG headline target.

Table 3-4: Alternative design of a reference target system for 2030 based on a 40% GHG headline target

Target formulation	Reference target system 2030 (based on 40% GHG headline target)				
	Medium growth (PRIMES 2009 economic development)	High growth		Low growth	
		EE/RES adapted equally	RES share constant	EE/RES adapted equally	RES share constant
EE Final					
Consumption	-25%	-39%	-41%	-17%	0%
Intensity	-25%	-39%	-41%	-17%	0%
Saving	-25%	-39%	-41%	-17%	0%
EE Primary					
Consumption	-32%	-44%	-45%	-26%	-13%
Intensity	-32%	-44%	-45%	-26%	-13%
Saving	-32%	-44%	-45%	-26%	-13%
RES	28%	35%	28%	18%	28%
GHG	-40%	-40%	-37%	-40%	-41%
ETS	-45%	-45%	-45%	-45%	-45%
Effort sharing	-28%	-28%	-22%	-28%	-29%

Source: Own calculations based on European Commission (2010b)

We again calculate sensitivities for the target system with regard to a higher or lower economic growth than expected in the reference system based on the medium growth variant. The result depends on whether the necessary adaptations of the EE and RES targets are distributed equally or if the RES share is kept constant (see last four columns in Table 3-4). The sensitivity analysis especially shows an extreme spread of the resulting final EE target which ranges from 0% in the case of low growth and constant RES share (last column in Table 3-4), that is, no effort on energy efficiency is required beyond 2020, and -41% in the high growth/constant RES case, that is, all economic potentials are realized. This clearly shows that in case of low economic growth, which is the most probable development at the moment according to the new PRIMES 2013 projections (European Commission, 2013b), a single GHG headline target of 40% below 1990, as recently proposed by the European Commission (2014c), would consid-

erably reduce the ambition of energy efficiency and renewable targets, independent of which format the EE target is formulated (i.e. in absolute or intensity terms or as a saving target). The opposite would happen in the higher than expected economic growth variant, which is, however, a rather unlikely development from today's view.

3.5 Discussion and conclusions

In our analysis we first of all showed that the problems of the 2020 target system mainly resulted from the unexpected deviation of GDP from the economic development expected in the PRIMES 2007 baseline projections. As a result, the original target system consisting of the three headline targets and two sub-targets lost its coherence. We then designed a coherent reference target system for 2030 based on an ambitious setting of EE and RES targets, which would go along with at least 50% GHG emission reduction and substantial reductions of emissions both in the ETS and effort-sharing sectors. There may be some uncertainties in the setting of the exact figures both for the EE and the RES target which were based on bottom-up modeling calculations in our approach. Nevertheless we showed by the calculation of sensitivities that the principle mechanisms will not change substantially in case of deviations from these figures.

The methodology applied in this paper enabled us to clarify the main mechanism behind the different formulation of energy and climate targets and to show how these targets interact within a system.

With regard to the principle options for formulating the EE target, we identified the following mechanisms:

- Energy consumption target: This formulation is strongly sensitive to economic growth, i.e. a lower than expected growth decreases the distance to the target achievement considerably. If the target is formulated in primary energy, it is also sensitive to the development of RES. The target also contains a high degree of uncertainty with regard to the realization of EE investment in times of low growth, even if energy efficiency policies and programmes are established. On the other hand, such a target is easy to formulate and to monitor.
- Relative (intensity) target: this formulation is almost independent from economic growth³⁹, but there is a strong impact of possible structural changes. The EE investments will also be lower when the economic growth is low. Additionally, a relative target does not guarantee that energy consumption is lowered in absolute

³⁹ There is a slight dependency due to capacity effects which we neglected in our analysis for simplicity reasons.

terms. As the absolute target, an intensity target is relatively easy to formulate and monitor.

- Energy saving target: Here the EE investments are fixed and do not depend on economic growth. An energy saving target turned out to be most stable with regard to unexpected economic growth and structural changes. However, as the intensity target, a saving target does not ensure that absolute energy consumption will decrease, too. The monitoring is more challenging than in the case of absolute or intensity targets. Crucial points are the clear definition of the type of savings to be considered, the definition of a baseline and the accounting method (see e.g. Thomas et al., 2012).

We could also identify several interactions between the targets. A different development of RES compared to the reference target system only has an impact on EE investments if the EE target is formulated in primary energy terms. This interaction between RES and EE is independent from the way of formulating the EE target.

The strongest interaction takes place between the EE and RES target on the one hand and the GHG target and its sub-target for ETS and non-ETS sectors on the other hand⁴⁰. This interaction strongly depends on the way the target system is constructed. This is shown in Figure 3-3. A target system which is derived from a full realization of cost-effective energy saving potentials and an ambitious setting of the RES target results in GHG emission reductions between 50 and 60% and goes along with substantial reductions of emissions both in the ETS and effort-sharing sectors. On the other hand, a single 40% GHG target combined with low economic growth (+1.5%/a) implies no additional energy savings by 2030 at all.

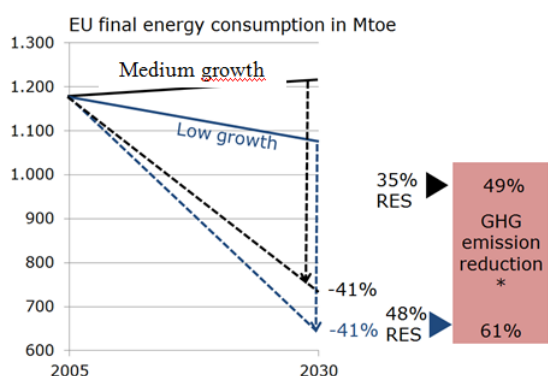
Our analysis finally shows that it is important to integrate dynamic elements into a target system for 2030 or at least foresee intermediate steps of target adaptation in regular intervals. There is certainly a compromise to be made between stability in targets to be provided to the actors and strong deviations from original targets. A recent example is the long discussion concerning an adaptation of the EU-ETS to the impact of the economic crisis (see Section 3.1). But otherwise, depending on the target formulation, the impacts of economic growth and structural changes can become so important that they threaten to render at least some of the targets irrelevant. The choice of an inten-

⁴⁰ A critical point in our argumentation is that if the target system is built around EE and RES (so EE and RES are the drivers, and GHG emissions merely the residual), while the EU has a downstream ETS cap that directly determines ETS emissions and cannot be changed easily, then this may be bound to result in inconsistencies. However, we think that it is feasible within a reasonable time frame to adapt more regularly the ETS cap. The ETS periods for example could be shortened from the present 8-year period to 4 years, or some dynamic features could be built into the ETS target setting.

sity or savings target could reduce the need for dynamic elements, since these targets proved to be more stable with regard to changes in the economic framework conditions. In particular, an intensity-based target is in itself a dynamic target, as it is automatically adjusted based on the economic growth performance. But these target formulations have other disadvantages in terms of monitoring and their inability to guarantee absolute consumption reductions, which have to be carefully weighed up.

A. Full realisation of a 41% energy savings potentials with

- Medium growth and 35% renewable energy share
 - Low growth and 48% renewable energy share
- ⇒ Results in at least 49 to 61% greenhouse gas emissions reductions compared to 1990



B. Reducing greenhouse gas emissions by 40% compared to 1990 levels with

- Medium growth and 28% renewable energy share
 - Low growth and 28% renewable energy share
- ⇒ Requires no additional energy savings and could lead to increasing wastage of energy

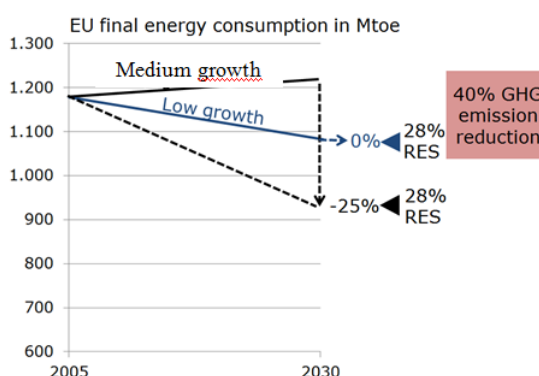


Figure 3-3: Interactions between the EE / RES and the GHG target

What we could not fully cover with our methodological approach is the question of a suitable distribution of the targets among Member States, taking into account the differences of national context. We only considered a differentiation by sectors which is possible in the reference target system which is derived from sectoral energy saving potentials. Here further research is needed. The same applies to additional macro-economic benefits of energy efficiency on competitiveness, growth and employment, which were not directly taken into account in our approach. But a wide exploitation of cost-effective energy-saving potentials having positive macroeconomic side-effects should not be neglected in the design phase of a target system.

To conclude, we showed that setting an ambitious EE target, based on the already available cost-effective energy saving potentials, is consistent with many more ambitious GHG targets than currently debated. A GHG target as the only headline target will not exploit all cost-effective energy saving potentials, unless it is formulated very ambi-

tiously. This means an order of magnitude of at least 50% or even 55 or 60%, which is considerably more than the recent proposal of 40% (compared to 1990) in the EU's White Paper on energy and climate policy for the period from 2020 to 2030 (European Commission, 2014b). Looking at this relatively low level of ambition at the political level, we think that ambitious GHG emission reductions can be more realistically achieved by the setting of ambitious EE targets. These targets can be justified by the cost-effectiveness of the EE potential and additionally by the macro-economic co-benefits of energy efficiency as increases in GDP, and employment, or an improvement of the competitiveness. From our point of view, it makes more sense to start with an assessment of what is possible with regard to the EE and RES potentials and then derive the GHG target from this. GHG targets are threatened by the lowest-level ambition world-wide, as they constitute the lowest common denominator at international level.

Especially in case of absolute EE targets, however, dynamic elements should be part of the design of a target system from the beginning or at least a periodic target adaptation should be foreseen. An EE target formulated as an intensity or savings target would be less sensitive to changes in the economic framework conditions, but it cannot guarantee that consumption is indeed lowered in absolute terms. And last but not least: ETS sectors can contribute significantly both to energy efficiency and renewable targets, provided that a stabilization of the carbon price level can be reached.

Acknowledgements

This paper is based on a research project funded by the Coalition for Energy Savings. We would especially like to thank the Members of the Coalition for the fruitful discussions during the work on the project. We further would like to thank Prof. Dr. Kornelis Blok and two anonymous reviewers for their helpful comments, as well as Vanessa Dolbé-Raffler for the proofreading of this paper.

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4 Energy saving potential of information and communication technology*

Abstract

Information and communication technology (ICT) strongly contributed to the rising global electricity demand in past years. On the other hand, technology dynamics produces a large potential for energy saving which is being discussed under the heading "Green IT". In this paper, we use a bottom-up stock modelling approach to determine the net impact of these opposite trends on the future development of electricity consumption in Germany. We show that there is a high technological improvement potential to reduce electricity consumption for ICT equipment, which can at least slow down the consumption increase or even stabilize consumption until 2020. However, whether these saving potentials will be exploited, also depends on the policies which countries introduce to stimulate the uptake of very efficient products and network solutions.

* Accepted for publication in the Int. J. of Decision Support Systems. Co-authors are Wolfgang Eichhammer and Lutz Stobbe.

4.1 Introduction

The European Union (EU) aims at limiting the global temperature rise to not more than 2°C beyond the pre-industrial level in this century, because there is strong scientific evidence that a larger temperature increase may imply considerable danger for the development of life. As part of this overall strategy, the European Union currently has a set of three combined energy and climate targets for 2020: a reduction of greenhouse gas emissions (GHG) by 20% compared to 1990 (30% under specific conditions), an increase of the share of renewable energies in total EU energy consumption to 20%, and the reduction of energy consumption by 20% compared to the trend up to 2020⁴¹. Whereas the EU is on track to achieve the GHG and renewable targets, there is evidence that the EU is not on track in meeting even its 2020 energy savings target (Harmsen et al. 2014). On 8 March 2011, the EU Commission also presented a 2050 Low Carbon Roadmap (COM(2011) 112 final) aiming at a long-term reduction of GHG emissions in the European Union by 80% by 2050 (compared to 1990). Several EU Member States also have set their own national energy and climate targets (Wade et al., 2011). Germany e.g. decided on a new Energy Concept in September 2010 (BMU, 2011) including medium and long-term energy saving targets: an absolute reduction of primary energy consumption by 20% in 2020 and 50% in 2050 and an absolute reduction of electricity consumption by 10% in 2020 and 25% in 2050 (all compared to 2008). Especially the electricity saving target is ambitious since there was a considerable increase in electricity consumption in almost all countries within and outside the EU in the last 10 to 20 years. Between 1990 and 2011, world electricity demand increased at an average rate of 3.1% per year (IEA, 2013).

Information and communication technology (ICT) and consumer electronics (CE) strongly contributed to the rising electricity demand in the past. ICT and CE equipment span a wide range of appliances found in varying quantities in residences and offices. In addition to televisions, desktop computers and laptops, these include telephones, several portable devices, servers and a lot more (also see Table 4-1). It currently accounts for around 15% of global residential electricity consumption (IEA 2009). Without additional saving policies, IEA even assumes a tripling of consumption by 2030. In Germany, electricity consumption for ICT and CE in households and companies reached a share of 11% in total electricity consumption in 2007 (Stobbe et al., 2009).

With regard to energy consumption for ICT and CE, two reverse developments could be observed during the last 10 to 15 years. On the one hand, alongside the growth in

⁴¹ The trend was set by the PRIMES 2007 projections (European Commission, 2008) and does not include impacts of the financial and economic crisis from 2008 onwards.

the stock of ICT appliances, new applications and services are constantly being introduced to the market. Furthermore, the strongly increasing number of home network devices which are required to be ready to operate at any time in digital home environment also consumes more electrical power, especially in the standby mode. On top of this, the fixed boundaries between voice, video and data communications are starting to blur and with them also the boundary between consumer electronics and ICT. This convergence of ICT services results in demands for the provision of more broadband services both for network access and fixed lines as well as greater compatibility requirements of end-use appliances. These combined developments cause an increase in the energy demand for ICT applications. On the other hand, technology dynamics produce a large potential for energy saving which is being discussed under the heading "Green IT". There is some empirical evidence that the increasing use of green IT may enhance electricity efficiency in production and consumption (e.g. Bernstein and Madlener, 2010, Faucheux and Nicolai, 2011, Rexhaeuser et al. 2014). There are, however, only a few studies available on the total impact of these opposite trends on the current and future energy consumption for ICT and CE equipment at the country level (see e.g. Urban et al., 2011 and Roth et al., 2007 for the U.S., Ropke et al., 2010 for Denmark or IEA, 2009).

In this paper, we calculate scenarios for possible developments of electricity consumption for ICT and CE over the next decade for Germany. Thus we want to make a contribution to the present lack of studies on the net impact of the opposite trends with regard to ICTs on total electricity consumption of a country. By showing medium and long-term energy saving potentials in these areas, we also address the possible contribution of ICT and CE to achieve energy saving targets.

The paper is organized as follows: In Section 4.2 we provide a description of the basic model and assumptions on which our calculations are based. The results of our projections are presented in Section 4.3. In Section 4.4, we interpret and discuss these results. Finally, in Section 4.5 we derive some conclusions and implications for policy making.

4.2 Methodology

In order to capture the wide variety of applications and products belonging to the ICT domain as fully as possible, we chose a sectoral demarcation with the following structure to determine ICT-related power consumption in Germany:

- ICT end-use appliances in private households
- ICT end-use appliances in companies (private and public)

- Server and data centre
- Network access and core networks

We developed a computational model to determine the current and future power demand of ICT applications. The model includes the following demand-determining components: the stock of appliances for each product group, the average power input of the products and applications in the different operating modes and the respective patterns of use (Figure 4-1).

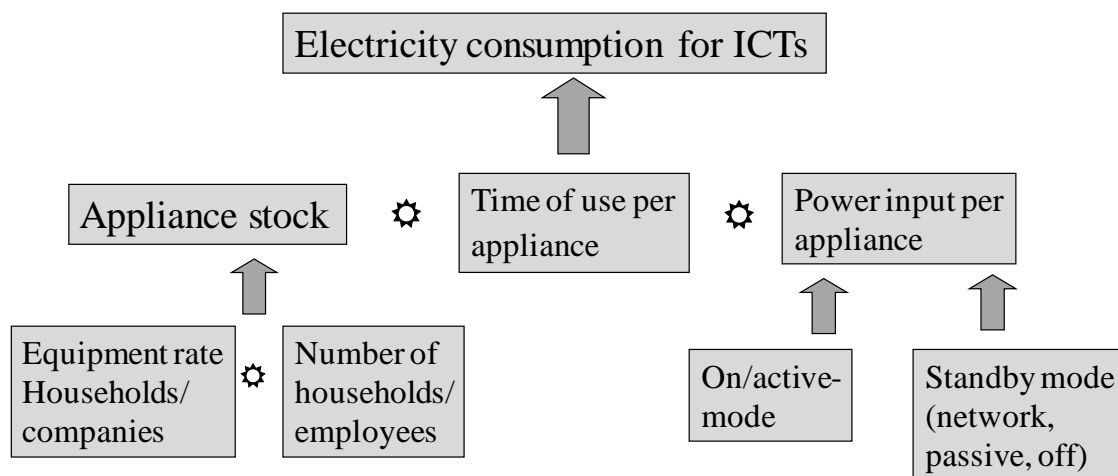


Figure 4-1: Structure of the computational model for electricity consumption of ICT and CE equipment

The model is based on the following data and assumptions about demand-determining components of the appliance stock, patterns of use and power input:

- The basis for determining the stock of ICT end-use devices in private households were data on household equipment rates in the base year taken from official statistics, company and sector association statistics as well as from market and opinion research. We then made assumptions on the future penetration rates. The stock of appliances was extrapolated using the number of private households (2007: 39.7 million).
- The stock of ICT appliances in private companies and public administrations was determined using data on equipment rates from a company survey (Schlomann et al., 2009). The total stock of ICT devices and servers was extrapolated using the number of employees in the respective sectors.

- The figures used in the model for the patterns of use and power input in the various operating modes of ICT end-use devices in households and companies are based on the preparatory studies under the Ecodesign Directive of the EU as they were available until 2009 (Lot 3 to 7; Jönbrink, 2007; Stobbe, 2007a/b; Nissen, 2009; Monier, 2007).
- The underlying power input for servers are based on the assumptions from the EU study "Efficient Servers" (Schäppi et al., 2007, 2009). The power consumption of the related data centre infrastructure has to be added to that of the actual server, i.e. of networks, storage and building infrastructure (among others, HVAC, USV). This was calculated in proportion to the electricity consumption of the server.
- Recording the appliance stock for network access and core networks was difficult because of the lack of an established structural model and statistics. For mobile communications, we developed our own model and used this to determine a stock of mobile communication base stations in Germany of about 135,000. For fixed lines, it was not possible to determine the power demand using stock figures and specific power consumption because of the limited data, instead a flat-rate consumption of 10 Wh per household was assumed.

4.3 Results

4.3.1 Results for the base year

For the base year 2007, a total electricity consumption of around 55 TWh results for ICT and CE in Germany (Table 4-1). This is equivalent to a share of around 11% of total electricity consumption.

End-use appliances in households are responsible for the largest share of ICT-related electricity consumption by far, with almost 60% or 33 TWh (Table 4-1). Compared to this, the share of end-use appliances in companies is much smaller, with only about 12% (6.8 TWh). The power consumption of servers and data centres is already more significant; this amounted to around 9.1 TWh in 2007. The power demand for network access and core network (mobile communications and fixed line) is already about the same order of magnitude with 6.4 TWh as that for ICT end-use devices in companies. This number is, however, relatively uncertain due to a lack of reliable data.

Table 4-1: Electricity consumption for ICT and CE in Germany 2007 and projection for 2020

Sector	Electricity consumption (GWh)					
	2007 Base year		2020 Reference Case		2020 Green IT Scenario	
	Power all modes	of which Standby ¹⁾	Power all modes	of which Standby ¹⁾	Power all modes	of which Standby ¹⁾
Private households (total)	33010	9462	40864	6235	33599	4878
Computer ²⁾	11217	2552	16016	1349	13299	1344
Portable devices	479	146	731	221	584	74
Television ²⁾	15833	3714	19047	2866	15442	2051
Audio devices	3212	1925	2114	779	1724	390
Telephone/router	2270	1125	2956	1020	2550	1020
Companies (total)	6817	1689	7037	1124	5869	969
Computer ²⁾	6196	1188	6386	518	5244	468
Telephone, router	622	501	651	605	625	502
Server/Data Centre (total)	9122	0	12319	0	10577	0
Server	3649	0	6159	0	5817	0
DC-infrastructure	5473	0	6159	0	4760	0
Network (total)	6436	0	6543	0	5889	0
Mobile	3107	0	3214	0	2560	0
Fixed line	3329	0	3329	0	3329	0
Total ICT / CE	55385	11151	66762	7358	55933	5847

1) Network standby, passive standby, off-mode

2) Incl. peripheral devices

Electricity consumption in standby mode, i.e. off-mode losses, passive standby and network standby, is 11.2 TWh/a in private households and companies, which constitutes around 28% of the total consumption of 39.8 TWh in these two sectors (Table 4-2). The standby mode is not relevant in the other two sectors.

Table 4-2: Electricity consumption for ICT and CE in German households and companies by mode

Mode	Electricity consumption (GWh)		
	2007 Base year	2020 Reference Case	2020 Green IT Scenario
Active mode	28676	40646	33620
Networked standby	5106	4741	4246
Passive standby	4660	2200	1288
Off-mode	1386	313	313
Total	39828	47900	39467

4.3.2 Reference forecast

Long-term or even mid-term forecasts in such a dynamic market environment as the ICT branch are difficult. The development of the ICT sector is not only ruled by the overall economic situation as much as all other sectors, but a characteristic feature of the ICT branch is the ongoing dynamic evolvement of technology and applications. This includes

- a fast-moving, sometimes parallel technology development
- an ongoing intrinsic development paradigm in semiconductor technology
- a partial hardware-independent software development
- a high cost share for research and development
- a strong patent and licence trade with high costs
- parallel technology standards and long-winded standardisation processes
- a heterogeneous network infrastructure, especially within access networks
- a high investment risk for measures concerning the network infrastructure.

Based on that, we derived several key trends from the general characterization of the ICT branch which could have an influence on future electricity consumption. The trend analysis focused on the possible development of data traffic, ICT applications and content, new computing concepts, the technical development of components, end-use devices and server technologies. There are both trends resulting in an increasing electricity demand and opposite trends which contribute to future electricity savings in the field of ICT and CE:

- Strongly increasing data traffic which is mainly due to a rising demand for video and TV internet applications mainly caused by private end-users (Cisco, 2008).
- Interactive internet usage and individualised offers.

- Longer active times of end-user devices (PC, TV) and increasing networked standby (home servers).
- Larger screens and more powerful devices.
- Increasing energy efficiency of electronic components and end-user devices both due to policy measures as minimum requirements and new energy labels in the European Union (EU Eco-Design and Labelling Directives) and inherent technological trends (as e.g. the technology progress in the semiconductor and optoelectronic industries, the trend towards a small form factor and greater mobility, or the reduction of redundant functionality leading to more modular products with the associated challenge of correct power supply and power management).
- Further spread of “Thin Client” concepts and Cloud Computing as an alternative to full-appointed workstations with full data storage; though there are still reservations in companies and even more in private households with regard to the guarantee of data privacy and data availability.
- Wider spread of energy-efficient server solutions (e.g. more efficient cooling, consolidation of servers through higher working loads based on virtualisation) due to rising awareness among the operators.
- On the other hand, higher demands on data security for servers and data centres will partly compensate these savings.

According to the reference forecast, electricity consumption for ICT in Germany will increase by 23% to about 67 TWh between 2007 and 2020, with a continuing increase for private households and servers and data centres, whereas the consumption in companies and for networks remains more or less constant (Table 4-1). With regard to standby consumption (Table 4-2), technical modernization and increasing consumer awareness together with legal regulations are expected to contribute to a clear reduction of energy consumption in off-mode and passive standby even in the reference case. Only networked standby remains almost stable.

4.3.3 Green IT Scenario

Besides the reference forecast, which assumes a probable power consumption development for devices and installations under current energy policy conditions and only considers autonomous technical change, we also calculated a Green IT Scenario. This scenario highlights additional saving potentials which exist technically, but are not necessarily being exploited under current framework conditions.

The assumptions about power consumption in the Green IT Scenario are oriented to best practice examples for end-use devices and systems engineering. The efficiency improvements concern the following areas:

- Technical optimization of appliances: larger and faster reduction in power consumption in (network) standby and off-mode than in the reference scenario; greater market penetration of energy-efficient electronic components (displays, processors); virtualization and optimization of air conditioning in servers and data centres.
- New utilization forms and patterns: greater use of energy-saving thin client applications in companies and "hybrid" thin clients in private households than in the reference scenario.
- Network optimization.

As a result, electricity consumption in the Green IT scenario can be almost stabilized at the level of the base year 2007, which means an additional saving potential of around 11 TWh compared to the reference case (Table 4-1). With regard to standby, the additional savings in the Green IT scenario are above average for passive standby, whereas networked standby only moderately decreases compared to the reference case (Table 4-2).

4.4 Discussion

The market for ICT and CE is highly dynamic and characterized by short product cycles and lifetimes of products, evolving using patterns and dynamics, and a rapid technology adoption (Urban et al., 2011). This makes projections of energy consumption in the field of ICT and CE more difficult than for other energy end-uses with a more stable structure of applications and usage patterns. In addition, there is a lack of statistical data on the installed base and the actual use of ICT and CE equipment in all fields. These restrictions have to be taken into account when judging the projection results. The main target of our paper was to show main trends and their possible impact on future electricity consumption and not exact figures. A sensitivity analysis of the main factors influencing future energy consumption for ICT and CE equipment could further stabilize our results.

With regard to the modeling approach, we used a bottom-up simulation model which depicts the diffusion of energy-efficient ICT and CE technologies and the main components determining future energy demand at the detailed level of products (see Figure 4-1). The application of this kind of modeling is relatively widespread for commercial and consumer products such as television and other IT product (Usha Rao and Kishore, 2010). Compared to more aggregate optimization models, the main advantage of these models is that they show potential impacts for alternative technology futures and energy demand in detail and provide useful insights in end-use energy efficiency techno-economic potentials (Mundaca et al., 2010). On the other hand, there are several disadvantages of such bottom-up energy models which are discussed in literature

(see e.g. Laitner et al., 2003; Rivers and Jaccard, 2006; Kavgić et al., 2010). In their review Mundaca et al. (2010, p. 307) especially mention that these bottom-up models often use a traditional “unbounded rational” approach of the market agents without taking into account market imperfections. In addition, learning processes related to the adoption of efficient technologies are often neglected. The introduction of learning curves in our computational model could further improve the results especially in the long-term beyond the year 2020.

Though these shortcomings have to be born in mind, our modeling approach enabled us to show that electricity consumption for ICT and CE is expected to further increase in future due to rising equipment rates and times of use, new applications, or increasing functionality of the devices which over-compensate the impact of efficiency gains. In our paper this was shown for the development in Germany. A similar development was, however, observed for all IEA countries (IEA, 2009) and in studies for the U.S. (Roth et al., 2007; Urban et al., 2011) or Denmark (Ropke et al., 2010). On the other hand, we found a great technological improvement potential to reduce ICT and CE energy consumption, which can at least slow down the consumption increase or even stabilize consumption in the medium and long-term. Thus ICT and CE can also contribute to energy and GHG saving targets as they are set in Germany and the EU for 2020.

With regard to standby consumption, our results show a considerable consumption decrease in all scenarios up to 2020. This is due to the expected technical efficiency improvements for passive standby and off-mode. The remaining standby consumption in 2020 is mainly caused by networked standby, which only showed a moderate decrease in the scenarios calculated for Germany (Table 4-2). Therefore future research and policies should have a specific focus on the issue of networked standby (also see Nissen, 2011 or the recent publication by IEA and IEA 4E, 2014).

4.5 Conclusions

Both for the energy consumption in active mode as for networked standby, the improvement of energy consumption related to CE and ICT should consider multiple levels of action. On a hardware level, technology progress in the semiconductor and optoelectronic industries provides a solid base for improvement. The trend towards a small form factor and greater mobility comprises an intrinsic force pushing the design of low power solutions. Another aspect is functional demand and the reduction of redundant functionality. As a result we will have more modular products with the associated challenge of correct power supply and power management. An important condition here is interoperability which needs to be addressed in operation systems and network technology.

Whether these saving potentials will be exploited, depends mainly on the policies which countries introduce to stimulate the uptake of very efficient products and network solutions. Up to now, mandatory or voluntary minimum energy performance standards and energy performance labels have been the most widely employed measures to enhance the market transformation of energy-efficient electronic devices. In future, standards and labels will have to take into account the convergence of ICT and CE and have increasingly to be defined by functionality and not only by products. This especially applies to networked standby, which should be addressed soon due to the rapidly increasing importance of this part of ICT energy consumption. At the level of the European Union, however, an implementing regulation for networked standby under the EU Ecodesign Directive (2009/125/EC) is still being discussed.

In addition, a user-oriented implementation of existing best practice in collaboration with industry and applied research can help to accelerate the market penetration of highly efficient ICT solutions. This could be realized by flagship projects focusing on exemplary implementation of the newest technology, infrastructure and configuration of end-user devices. From this, marketable incentives can be deduced which support a rapid spread of best practice into the market.

Based on the results shown here the key areas of such an initiative could be high-capacity and energy efficient communication networks, system solutions for efficient computing and storage performance, or software-based network adjustments.

The analysis of current energy consumption of ICT and CE and the deduction of energy saving potentials is considerably affected by the lack of statistical data on the installed base and the actual use of ICT and CE equipment in all fields. A regular and more reliable statistical data base is also necessary for a regular monitoring of energy consumption and energy savings. Such monitoring will become more relevant in future due to the growing importance of GHG and energy saving targets both at the level of the European Union and individual countries. In addition, standardized methods for the measuring of real-life efficiency of networks, servers and data centres and local ICT networks are necessary.

Current research and policy mainly refer to the energy consumption caused by ICT and CE. However, more effort is also needed regarding possible energy and GHG saving potentials through ICT and CE in order to show the net impact of ICT on energy consumption and GHG emissions (TIAXX, 2007; Faucheux and Nicolai, 2011; Bernstein and Madlener, 2010).

Acknowledgements

This paper is mainly based on a research project funded by the Federal Ministry of Economics and Technology (BMWi) in Germany. We further would like to thank Prof. Dr. Kornelis Blok and two anonymous reviewers for their helpful comments.

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5 Which role for market-oriented instruments for achieving energy efficiency targets in Germany?*

Abstract

In order to achieve national or EU-wide energy efficiency targets, a variety of policies is available. Apart from the traditional set of regulative, financial, fiscal and informative instruments, market-oriented instruments as e.g. energy efficiency obligations (EEOs) become more and more important. The new EU Energy Efficiency Directive (EED) even suggests EEOs as the preferred instrument for promoting energy efficiency in all Member States. Their actual impact, however, depends highly on the national framework. With a multi-criteria, semi-quantitative approach we evaluate the strengths and weaknesses of these instruments, taking Germany as an example. The evaluation shows that none of the instruments alone can achieve the prescribed energy efficiency targets, but that a mix of instruments is necessary. The possibility of a budget-independence of the funding in particular supports a supplementary deployment of new market-oriented instruments such as an EEO as part of the future mix of policy instruments in Germany.

* This paper is a slightly adapted version of a paper published in *Energy & Environment*, Vol. 24 (2013), No. 1, pp. 27-56. Co-authors are Wolfgang Eichhammer, Clemens Rohde, Veit Bürger and Daniel Becker.

5.1 Introduction

The EU Directive on energy end-use efficiency and energy services (Directive 2006/32/EC; ESD) already named both energy efficiency obligation (EEO) schemes (frequently also known as “white certificates” or “energy-saving quota”) and an energy-efficiency fund (EEF) as potential new instruments for achieving energy-savings in the Member States. To date the United Kingdom, Italy, France, Denmark and the region of Flanders have introduced EEOs in Europe.⁴² Internationally, these schemes are especially widespread in the United States and Australia (RAP, 2012). However, the existing schemes appear in very different forms. Furthermore, energy-saving funds have been long established in the United Kingdom and Denmark. In the new EU Energy Efficiency Directive from 25 October 2012 (Directive 2012/27/EU; EED), which repeals the ESD, the introduction of energy efficiency obligation schemes is even demanded of all Member States. According to Article 7, paragraph 1 of the EED, energy distributors and/or retail energy sales companies should be committed to new annual energy-savings of 1.5% of the energy sales by volume, averaged over the most recent three-year period prior to 1 January 2013. Paragraph 9 gives Member States the option of meeting the target using other instruments and measures as an alternative to the energy efficiency obligations.

In Germany the instrument of energy efficiency obligations was included in the Federal Government’s Energy Concept of September 2010 (BMW_i, 2010) by announcing a “white certificates” pilot project in conjunction with associations of the energy industry. The Energy Concept also sets out further ambitious energy-saving objectives. By 2020 primary energy consumption and the energy demand for heating in buildings are to be reduced by 20% and electricity consumption by 10% compared to 2008. These targets were confirmed by the decisions of the Federal Government on a far-reaching transformation of the energy system in summer 2011 as a response to the nuclear disaster in Fukushima (the so-called German “Energiewende”). The first monitoring report by the Federal Government on the progress towards these targets (BMW_i and BMU, 2012) showed that further efforts in the field of energy efficiency are necessary.

Additionally, according to first estimates (Schlomann et al., 2012), the energy-saving target set by Article 7 of the new EED demands from Germany new final energy-savings of around 26 TWh per year (without the transport sector). In the 2nd National Energy Efficiency Action Plan (NEEAP) under the former ESD (BMW_i, 2011), however,

⁴² Comprehensive overviews on EEOs in Europe can be found in Bertoldi et al., 2010; Lees, 2012; Staniaszek and Lees, 2012; Bertoldi, 2012. For the international perspective see e.g. RAP, 2012.

Germany could only demonstrate yearly savings of 13 TWh through new energy efficiency measures, i.e. around half of the EED target.

Given that, achieving the national energy efficiency targets set both by the Energy Concept and the EED will require additional policy measures and thus also a growing funding framework. The portfolio of existing and new instruments is increasingly being discussed from the perspective of being able to provide budget-independent funding of energy-saving measures. The past and present energy efficiency policy in Germany, however, is still dominated by regulation and state-financed financial and fiscal incentives, which are accompanied by a variety of information and education programmes (Schlomann and Eichhammer, 2012).

The previous discussion at national and at EU level has shown that there are still many open questions with respect to cost/benefits of a potential introduction of more market-related instruments. This is valid for the macroeconomic perspective as well as for the micro-economic perspective of the affected actors. Another question of particular importance for Germany is how existing instruments and measures as well as those proposed by the Energy Concept can be effectively combined with potential new instruments. Within this context, we performed a cost-benefit analysis on the introduction of an EEO scheme and of an EEF in Germany. Further analysis is made concerning how the expansion and improvement of the existing set of energy-efficiency policy instruments is to be evaluated compared to the new instruments.⁴³ This option will be described in more detail in Section 5.2.1.

The key question in this paper is the possible role of new market-oriented instruments for achieving the energy efficiency targets set for Germany by the national Energy Concept and by the new EED. We discuss various evaluation criteria starting with a quantitative assessment of the achievable energy-savings. Further to this quantitative assessment, we perform a qualitative evaluation of the main micro- and macro-economic impacts of these instruments.

The paper is structured as follows: Section 5.2 introduces the methodological approach. Section 5.3 will be devoted to the results of the evaluation of the instruments with regard to the different evaluation criteria. The final Section 5.4 will draw conclusions on the possible role of market-oriented instruments for achieving the actual energy efficiency targets in Germany.

⁴³ The results presented here are primarily based on a study on the costs-benefits of the introduction of market-oriented instruments for realizing final energy savings in Germany which was carried out by the authors on behalf of the Federal Ministry of Economics and Technology (Schlomann et al., 2012).

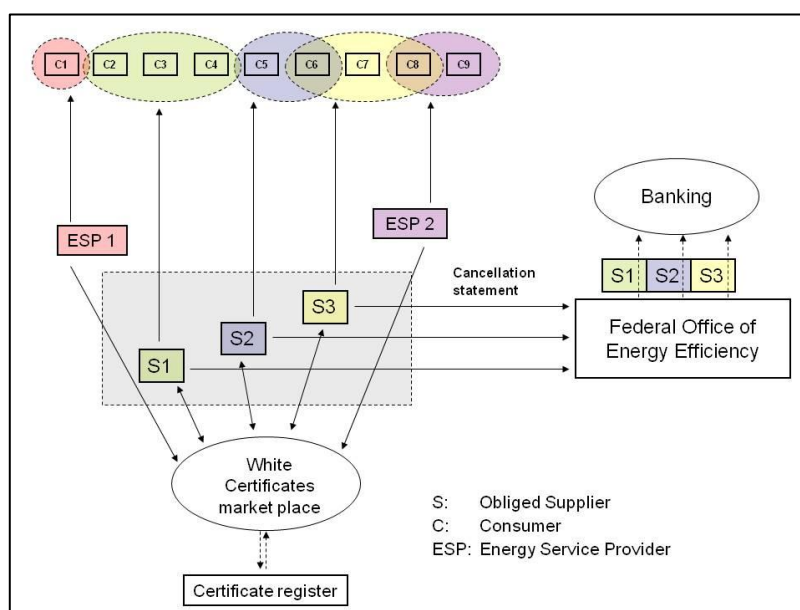
5.2 Methodology

The methodological approach chosen for the analysis is based on three pillars:

- A thorough design analysis of the energy efficiency (EE) instruments taking into account: an energy-efficiency obligation scheme (EEO), an energy-efficiency fund (EEF) and, as a third option, the expansion and improvement of the existing set of EE instruments and EE measures (such as the present subsidy programmes based on state budgets). The chosen design parameters are intended to serve as the basis for the comparative evaluation.
- The calculation of EE potentials, using bottom-up simulation models for all final energy consumption sectors except transport, which are regularly used for the determination of energy-saving potentials in Germany (Schlomann et al., 2012; Öko-Institut et al., 2009, 2013) and the EU (Fraunhofer ISI, 2012; Ecofys and Fraunhofer ISI, 2010; Fraunhofer ISI et al., 2009). The use of such models for forecasting purposes is already state of the art (Lapillonne and Chateau, 1981; Worrell et al., 2004). We apply these calculations both to the deriving of the energy-saving target which should be achieved by the EE instruments and to the quantitative evaluation of the suitability of the EE instruments to meet these targets.
- A qualitative analysis of additional criteria for the comparative evaluation of the EE instruments, as e.g. different types of costs related to the instruments, impacts on the competitiveness, on the market for energy services, distribution effects, interaction with existing instruments, or the refinancing.

5.2.1 Design of the evaluated EE instruments

The key element of an EEO is the obligation of a particular group of actors (usually energy suppliers, i.e. retailers or distributors) to meet an energy-saving target by delivering a certain amount of energy-savings within a specific period (Figure 5-1).



Source: Schlomann et al., 2012

Figure 5-1: Basic operating principles of an EEO

Obligated parties can fulfil their saving obligations in two ways: by initiating their own EE measures in their field of activity or by purchasing standardized savings titles (often called “white certificates”) from other obliged or third parties (usually energy service providers). This means that an EE is essentially an obligation (defined as a saving target) that is managed via a system of white certificates. Another key element of such a scheme is the existence of an - usually state-owned⁴⁴ - institution that defines and verifies the EE measures and reports the energy-savings achieved (RAP, 2012).

Though the already existing EEO schemes in Europe and worldwide are designed rather differently (Bertoldi et al., 2010; RAP, 2012), there are some key elements which have to be decided on before performing a cost-benefit analysis of such an instrument:

- Specification of the scope: for the purpose of our analysis a broad scope with few restrictions in terms of fuel sources subject to targets, sectors and types of measure is chosen. This offers the potentially obliged parties a broad variety of cost-effective energy-saving measures to adopt and, hence, more flexibility. To avoid double accounting, however, it is recommended that efficiency measures in processes that are directly subject to the EU Emission Trading Scheme ETS are excluded. Transport energy uses are also not considered in the first instance, as is done in most of the existing systems (RAP, 2012), i.e. the scope is restricted to buildings, electrical

⁴⁴ In Germany, this could e.g. be the institution which was already established for the implementation of the ESD and the new EED, the Federal Office for Energy Efficiency (BfEE).

devices, and industrial cross-cutting and process technologies except for processes subject to EU-ETS.

- The choice of the baseline is of particular importance. Only energy-savings that exceed a standard defined by the baseline should be legitimated for the generation of saving titles. If a non-ambitious standard is used as a basis (e.g. the average of current stock), many savings would be accounted for under the obligation which represents a pure deadweight effect. Measures that had been taken anyway would then be entitled to meet the target. Thus, the market average is generally recommended as the baseline, since it is usually known for many products and energy uses predefined by a European or national standard (as e.g. current building standards or the EU Directive 2009/125/EC on ecodesign requirements for energy-related products).⁴⁵ Such standards may also evolve dynamically over time. It must be emphasized, however, that there are also opposite views on the ambition of the baseline and measure overlap. The argument is that overlap between instruments may overcome gaps in the implementation of one instrument alone.
- The principle of additionality of the eligible energy-savings is closely linked to the choice of the baseline. It means that the energy-savings should exceed an autonomous development which would in any case occur either due to the general technical progress or due to already implemented policy measures setting minimum efficiency standards (Vine, 2008; Thomas et al., 2012; Sorrell et al., 2009a).

To guarantee direct comparability of the instruments for the cost-benefit analysis, we applied the same key principles to all instruments investigated; i.e. the same scope and the same degree of ambition for the eligible energy-saving measures are assumed. The principle difference between an EEO and the other EE instruments analyzed here is that for the latter the specification of an energy-saving target is not necessary. The amount of energy-savings achieved by an EEF is determined by the financial volume of the EE programmes which are carried out under the fund. For analytical reasons it is assumed that the savings achievable with this financial volume correspond to the energy-saving target which is set for the EEO (see Section 5.2.2). The instrument is designed as an institutionalized fund that possesses an administrative organizational

⁴⁵ The principles for baseline setting are discussed generally in Staniaszek and Lees (2012), Vine (2008), Thomas et al., 2012). Concrete examples for the setting of the baseline for specific products or energy uses were developed in several case studies which were carried out within the EMEES project (Wuppertal Institute, 2009).

structure, as e.g. the established funds in the UK and Denmark.⁴⁶ The third option of an “expansion and improvement of existing instruments” is examined as a further instrument besides the EEO and the EEF. It is designed as a mix of improved and tighter regulations (incl. improvement of compliance), expansion of financing in the form of low-interest loans, direct grants or tax incentives as well as additional advisory programmes (audits, efficiency networks). The financing is provided by the state budget.

5.2.2 Calculation of EE potentials and derivation of the energy-saving target

In this section we derive an energy-saving target which should be achieved by the EE instruments from existing energy-saving potentials in Germany.

The energy-saving potentials are calculated using bottom-up models of the Fraunhofer ISI for the sectors of buildings (residential and non-residential buildings), electrical household devices, electrical cross-cutting technologies in the commercial sector and industry (with and without ETS processes). These models are fundamentally set up to be dynamic, i.e. they take into account cost reductions through technological progress and broader market penetration through efficiency technologies.⁴⁷ The framework data for the development of energy-relevant activity factors and the energy prices used for the calculations correspond to those from the energy scenarios for the national Energy Concept (Prognos et al., 2010). The potentials are calculated based on a reference development (baseline) in line with the design principles for the instruments (see Section 5.2.1). That is to say, only potentials exceeding a specific standard set by the market average are considered, taking into account the dynamic development of such standards. This means that a saving potential which is calculated against such an ambitious baseline is considerably smaller than a potential which is e.g. calculated against a so-called frozen efficiency scenario which assumes no further penetration of more energy efficient technologies. An exception to this rule is made for any potential that

⁴⁶ See www.savingtrust.dk and www.energysavingtrust.org.uk. As opposed to that, the energy-efficiency fund established in the wake of the German Government’s Energy Concept is managed by the Federal Ministry of Economics and Technology. The funding provided for this to date is under €100m for 2011 and 2012 and an increase to a maximum of €300m by 2015 (BMF, 2012) is considerably less than the funds in the UK and Denmark and also clearly below what was recommended for the creation of an energy-efficiency fund in Germany of around 1 to 1.5 billion €/a (Öko-Institut et al., 2009; Irrek and Thomas, 2006). The same applies to an audit programme for small and medium companies managed by the public bank KfW which is also called a “fund”, but which is far from reaching the financial volume which is assumed here (Fleiter et al., 2012a).

⁴⁷ A detailed description of these models and of the technologies and energy-saving options which are included can be found in Schlomann et al. (2012).

could be exploited by improved enforcement of the current building regulations (EnEV) in renovating existing buildings and that ought not to be taken into account pursuant to the delimitation as defined here, which assumes a perfect implementation of the standards. This potential is included in the consideration because the deficiencies in the implementation of existing instruments for improving the insulation standards of existing buildings cannot be ignored. In addition, this can also be justified by the challenge to increase the current renovation rate of less than 1% a year to 2% of the total building stock, which is one of the sectoral targets of the German Energy Concept (BMWi, 2010).

Table 5-1 summarizes the respective energy-saving potentials taken into account by 2020. They are calculated based on the reference year 2008 and presented both as the average annual saving up to 2020 and as the cumulative annual saving that can be achieved in 2020. The majority of the potentials can be found in the building sector, which includes both residential and non-residential buildings. The potential assigned to industry is relatively small, especially when not taking into account the energy consumption falling under the EU-ETS (which is, however, possible in the new EED). The total additional saving potential calculated against an ambitious baseline (represented by the market average) amounts to an average annual saving up to 2020 of almost 29 TWh or a cumulative annual saving in 2020 of around 343 TWh.

Table 5-1: Estimated saving potential in the final energy consumption sectors (excl. transport) in Germany up to 2020

	Average annual saving up to 2020 (compared with 2008)	Cumulative annual saving in 2020 (compared with 2008)
	TWh/a	TWh/a
Energy-saving potential¹		
Buildings (residential and non-residential)	22.0	265
Residential Electricity (without buildings)	2.3	27
Tertiary Electricity (without buildings)	1.8	22
Industry (without EU-ETS) (incl. EU-ETS)	2.4 (3.9)	29 (47)
Total potential considered (without transport and EU-ETS)	28.5	343

¹ As compared to an ambitious baseline which also assumes a better enforcement of the current building regulations (EnEV)

Source: Schlomann et al., 2012

Comparing these energy-saving potentials with the 1.5% energy-saving value for Germany of roughly 26 TWh new annual savings resulting from the EED (see Section 5.1), this target is not far below the total saving potential as it was calculated here (Table 5-2). This means that with an ambitious baseline for the design of an energy-efficiency obligation scheme or alternative instruments as proposed here, such a target value of 1.5% is to be considered ambitious for Germany. The ambition of the target specification depends in particular on the degree of additionality of the energy-saving measures that an instrument is intended to achieve. If additionality is not a major design feature of the instrument, the annual savings achieved autonomously or on the basis of past political efforts must be considered as the minimum threshold to be exceeded by the new instruments. According to the ODYSSEE energy-efficiency indicators, these were around 1.2% per year in Germany in the period 1991-2010 (Schlomann and Eichhammer, 2012) and thus 1.5% saving per year would be an easily achievable requirement. Therefore, it should once again be stressed that the level of the target alone does not determine how ambitious the target is in the respective country, but instead that the baseline for the individual measures should be defined in detail because this determines whether the target is ambitious or not. Hence, as already mentioned in the previous chapter, the setting of the baseline is one of the key elements of the design of EEOs or other market-oriented instruments.

Table 5-2 summarizes the total energy-saving potentials actually taken into account for the determination of the energy-saving target. The derived energy-saving target is expressed in three variants (high, medium, low), which should be achieved by the EE instruments evaluated here. The targets are again set out both as an average annual saving up to 2020 and also as a cumulative annual saving in 2020. The high energy-saving target includes both profitable energy-saving potentials for the investor under defined economic framework conditions and assumptions on the cost-effectiveness (with sector-specific discount rates) as well as energy-savings that are economic or near-economic across the whole lifetime of the saving measure (i.e. that do not lead to higher costs than at present as compared to least life-cycle costs). Non-economic barriers to energy efficiency are supposed to be removed in the high potential. For the medium and low energy-saving potential an exploitation of 2/3 and 1/3 respectively was assumed. The medium target corresponds to a potential which is micro-economically profitable for the investor up to 2020, taking into account barriers to energy efficiency. The low energy-saving target merely exploits part of this micro-economically profitable potential.

Table 5-2: Derived energy-saving target in three variants

	Average annual saving up to 2020	Cumulative annual saving in 2020
	TWh/a	TWh/a
Energy-saving potential		
Total potential considered (without transport and EU-ETS)	29	343
Derived energy-saving target in three variants		
High (= total potential)	29	343
Medium (= 2/3 of the total potential)	19	228
Low (= 1/3 of the total potential)	10	114

5.2.3 Criteria for the qualitative analysis

For the qualitative assessment of the EE instruments, we take into account the theoretical work which was already done on the main economic impacts of EEOs and their interaction with other policy instruments (e.g. Sorell et al., 2009a; Harrison et al., 2005; Meran and Wittmann, 2008). The following evaluation criteria are considered:

- Cost of the instruments: different cost categories are taken into account and compared between the EE instruments in a semi-quantitative way.
- Market conformity and impacts on competitiveness of the instrument options: these criteria are discussed and compared with an eye on obligated actors and energy service providers; in particular the conditions under which certificate trading could develop.
- Market for energy services: the possible effects of the new instruments on the market are examined.
- Secondary effects of the instruments: e.g. distributional and structural effects as well as effects on the energy price trends that cannot be measured quantitatively are discussed.
- Interactions with existing instruments: each new instrument encounters an energy-policy landscape that is already covered by existing instruments; such interactions are considered in particular with respect to Emission Trading, the Energy-Saving Ordinance, the Ecodesign Directive and existing financial programmes in Germany (such as the KfW subsidy programme for buildings).
- Political acceptance: here the different points of view of the affected actors are considered and starting points derived for the implementation of the different EE instruments in the political environment.

- Scope for refinancing: this examines the extent to which the instruments differ in terms of their funding; one focus is on the aspect of budget-independence of the funding.

5.3 Results

5.3.1 Suitability of the instruments investigated to achieve the targeted energy-savings

The evaluation of the scope and quality of the instruments is based on the underlying assumption that the technical EE measures implemented to meet the targets have a different suitability for the EE instruments examined here. In order to assess the suitability of the EE instruments in a semi-quantitative scheme, each technical EE measure in the different sectors is individually evaluated using three categories:

- Technical complexity: this criterion addresses the suitability of an EE measure for standardization, which is easier in the case of a simple measure (e.g. replacement of a product) than in a case when complex systems are addressed (e.g. deep retrofit of a building or improvement of whole electric motor systems). It results from experience with existing EEOs whereby simple, standardizable EE measures seem to be more suitable for implementation in the scope of an EEO than measures with a high level of complexity.
- Financial complexity: this criterion refers to the funding models required for the performance of an EE measure. It takes into account the ownership of the measure and the need for internal and/or external capital. If complex funding models are needed in order to implement an EE measure, the demand on the quality of the financial programmes increases. This also influences the suitability of the EE instruments.
- Complexity of the transaction: this criterion refers to the fact that in reality various barriers prevent private households and companies from realizing even a profitable energy-saving potential as it was calculated in Section 5.2.2 (e.g. Sorrell et al., 2004; Worrell et al., 2009). Although this discussion is not new, the persistent existence of barriers to energy-efficiency deployment was only recently pointed out in the World Energy Outlook 2012 by IEA (2012). Usually, the following main types of barriers are distinguished: information and knowledge deficits; capital constraints both including external and internal funds; risk and uncertainties, often leading to very short pay-back times for an EE investment; or split incentives when the costs and benefits of an EE investment decision fall on different actors. In order to assess the suitability of an EE instrument to overcome these barriers, we could rely on a lot of literature on this issue.⁴⁸

⁴⁸ A comprehensive overview of the literature over the last two decades on barriers for EE investments and policies to overcome these barriers was recently given in Fleiter et al. (2012b).

Table 5-3 gives a semi-quantitative assessment, based on these three categories, of how well the technical EE measures can be addressed by the respective EE instrument options.⁴⁹ This evaluation matrix sets the basis for the following quantitative evaluation of the different instruments as to how far they may be able to realize the potentials discussed earlier. In each case only those energy-saving measures that are evaluated as “neutral (0), suitable (+) or very suitable (++)” are taken into account in the quantitative assessment.

Table 5-3: Semi-quantitative evaluation¹ of the suitability of the technical EE for the EE instruments² (overall evaluation across all criteria)

Targeted end-use	Appropriate instrument				
	Energy Efficiency Obligation Scheme	Financial grants / subsidies, Funds	Tax reduction / exemption	New / tightened regulation	Information / Advisory service
Buildings					
Refurbishment of building facade with best available technology (BAT)	-	+	+	++	-
Refurbishment of roof/bottom with BAT	o	+	+	++	-
Refurbishment of windows with BAT	+	+	++	+	-
Enhancement of the rate of refurbishment of building facade (at the level of the current building regulation)	o	+	++	++	-
Enhancement of the rate of refurbishment of windows (at the level of the current building regulation)	-	o	o	+	-
Enhancement of the rate of refurbishment of roof/bottom (at the level of the current building regulation)	o	+	+	+	-
New buildings with BAT	o	+	++	++	-
Change of heating system	+	++	++	++	o
Full compliance with existing regulations	o	+	+	++	--
Tertiary Electricity					
Cross-cutting technologies (Elevators, Lighting, Ventilation and air-conditioning, process refrigeration, hot water)	++	+	+	++	+
Various building technologies	-	-	o	--	+
ICT offices / server rooms	+	+	+	+	+
Street Lighting	++	++	--	++	-
Complex heating systems/regulation	o	o	--	-	++
Residential Electricity					
Lighting, large household appliances, IT appliances	++	++	+	o	o
Industry					
Cross cutting technologies - use of best available technology (BAT)	++	+	+	++	+
Cross-cutting technologies - Optimized operation	--	--	--	--	++
Process technologies - use of best available technology (BAT)	-	o	-	+	o
Process technologies - Optimized operation	--	--	--	--	+
Process technologies - Waste heat recovery	o	o	o	+	+
Process technologies - Process innovation	--	-	--	--	o

¹ Evaluation categories ranging from „-“ fully unsuitable via „o“ neutral up to „++“ very suitable

² Explanatory note on the instrument columns: the first column only refers to an EEO, the second column both refers to a new EEF and existing (state-based) financial instruments, the remaining three columns only belong to the option “extension of existing instruments”.

Source: Schlomann et al., 2012

⁴⁹ For analytical reasons we had to split up the instrument option “extension of existing instruments” into four separate EE instruments (financial incentives, tax reduction, regulation, information) since they cannot be evaluated altogether with regard to the chosen categories.

Some central points of the evaluation are presented below for the sectors and target applications under consideration.⁵⁰

- **Buildings:** In the building sector two types of energy-saving measures need to be evaluated differently. On the one hand these are measures where the impetus for renovation is to be provided by the instrument itself and where only the quality level of the current German building regulation (EnEV) is reached. On the other hand, in the case of measures that go beyond this level, it is assumed that the investment decision has essentially already been made and all that is required is a decision about the level of investment. The issue of barriers is much less marked for the second group than for measures where a fundamental decision still needs to be taken. Next to these two categories the more easily standardizable measures such as replacing heating systems or windows and renovation of the upper and lower building envelope need to be distinguished from measures applied to the façade because of their differing complexity. These EE measures are largely comparable in terms of the complexity of funding as they are all linked to comparatively similarly high levels of investment and usually financed via credit-based capital. In that case the number of the actors involved in the financing of these EE measures is an important criterion for differentiating the complexity of the funding models. In the case of one or a small number of actors, as is the case where financing is provided in the form of tax reduction or institutional funding organizations, the transaction cost in terms of searching, comparing and procedure is considerably lower than estimated for a saving quota with a thousand actors. The building stock, which offers the highest energy-saving potentials, can thus best be addressed via the instruments financial or tax incentives and new regulatory instruments.
- **Tertiary Electricity:** The highest number of cross-cutting technologies (mainly electrical appliances) can be grouped in the tertiary sector (public and private services) in terms of their suitability. Due to the high scope for introducing standardized measures and the large number of cases, technologies such as lifts, lighting, ventilation etc. are suitable for an energy efficiency obligation scheme. Information and communication technologies are equally well-suited for such a scheme, as is street lighting. In contrast, optimizations in the area of control/regulation of heat pumps through integration in building technology are more difficult to address via an energy-efficiency obligation scheme. Financing instruments enable all measures to be supported equally well.
- **Residential Electricity:** Electrical devices in private households are equally very suitable for all instruments observed. Only the effect of informative instruments is to be ranked lower as these often act as accompanying measures. Due to the low investment involved, the high number of actors is considerably less significant than in the building sector, because a simple voucher model can be used, for example. In terms

⁵⁰ For a more detailed discussion see Schlomann et al. (2012): in Annex 5 of this study, all technical EE measures are evaluated individually by the three categories.

of regulation, EE measures for electrical devices can be addressed well, above all via the mandatory introduction of audits, energy management schemes and the setting of minimum standards.

- Industry: In industry a distinction must be made between process and cross-cutting technologies. EE Measures that address the application of the best available technologies (BAT) for cross-cutting technologies are particularly suitable for an EEO, while the optimization of management, and in particular the use of the best available technology in terms of the process technologies and innovations, are less suitable for such a scheme due to the high investment costs, the long lifetime of investments and the difficulty in assessing the associated savings. With financing instruments, on the other hand, all technical measures are well addressed, with the exception of process innovations. Measures for optimized management, in contrast, are not suitable for direct financing; in this case information instruments such as energy management schemes are estimated to be more suitable. These can also suitably address measures for the use of the best available technologies, in particular for cross-cutting technologies (less so for process technologies). Similarly, the setting of ambitious minimum regulatory standards is similarly suitable. A regulatory approach for process technologies, in contrast, is evaluated as merely average due to the problem of defining standardized measures, the high investment costs and long investment cycles.

Based on the semi-quantitative assessment of suitability of the different instruments and the remarks made above, the energy-saving potentials that can be achieved with technical EE measures by the various instruments can be calculated (Table 5-4).

Table 5-4: Achievable cumulative annual energy-saving potentials in 2020 by suitability of the instruments^{1, 2}

		Energy Efficiency Obligation Scheme	Financial grants / subsidies, Funds	Tax reduction / exemption	Improvement of existing regulation (esp. compliance)	New / tightened regulation	Information / Advisory service
Buildings	TWh	207	265	265	57	208	68
Private Household	TWh	27	27	27	-	27	27
Tertiary Sector	TWh	20	20	21	-	20	21
Industry	TWh	15	17	15	-	17	29
Buildings	share of total potential	● 78%	● 100%	● 100%	● 21%	● 79%	● 26%
Private Household	share of total potential	● 100%	● 100%	● 100%	● 0%	● 100%	● 100%
Tertiary Sector	share of total potential	● 95%	● 95%	● 95%	● 0%	● 94%	● 96%
Industry	share of total potential	● 52%	● 58%	● 52%	● 0%	● 58%	● 100%

Legend:

●	> 75 %
●	25-75%
●	< 25 %

¹ Only very suitable, suitable and neutral EE measures are considered

² Explanatory note on the instrument columns: the first column only refers to an EEO, the second column both refers to a new EEF and existing (state-based) financial instruments, the remaining three columns only belong to the option "extension of existing instruments".

Source: Schlomann et al., 2012

The buildings sector, which offers the highest potentials, can be addressed suitably through financing programmes and regulation. If neutral EE measures are also included, a saving quota can also address large parts of the potential. In the area of household devices and electricity consumption in the tertiary sector, regulatory instruments with the setting of standards, saving quotas or financial instruments are equally suitable for realizing the potentials. This is because for appliances, unlike buildings, the size of the investment is not a fundamental parameter. The same applies for industry, in particular in the area of cross-cutting technologies. Mandatory audits or energy management schemes and the consistent setting of minimum standards can be beneficial in this context. An EEO can be effective with respect to easily standardized measures, whereas the effect of a financing instrument is assessed to be more beneficial for process-related measures.

The potential exploitation presented in Table 5-4 relates solely to the overall potential and thus to the specified energy-saving target in its high variant (Table 5-3). The figure only indicates the potential theoretically addressed by the respective instrument based on the assessment in Table 5-3. A complete actual exploitation of the potential is not likely due to several restrictions which will be discussed in the following sections. The high impact of a tightening and expansion of regulations in all sectors except industry represents rather a theoretical option, as the required regulatory scope would be unrealistic and implies distributional problems (see Section 5.3.5). The theoretically high rate of exploitation in the building sector by an extension of the existing financial or a more important role of fiscal EE instruments or an EEF has to be reflected against the budget-restrictions in the public sector (see Sections 5.3.7 and 5.3.8). The main challenge in this sector is to cover the large investment needs for the built environment by a mix of private and public capital in order to actually mobilize these potentials (Eichhammer et al., 2012; BPIE, 2012; RAP, 2011).

This enables us to conclude that by 2020 the high saving target as defined here cannot be achieved using any single one of the EE instruments examined here. Instead, a combination of at least two of the instruments listed in Table 5-4 is essential. The medium and low energy-saving target could be met solely by the extension of one of the already existing EE instruments, i.e. financial incentives or regulation. Whether this is in fact expedient, however, again depends on the further qualitative evaluation criteria that are discussed in the following sections.

5.3.2 Costs of the instruments

The overall costs of the instruments are differentiated using various cost categories, which are in turn incurred by different actors. We took into account the following cost categories:

- *Administrative costs* for the set-up, operation and monitoring of the instruments. These costs basically occur for all actors involved: for the state there is a need for the control of compliance both in the case of an EEO and even more in the case of regulatory instruments as e.g. building regulations or the implementation of EU Directives regulating energy-related products (Ecodesign and Labeling Directive); in the case of an EEO, the obliged actor has to build up such a system, too, which may lower the cost of the state compared to regulatory instruments, since the burden is shared between two actors. In any case, the implementer of an EE investment has to bear administrative costs which can be additional personnel and external consultation fees for companies and additional time needed for private households.
- *Programme costs*, i.e. the costs of the programmes actually performed. These costs occur in the case of all financial support programmes for EE technologies and also in the case of information and advice programmes, which can both be carried out under an EEO and an EEF or by the state or state-owned institutions (as in Germany the public bank KfW).
- *Additional investment costs*, i.e. the differential costs for the investment in an energy-efficient technology as compared to a standard technology; these costs are initially paid by the implementer of the investment, but are reduced by the programme costs; this is, however, not occurring in the case of regulatory instruments, where the implementation of EE has to be borne only by the investor.

An ex-ante quantification of these costs for all EE instruments analyzed here is, however, difficult due to a lack of detailed cost information. Additionally, in order to assess the costs in a comparable manner, many assumptions are necessary which make the assessment rather uncertain.⁵¹ Information on the possible administrative cost of the introduction of an EEO in Germany can be derived from existing experiences in other countries. In the impact assessment of the new EED, the European Commission

⁵¹ In Schlomann et al. (2012) we made a quantitative cost assessment, but the underlying assumptions have to be explained very carefully, which cannot be presented in detail in this paper. In the following, we confine ourselves to a semi-quantitative cost comparison. The principal conclusions, however, will be the same.

(2011) gives some evidence.⁵² These figures are, however, not directly transferable to our approach for Germany since we refer to additional savings assuming an ambitious baseline (see Section 5.2.1). This requires more complex and also individual EE measures (e.g. deep retrofit instead of low-cost insulation measures or partial refurbishment in the case of buildings) which will raise the administrative costs. Apart from that, the number of obliged actors under an EEO in Germany will probably be much higher than in most of the already existing systems. This will further raise the administrative costs both for the state and the obliged parties.⁵³

Taking these restrictions into account, we made a qualitative comparative assessment for the various cost categories of an EEO compared to the existing set of EE instruments in Germany (Table 5-5). For methodological reasons we assume that all EE instruments have to achieve the same amount of energy-savings. For the existing set of instruments this means a considerable increase of financial incentive programmes and/or a considerable enforcement in the control of compliance of regulatory instruments. Both imply rising programme and/or administrative costs.

Under these conditions, we conclude that similar overall amounts of costs are incurred across the different cost categories during the deployment of any EE instrument option when comparable energy-savings are to be achieved. The essential difference is which actor incurs the costs in the first instance, whether and how costs are to be passed on (see Section 5.3.5) and whether the funds are from the public or private sector (see Section 5.3.8). This means that the issue of costs is strongly connected to other evaluation criteria which will be analyzed in the following sections.

⁵² According to that source, the yearly administrative costs for the state amount to around 400 thousand Euro in UK and around 700 thousand Euro in France, the respective costs for the obliged actors lie between 195 million Euro for the second phase of the system in UK and 136 million Euro in France. These costs are, however, restricted to standardized EE measures which are usually not checked by an on-site visit and also depend on the way of the financing of the EEO scheme, which considerably differs between the countries (see Section 5.3.8).

⁵³ We estimate a number between 2.400 and 1.700 companies depending on how far smaller companies will be excluded from the system (Schlomann et al., 2012).

Table 5-5: Qualitative comparative assessment for the various cost categories of an EEO compared to the existing set of EE instruments in Germany (assuming the same amount of energy-savings)

Cost category / affected actor	Costs of an EEO compared to existing set of EE instruments ¹	Explanatory note
Administrative costs		
for the state	-	Assuming an ambitious control of compliance of existing (regulatory) instruments (building regulations, ecodesign, labeling).
for the obliged actor	+	New costs in the case of an EEO since a new administration must be built up by the obliged actor.
for the implementer of the EE measure	0	These costs are independent from the type of instrument and arise in any case.
Programme costs in case of EEO: obliged actor in case of existing EE instruments: state	0	The main difference is not the amount of costs, but who actually bears the costs and how they are passed on; we could not evaluate if one instrument is more efficient and therefore may need less programme costs for the same amount of energy-savings.
Additional investment costs for EE measures (compared to standard technology) for the implementer of the EE measure	0 (-)	These costs are initially independent from the type of instrument; they are reduced by financial incentives in the case of an EEO or financial support programmes, but not in the case of regulation.
Significantly lower	0 no significant difference	+ significantly higher

¹ For an EEO, the assessment depends on the organisational structure and the financing of the fund and therefore can be more comparable with the existing set (in the case of a state-owned structure) or an EEO (in the case of private financing and a more competitive organisation).

Source: Our own compilation based on Bürger et al., 2012

5.3.3 Market conformity and competitiveness

The EEO is the only approach of the instruments examined here that is directly applicable to energy utilities by imposing a concrete obligation which directly reduces the amount of energy. The other EE instruments analyzed are subject to other control mechanisms. A quantity control as in the case of an EEO is generally classified as particularly market-conform and competitive. This is mainly justified by the fact that the

most cost-effective EE improvement actions can in principle be chosen to comply with the obligation without distorting the market by subsidizing specific solutions available on the market. With respect to this principal advantage of EEOs some further issues have to be mentioned:

- In the competition between large and small companies the EEO represents a comparatively larger cost burden for smaller companies because larger companies have better opportunities to absorb their administrative and programme costs via scaling effects.
- Obligated companies with a regional distribution structure have better implementation prerequisites than new suppliers without a local anchoring and only a low level of customer proximity.
- The possibility that obliged energy suppliers can improve customers' loyalty or attract new customers by implementing EE measures for energy end-users has proved quite relevant e.g. in the existing EEO schemes in France and UK. This experience could also be valid for Germany.
- Whether the search process for the most cost-effective energy-saving potentials carries the lowest transaction cost in the case of an EEO depends to a large extent on the criteria, based on which the alternative EE instruments are designed. If the latter are strongly oriented toward the cost-potential curve, they may also realize the most cost-effective potentials at an equal search cost: to what extent this assumption differs from reality, could not be finally evaluated. Nevertheless, any deviation had a noticeable impact on the whole cost-benefit analysis as it is carried out here.
- No reliable statements can be made concerning the trading option, since for trading the experience from existing EEO schemes is rather limited and the role of certificate trading is generally evaluated as ambiguous (see e.g. Bertoldi et al., 2010).

5.3.4 Effects on the market for energy services

The introduction of an EEO can help to pursue the objective of strengthening the market for energy efficiency and energy services (e.g. in the form of new actors). Although broadly structured financial programmes and other EE instruments can stimulate energy services, too, the main advantage of an EEO is that it attributes an explicit economic value to savings. In the case of the other EE instruments there is only an implicit (and hidden) value to investors in energy efficiency.

The following evaluation takes into account the experience gained from other countries that have already introduced an EEO. However, what needs to be considered is the fact that the situation in those countries cannot be directly compared with Germany. First of all, the number of obligated companies and thus potential market entrants would probably be a lot higher in Germany than in the other countries (see Section

5.3.2). Further, different definitions of the concept of “energy services” need to be taken into account. In the narrow sense this can be limited to services where the energy-saving represents the strategic commercial objective; i.e. the customer is not sold energy in the form of electricity, gas etc., but instead a more complex service that may also include investments in buildings and facilities (e.g. contracting, energy audits, energy management or energy monitoring). In the broader sense the definition includes all services that result in energy-savings for the customers. In countries that have already introduced an energy efficiency obligation scheme, the broader definition is usually applied. In Germany the definition in the current discussion is only common in the narrow sense. Nevertheless, subcontractor and consultancy services under the broader definition have long been established in Germany: a differentiated supplier spectrum has emerged in the course of regulatory measures and financial programmes of recent decades.

The main difference between the actual grant schemes in Germany and an energy efficiency obligation with respect to the market for energy services lies in the general principle of these schemes (see Section 5.2.1). The EEO defines a certain amount of savings, thus the demand for energy services is directly created by the instrument. In contrast the grants do not directly create a demand for energy services, but customers still have to take an autonomous decision to create the demand.

As a result of the analysis it can initially be noted that an EEO has a stimulating effect on the market for energy services in the broad sense. Thus a saving obligation offers a cost-effective and comparatively simple-to-implement opportunity of implementing energy-savings via market actors. A market for energy services in the broader sense is established. For Germany such a context is not given, however, as the market for energy services (scope and diversity of suppliers and services offered, intensity of competition etc.) is already comparatively well-developed there, even if it is still a long way from a broad services market. Increasing the market size through EEOs may, however, open the road to further market actors.

The effect of an EEO becomes more complex where services are already established on the market. Above all, market size and the qualitative configuration of the measures need to be considered as influencing factors. In an already differentiated service spectrum, the introduction of a saving obligation would lead to a higher concentration of providers in a static market, which could lead to predatory competition. The development of new services would not be anticipated. That is to say, this situation would not result in an improvement as compared with the status quo and – if suppliers are crowded out – could even constitute a deterioration. The basic requirement for preventing such a development is therefore to extend the market and develop new services.

The development of new services pursuant to the narrow definition requires first of all the dismantling of specific barriers that exist in the market (e.g. through regulatory policies or risk minimization in the start-up phase etc.). This requires at least a combination of different instruments that, with a certain degree of political guidance, ensure that existing or new market actors focus on energy services that were not previously available, or only to a limited extent.

5.3.5 Secondary effects of the instruments

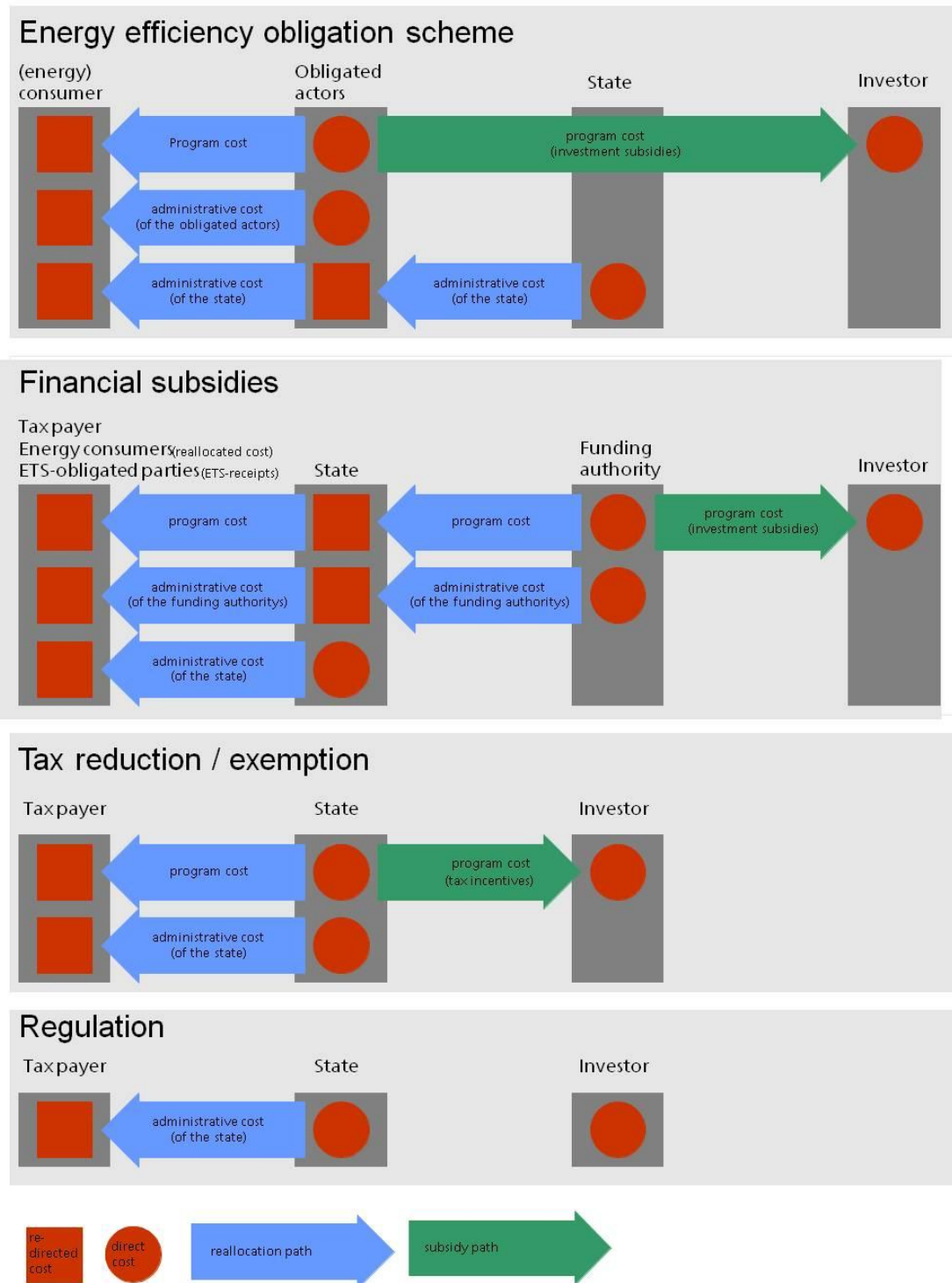
Due to methodological restrictions not all secondary effects of the instruments can be considered in quantitative terms. This mainly includes distributional effects of the instruments, their possible impact on the energy price and a possible impact of the energy cost savings if initial cost savings are used to generate new energy consumption (known as the “rebound effect”).

With regard to the *distributional effects* of the instruments, a distinction needs to be made between the costs incurred directly by the various actors and the costs passed on. For energy-efficiency obligation schemes, it can be assumed from theoretical considerations (Sorrell et al., 2009a) and the experience of existing schemes in other countries that the obligated companies will pass on both the programme costs as well as the administrative costs, usually via the energy price, to the end customer, if the obliged actors are not regulated.⁵⁴ This means that all end customers, and energy-intensive users in particular, are initially burdened by higher energy prices, which fundamentally complies with the “consumer-pays” principle. However, the burden would effectively largely fall on those demand segments that have the lowest elasticity in terms of demand (especially private households and smaller companies) in the first instance. In a financial scheme the distributional effects depend largely on the way the funds are raised. With apportionment funding a passing on to the end customer can be assumed, as with an EEO; with funding from general state budgets, costs are passed on to the tax payer. The distributional effects then also depend on which taxes are increased (income taxes or excise duties). For regulatory measures the large part of the costs falls on the investor obligated under the regulatory provisions. Figure 5-2 summarizes the main distribution paths of the costs of the EE instruments.

⁵⁴ As e.g. in Italy and France, where the obliged actors cannot fully recover the obligation costs through energy tariffs because they are not allowed to freely change the energy tariffs applied (see e.g. Bertoldi et al., 2010).

In terms of further *energy price effects* induced by the instruments it should be noted that a rise in prices increases the profitability of the energy-efficiency investments. This also tends to increase the scope of the savings achievable by the instruments.

A further possible secondary effect is that all instruments investigated are aimed at implementing additional energy-efficiency measures. These result in a reduction of the energy costs for all actors that are implementing such an investment in the respective scheme. The consequence can be direct *rebound effects* (negligent handling of energy) and indirect rebound effects across economic interrelations. However, due to the basic assumption that all instruments will achieve comparable energy-savings, we observe that the level of these effects will not be fundamentally different across the EE instruments. It should not be neglected, however, that rebound effects vary widely between different technologies, sectors and income groups (Sorrell, 2007; Sorrell et al., 2009b). For Germany, there is first evidence for a few technologies (cars, lighting) on the existence of a rebound effect (Frondel et al., 2008 and 2012), though empirical research is only at the beginning.



Source: Schlomann et al., 2012

Figure 5-2: Distribution paths of the costs of EE instruments along the involved actors

5.3.6 Interactions with existing instruments

With the introduction of new instruments for promoting energy efficiency, the interaction with the existing legal and funding framework needs to be precisely investigated. This applies in particular where the new instrument is to be introduced in a complementary manner to the existing instruments and not as a substitute. As many energy efficiency policies introduced in Germany are based on European regulations (e.g. minimum standards for electrical devices or the EU emissions trading scheme EU ETS)⁵⁵, any introduction of a new instrument would be on a complementary basis in any case. If we assume that both an EEO and an EEF are comprehensive meta-instruments and designed in such a way that they both initiate a comparable mix of measures, the interactions with the existing instruments are comparable in many respects. Interactions occur above all at the following levels:

- Selection of the baseline against which savings in the scope of the saving quota or financing through the efficiency fund are accounted for.
- Selection of approved measures (scope of validity of the saving quota or target sectors that are financed through programmes and measures under the efficiency fund).
- For financial incentive programmes: possibly dual financing by different financing programmes.

In order to keep interactions to a minimum from the outset, or to exclude them as far as possible, the design of all EE instruments considered was selected to exploit synergies (e.g. in the context of the completion routines) with existing instruments (above all energy and electricity tax) and to maximize the effect in terms of the intended target (additional saving of energy). This is reflected in particular in the selection of the baselines and EE measures approved in the scope of the instruments examined. In the case of the existing financing programmes, the possible introduction of an EEO and/or an EEF may cause the need for an adaption of the financing conditions.

Though we tried to minimize interactions between the EE instruments in order to prevent negative effects such as e.g. inefficiencies, free-rider-effects and a high complexity of the landscape of EE instruments, there may also be good arguments for a certain degree of double- or even multiple-instrumentation. Deficiencies of one instrument (e.g. of regulation due to a lack of control) could be compensated by the combination with another incentive instrument (e.g. subsidies) (Schlomann et al., 2012). A certain

⁵⁵ The main focus of existing analysis is on the possible interaction of EEOs with the EU ETS (e.g. Sorrell et al., 2009a; Harrison et al., 2005; Meran et al., 2008; Gaudioso, 2007); but similar considerations have to be taken into account for other policy instruments (e.g. Perrels and Oranen, 2007).

amount of overlap of the EE instruments will even be unavoidable if the ambitious energy-efficiency targets especially for the building sector shall be reached.

5.3.7 Political acceptance

The probability of a new instrument being introduced depends strongly on its (partially very subjective) assessment by politically relevant interest groups. In particular there has to date only been little information on the acceptance of the instrument of an EEO in Germany. Overall, there is a comparatively high level of uncertainty. The majority of the potentially obligated energy providers are rather sceptically disposed to the instrument. Supporters of the instrument can be found above all at the level of the associations and companies of the energy-efficiency sector (especially manufacturers providing single devices as e.g. electrical appliances or heating systems). Some actors have developed their own concepts for an EEO. The position of the consumer side is divided and mainly depends on the question concerning which party is mainly carrying the load (e.g. the obligated actor or the consumer by apportionment of the costs).

However, the acceptance of other EE instruments investigated also differs. The acceptance of a broader EEF is dependent to a large extent on its financing. If this is done by apportionment to the energy prices, the reaction of the consumers would probably be similar to the price increase linked to costs incurred by energy supply companies and passed on to the energy price within an EEO. Conversely, this instrument would be favoured by the energy suppliers because it is not connected to any obligation on the part of the companies. Experience shows that a tightening of regulatory provisions, or even the introduction of new obligations, results in considerable resistance on the part of the affected associations. Tighter enforcement of the existing regulatory provisions (e.g. Ecodesign), usually the responsibility of the Federal States, is being seen as a problem, as it is connected to additional costs. However, its acceptance amongst the other affected actors (investors, craftsmen) ought to be higher. This applies even more to the expansion of the public-funded financing programmes in the scope of the current range of EE instruments. However, an expansion of this instrument would lead to an increased burden on the national budget and conflicts with the target of reducing debt and easing the burden on public budgets.

In sum, it can be determined that no clear preference for any of the EE instruments investigated can be identified with regard to the criterion of political acceptance. There are supporters and opponents for all instrument options.

5.3.8 Scope for refinancing

With respect to the scope for refinancing of EE measures there are fundamental differences between the EE instruments investigated here. There are further different financing options within the same instrument, which in turn may lead to a different evaluation.

For an EEO this affects in particular the question of apportioning the additional costs to the end energy price or its potential regulation, the option for refinancing through the sale of certificates and the ratio of private-sector and public funds used for financing the scheme. The schemes already operating in other countries differ with respect to these features, some quite markedly. An EEO permits budget-independent funding of EE measures, albeit with the drawback of higher energy prices with associated follow-up effects such as distribution effects (see Section 5.3.5) or low acceptance amongst the affected groups (see Section 5.3.7). Additional funding from the sale of surplus certificates may be possible in theory, but in most existing schemes (with the exception of Italy) trading does not take place *de facto*, or is excluded from the outset (see e.g. Bertoldi et al., 2010). This means that the level of private-sector funds that can be generated using this instrument is limited, unless either the consumers accept the costs which are passed on to them or the obliged parties develop business models that compensate for the investments to be undertaken with benefits from energy-savings. The existing schemes in other countries show that so far further (public) funds or supplementary instruments of financing mechanisms have been used, in particular for funding larger measures in the buildings sector.

There are a number of proposals from various expert reports (Irrek and Thomas, 2006; Perrels and Oranen, 2007) for financing a broader EEF in Germany, which vary according to whether it is being financed only from public funds, via cost apportionment by a levy on the energy price, or by a mixed financing from private and public-sector capital. The following financing options are being discussed: financing from the revenue generated by the eco tax, from the Federal budget or the revenues generated by emissions trading (as in the case of the already existing energy and climate fund), via a surcharge on the energy price or energy bills, via public-private partnerships and via an “optional fund” that is funded, for instance, from the fines from a possible EEO in the case of non-compliance. We examined these funding options in terms of how targeted the funds are allocated to the promoted EE technologies, the market dynamic they generate and the potential mobilization of additional private-sector capital. In sum, it can be determined that a design via consumption-dependent apportionment exhibits most benefits in respect of the tapping into private joint-funding, anticipated market dynamics and targeted allocation. However, this option is currently difficult to implement given the competing pressure of renewables on electricity prices though, in con-

trast to renewable electricity the surcharge could be distributed on all energy uses. To that extent the simplest variant for implementation – public funding – appears to be pragmatically expedient, whereby the financing of the fund would in turn be subject to an upper ceiling due to the high priority of reducing national debt. It is unlikely, however, that by this variant sufficient funds could be mobilized as long as the state budgets are under pressure.

Similar restrictions apply to the instrument option “expansion and improvement of the existing range of instruments”, for which no separate analysis was made, but instead a continuation of the existing financing from state funds (largely tax-funded or funded by the revenues from emissions trading) was assumed. Here both the expansion of financing as well as improved enforcement of regulatory provisions, and also supplementary informative and advising measures, require an additional level of funding that largely needs to come from public budgets.

5.4 Conclusions

In this paper, we evaluated different EE instruments – an EEO, an EEF, and the expansion of the existing set of EE instruments in Germany – in terms of several quantitative and qualitative criteria. We showed, that the evaluation of the EE policy instruments investigated here needs to consider many dimensions and affects many actors. In this sense, our analysis can form the analytical foundation for political decisions on a suitable mix of EE instruments in order to achieve ambitious energy-saving targets.

The starting point for the evaluation was the specification of an energy efficiency target for 2020 in three variants (high, medium, low). This target was determined based on the existing energy-efficiency potentials in Germany in the final energy consumption sectors (without transport). The potentials are measured against an ambitious reference development which includes present standards and regulations in Germany. Excluding the transport sector, the target in its high variant comprises a required saving of 343 TWh (cumulative annual saving) in 2020, corresponding to an average annual saving of 29 TWh by 2020. For the medium and low target an exploitation of the total potential of 2/3 and 1/3 respectively was assumed. The highest contribution to the target comes from the building sector. Given the flexibility mechanisms introduced by the EED (such as the recognition of Early Action, i.e. measures initiated from the beginning of 2009 to the start of the EED period in 2014) only part of these potentials may need to be realized in Germany in fulfillment of the EED (Art. 7) requirements.

On this basis we analyzed first in a quantitative approach whether the scope of the EE instruments discussed is suitable for exploiting the energy-saving potentials deter-

mined. The main result was that the high saving target cannot be achieved using any single one of the EE instruments examined here. Instead, a combination of at least two of the instruments is essential. The medium and low energy-saving target could be met solely by the extension of one of the already existing EE instruments, i.e. financial incentives or regulation. Whether this is in fact expedient, should not solely be assessed on the basis of the suitability of the instruments for exploiting the saving potential. Instead, an array of further evaluation criteria needs to be considered. Alongside cost aspects, political considerations play an important part, such as the strategic view of the development of an energy services market, the question of refinancing, the market and competitive compatibility, and not least distributional impacts. A key requirement is that the combination of instruments fits the existing instrument landscape.

The evaluation of the EE instruments along these criteria showed an ambiguous picture. With regard to some of the criteria mentioned above, we could find advantages of an EEO compared to alternative EE instruments:

- The identification of the most cost-effective energy-saving potentials can be a benefit of an EEO, if the design of the system gives enough incentives for the creation of cost-effective bundles of EE measures. The amount of the benefit, however, depends on the organization of the search process for EE measures in the case of alternative EE instruments.
- Based on the experience of other countries, EEOs can have a stimulating effect for the market of energy services. This may also be true for Germany, though this market is already comparatively well-developed with regard to the scope and diversity of suppliers and services on offer and the intensity of competition. A further expansion of the energy service market could, however, motivate further market actors, especially among the obligated parties.
- Looking at the large investments needed to tap the identified saving potentials especially in the building sector, the issue of refinancing is extremely important. If public funds with unlimited availability were forthcoming in the longer term then, according to our results, even the high energy-saving target could be achieved with a combination of new and increased regulation and traditional state financing. But as the recent financing problems of the newly established energy and climate fund in Germany confirmed, the financing of EE measures by public funds is rather restricted and volatile. Therefore, the possibility of a budget-independence of the funding in particular supports a supplementary deployment of new instruments such as an EEO and/or an (apportionment-funded) EEF.

With regard to other criteria, however, no clear advantage of any of the EE instruments could be identified:

- With regard to the cost aspects we referred in this paper results from a comprehensive cost evaluation (Schlomann et al., 2012) that comprises both the (additional) in-

vestment costs required for the implementation of EE measures as well as all administrative and programme costs. The largest cost factor are the investments, which are initially independent from the instrument. The remaining costs are also ultimately incurred by all instruments if they are to achieve comparable energy-savings, as it was assumed here. Under these conditions, we conclude that the overall amount of costs across the different cost categories are is rather similar in the deployment of any EE instrument.

- There is, however, an essential difference between the EE instruments with regard to the initial and final allocation of the system costs. The central question is which actor incurs the costs in the first instance and whether and how they are passed on. This implies significant distributional differences between the EE instruments, which must, however, be finally evaluated at the political level.
- In terms of political acceptance, the analysis shows that all EE instruments exhibit weak points that may vary depending on the actors and social groups affected as well as the respective design of the instruments. Finally, no clear preference for any of the instrument options could be identified since there are supporters and opponents for all.

Germany is, hence, arriving at a possible turning point in its policy landscape. That is, the country has to decide whether it can continue further with the past policy of an instrument mix based on subsidies from public budgets, regulation as well as informational measures. Given the different flexibility options foreseen by the new EED in fulfillment of Article 7, it is possible that it is not necessary to tap all of the additional saving potentials calculated here. In that case, Germany may still be able to opt for its traditional approach, which has proved to be very successful in the past. This may be the easiest way to achieve the targets set out by the EED as there is no need to introduce new policies with associated uncertainties and transaction costs.

However, Germany may also realize that for the long-term targets up to 2050 and for the fulfillment of the “Energiewende” targets such as the doubling of the refurbishment for existing buildings, more ambitious policies will be necessary already before 2020. This requires an urgent need for mobilizing both public and private funds. Several variants have been discussed in this analysis. Common to all these financing schemes is that the end consumers may have to carry the costs which are passed on to them, e.g. by the obliged parties in EEOs or by direct charges on energy prices to feed an EEF. These charges come in addition to already existing, and possibly further increasing charges on energy prices from renewable energy sources, though they could be spread out over a larger set of energy carriers than just electricity. In absolute terms, they may add a burden, especially to the low-income households, which may exceed their ability and willingness to pay. An important aspect for stabilizing such a system is therefore to create suitable business models in a functioning energy service market,

which both allow sharing the burden of the upfront investments between consumers and market actors and the benefits from saved energy. Only such an integrated approach will allow the financing of the EE investment needed in the end. The earlier such an expanding market for new business models is initiated, the more actors are involved, and the more efficient private financing may become part of supplementing the present EE policy mix. Stimulating such a development may therefore be a major argument for Germany to enter a learning process regarding one of the new instruments discussed in this paper.

The results of this analysis were too ambiguous in order to judge finally whether an EEF or an EEO is more suitable in that respect. But the theoretically more market-conform properties of an EEO may make it at least a candidate for further policy learning. Combining this instrument with additional supporting instruments such as risk-minimizing elements for new actors in the market could be the ladder on which energy services and new business opportunities can develop favourably. Financial actors at least seem to realize more and more that the rate of return on EE investments may be lower in the short term than with alternative investments, but that this may be compensated by the fact that the risk in the market is relatively low.

Acknowledgements

This paper is partly based on a research project funded by the Federal Ministry of Economics and Technology in Germany. We would especially like to thank the representatives from the Federal Agency for Energy Efficiency (BfEE), the Federal Ministry of Economics and Technology (BMWi), and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) for the fruitful discussions during the work on the project. And we thank the three anonymous reviewers of this paper for their constructive and helpful comments and suggestions as well as Vanessa Dolbér-Raffler for the proofreading of this paper.

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6 Understanding retailer compliance with product label regulations: A framework and empirical test for the European Energy Label*

Abstract

Retailers play an important role in the implementation of many product labeling regulations, yet they sometimes fail to comply with these regulations. In order to understand retailers' (lack of) compliance with product label regulations, we first develop a theoretical framework that encompasses instrumental and normative motives. We then test this framework in the energy label context through a large-scale empirical study covering 1,314 retail stores in all 27 European Union countries. We use two separate sets of data collected at the store level: a compliance audit (providing for each store the percentage of correctly labelled appliances) and a standardized survey of store managers. The results show that both instrumental factors (especially fear of internal sanctions) and normative factors (internalization of regulation and consumer pressure) help explain retailer compliance with product label regulations. Both results have policy implications. The relevance of internal sanctions suggests that policy makers could rely on voluntary controls through retailers rather than invest in costly governmental controls. The fact that retailers were found to be sensitive to consumer pressure indicate that communication about energy labels should be increasingly geared towards consumers.

* A slightly adapted version of this paper was submitted to the Journal of Marketing. Authors are Corinne Faure, Joachim Schleich and Barbara Schlomann.

6.1 Introduction

Recent years have witnessed some interesting legal cases involving retailer violations of product labeling regulations. Retailers have been pursued both for violations involving their own private labels and for violations linked more directly to their role as distributors. First, a few high profile lawsuits have made it clear that retailers have to respect labeling regulations for their private label brands: in 2004, Sears was pursued for allegedly misleading consumers with “Made in USA” labels on its Craftsman tools (Vigiletti v. Sears, Roebuck & Co, 2005, 2007); in 2013, a class action lawsuit was filed against Whole Foods for its use of the label “all natural” on baked products containing some synthetic ingredients (Mary Garrison, et al. v. Whole Foods Market Inc., 2013); in early 2014, Kroger also faces a class action lawsuit for its use of the labels “cage free” and “raised in a humane environment” for its premium branded Simple Truth chicken produces (Anna Ortega v. The Kroger Co, 2014). Even more interestingly, some recent legal cases directly focus on retailers’ implementation of product label regulations (beyond the private labels special case, for which retailers are treated like manufacturers). In 2013, the Federal Trade Commission (FTC)⁵⁶ settled charges with three retailers for wrongly selling real fur products as fake fur, thereby violating the Fur Product Labeling Act (FTC, 2013); in 2010 and 2011, the FTC charged some online retailers for failing to post EnergyGuide information for major appliances on their websites, as required by the Appliance Labeling Rule (FTC, 2010, 2011); settlements in these latter cases involved fines of over 500,000 USD. In another 2013 case, a product liability lawsuit for a roof shingle cleaning solution led into convoluted responsibility identification between manufacturer and retailer: as stated by the plaintiffs, the retailer’s employees discarded the warning labels provided by the manufacturer that informed consumers about the highly abrasive nature of the product; the court therefore had to determine whether the retailer had been negligent through removal of product labels (Neil v. Shingle Care, LLC, 2013).

These legal cases and ensuing settlements bring to our attention the important role of retailers in the implementation of product labeling regulations: retailers are typically responsible for diffusing the product label information (usually provided by the manufacturers) at the point of purchase. These cases also indicate that retailers sometimes do not comply with these regulations. In the marketing literature, a few papers have investigated retailer compliance with some regulations (for instance, Adams (2004) for the distribution of firearms, Gilliland and Manning (2002) on restaurant compliance with

⁵⁶ The Federal Trade Commission (FTC) is an independent agency of the United States government responsible for the promotion of consumer protection and the elimination and prevention of anticompetitive business practices.

food safety rules, Wayland and Swift (2002) for retailer compliance with the American Disability Act, or Antia et al. (2006) for gray market compliance). So far however, the marketing academic literature has not investigated retailer compliance with product label regulations. While there have been numerous papers published on consumer reactions to various product labels (e.g., Balasubramanian and Cole, 2002; Burton et al., 2009, Wansink and Chandon, 2006), the role of retailers in the implementation of these regulations has not yet been explored. Our purpose in this research is to develop an understanding of the factors leading to retailers' (lack of) compliance with product labeling regulations. Identifying the reasons for retailer lack of compliance with product labeling regulations should help policy makers in the design of better regulations (or enforcement) as well as retail management in the avoidance of costly fines and sanctions.

Our objective in this research is to explain why retailers might (fail to) comply with product labeling regulations. For this purpose, we first develop a theoretical framework that reconciles both instrumental and normative approaches to compliance. We then test this framework empirically with a large-scaled international study focusing on a specific context: retailer compliance with the EU energy labeling regulations. The results show that both instrumental (especially fear of sanctions) and normative (internalization of regulation and social norms) factors help explain retailers' compliance with regulations. Using these results, we develop specific recommendations for retailers and public policy makers.

The main contributions of this article are as follows. From a theoretical perspective, our framework reconciles instrumental and normative models of compliance; we conceptualize compliance as being influenced by two types of instrumental factors, (1) the perceived costs associated with compliance and lack thereof and (2) the perceived benefits associated with compliance and lack thereof and by two types of normative factors, (3) internalization of the regulation and (4) social pressure to comply. Methodologically, unlike previous studies of compliance with regulations, our study focuses on observed compliance rather than self-reports of compliance or of intention to comply. The use of observational data alleviates concerns about social desirability biases that are common to surveys using stated intentions to comply (Steenkamp et al., 2010). The combination of observational and survey data allows a clear separation between dependent and independent variables, thereby addressing concerns about common method bias. Moreover, our study is aiming for a high degree of generalizability: we test our framework for the worldwide most widespread energy label (European energy label) on 6 product categories and in all 27 European Union countries, using a representative sample of retail stores in each of these countries; in total, compliance was checked for 94,094 appliances in 1,314 stores. Methodologically, we introduce the fractional logit

approach, an approach developed to analyze bounded dependent variables such as proportions and particularly adapted when many responses are at the extremes (0 or 100%). Finally, substantively our study is to our knowledge the first attempt at obtaining insights on retailer compliance with energy labeling regulations, thereby contributing on one hand to the growing literature on product labels (with a focus on retailers instead of consumers) and on the other hand to the literature on sustainable marketing and especially energy consumption.

The remainder of the paper is organized as follows. We first develop a theoretical framework of compliance (Section 6.2). We then provide a brief background of the EU energy labeling framework and the demands put on retailers through this regulation, before describing the operationalization and test of the framework for the empirical study (Section 6.3). Section 6.4 summarizes and discusses the main findings. The concluding Section 6.5 offers suggestions for future research.

6.2 Theoretical framework: model of regulatory compliance

Regulatory compliance has been studied intensively at the individual level in the area of criminology (e.g. Becker, 1968) but also at the organizational level (e.g. Gilliland and Manning, 2002). Two main approaches can be found in the literature. Instrumental models explain compliance through functional motives in which social actors comply either in order to further their own self-interest or to avoid possible sanctions. Normative models explain compliance through the actors' internalization of the regulations or through social norms to comply. While most research focuses on either one or the other approach, recent research suggests that both models are complementary rather than substitutes (Beach, 2005), and can therefore both contribute to our understanding of regulatory compliance. Following this logic, we therefore include both approaches in our theoretical framework.

6.2.1 Instrumental models

Instrumental models stem from a functional perspective: actors comply with regulations as the result of a cost-benefit analysis (Becker, 1968). First developed in criminology, this approach has been used for a variety of regulations, such as for instance safety belt, drink and drive, or non-smoking regulations. It has also been used in a business context, for instance for the respect of accounting reporting laws. In this approach, costs attached with compliance with a particular regulation are compared to the costs attached with non-compliance (typically sanctions in the case of discovery) and with the associated benefits of complying (or not complying) (Baron and Baron, 1980). Regu-

lated actors therefore make trade-offs between costs and benefits and mentally compute an expected value for complying and not complying. Following this comparison, actors then decide whether to abide by a regulation or not.

Typical compliance costs include effort and time associated with complying (for instance, cleaning time necessary to follow food sanitary regulations (Henson and Heasman, 1998; Traill and Koenig, 2010) as well as possible monetary costs associated with compliance (for instance, the equipment or personal costs necessary for retailers to abide with regulations on store access to disabled consumers (Wayland and Swift, 2002)). Such costs have been shown to be negatively related with compliance. Costs of non-compliance are usually subsumed under sanctions, either monetary or of other nature, received as a consequence of not following the regulation (Beach, 2005), such as for instance fines for non-compliance (for instance, fines for retailers who do not provide Energy Guide information; FTC, 2010, 2011), or consumers boycotting products of companies that are caught not following regulations (such as for instance the current UK boycott of Amazon for tax evasion or the US boycott of tuna products because of dolphin fishing (Wright, 2000)). Typical compliance benefits may include favorable treatment through control institutions or through customers. For instance, research has shown that many consumers (especially non-smokers) report increased intentions to go to bars and restaurants following non-smoking regulations (Biener and Siegel, 1997). Compliance benefits may also include other dimensions, for instance reduced costs. For instance, non-smoking ordinances in restaurants have been shown to help reduce cleaning and maintenance costs due to cigarette butts and tar on walls and windows as well as fire insurance fees, thereby directly affecting the operating costs of the companies concerned (Alamar and Glantz, 2004).

Overall, the functional approach suggests the following hypotheses:

H1a: Perceived costs of complying with a regulation are negatively related to compliance rate.

H1b: Perceived benefits of complying with a regulation are positively related to compliance rate.

H2: Perceived costs of non-compliance are positively related to compliance rate.

6.2.2 Normative models

Normative models are consistent with Giddens' (1984) theory of structuration. Giddens (1984) points out that while laws and regulations are typically created on the basis of instrumental motives, they form over time a frame for social action, indicating what is

socially acceptable and what is right. Two factors are at the core of normative models: 1) internalization of the regulation, that is, the conviction that the regulation is actually legitimate and can help achieve a worthwhile societal goal and 2) social norms, that is, the social pressure perceived by members of a society to comply with the regulation—or the social costs attached with acts of non-compliance.

According to Giddens (1984), *internalization* occurs over time: regulations gain legitimacy over time, as the motives for the regulation become internalized and the benefits get weighted higher than the costs. Safety belts regulations exemplify this process: while at the outset, these regulations generated quite some resistance, “buckling up” has over time become a reflex in most industrialized countries. Internalization may also occur from the beginning, when the regulated actors are in strong agreement with the objectives of the regulation and therefore follow this regulation out of conviction and not only obligation (Andenaes, 1977; Tyler, 1990). For instance, Nörstrom (1978) found that moral agreement with drinking laws was the best predictor of compliance with these laws. Conversely, internalization may be jeopardized if a regulation is perceived to be at odds with some other important internalized goals or values. For instance, the phasing-out of incandescent light bulbs has encountered serious resistance because efficient light bulbs are perceived as less aesthetic and as potentially damaging to the environment because of their mercury content (Remodece, 2008; Frondel and Lohmann, 2011). In summary, we therefore predict that:

H3a: The length of implementation of a regulation is positively related to compliance rate.

H3b: Agreement with a regulation is positively related to compliance rate.

H3c: Perceptions that a regulation is directly at odds with other important goals of the regulated actors is negatively related to compliance rate.

Beside internalization of regulations, normative models also point to the importance of social norms. Consistent with Festinger's (1954) theory of social comparison, as a regulation gets implemented through more and more actors in a society, compliance becomes the social norm, and as a consequence lack of compliance becomes more and more difficult to justify and more remarkable: actors who do not comply may fear standing out and becoming isolated. Research on descriptive social norms indicates that actors use information about what others in their environment do as an orientation for what they themselves should do. Cialdini et al. (1991) for instance explain that descriptive norms are effective because they provide a signal about what is an effective behavior in a given situation. Descriptive norms have been shown to be particularly effective when the focal actors feel similar or feel close to the actors represented

(Cialdini and Goldstein, 2004; Goldstein et al., 2008). The fact that many other regulated actors follow a regulation therefore provides a signal that the costs of compliance are not excessively high, and that its benefits have been internalized by many and are therefore socially accepted. This therefore creates a social pressure to follow the regulation that builds up as more and more regulated actors do follow it. Previous research has shown that such norms are at play in a business context (Heide and John, 1992). In a retailing context, we therefore expect that compliance will increase as the rate of compliance of surrounding stores (peers) increases.

H4: Peer normative pressure to comply is positively related with compliance rate.

Besides peer normative pressure, normative pressure to comply may also stem through other important stakeholders, especially customers. As suggested by the theory of planned behavior (Ajzen, 1991), decision-makers are affected by what they believe that other significant others want them to do. In a business context, customer expectations are of course of particular relevance for retailer actions. At the origin, product labeling regulations are developed with consumer protection in mind; through the labels, consumers are meant to be better informed about important characteristics of the products (Sutherland, 1991, 1996; Howarth et al., 2000). It is therefore logical that consumers may exert pressure on business to actually comply with these regulations. Retailing managers' perceptions of the extent to which the content of this regulation is important or not for consumers are likely to affect the extent to which retailers comply or not with a regulation. We can therefore expect that store compliance will increase as the perceived customer pressure to comply increases.

H5: Customer normative pressure to comply is positively related with compliance rate.

To summarize, frameworks of regulatory compliance are dominated by an instrumental and a normative approach. While most authors typically advocate one or the other, both approaches appear to be more complementary than contradictory. This is particularly apparent when considering the (social) costs that are explicitly considered in both frameworks, or the fact that internalization of a regulation can also be framed as leading to changes in the weighting of costs and benefits. Pushing one step further, one could consider that the costs of implementing a regulation decrease as actors become more apt at it. In a recent paper, Beach (2005) proposes to use an integrative framework of regulatory compliance in which both instrumental and normative models contribute to explaining compliance. We follow this approach and include both instrumental and normative factors to explain the antecedents of retailer compliance with the product labeling regulation. The proposed framework therefore includes costs and benefits,

internalization of the regulations, and social pressure. We expect that compliance with the regulation will be negatively related to perceptions of costs of implementing the regulation and positively related to perceived benefits, internalization and social pressure.

So far, we have discussed compliance with a regulation as a willing act through the regulated actors (Kumar et al., 1992). However, it is also important to note that failure to comply may also be due to an inability to comply rather than to a purposeful attempt to break the rules, which would be opportunism (John, 1984). To be complete, our framework should therefore also account for the fact that the regulated actors may not be able to comply with the regulations, and this, independent of their motives to comply.

H6: Factors leading to retailer inability to comply are negatively related to compliance rate.

Figure 6-1 represents the proposed conceptual framework.

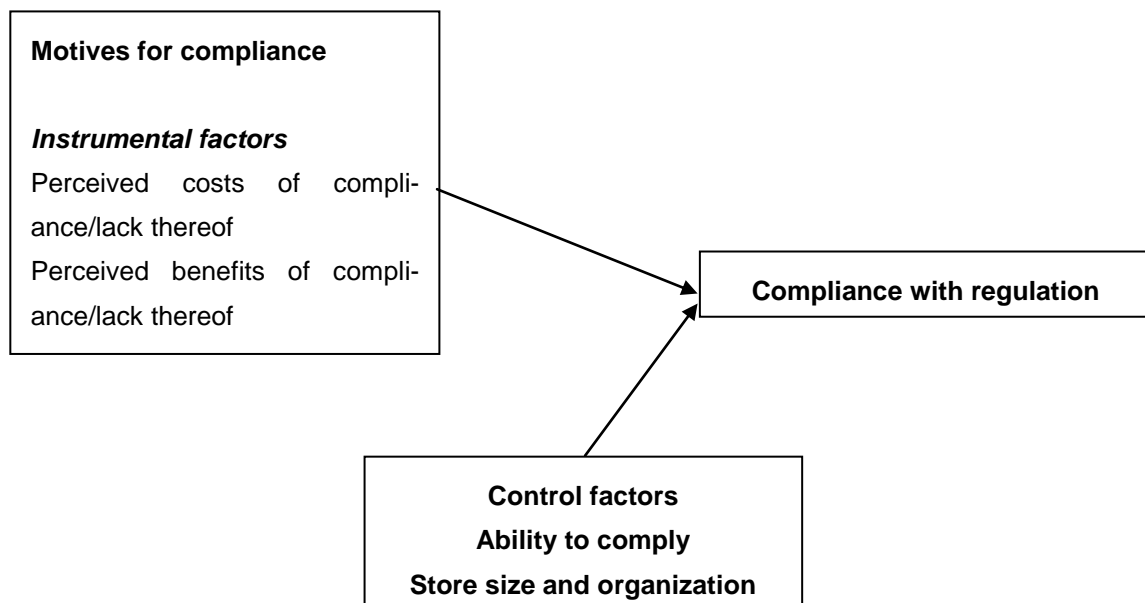


Figure 6-1: Theoretical framework of compliance with product labeling regulations

6.3 Empirical Study

The proposed framework was tested in the context of compliance with energy labeling in the European Union (EU). Before describing the method and results of the study, we will provide some background on this context.

6.3.1 Background on EU energy label

Household appliances, which are estimated to account for 34% of EU household residential electricity consumption (Bertoldi and Atanasiu, 2009), have long been the target of regulatory attention. One of the largest regulatory attempts to deal with energy consumption of household appliances was initiated in Europe in the early 1990s. Through the Framework Directive 92/75/EEC on Energy Labelling of Household Appliances, the European Union (EU) introduced a mandatory labeling system that over time has been applied to the following household appliances: refrigerators, freezers, washing machines, driers, dishwashers, electric ovens, air-conditioners, TVs, and household lamps; the system was recently extended to cover further appliances, including computers, monitors, electric motors, ventilation fans, or electric pumps (eceee, 2011). Currently, mandatory labeling schemes exist in 54 countries, voluntary schemes in five countries and nine more countries are in the process of introducing such schemes (World Energy Council, 2013, p. 95). Among the existing schemes, the EU labeling scheme, which served as a model for several countries, including Argentina, Brazil, China, Egypt, Iceland, Iran, Israel, Norway, Russia, South Africa, Switzerland, and Tunisia (Harrington and Damnics, 2004; World Energy Council, 2013) is the most widespread energy labeling program worldwide.

The EU energy label is a comparative label system (Harrington and Damnics, 2004). Appliances are rated on a letter scale (with A being the best and G the worse rating⁵⁷) that is also color-coded from a green code for A-rated appliances to a red code for G-rated appliances (Figure 6-2). Physically, the EU energy label consists of two parts: a basic label and a product fiche (see Figure 6-2). The basic label depicts the label's color codes and the information requested for a given product category; for instance, washing machine labels require information about electricity consumption per cycle, washing and spin drying performance, capacity, and noise level; refrigerators require information about electricity consumption, fresh and frozen food volume, and noise level. The product fiche consists of the information specific to a given appliance; it pro-

⁵⁷ At the time our surveys were carried out.

vides for instance the exact rating, number of kWh, volume, and decibels of a given refrigerator; it is normally provided with each appliance by the manufacturer.

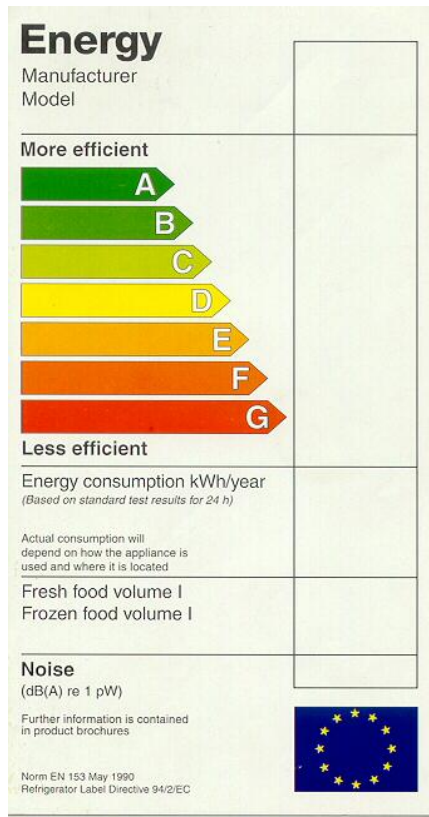


Figure 6-2: Picture of a basic energy label (refrigerator)

The EU energy label was progressively introduced in Europe. The implementation of the Directive into individual country law differed, with individual EU countries applying the Directive immediately and others taking up to 5 years to adopt it into national law; of course, the countries joining the EU in the 21st century could only apply the regulation after being part of the EU. As a consequence, the regulation was implemented at different points in time in different EU countries.

The EU Directive is mandatory for two parties: manufacturers and retailers. Under the Directive, manufacturers have to provide the product fiche (accurate product energy consumption information) with each appliance to the retailers. Retailers are then under the Directive compelled to “provide all the appliances displayed in salesrooms with complete energy labels placed on top or front of the appliance in original size and colour and clearly visible” (Directive 92/75/EEC). Retailers therefore play a crucial role in the implementation of the European energy label program. It is under their responsibility to physically associate each appliance with the correct label and to ensure that the label is visible. It is possible to check, for every appliance in a showroom, whether the

regulation is followed. This therefore provides an ideal context to test the proposed framework of regulatory compliance.

6.3.2 Fieldwork and data collection

To test the proposed conceptual framework, we used data collected in June 2008 by GfK interviewers in 1,314 stores spread through all 27 EU countries⁵⁸. To account for common method bias, this study followed the procedure recommended by Podsakoff et al (2003) and separated the measurement of the dependent and the independent variables. We therefore split data collection in two separate stages, both of them conducted in the same stores: a compliance audit, and a store employee survey. This procedure ensured no contamination of the variables. Moreover, the assessment of compliance through external observers also guaranteed that the dependent variable was free of social desirability (Steenkamp et al., 2010), a major concern with previous studies relying on self-reported levels of compliance. In this study, not only the dependent and independent variables were kept separated, but the surveyed store managers were also not aware that compliance had been measured, as they thought that the audit had consisted of the usual product and price audit regularly conducted by GfK field workers in their store.

The compliance audit was conducted through experienced field workers as part of a regular store audit. Within this audit, field workers checked, for all appliances falling under the EU Labeling Directive, whether the regulation was followed. Specifically, field workers noted for each appliance whether a label was present and if it was, whether the label was complete (basic label and fiche), in the correct form and color, where the label was placed, and whether it was visible. This audit was conducted for six white appliances falling under the EU Energy Labeling Directive at the time of the study: refrigerators, freezers, washing machines, driers, dishwashers, and electric ovens.

The store employee survey was conducted in the same stores immediately after the audit. This standardized survey was administered face-to-face by the field workers. In large stores, the survey was administered to the employee responsible for the white appliances department; in smaller stores, it was administered to the store manager. This survey focused on store employee perceptions about factors expected to affect compliance with the Directive, as developed in the conceptual framework. Because the stores surveyed were all members of the GfK retail panel, they had agreed to have the

⁵⁸ The data were collected as part of a project for the European Union. A report of the full descriptive results of the project was provided to the European Union.

GfK field workers come regularly in the stores and had also agreed to participate in regular surveys. As a consequence, non-response was not an issue in this study.

For the survey, the questionnaire was developed in English and translated into the relevant languages using standard back translation procedures through GfK. The questionnaires were administered face-to-face by the GfK field workers in the stores. Store managers therefore responded to the questionnaire in their own language. Usual checks for the quality of the data were conducted internally by GfK.

To ensure representativeness of the results, stores were randomly sampled in each country so that they respected the retail structure in the country (GfK retail panel). 75 stores were sampled in the largest European countries, 25 in the smallest countries, and 50 in all others. The panel included the following types of retail stores: electro superstores, electric specialists, kitchen/furniture stores, hypermarkets/cash & carry, and department stores⁵⁹.

In total, 1,314 stores were included in the survey; 94,094 appliances were audited (28,152 refrigerators, 9,328 freezers, 24,331 washers, 7,305 dryers, 12,555 dishwashers, and 12,423 ovens). The number of appliances audited by store ranged from a minimum of one to a maximum of 409, with an average of 71.5 appliances checked in each store. Note that some stores did not offer certain product categories so that the number of stores to be included in the analyses varied for each product category.

At the product level, the compliance rates with the regulation were as follow: 9.9% of the audited appliances had no label; another 27.7% of the appliances did not have a label in compliance with EU regulations (that is, either part of the label was missing or the label was not in the proper colors or was not placed visibly in front or on top of the appliance). Therefore, only 62.4% of the audited appliances complied with EU regulations. We found large differences across countries (with compliance rates between 80 and 90% in Denmark, Hungary and Portugal and below 35% in Greece and Bulgaria), across types of stores (with a compliance rate of 67% found in superstores and department stores and of 40% in kitchen specialty stores), and across types of appliances (with compliance rates of 70% for tumble dryers and of 45% for electric ovens).

6.3.3 Construct operationalization

To test the theoretical framework, a careful consideration of construct operationalization was necessary. Whenever possible, we used multiple item scales to assess the

⁵⁹ Note that online stores could not be included in this study because of the impracticability to administer the survey to these stores.

constructs of interest. However, because of space constraints in the store employee survey, many constructs were assessed with single items. Bergkvist and Rossiter (2007) convincingly argue that single item measures are adequate for concrete constructs with a single object. We therefore used single items for simple constructs to avoid respondent fatigue.

Instrumental benefits of compliance

The main purpose of the EU energy label system was to create a system that is easily understandable (by both retailers and consumers) and therefore helps consumers identify appliance efficiency. As a consequence, the main benefit of these labels for retailers should be as an advising tool: the labels should help them advising consumers more effectively for their choice of appliances. This notion was assessed on an 8-item 10-point scale that tapped the extent to which retailers perceive that the energy labels are helpful to them to sell efficient appliances. An exploratory factor analysis showed that these 8 items all loaded on a single factor. After checking adequate reliability (Cronbach's alpha = .86), these items were averaged.

Instrumental costs of compliance/non compliance

Following the literature, we identified two main types of costs of the label system for retailers. First, there is a certain level of effort involved in attaching the correct labels to the appliances. Perceived effort to administer the labels was measured through a 10-point item. Second, as indicated by instrumental models of compliance, a core cost linked to non-compliance with regulations is the fear of sanctions. As sanctions can only happen to the extent that some control occurs, we assessed the extent to which compliance with the regulation is being controlled, either externally (through the regulating authorities) or internally (through store management). Both of these measures were assessed nominally (occurrence of control in the preceding 12 months).

Internalization of regulation

As stressed by Giddens (1984), time is a key factor leading to the internalization of regulations. The longer a regulation has been in place, the more "normal" it appears, and the less resistance is built against it. As mentioned earlier in the paper, the EU Energy Labeling Directive was not applied simultaneously throughout the EU. Using external databases (MURE, 2011), we obtained for each of the 27 EU countries the first date of implementation of the Directive in national law. We then subtracted this date from 2008 (year of data collection) to obtain the years since first implementation of the Directive in each country.

Interviews with retailers conducted at the outset of the study indicated that label design and aesthetics were a major concern for many retailers. This appeared to be particularly a problem for appliances presented in furniture stores, for instance electric ovens or dishwashers presented within a model kitchen. We therefore included a question about perceptions of the effects of the label on appliance aesthetics; this question was assessed on an 10-point scale, anchored by 1 (no effect on aesthetics) and 10 (negative effect on aesthetics). We expected compliance to decrease when retailers perceive that the labels have a negative aesthetical impact, that is, when they are at odds with an important goal for retailers.

Social norms

As indicated by normative models, social norms stem from the adoption of a regulation among one's peers. Because previous research has shown the importance of identifying the right reference group for these norms, we decided to focus on the rate of implementation within countries. To tap this notion, we computed within each country the rate of compliance with the regulation and used this country compliance rate as a measure of peer pressure. We expected compliance at the retailer level to increase when the level of compliance within the country increases.

Social pressure may also originate from consumers. These may exert pressure on the retailer in a number of ways. First, they may demand efficient appliances; second, they may be willing to pay more for efficient appliances and give a large importance to energy labels. Finally, they may be paying attention to a number of factors when purchasing an appliance, some of them consistent with energy labels (energy costs), others inconsistent (price or design). We therefore operationalized consumer pressure through the following constructs: trend for demand for efficient appliances in the preceding 2 years, willingness-to-pay more for efficient appliances and importance of the label (both of these measures were taken separately for each product category), and relevance of energy costs, design, and price as purchase factors (as perceived by retailers). These variables were all measured on 10-point Likert scales. We expected a positive effect of perceived consumer focus on energy costs, demand and willingness-to-pay for efficient appliances on retailer compliance and a negative effect of perceived consumer focus on price and on design on compliance.

Control variables

As explained earlier, retailers depend on the manufacturers to obtain the product fiches for the energy labels. When manufacturers fail to provide this product fiche for a given appliance, retailers cannot comply with the law. Missing fiches therefore generate a

possibility for retailer inability to comply. We therefore assessed perceived frequency of missing fiches and expected that compliance would decline when the proportion of missing fiches increased.

In addition to missing fiches, we also included the following control variables: type of store, country, and store size which was assessed as the number of appliances sold in the store. We expected to find higher levels of compliance in the better organized stores, as indicated by store size and retail chains (superstores).

Dependent variable

To ensure comparability across stores, we did not use the absolute number of correctly labeled appliances per store but computed instead the share of correctly labelled appliances (by appliance type) at the level of individual retailers. The descriptive statistics for the dependent and the explanatory variables appear in Table 6-1.

Table 6-1: Descriptive statistics of variables used

Variable	Unit	Observations	Mean	Std. Dev.	Min	Max
Compliance rate fridge	Share	1268	0.539	0.434	0	1
Compliance rate dishwasher	Share	1172	0.536	0.447	0	1
Compliance rate oven	Share	1145	0.405	0.438	0	1
Compliance rate washing machine	Share	997	0.590	0.447	0	1
Compliance rate freezer	Share	1183	0.573	0.438	0	1
Compliance rate dryer	Share	853	0.598	0.451	0	1
Effort	Likert	1191	3.785	2.850	1	10
Helpful to advise	Likert	1286	7.339	1.746	1	10
Official check	Dummy	1314	1.614	0.487	0	1
Manager check	Dummy	1314	1.159	0.366	0	1
Time lag since implementation	years	1314	9.044	4.828	1	14
Poor aesthetics	Likert	1272	13.308	5.409	1	21
Compliance rate fridge in country	%	1314	63.376	17.768	26	89
Compliance rate dishwasher in country	%	1314	61.774	19.736	16	95
Compliance rate oven in country	%	1314	42.451	20.842	2	81
Compliance rate washing machine in country	%	1227	64.610	18.085	23	95

Variable	Unit	Observations	Mean	Std. Dev.	Min	Max
Compliance rate freezer in country	%	1314	65.096	18.890	22	97
Compliance rate dryer in country	%	1266	66.015	20.530	10	100
Past demand	Likert	1303	1.327	0.539	1	3
WTP fridge	Likert	1280	7.705	2.316	1	10
WTP dishwasher	Likert	1252	6.975	2.333	1	10
WTP oven	Likert	1216	6.483	2.505	1	10
WTP freezer	Likert	1259	7.512	2.345	1	10
WTP washing machine	Likert	1244	7.105	2.396	1	10
WTP dryer	Likert	1183	6.715	2.492	1	10
Perceived importance of label fridge	Likert	1292	8.674	1.861	1	10
Perceived importance of label dishwasher	Likert	1268	7.987	2.063	1	10
Perceived importance of label oven	Likert	1231	7.162	2.448	1	10
Perceived importance of label freezer	Likert	1274	8.519	1.931	1	10
Perceived importance of label washing machine	Likert	1256	8.302	2.005	1	10
Perceived importance of label dryer	Likert	1193	7.787	2.260	1	10
Perceived importance of energy costs	Likert	1309	8.257	1.803	1	10
Perceived importance of design	Likert	1309	7.438	1.980	1	10
Perceived importance of price	Likert	1309	8.803	1.469	1	10
Missing fiche	Likert	1314	2.070	2.973	0	10
Store size		1314	73.524	66.131	1	409
Superstore	Dummy	1314	0.290	0.454	0	1

6.3.4 Analyses and results

By design, our dependent variable was bound between zero and one. In addition, a large share of retailers had either labeled all their appliances correctly, or none of them (Table 6-2). With high shares of observations at the boundaries, the effects of the explanatory variables tend to be non-linear and the variance tends to decrease when the

mean approaches zero or one. Hence, linear regression analysis is not appropriate. Instead, we apply the fractional logit model (FLM) originally developed by Papke and Woolridge (1996). The fractional logit model implicitly assumes that the zeroes and ones were generated by the same process as the fractions. Using the FLM model means an improvement compared to traditional approaches. It is better than the alternative consisting of transforming the compliance rate into a dichotomous dependent variable (for instance, in a recent papers, Schleich and Gruber (2008) and Schleich (2009) apply logit models after transforming a rate into a dichotomous dependent variable that is set to one if the adoption rate exceeds an arbitrary cut-off point of 50% and zero otherwise). FLM avoids the loss of information resulting from the transformation of a continuous adoption rate into a dichotomous index.

Table 6-2: Share of observations for dependent variables at boundaries

Dependent variable	Share of outcome 0 (in %)	Share of outcome 1 (in %)
Compliance rate fridge	21	26
Compliance rate dishwasher	35	35
Compliance rate oven	46	22
Compliance rate washing machine	32	42
Compliance rate freezer	29	33
Compliance rate dryer	32	44

We used the fractional logit command (robust standard errors) provided by STATA 11 to estimate our model. Results for all six appliance types appear in Table 6-3.⁶⁰

⁶⁰ To save space we abstract from presenting results for the country dummies. All results are available upon request.

Table 6-3: Results for fractional logit regression (robust standard errors in parentheses). Dependent variable: share of correctly labelled appliances

	Fridge	Freezer	Washer	Dryer		Dishwasher	Oven		
effort	-0.004 (0.024)	0.025 (0.028)	-0.011 (0.024)	-0.058 (0.031)	*	-0.007 (0.025)	-0.025 (0.025)		
Helpful to advise	0.019 (0.048)	-0.013 (0.061)	-0.015 (0.047)	-0.119 (0.078)		0.011 (0.054)	-0.040 (0.052)		
Official check	0.313 (0.1379)	* 0.279 (0.167)	* 0.395 (0.150)	*** 0.610 (0.200)	***	0.355 (0.148)	* 0.412 (0.149)	***	
Manager check	0.685 (0.184)	*** 0.712 (0.234)	*** 0.427 (0.204)	* 0.447 (0.242)	*	* 0.614 (0.216)	*** 0.423 (0.239)	*	
Time lag since implementation	0.132 (0.076)	* 0.173 (0.081)	* 0.072 (0.061)	0.081 (0.072)		0.060 (0.109)	0.103 (0.062)		*
Poor aesthetics	0.040 (0.012)	*** 0.045 (0.015)	*** 0.045 (0.013)	0.077 (0.018)	***	0.062 (0.014)	0.036 (0.013)	***	***
Compliance rate in country	-0.009 (0.027)	-0.014 (0.022)	0.014 (0.026)	0.016 (0.029)		0.018 (0.030)	-0.012 (0.043)		
Past demand	0.248 (0.122)	* 0.138 (0.139)	0.192 (0.128)	-0.084 (0.166)		0.239 (0.132)	* -0.008 (0.134)		
WTP	0.003 (0.034)	0.028 (0.040)	0.011 (0.032)	0.008 (0.045)		-0.032 (0.034)	-0.013 (0.035)		
Perceived importance of label	0.022 (0.044)	0.051 (0.049)	0.045 (0.039)	0.172 (0.052)	***	0.069 (0.041)	* 0.062 (0.038)	*	
Perceived importance of energy costs	-0.050 (0.038)	-0.086 (0.046)	* 0.042 (0.039)	-0.016 (0.049)		-0.044 (0.040)	-0.018 (0.043)		
Perceived importance of design	-0.001 (0.034)	-0.002 (0.042)	-0.061 (0.035)	* -0.089 (0.047)	*	-0.013 (0.036)	-0.045 (0.039)		
Perceived importance of price	0.054 (0.044)	-0.032 (0.052)	0.001 (0.045)	0.016 (0.059)		0.042 (0.048)	0.017 (0.047)		
Missing fiche	-0.061 (0.023)	*** -0.067 (0.029)	* -0.083 (0.026)	*** -0.106 (0.035)	***	-0.053 (0.027)	* -0.058 (0.026)	*	
Store size	0.007 (0.001)	*** 0.005 (0.001)	*** 0.008 (0.001)	0.004 (0.001)	***	0.007 (0.001)	0.004 (0.001)	***	***
Superstore	0.322 (0.150)	* 0.334 (0.174)	* 0.306 (0.158)	0.771 (0.200)	***	0.443 (0.161)	0.168 (0.164)	***	
Log likelihood	-553.70	-449.52	-511.23	-352.49		-504.93	-500.24		
Sample size	1075	859	1013	717		993	940		

Note: *** indicates significance at the p=0.01 level, ** indicates significance at the p=0.05 level and * indicates significance at the p=0.1 level in a two-tailed test

Table 6-3 suggests that findings in terms of significance levels, signs, and order of magnitude of parameter estimates are quite consistent across appliance types. Rather than discussing the findings for each appliance type individually, we focus, where possible, on the generic findings across all appliance types.

Instrumental benefits

The extent to which retailers perceive the labels to be helpful in selling more efficient appliances is not found to be significant. Therefore, the results indicate no effects of instrumental benefits on compliance.

Instrumental costs

The parameter estimates associated with perceived effort exhibit the expected negative sign for all appliance types, but are only statistically significant for dryers. Hence, for most appliances, perceived effort to comply with labeling requirements does not appear to affect compliance.

Controls through officials and internal management controls are usually found to be statistically significant, implying that, as expected, monitoring of labeling improves compliance. Furthermore, the point estimates suggest that monitoring by managers tends to be more effective than monitoring by officials (but the difference is not statistically significant at conventional levels).

Internalization

The first variable focusing on retailer internalization of the labeling regulation is the time since implementation of the Directive. As suggested by theory, this factor exhibits the expected positive sign and is statistically significant at conventional levels for three types of appliances. Hence, there is some empirical support for the hypothesis that as the regulation has been in place longer in a country, retailer compliance with the regulation increases.

As expected, perceptions that the labels negatively affect the aesthetics of the appliances are found to have a significant negative effect on compliance ($p=0.01$) for all appliances, suggesting that retailers comply less when they see the label as jeopardizing an important goal.

Social norms

The overall compliance rate for a particular appliance within a country is not found to affect compliance of individual retailers. The results therefore show little support for the notion that peer norms affect compliance.

However, the results show more effects for consumer pressure. While willingness-to-pay is not found to be statistically significant (that is, consumer willingness to pay more for higher efficiency appliances appears to have no impact on retailers' compliance with the labeling regulation), consumer perceived importance of labels (always positive and significant in 3 product categories) and consumer demand for efficient appliances (always positive and significant in 2 product categories) have the expected impact on retailer compliance. Moreover, while retailer beliefs that consumer choice is mostly driven by energy costs or price have no effect on compliance, the belief that consumer choice is driven by design considerations does exhibit the expected negative impact on compliance and is significant in 2 product categories.

Control factors

As expected, retailers' labeling compliance is negatively affected if manufacturers do not provide the product fiche. This parameter associated with missing fiches is found to be statistically significant for all appliances. Retailers selling a larger variety of products are also found to perform better in terms of labeling compliance, with store size statistically significant for all appliances. Finally, for most appliances, superstore retailers are found to be associated with statistically significant higher labeling compliance rates than other stores.

6.4 Discussion

Interestingly, with the exception of compliance controls, the data showed little impact of instrumental factors on compliance: neither effort nor benefits directly linked to the labels had an effect on retailer compliance. Fear of sanctions however appeared relevant, especially internal sanctions. This is interesting as it suggests that policy makers could rely on voluntary controls through retailers rather than invest in costly governmental controls.

Normative factors were found to have a particularly strong impact on compliance: internalization of the Directive appeared to play a strong role, as did perceived consumer pressure. Peer pressure however showed little if any impact; this might however be due to the fact that we did not measure this factor directly but instead used a proxy based on overall compliance in the focal country; we cannot be sure that store manag-

ers visit one another's stores and see whether their competitors comply or not. Retailers were however found to be sensitive to consumer pressure; this result has policy implications as it suggests that communication about energy labels should be increasingly geared towards consumers.

6.5 Conclusions

From a **theoretical** perspective, our paper reconciles instrumental and normative models of compliance; we conceptualize compliance as being influenced by two types of instrumental factors, (1) the perceived costs associated with compliance and lack thereof and (2) the perceived benefits associated with compliance and lack thereof and by two types of normative factors, (3) internalization of the regulation and (4) social pressure to comply. The results show that both instrumental and normative factors play a role in explaining regulatory compliance. It therefore provides further support for integrated models of compliance that combine both types of approaches (see also Beach, 2005). Moreover, the study also indicates a greater impact of normative factors, especially internalization and consumer pressure.

Note that our main objective in this research was to investigate a relevant and timely substantive marketing issue. As a consequence, we acknowledge that we were more interested in applying theory rather than with the development of new theory in this project. Nevertheless, this study suggests a number of further more conceptually oriented extensions worth pursuing in this area. Future studies could for instance focus on the development of incentive-compatible mechanisms to incite retailers to comply with regulations, or on empirical tests of the effectiveness of specific training programs in increasing retailer internalization of product labeling regulations. It would also be interesting to compare the effectiveness of voluntary agreements with that of mandatory regulations, thereby focusing on self-regulation mechanisms. In short, this study opens the door to a number of projects that would be focusing in this substantive area but consider some of the facets of the problem with a variety of approaches (experiments, qualitative research, mathematical modelling), while having the merit to be anchored in an issue that is of relevance to both public policy makers and retailers.

Methodologically, unlike previous studies of compliance with regulations, our study focuses on observed compliance rather than self-reports of compliance or of intention to comply. The use of observational data alleviates concerns about social desirability biases that are common to surveys using stated intentions to comply (Steenkamp et al., 2010). A particular methodological strength of the study is the clear separation between survey responses (explanatory variables) and audit results (dependent variable): this separation guarantees low common method bias and makes the results particularly

impressive. Indeed, past studies focusing on regulation compliance have often suffered from common method bias, where both dependent and independent variables were measured in the same survey and relationships between the two were likely to be inflated.

Moreover, our study is aiming for a high degree of generalizability: we test our framework for the worldwide most widespread energy label (European energy label) on 6 product categories and in all 27 European Union countries, using a representative sample of retail stores in each of these countries. Since our study focused on compliance with energy label regulations, we can only speculate about the generalizability of the results to other types of product labeling, for instance compliance with country of origin labeling or ingredient content, where retailer violations of regulations were recently found. Clearly, the results obtained in this study are specific to the context studied and further studies are needed in other contexts to ensure generalizability across different areas of product label regulation compliance. Still, our theoretical framework could easily be adapted and tested in such contexts.

Statistically, we are to our knowledge the first to introduce the fractional logit approach in the marketing literature. This approach, developed to analyze bounded dependent variables such as proportions and particularly adapted when many responses are at the extremes (0 or 100%), should be useful in many other marketing projects where the dependent variable is a proportion, such as for instance share of wallet studies.

Finally, **substantively** our study is to our knowledge the first attempt at obtaining insights on retailer compliance with energy labeling regulations, thereby contributing on one hand to the growing literature on product labels (with a focus on retailers instead of consumers) and on the other hand to the literature on sustainable marketing and especially energy consumption.

Our results have implications for policy makers as well as retailer management. Policy makers can use the results to better fine tune labeling programs. Our results show for instance that perceived effort to paste the labels on the appliances has much less impact than originally supposed. Instead, our results show the importance of regular checks through regulatory institutions, as well as the impact of consumer pressure. They therefore suggest that consumer education programs bringing attention to the labels may be useful, not only through their direct effects on consumers through heightened awareness, but indirectly by putting pressure on retailers

The results are also potentially useful for retailers, helping retail management understand why their employees do or not follow regulations. Based on this study, we can advise to retail management to implement regular internal checks of regulation compli-

ance; furthermore, our results show that store managers are more respectful of regulation when they are internally convinced of the regulation. Training programs aimed at developing acceptance of a regulation by store employees may help curb non-compliance and therefore avoid possible sanctions or fines.

Some puzzling results would deserve attention in further studies. We were surprised to find that retailer perceptions that consumers give a lot of importance to energy costs when purchasing appliances was found to be non-significant. This non-result may be due to the fact that the labels do not explicitly include energy costs, but only energy consumption, which may be too abstract for consumers. Alternatively, one could also speculate that retailers may use the labels strategically, complying with the regulation for high efficiency appliances but failing to do so for low efficiency appliances. Unfortunately, we could not check this possibility with the current data since the energy class of the audited appliances was not collected for non labelled appliances. Exploring this phenomenon would however be highly interesting.

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7 **Energy management in the tertiary sector – An empirical analysis based on survey data from Germany***

Abstract

This paper empirically explores factors driving the adoption of energy management procedures and of other low cost energy-saving measures in the so-called tertiary sector in Germany, mainly comprising small and medium companies from a variety of sectors (such as services, trade, commerce, or agriculture). Our statistical analysis relies on more than 1500 observations from a recent representative survey of this sector. By focusing on low cost measures our analysis also adds to the empirical evidence on factors driving adoption of this type of energy efficiency measures. The findings from single and multivariate probit model analyses suggest that the adoption of these measures is highly related to organizational factors and split incentives. More specifically, our findings suggest that the landlord-tenant dilemma also holds for energy management and low-cost energy efficiency measures in the tertiary sector. Additionally, factors such as organizational culture and social factors seem to be more important than financial incentives for the decision to adopt low-cost energy efficiency measures. In comparison, organizations' adoption of low-cost measures appears to be only weakly related with electricity prices and heterogeneity across sectors. Thus, efficient policy making for these measures would involve a generic rather than a sector-specific design. Organizational culture and social factors could be strengthened by policies and programs addressing social mechanisms to raise top management awareness of energy costs.

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7.1 Introduction

With its climate and energy policy package from 2008 (European Commission, 2012), the European Union launched a system of climate and energy targets up to 2020. The package also included an energy efficiency target aiming at the reduction of primary energy consumption by 20% compared to the trend by 2020. Though this target has not been translated into a legally binding text, energy efficiency is considered as one of the most cost-effective ways to address climate change. Recent study results show that there is a cost-effective potential for final energy savings of around 40% by 2030 to which all energy consumption sectors need to contribute in different proportions (Eichhammer, 2013). Though the largest potential is seen in the residential sector, there are still many unexploited energy efficiency potentials in companies both in industry and in the tertiary sector. The latter is a rather heterogeneous aggregate, mainly comprising small and medium companies from a variety of sectors⁶¹. On the other hand, there is evidence that the EU is not on track in meeting even its 2020 energy savings target, but that without intensified policies a gap will remain (Harmsen et al., 2014).

Implementing energy management practices has often been suggested for overcoming barriers to energy efficiency in companies in order to better exploit the cost-effective energy savings potential in the industry and tertiary sectors (Brown, 2001; Jochem and Gruber, 1990; Stenqvist and Nilsson, 2012; Thollander and Dotzauer, 2010). Such barriers prevent companies and organizations from realizing energy savings potentials even though they are cost-effective under current economic conditions (e.g. Granade et al., 2009). Following the classification by Sorrell et al. (2004)⁶², such barriers fall into the following broad (overlapping and co-existing) categories: *imperfect information* and other *transaction costs* (e.g. search costs) for identifying energy use of buildings, products and services; *hidden costs*, which include the overhead costs for management, the costs associated with disruptions to production or quality losses, or with staff replacement and training; *technical risks* of energy-efficient technologies, the *financial risks* associated with irreversible investments and the uncertainty about the returns of

⁶¹ In this paper we define the sector in the same way as in the German national energy balances (AGEB, 2013). Apart from private and public services, trade and commerce it also comprises agriculture, construction and military. From manufacturing industry, the energy consumption of small firms and enterprises with up to 19 employees (small industrial enterprises) is also assigned to this sector. In the following, this aggregate is only referred to as “tertiary sector”.

⁶² The Sorrell et al. (2004) taxonomy of barriers has frequently been used in empirical analyses of barriers to energy efficiency. Relying on this taxonomy, Sorrell et al. (2011) provide a comprehensive literature review on barriers in industry and in the public and commercial sector. For recent extensions and modifications of the barriers taxonomy see Backlund et al. (2012) and Cagno et al. (2013).

energy efficiency measures; *lack of access to external capital* such as the costs to assess the risks associated with the investor or the technology might be too high; lack of internal capital funds may be inhibited by internal capital budgeting procedures, investment appraisal rules, or the short-term incentives of energy management staff; *split incentives*, which imply that the investor in energy efficiency measures cannot fully appropriate the benefits (e.g. the well-known landlord-tenant or user-investor problem), and *bounded rationality*, which means that constraints on time, attention, and the ability to process information prevent individuals from making “rational” choices in complex decision problems. Rather than optimizing, they use heuristics and rules of thumb to decide on investments.

Findings suggest that the barriers to energy efficiency differ by sectors, technologies and by company characteristics. In particular, energy-intensive organizations tend to allocate a higher priority to energy-efficiency projects than less energy-intensive firms, hence lower energy costs usually yield lower perception of barriers (e.g. Trianni et al., 2013a). Similarly, smaller organizations are less likely to adopt energy efficiency measures than larger organizations (Schleich, 2009). Notably, small- and medium-sized enterprises (SMEs) tend to consider investments in energy efficiency low priority projects, devote fewer resources to energy management, and exhibit lower adoption rates for energy efficiency measures (Cagno et al., 2010; Gruber and Brand, 1991). The empirical literature on energy efficiency in smaller organizations and enterprises has been growing in recent years.⁶³ In their recent review of this literature on barriers to energy efficiency for the industry and the tertiary sector, Fleiter et al. (2012) conclude that both the services sector and SMEs from the industry sector tend to face more barriers to adopting energy efficiency measures than larger companies. The most prevalent barriers in these sectors appear to be lack of capital, lack of information and lack of staff time. These latter barriers could effectively be overcome by energy management procedures.

The term energy management, however, is not defined homogeneously either in the scientific literature or in the operational practice of enterprises. Backlund et al. (2012) give a comprehensive overview of available descriptions. In general, energy management summarizes a number of practices dealing with the efficient use of energy in a company or organization. According to Backlund et al. (2012), these include the implementation of energy-efficient technologies but also their efficient usage. Energy

⁶³ Survey-based analyses of barriers to energy efficiency in SMEs include, among others, Thollander et al. (2007), Thollander and Dotzauer (2010) for SMEs in Sweden, Trianni and Cagno (2012), Trianni et al. (2013a,b) in Italy or Schleich and Gruber (2008), Schleich (2009), Fleiter et al. (2012) in Germany.

management typically comprises of three components: (i) gaining knowledge about energy flows by collecting data on energy consumption, (ii) identifying energy efficiency potentials and implementation of actions to capture them, and (iii) reporting and monitoring these actions (see e.g. Swords et al., 2008; Abdelaziz et al., 2011; IEA, 2011; Reinaud et al., 2012).

In order to systemize and standardize the energy management procedures, energy management systems (EnMS) have been developed. An EnMS is a collection of procedures and practices to ensure the systematic tracking, analysis and planning of energy use in a company (Reinaud et al., 2012). The development of national EnMS standards and specifications started from around the year 2000, especially in some pioneering countries such as the Netherlands, Denmark, Sweden, Ireland or the USA (for a comparative overview see Kahlenborn et al., 2010; Stenqvist, 2012). Based on these experiences, energy management standards have been developed at the European level (EN 16001 Standard published in 2009) and at the international level (ISO 50001 Standard published in 2011).

Though this international harmonization strengthened the importance of EnMS, the empirical knowledge on the spread of energy management procedures and their impact is still limited. In addition, the few existing empirical studies refer to the industry sector, in particular to the energy-intensive industry. Examples include Thollander and Ottosson (2010) for the Swedish energy-intensive industry and Stenqvist et al. (2011) for the Swedish pulp and paper industry.

In this paper, we empirically explore factors driving adoption of energy management procedures and of other low cost energy-saving measures in the tertiary sector. Our statistical analyses rely on data from a recent representative survey of the tertiary sector in Germany. By focusing on low cost measures our analyses also add to the empirical evidence on factors driving adoption of this type of energy efficiency measures.

The paper is organized as follows: In Section 7.2 we provide a description of the basic survey together with descriptive statistics and the econometric model used in the analyses. The estimation results are presented in Section 7.3. In the concluding Section 7.4, we interpret and discuss these results and derive implications for policy making.

7.2 Methodology

7.2.1 Survey methodology

We base our analyses on data from a representative survey on energy consumption in the tertiary sector in Germany (Schlomann et al., 2013; Schlomann et al., 2014). A total of 2,131 companies and public institutions were interviewed personally (Computer Assisted Personal Interviews – CAPI) by experienced interviewers from GfK⁶⁴. Data from 2,113 respondents could be used for our analyses. The interviews were conducted between July and November 2011. The survey on energy consumption was carried out for the 5th time since 2001, and is subject to strict quality control. In the survey, the tertiary sector was defined in the same way as in the German national energy balances (AGEB, 2013), i.e. it includes all public and private services and trade, but also agriculture, construction and some small industrial enterprises. Because of its heterogeneity, the sector was broken down into 14 sub-sectors, 11 of which were covered by interviews (see Table 7-1). The sub-sectors were clustered and based on similar energy consumption patterns. The tertiary sector as it is defined here covers 32.8 million employees, hence accounting for around 80% of total employees in Germany. The energy consumption of the sector amounted to 366 TWh in 2011, i.e. 15% of total final energy consumption in Germany.

The complete survey questionnaire consists of three parts. The first part comprises general questions on the general structure of the companies involved (e.g. number of employees, floor space, organizational structure), and on economic and technical information on energy use (as e.g. total energy consumption and energy costs, energy consumption for different end-uses like space heating or lighting). The second part involves questions about energy management and measures to improve energy performance. The third part includes additional questions on the specific sub-sector. The analyses in this paper mainly employ information from the energy management part of the questionnaire and relate them to general and economic characteristic of the companies (see Section 7.2.1). Appendix A presents the questions relevant to our analyses.

⁶⁴ GfK is a market research company collecting market and consumer information in more than 100 countries worldwide (www.gfk.com).

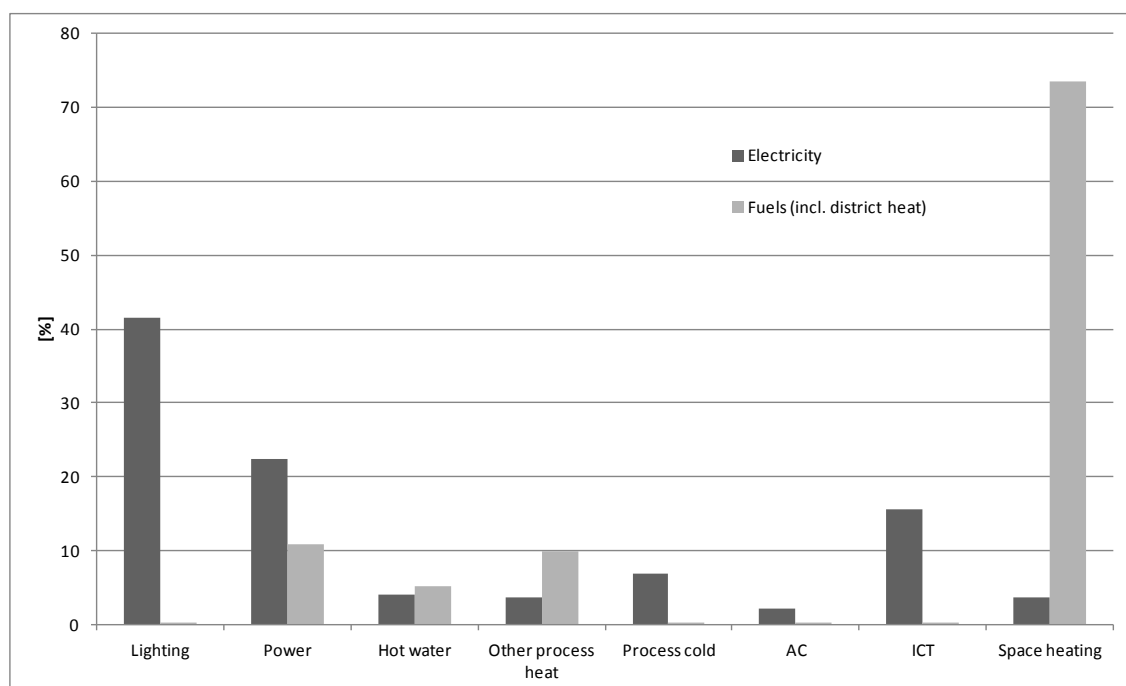
Table 7-1: Employment and energy consumption in the sub-sectors covered by the survey in the tertiary sector (in 2011)

Sub-sector	Number of interviews	Number of employees [in 1000]	Energy consumption [in TWh]
<i>Construction</i>	171	2,428	15.4
<i>Offices</i>	467	13,294	86.0
<i>Small manufacturing</i>	216	924	11.5
<i>Retail trade</i>	458	5,479	60.3
<i>Hospitals/schools/pools</i>	212	2,707	45.0
<i>Hotels/restaurants</i>	247	3,983	62.8
<i>Food</i>	141	166	2.6
<i>Laundries</i>	35	53	1.0
<i>Agriculture</i>	104	642	44.2
<i>Horticulture</i>	18	195	4.7
<i>Textile</i>	44	858	3.9
<i>Others*</i>	0	2,029	28.2
<i>Total tertiary</i>	2,113	32,758	365.6

* The remaining sub-sector (mainly airports, military, street lighting) were only analyzed based on secondary data.

Source: Schlomann et al., 2013; Schlomann et al., 2014

The energy management section of the questionnaire includes first of all questions addressing the general attitude of the company towards energy efficiency and the undertaking of energy saving measures. In addition, the survey asked for concrete energy savings measures, which refer to a specific end-use, i.e. lighting (see Appendix A, questions 7 to 9). We chose lighting since - with a share of around 40% - it is the main electrical end-use in the tertiary sector (see Figure 7-1). In addition, lighting offers a large energy savings potential which can be addressed both by technical (low-cost) and by organizational and behavioral measures (Fraunhofer ISI, 2012). Other important end-uses for electricity in the tertiary sector are motor drives (power), information and communication technologies (ICT) and process cooling. Most energy use in the tertiary sector - about 70% - is used for heating purposes, however, but most measures to reduce heating demand are rather high-cost.



Source: Schломann et al., 2013, 2014

Figure 7-1: Energy consumption in the tertiary sector by end-uses

7.2.2 Econometric model

The factors driving the adoption of energy-efficiency measures are explored econometrically. In this section, we present the dependent and explanatory variables.

Dependent and explanatory variables

In the energy management part of the questionnaire, respondents were asked to state whether they had adopted particular energy efficiency measures in their company. These items serve as dependent variables in our multivariate analyses and are further described in Table 7-2. A full set of dependent and explanatory variables was available for 1,528 observations.

Table 7-2: Overview of dependent variables

Name	Explanation
<i>switchoff</i>	1, if energy-using installations are switched off and daylight is used whenever possible; otherwise 0;
<i>lightoff</i>	1, if lighting only switched on when needed; otherwise 0;
<i>management</i>	1, if energy management measures or energy controlling measures implemented; otherwise 0;
<i>purchase</i>	1, if energy efficiency is always considered for new purchases; otherwise 0;

Thus, all measures considered are rather low-cost measures. *Switchoff* and *lightoff* are directly related to energy cost savings. The set of explanatory variables available is described in Table 7-3.

Table 7-3: Overview of explanatory variables and expected sign

Name	Explanation	Expected sign
<i>powerprice</i>	in Euro/kWh calculated as the ratio of total electricity costs and total electricity consumption;	+
<i>floorspace</i>	total floor space of organization (in 1000 m ²)	+
<i>employees</i>	total number of employees (including part time employees) (in 1000)	+
<i>rented</i>	1, if buildings are (mostly) rented; otherwise 0;	-
<i>subsidiary</i>	1, if organization is a subsidiary; otherwise 0;	+/-
<i>rural</i>	1, if organization is located in rural area; 0;	-

Powerprice is supposed to reflect the economic incentive to adopt energy efficiency measures, hence the sign should be positive for all four adoption decisions⁶⁵. Similarly, organizations with larger *floorspace*, exhibit higher energy consumption and are expected to have stronger economic incentives to adopt energy efficient measures, ceteris paribus. The number of employees is frequently used as a proxy for the size of an organization in empirical analyses. Since larger organizations are typically associated with less barriers to energy efficiency (e.g. because of lower specific transaction costs), the parameter estimate associated with *employees* should be positive. The variable *rented* is considered to reflect the landlord tenant problem, and should be negatively related with the dependent variables. Organizations which are subsidiaries of a larger mother organization may benefit from the diffusion of knowledge and procedures about energy efficiency measures generated at the level of the mother organization. On the other hand, incentives to save energy costs at the subsidiary level are low if the mother organization appropriates the benefits (split-incentives problem). Hence, the expected sign of *subsidiary* is ambiguous. Finally, organizations in rural areas are less likely to benefit from knowledge spillovers from other organizations, and face a more difficult access to information and know-how about energy-efficiency measures. Thus, *rural* should exhibit a negative sign in the multivariate analysis.

In addition, eleven dummies were included to capture heterogeneity across sectors. Table 7-4 provides descriptive statistics of the dependent and explanatory variables included in the subsequent econometric analysis. The data for the dependents variables appear in the first four rows. For example, the mean of 0.362 for *management*

⁶⁵ Data did not allow calculation of a corresponding measure for a fuel price.

implies that 36.2% of the organizations in our sample had implemented energy management measures or energy controlling measures. Similarly, 0.013 for the sector dummy *agriculture* means that agricultural units account for 13% of the observations in our sample. Note that the means of the sector dummies add up to 1.

Table 7-4: Descriptive statistics of dependent and explanatory variables (N= 1528)

Variable	Unit	Mean	Std. Dev.	Min.	Max.
<i>switchoff</i>	0/1 dummy	0.622	0.485	0	1
<i>lightoff</i>	0/1 dummy	0.750	0.433	0	1
<i>management</i>	0/1 dummy	0.362	0.481	0	1
<i>purch</i>	0/1 dummy	0.662	0.473	0	1
<i>powerprice</i>	Euro/kWh	0.205	0.035	0.06	0.29
<i>floorsize</i>	1000 m ²	1.613	5.534	0.02	140
<i>employees</i>	Number (in 1000)	20.88	68.73	1	1150
<i>rented</i>	0/1 dummy	0.448	0.497	0	1
<i>subsidiary</i>	0/1 dummy	0.181	0.385	0	1
<i>rural</i>	0/1 dummy	0.367	0.482	0	1
<i>construction</i>	0/1 dummy	0.082	0.274	0	1
<i>offices</i>	0/1 dummy	0.219	0.413	0	1
<i>small manufacturing</i>	0/1 dummy	0.104	0.305	0	1
<i>retail trade</i>	0/1 dummy	0.215	0.411	0	1
<i>hospitals/schools/pools</i>	0/1 dummy	0.088	0.283	0	1
<i>hotels/restaurants</i>	0/1 dummy	0.130	0.337	0	1
<i>food</i>	0/1 dummy	0.070	0.255	0	1
<i>laundries</i>	0/1 dummy	0.013	0.114	0	1
<i>agriculture</i>	0/1 dummy	0.046	0.211	0	1
<i>horticulture</i>	0/1 dummy	0.009	0.095	0	1
<i>textile</i>	0/1 dummy	0.024	0.152	0	1

Econometric methodology

The dependent variables are all binary, and standard univariate probit models could be applied to estimate the adoption of the energy efficiency measures. However, to allow for the possibility that organizations do not adopt these measures individually, we estimate a multivariate probit model instead, thus accounting for possible correlations between the dependent variables through the corresponding error terms. Unless these correlations are zero, parameter estimates from univariate probit models are biased

and inconsistent (e.g. Greene, 2012). We use STATA 13 to estimate the four probit models jointly. For comparison, we also estimate individual univariate probit models. To prevent singularity of the regressor matrix we do not include a dummy for the last sub-sector *textile*.

7.3 Results

For the multivariate probit model results appear in Table 7-5. Heteroskedasticity-robust standard errors appear in parenthesis below parameter estimates. To save space, the findings for the individual probit models are presented in the Appendix Table B.1. We find that the correlation between the dependent and explanatory variables is positive in all cases, and statistically significant (at $p < 0.01$) for most of the correlations (only for *management* and *lightoff*, correlation was found to be zero).⁶⁶ Hence, as suspected, decisions to adopt the energy efficiency measures considered do not tend to be independent⁶⁷. However, comparing the results in Table 7-5 and Table B.1 suggests that the parameter estimates (and the significance levels) hardly differ between the multivariate probit model and the univariate probit models (see Appendix B, Table B.1). Thus, the bias from running individual probits appears to be rather marginal.

The price of electricity (*powerprice*) was found to be statistically significant ($p < 0.05$) for *lightoff* only, also exhibiting the expected positive sign, but does not appear to be relevant for the adoption of the other low-cost measures considered. For *lightoff* we also calculate the marginal effect of *powerprice* (evaluating all other explanatory variables at their means). Accordingly, an increase in the power price by 10€cts per kWh (i.e. an increase by almost 50% compared to the mean) increases the probability that lighting is only switched on when needed by 6 percentage points. Hence, while statistically significant, the effect of the electricity price on *lightoff* is rather limited.

Similarly, while the parameter estimate associated with *floorsize* exhibits the expected positive sign, it is only statistically significant ($p < 0.1$) for *lightoff*. Organizations with larger buildings (in m^2) need more lighting services. Thus, switching off lights when they are not needed is expected to lead to higher electricity cost services, ceteris paribus. The parameter estimate associated with *employees* is positive for three equations. Larger organizations are more likely ($p < 0.01$) to adopt energy *management* and controlling systems, arguably because of lower specific transaction costs. For *lightoff*,

⁶⁶ All results which are not shown here to save space are available from the authors upon request.

⁶⁷ Based on a Likelihood-Ratio test, the Null Hypothesis “all correlations are zero” can be rejected at $p < 0.01$ ($\chi^2(6) = 439.44$).

however, the sign is negative and statistically significant (at $p < 0.05$). The more employees there are, the less likely it is that an organization switches off lights and relies on daylight whenever possible. Since minimum lighting needs are subjective and vary by individuals, a higher number of employees may result in higher expected minimum lighting needs.

Rented is found to be far most statistically significant and to exhibit the expected negative sign in all four adoption equations, suggesting that the landlord-tenant dilemma also holds for low-cost energy efficiency measures. For interpretation, we calculate the estimates of the marginal effects, taking into account the dichotomous character of *rented*⁶⁸. Accordingly, renting rather than owning decreases the probability of adopting management measures by 12 percentage points, the probability of switching off energy-using installations whenever possible by 19 percentage points, the probability of switching off the lights by 11 percentage points, and the probability of considering energy efficiency for new purchases by 15 percentage points.

For *management* and *purch*, *subsidiary* exhibits a positive sign, and is also statistically significant (at $p < 0.1$ and $p < 0.01$, respectively). Implementation of energy management systems or requirements about purchasing procedures are likely be decided at the level of the mother organization, which then diffuses the relevant information and know-how to its subsidiaries. For *switchoff* and also *lightoff*, which both result in energy cost savings, the parameter sign is negative and statistically significant for *switch.off*. Thus, split incentives may prohibit diffusion of these low cost measures to save energy and energy costs.

The result for *rural* is rather mixed, and no clear pattern emerges: organizations in rural areas are more likely to switch off lights, but less likely to require energy efficiency to be required for new purchases.

Finally, only very few sector dummies are found to be statistically significant. Given sector heterogeneity, this is somewhat surprising. Thus, unlike energy efficiency measures in general (e.g. Schleich, 2009), differences across sectors do not appear to have a strong effect on the adoption of energy management procedures and low cost energy efficiency measures. An explanation may be that most of the companies in the survey have in common that they are not very energy-intensive.

⁶⁸ For all other explanatory variables the means were taken when evaluating the marginal effects of *rented*.

Table 7-5: Results of multivariate probit model

Explanatory variables	<i>switchoff</i>	<i>lightoff</i>	<i>management</i>	<i>purchase</i>
<i>powerprice</i>	0.453 (0.983)	2.208** (1.048)	-0.448 (1.054)	-0.359 (0.985)
<i>floorsize</i>	0.0104 (0.0106)	0.0228* (0.0119)	0.0111 (0.0163)	0.0168 (0.0163)
<i>employees</i>	0.262 (0.704)	-1.16* (0.647)	11.64*** (2.55)	0.727 (1.09)
<i>rented</i>	-0.499*** (0.0754)	-0.348*** (0.0788)	-0.320*** (0.0785)	-0.409*** (0.0770)
<i>subsidiary</i>	-0.150* (0.0877)	-0.0645 (0.0936)	0.161* (0.0907)	0.263*** (0.0922)
<i>rural</i>	-0.0830 (0.0747)	0.137* (0.0804)	0.0996 (0.0768)	-0.388*** (0.0771)
<i>construction</i>	0.0822 (0.246)	-0.106 (0.276)	0.0990 (0.266)	0.293 (0.249)
<i>offices</i>	0.395* (0.228)	0.0357 (0.258)	0.427* (0.249)	0.377 (0.233)
<i>small manufacturing</i>	0.132 (0.241)	-0.206 (0.269)	0.268 (0.260)	0.347 (0.244)
<i>retail trade</i>	0.155 (0.227)	-0.213 (0.256)	0.293 (0.250)	0.417* (0.233)
<i>hospitals/schools/pools</i>	0.344 (0.251)	0.106 (0.284)	0.641** (0.274)	0.466* (0.256)
<i>hotels/restaurants</i>	0.411* (0.237)	-0.187 (0.264)	0.619** (0.254)	0.638*** (0.241)
<i>food</i>	0.251 (0.248)	-0.339 (0.279)	0.170 (0.272)	0.593** (0.260)
<i>laundries</i>	0.152 (0.368)	-0.331 (0.382)	-0.444 (0.436)	0.160 (0.359)
<i>agriculture</i>	0.219 (0.274)	0.0108 (0.313)	-0.174 (0.296)	0.390 (0.276)
<i>horticulture</i>	0.306 (0.411)	-0.621 (0.433)	0.112 (0.440)	0.389 (0.427)
<i>constant</i>	0.249 (0.310)	0.468 (0.339)	-0.718** (0.343)	0.338 (0.315)
<i>Wald</i> ($\chi^2(64) = 293.39$ ($p > \chi^2 = 0$))				
<i>N</i>	1,528	1,528	1,528	1,528

Note: *** indicates significance at $p < 0.01$, ** indicates significance at $p < 0.05$ and * indicates significance at $p < 0.1$ in an individual two-tailed z-test

7.4 Discussion and conclusions

In general, most (but not all) estimation results support the hypotheses derived from the theoretical literature. Organizational factors and split incentives were found to be highly correlated with the adoption of all four low-cost measures considered. In comparison financial incentives (here electricity prices) and heterogeneity across sectors appear to be only slightly related to organizations' adoption of low-cost measures. Since some of the sub-sectors (especially SMEs in industrial sectors) exhibit similar energy consumption characteristics as industrial companies, the results of our analysis may also apply to these larger organizations.

More specifically, our findings suggest that the landlord-tenant dilemma also holds for energy management and low-cost energy efficiency measures in the tertiary sector in Germany. The measures are often physically linked to the buildings infrastructure, such as automatic lighting systems or metering systems, and may thus qualify for the landlord-tenant dilemma. Hence, our findings complement the tendency of the literature, which finds the landlord-tenant problem to be a prevalent barrier to energy efficiency in residential buildings (see e.g. Ástmarsson (2013), and for (rather high cost) energy efficiency measures in the tertiary sector Schleich and Gruber (2008) and Schleich (2009), which also tend to mostly refer to buildings).

Somewhat surprisingly, sectoral heterogeneity appears to have little impact on the adoption of energy management procedures and low cost measures to enhance energy efficiency. Results from other studies imply that the barriers to energy efficiency differ by sectors, though (e.g. Schleich and Gruber, 2008; Schleich, 2009). But these studies explore measures requiring larger investments in energy-efficient technologies, while our analysis focuses on low-cost measures. Thus, the findings of this paper provide empirical support for generic rather than for sector-specific policies to accelerate the diffusion of energy management and low-cost energy savings measures.

Based on our findings, higher electricity prices may be expected to make institutions in the tertiary sector switch off lights more often. But for the other measures considered in our analysis, electricity prices do not appear to matter. Arguably, other factors such as organizational culture and social factors may be more important than financial incentives for the decision to adopt low-cost energy efficiency measures. Organizational culture and social factors could be strengthened by policies and programs addressing social mechanisms to raise top management awareness of energy costs. Successful examples of this kind of programs are e.g. regionally or locally-organized learning networks of companies as they have been established in Switzerland and Germany (Jochem and Gruber, 2007). A similar network initiative specifically addressing energy

efficiency in SMEs is established in Denmark (Drivsholm and Petersen, 2012). As a main element, these networks include the implementation of energy management systems together with energy audits, common target setting for energy efficiency performance, and a scientific monitoring and evaluation of the process.

Acknowledgements

The survey on energy use in the German tertiary sector was sponsored by the German Federal Ministry of Economics and Technology (BMWi). We would further like to thank Prof. Dr. Kornelis Blok for his helpful comments and Vanessa Dolbé-Raffler for the proofreading of this paper.

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Appendix A

Excerpt from the Survey Questionnaire in the Tertiary Sector

Questions on general characteristics of the company/institution

- 1) Number of employees in the company/institution under review?

- 2) Size of floor area at this site (only inside buildings, not outside)?

- 3) Is your company/institution situated in a rural or in an urban area?
 rural area urban area central urban area
- 4) Are your company rooms rented, leased or your own property?
 rented leased own property
- 5) Is this company/institution a subsidiary of a group?
 yes no
- 6) Energy consumption and energy costs by energy carrier in the year 2010

Energy carrier	Total amount of energy consumption	Unit of consumption	Energy costs (in Euro)
Electricity.....			

Questions on energy management

- 7) Is energy efficiency considered in your company/institution in case of new investments?
 always partially seldom never
- 8) Which of these statements are true for your company/institution?
 Energy saving measures have been taken in the last 5-7 years.
 Energy saving measure are ongoing or planned in the near future.
 There is a need for action on energy efficiency.
- 9) Which of these energy saving measures have already been taken in your company/institution?
 Energy management, energy controlling
 Energy-using installations are switched off whenever possible
 Lighting is only switched on when needed, use of daylight whenever possible
 Implementation of technical saving measures, energy-saving investments
 Other energy saving measures, which?

Source: Translated by authors from Schlomann et al. (2014)

Appendix B

Results of the univariate probit model appear in Table 7-6. The parameters are estimated via maximum likelihood, heteroskedasticity robust standard errors are reported in parentheses below the parameter estimates.

Table 7-6: Results of univariate probit models

Explanatory variables	<i>switchoff</i>	<i>lightoff</i>	<i>management</i>	<i>purchase</i>
<i>powerprice</i>	0.449 (0.985)	2.099** (1.043)	-0.431 (1.067)	-0.612 (0.991)
<i>floorsize</i>	0.0113 (0.0109)	0.0221* (0.0134)	0.0112 (0.0165)	0.0193 (0.0166)
<i>employees</i>	0.169 (0.755)	-1.22* (0.721)	11.68*** (2.59)	0.331 (1.04)
<i>rented</i>	-0.503*** (0.0757)	-0.355*** (0.0796)	-0.329*** (0.0791)	-0.414*** (0.0770)
<i>subsidiary</i>	-0.159* (0.0885)	-0.0582 (0.0942)	0.156* (0.0914)	0.247*** (0.0927)
<i>rural</i>	-0.0931 (0.0750)	0.138* (0.0809)	0.0934 (0.0772)	-0.398*** (0.0766)
<i>construction</i>	0.0890 (0.240)	-0.0969 (0.269)	0.0846 (0.264)	0.273 (0.241)
<i>offices</i>	0.377* (0.222)	0.0930 (0.251)	0.412* (0.246)	0.347 (0.223)
<i>small manufacturing</i>	0.124 (0.234)	-0.157 (0.262)	0.247 (0.258)	0.315 (0.234)
<i>retail trade</i>	0.165 (0.222)	-0.165 (0.249)	0.284 (0.246)	0.413* (0.223)
<i>hospitals/schools/pools</i>	0.324 (0.242)	0.149 (0.278)	0.637** (0.271)	0.424* (0.244)
<i>hotels/restaurants</i>	0.386* (0.230)	-0.155 (0.256)	0.600** (0.251)	0.597*** (0.231)
<i>food</i>	0.265 (0.246)	-0.291 (0.273)	0.164 (0.269)	0.582** (0.251)
<i>laundries</i>	0.188 (0.360)	-0.307 (0.372)	-0.457 (0.437)	0.167 (0.359)
<i>agriculture</i>	0.200 (0.266)	-0.0355 (0.305)	-0.204 (0.296)	0.335 (0.265)
<i>horticulture</i>	0.316 (0.406)	-0.594 (0.417)	0.110 (0.437)	0.437 (0.421)
<i>constant</i>	0.248 (0.306)	0.455 (0.335)	-0.706** (0.343)	0.420 (0.310)
<i>Wald ($\chi^2(16)$)</i>	73.99	54.61	132.29	75.89
<i>p > χ^2</i>	0.00	0.00	0.00	0.00
<i>Pseudo R²</i>	0.038	0.032	0.107	0.043
<i>N</i>	1,528	1,528	1,528	1,528

Note: *** indicates significance at p<0.01, ** indicates significance at p<0.05 and * indicates significance at p<0.1 in an individual two-tailed z-test

8 Monitoring the “Energiewende” – Energy efficiency indicators for Germany^{*}

Abstract

The increasing number of energy and climate targets both at national and international level induces a rising demand for regular monitoring. In this paper, we analyse the possibilities and limits of using energy efficiency indicators as a tool for monitoring these targets. We refer to the energy efficiency targets of the German “Energiewende” and calculate and discuss several energy efficiency indicators for Germany both at the level of the overall economy and the main energy consumption sectors. We make use of the energy efficiency indicator toolbox that we have developed within the ODYSSEE database in recent years and find that there is still a considerable gap to close to achieve the overall energy efficiency targets in Germany by 2020. We also show that progress in energy efficiency slowed down between 2008 and 2012, i.e. compared to the base year of most of the German energy efficiency targets and find that energy efficiency progress in the industrial sector during the last decade has been especially slow. We conclude that improvements in energy efficiency have to speed up considerably in order to achieve the targets for 2020. Although the use of energy efficiency indicators is limited by data constraints and some methodological problems, these indicators give a deep insight into the factors determining energy consumption and can therefore complement the official monitoring process of the German “Energiewende” which only relies on highly aggregated indicators for energy efficiency.

^{*} Published as Fraunhofer ISI Working Paper Sustainability and Innovation, No. S 10/2014. A shortened version of the paper is submitted to Energy the International Journal. Co-authors are Matthias Reuter, Bruno Lapillonne, Karine Pollier and Jan Rosenow.

8.1 Introduction

Targets for the reduction of energy consumption or greenhouse gas emissions play an increasing role in the field of energy and climate policy. Against the backdrop of a growing number of targets and the introduction of new policy instruments to meet them at national and international levels, it has become more important to regularly monitor the progress made towards these targets in order to make sure they are reached.

The European Union (EU) launched a system of climate and energy targets for 2020 (EC, 2008) aimed at a reduction in GHG emissions by 20% compared to 1990, an increase of the share of renewables in the total EU gross final energy consumption to 20% and a reduction of primary energy consumption by 20% against a reference development. A new framework for energy and climate targets up to 2030 is now being developed (EC, 2013). With its Low Carbon Roadmap from 2011 (EC, 2011), which demands reduction of GHG emissions to 80-95% below 1990 levels by 2050, the EU has also set, for the first time, a long-term decarbonisation target. At national level, an increasing number of European and other countries have introduced targets or target systems with regard to energy and climate issues (for an overview see Wade et al., 2011; Enerdata, 2011a). In Germany, the Federal government adopted an Energy Concept (German Government, 2010) which laid down the main strategic targets of Germany's energy and climate policy for the medium-term up until 2020 and the long-term up until 2050. These targets remained in place when the Federal government, as a response to the nuclear disaster in Fukushima, took decisions to fundamentally transform the German energy system in summer 2011: the so-called “Energiewende” (BMU, 2011).

Our paper focuses on targets addressing energy efficiency given its relative importance for decarbonising the economy. According to the IEA (2012, p. 253), energy efficiency accounts for more than 70% of the CO₂ emission savings in 2020 in a policy scenario targeted to limit the long-term increase of global temperature to 2°C above pre-industrial levels. Energy efficiency is accordingly a corner stone of European energy and climate policies. In Germany, a significant improvement in energy efficiency is, besides an accelerated switch to renewable energies, a key pillar of the “Energiewende” (see Section 8.2).

In this paper, we analyse the possible role and limits of energy efficiency indicators as an instrument for the regular monitoring of energy consumption and energy efficiency targets, and refer to the targets incorporated in the German “Energiewende”. With these targets, Germany has become one of the most ambitious countries in terms of

energy transition. So monitoring the transition is not only relevant for Germany, but also for countries that take her lead. The “Energiewende” has now been running for a few years, so with the statistical data it provides, the time is right to do an evaluation. In this paper we analyse the progress on the demand side, i.e. for the energy efficiency-related targets of the “Energiewende”⁶⁹, making use of the energy efficiency indicator toolbox that we have developed within the ODYSSEE database in recent years⁷⁰. We believe that the current “Energiewende” targets are good, but do not provide explanations of the underlying processes (i.e. especially activity, structure, behaviour and efficiency). Therefore, we calculate and discuss several energy efficiency indicators for Germany both at the macro-economic and sectoral level, which enable us to reveal some central developments behind the progress to the targets.

We present and discuss a possible tool for the regular monitoring of energy efficiency targets. Methodologically, our tool is based on index decomposition analysis which has been used for analysing energy-related trends since the 1970s⁷¹. An aggregated component, for example the energy consumption or the energy intensity of a country or a sector, is broken down into several determining factors to analyse their influence on the aggregate. This aims to analyse the extent to which improvements in energy efficiency have been responsible for the observed changes in energy consumption in a country. This is done by analytically separating the impact of energy efficiency improvement from other factors that influence the demand for energy (e.g. economic growth, structural changes within an economy or a sector, or fluctuations in weather). There are several competing methods for index decomposition (for an overview see Ang, 1995,

69 Compared to energy efficiency, the targets addressing renewable energy sources (RES), which are the second pillar of the German “Energiewende” (see Chapter 8.2), are much easier to define and monitor, since there are less defining options (see e.g. Harmsen et al., 2014 or Schlomann and Eichhammer, 2014) and less problems interpreting a certain development.

70 The ODYSSEE database was developed within the ODYSSEE-MURE project which has been financed by the European SAVE and IEE programs since 1993. Within the project, a huge statistical database on energy consumption in the EU Member States and Norway was built-up and is regularly updated. Based on these data, a comprehensive set of energy efficiency indicators was developed which are calculated both at the level of the whole economy and at the sectoral level. For more information see <http://www.odyssee-mure.eu/> and Section 8.3.1.

71 The use of index decomposition analysis in order to describe and analyse trends in energy consumption started in the 2nd half of the 1970s in the U.S. (see e.g. Schipper and Lichtenberg 1976, Darmstadter et al., 1977; Berndt, 1978 and Schipper, 1979). During the 1980s and 1990s, energy efficiency indicator projects started both at the country level (see EIA, 1995 for the U.S., Farla et al., 1998 and Farla and Blok, 2000a for the Netherlands, Diekmann et al., 1999 for Germany, Natural Resources Canada, 2004 for Canada) and for the IEA (2004) and the European Union (Morovic et al., 1989; Bosseboeuf et al., 1999).

2004). Generally, however, such analysis and the resulting calculation of so-called “energy efficiency indicators” is widely accepted as an important tool for policy making in the field of energy efficiency (IEA, 2014a).

The paper is organised as follows. Section 8.2 provides background on the German “Energiewende” outlining its suitability as a case study. In Section 8.3 we describe the methodological approach and the statistical data which we use for our analysis. In the following Section 8.4, we show the development of energy efficiency indicators in Germany for the period 2000 to 2012 and reflect the results in the energy efficiency-related targets of the German “Energiewende”. In Section 8.5, we interpret our results and discuss the strengths and limits of energy efficiency indicators as monitoring instruments. In the final Section 8.6, we summarise the main results and draw some conclusions.

8.2 Background to the German “Energiewende”

In Germany, the Federal government adopted an Energy Concept (German Government, 2010) which laid down the main strategic targets of Germany's energy and climate policy in the medium-term up to 2020 and in the long-term up to 2050 (see Table 8-1). These targets also remained in place when the Federal government, as a response to the nuclear disaster in Fukushima, took decisions to fundamentally transform the German energy system in summer 2011 creating the so-called “Energiewende” (BMWi 2011 and BMU 2011). The main pillars of the “Energiewende” are (i) the gradual phase-out of nuclear power by 2022, (ii) a significant improvement in energy efficiency to reduce the demand for energy and (iii) an accelerated switch to renewable energies for the remaining energy demand.

Table 8-1: Quantitative targets of the German Energiewende

Sector	Target	Target value 2020	Target value 2050
Total Emissions	Greenhouse gas (GHG) emissions	-40% (comp. to 1990)	-80 to -95% (comp. to 1990)
Energy Consumption / Energy Efficiency (EE)	Primary energy consumption	-20% (comp. to 2008)	-50% (comp. to 2008)
	Final energy productivity (i.e. GDP related to total final energy consumption)		2.1% per year
	Gross electricity consumption	-10% (comp. to 2008)	-25% (comp. to 2008)
	Share of CHP in total electricity production	25%	-
Building stock	Heating requirement	-20% (base year not specified)	
	Primary energy demand		-80%
	Building renovation rate	Doubling to around 2% per year	
Transport	Final energy consumption in transport	-10% (comp. to 2005)	-40% (comp. to 2005)
	Number of electric cars	1 million	6 million (in 2030)
Renewable Energy Sources (RES)	Share of RES in gross final energy consumption	18%	60%
	Share of RES in gross electricity consumption	35%	80%

Source: German Government, 2010

The progress made towards the overall targets and the current status of implementation is evaluated in annual monitoring reports. After three years, a progress report has to be provided which also includes some information on the actual impact of policy instruments and programmes. The corresponding monitoring process “Energy of the future” was approved by the Federal government in October 2011 (German government, 2011). The first two annual reports for the reporting years 2011 and 2012 have already been submitted (BMW i and BMU, 2012; BMW i, 2014). The governmental reports are accompanied by an expert's opinion from an independent commission which was appointed by the Government (Löschel et al. 2012, 2014). The focus of the annual reporting is on the verification of the progress towards the quantitative targets of the Energiewende. A set of 49 monitoring indicators was defined for the first monitoring report (BMW i and BMU, 2012) and further developed in the second report (BMW i, 2014). In contrast to our paper, which only refers to the energy efficiency-related targets, these indicators cover all relevant areas of the “Energiewende”, i.e. energy supply, energy efficiency, renewable energies, power plants, grid infrastructure, buildings, transport and mobility, greenhouse gas emissions, energy costs and macro-economic impacts. With regard to energy efficiency, however, the indicators in the official monitoring proc-

ess are less detailed than those we discuss in this paper (see Section 8.3.3), but remain at a highly aggregated level of energy statistics.

Most of the targets of the “Energiewende” refer to an absolute reduction in primary and final energy consumption and a respective improvement in energy efficiency (see Table 8-1). The sectoral targets for the building stock and the transport sector also primarily relate to energy efficiency. This means that the improvement in energy efficiency - besides the increased use of renewable energies – is a key pillar of the “Energiewende”.

In this paper, we purely focus on the energy efficiency element of the “Energiewende”. We take into account the development of both energy consumption and energy efficiency at the level of the whole economy and at the sectoral level. Although there are no explicit energy efficiency (EE) targets for the industrial and tertiary⁷² sectors, these sectors will also be taken into account, because an energy efficiency improvement in these sectors is a prerequisite for the achievement of the overall EE targets. For our analysis, we not only rely on the aggregated energy consumption data and simple ratios as they are used in the official monitoring process, but also on energy efficiency indicators which are calculated based on index decomposition methods. These indicators give more insight into the factors determining energy consumption and can therefore complement the official monitoring process of the German “Energiewende”.

8.3 Methodology and statistical database

8.3.1 The ODYSSEE approach of monitoring energy efficiency targets

The ODYSSEE database on the one hand contains detailed data on energy consumption and its drivers in the main energy consumption sectors and, on the other hand, energy efficiency-related indicators. The following types of indicators are considered in ODYSSEE to describe and characterise energy efficiency trends and thereby monitor energy efficiency targets (for a detailed description of the methodology see Appendix A and Enerdata 2008, 2010, 2011b; Lapillonne and Pollier, 2011):

1. Different types of ratios relating energy consumption to an activity driving energy consumption of the overall economy or sector:
 - Economic ratios, relating energy consumption to an activity measured in monetary units; these indicators are called "energy intensities" in ODYSSEE.

⁷² In the German energy balances, this sector comprises public and private services, trade, commerce, agriculture, construction industry and some small industrial companies below 20 employees.

- Technical-economic ratios, relating energy consumption to an indicator of activity measured in physical terms; these ratios are called "unit consumption" and are usually calculated at the level of sub-sectors. Examples include energy consumption per passenger or tonne-kilometre in passenger and freight transport, physical production in manufacturing industry or energy consumption per electrical appliance type or per dwelling or square metre in the residential sector.
 - Adjusted ratios, from which external factors, which are not primarily attributable to changes in energy efficiency, have been removed (e.g. weather conditions or economic structure). These ratios are also used to make cross-country comparisons unaffected by such distortion.
 - Ratios at constant structure of the economy, which are derived from the ratios described above keeping the structure within one sector or the economy constant (over one reference year). These ratios are calculated by the Divisia method, which is a frequently used method of factor decomposition, separating the impact of structural changes from changes in sectoral energy intensities. It is especially applied to an analysis of the industrial sector (see Ang, 1995 and 2004).
2. Re-aggregated indicators at total economy or sectoral level, which are calculated by aggregating the individual indicators described above. The re-aggregated indicators are calculated in two forms:
- As an energy efficiency index, called "ODEX", measuring the energy efficiency progress at the level of the main final energy consumption sector (industry, transport, households⁷³) and for the whole economy. Broadly speaking, this index is obtained by aggregating the unit consumption changes at detailed levels (i.e. by sub-sector or end-use): the ODEX of a given sector is calculated from the variation of unit consumption indices by sub-sector (end-use or equipment) weighted by the share of each sub-sector in the total consumption of the sector. Measuring the variation in terms of indices enables the use of different units for the detailed indicators (e.g. kWh/appliance, MJ/m²). A decrease in the ODEX implies an improvement in energy efficiency.
 - As energy savings, expressing the variations of the ODEX in terms of amount of energy saved compared to a situation without energy efficiency progress; in the case of a worsening of energy efficiency, these savings can also be negative.
3. A decomposed indicator, which breaks down the variation in energy consumption over a given period into various components (e.g. economic growth, lifestyles,

⁷³ For the tertiary sector, the ODEX is not calculated in ODYSSEE up to now due to data gaps in many European countries.

and energy savings) to analyse their influence on the aggregate.⁷⁴ This indicator is calculated at the following levels:

- the main energy consumption sectors (industry, households, transport, tertiary, agriculture)
- total final energy consumption
- the power sector
- total primary energy consumption.

8.3.2 Statistical database for the German energy efficiency indicators

Detailed, complete, timely and reliable energy statistics are essential to monitor the development of energy efficiency at a country level (see IEA 2005 and 2014b). They are used to calculate statistically-based energy efficiency indicators in the ODYSSEE database. The data demands generally increase with the level of disaggregation. This is especially true for the calculation of unit consumption indicators at the sub-sectoral level and for the re-aggregated and decomposed indicators (see Section 8.3.1), which need highly detailed statistics. For the calculation of most of the indicators described above, ODYSSEE relies on statistical data from national sources. Only for the power sector, the data are taken from Eurostat (2014). They are only used for the decomposition of primary energy consumption, since the transformation sector is not explicitly covered by the ODYSSEE database.

In Germany, the statistics on energy consumption and on the main activities driving energy demand is relatively good compared to some other European countries and at the international level, where data gaps still exist (IEA, 2014b). The most important source of statistical energy consumption data in Germany is that of the Working Group on Energy Balances⁷⁵. They provide the national energy balances (AGEB, 2013) and – in collaboration with three research institutions – the yearly end-use balances for Germany (AGEB, 2014). Most of the macro-economic data in the ODYSSEE database, at

⁷⁴ For a user-friendly calculation of the decomposed indicator, a new “decomposition facility” was developed which enables the user to make their own calculations by selecting a country, a sector, an energy unit and a time period for the analysis. See <http://www.indicators.odyssee-mure.eu/decomposition.html>

⁷⁵ The Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen - AGEB) in Germany is a merger of some industrial associations and research institutes in the field of energy which both provides the national energy balances and the energy balances by end-uses on an annual basis (see <http://www.ag-energiebilanzen.de/EN/downloads/downloads.html>).

both the total economy and sectoral levels (GDP, added value of industry and industrial branches, added value of the commercial/public sector, private consumption, number of employees) are directly taken from the National Accounts (Federal Statistical Office, 2014). The Federal Statistical Office also provides the statistics on energy consumption in industry in accordance with the European classification (NACE Rev. 2) of industrial branches at a detailed 4-digit level (Federal Statistical Office, 2014). Detailed data on energy consumption in the residential and tertiary sectors, which go beyond energy balances, are collected through regular surveys which are carried out every two years (RWI and forsa, 2013; Fraunhofer ISI et al., 2014; Schlomann et al., 2014). The survey data are extrapolated for Germany as a whole and interpolations and extrapolations are made for years not covered by the original surveys. The most important data source for the transport sector is an annual publication (“Verkehr in Zahlen”), which is produced by the DIW Berlin on behalf of the Federal Ministry of Transport (DIW and BMVBS, 2014): it includes detailed data on the stock of vehicles, kilometres travelled, passenger and freight traffic and energy consumption by transport mode, and passenger and freight transport.

A detailed overview of the data sources for Germany in the ODYSSEE database, including a classification of the sources, is given in Appendix B. These data sources are also the main data bases for the official monitoring of the energy efficiency elements of the Energiewende (BMW i and BMU, 2012; BMW i, 2014) and for the German reporting of the energy efficiency progress in the National Energy Efficiency Action Plans (NEEAPs) under the former EU Directive on energy efficiency and energy services (ESD) (BMW i, 2011). Despite the relatively satisfactory data situation in Germany, there are still some data gaps which affect both the calculation of energy efficiency indicators in the ODYSSEE database and the official reporting obligations mentioned above. The Expert Commission accompanying the official monitoring of the “Energiewende” targets refers particularly to data gaps in the building and tertiary sector and recommends an improvement of the statistical database in these fields (Löschel et al., 2014, p. 4) The reporting of top-down energy savings under the ESD was mainly limited by missing statistical data on energy consumption for electrical appliances and cooling in the residential sector (BMW i, 2011).

In the ODYSSEE database (and in the German NEEAP) these data gaps were partly filled by the use of data from stock models (see Appendix B), allowing all types of indicators as described in Section 8.3.1 to be calculated for Germany. Most German indicators go back to 1991 (the year of the German reunification) or at least to 1995 or 2000. The last year statistically available for our analysis was 2012.

8.3.3 Choice of energy efficiency indicators for the monitoring of the German “Energiewende”

The choice of energy efficiency indicators, as presented in this paper, is oriented towards the targets of the “Energiewende” which are related to energy efficiency (see Table 8-2). First of all we consider indicators which directly refer to the EE targets as they are formulated in the energy concept. However we also consider EE indicators from which external factors not attributable to energy efficiency are completely removed (see Section 8.3.1). These are not only suitable to describe the progress achieved towards the targets, but also help analyse and explain the developments which are behind the observed trends. They include ratios for the overall economy and the main energy consumption sectors (private households, transport, industry, and tertiary) and re-aggregated ODEX and decomposed indicators.

We calculate these indicators on an annual basis over two time periods:

- 2000-2012 in order to give a detailed picture of the development of primary and final energy consumption in Germany over the last decade, and
- 2008-2012 (transport: 2005-2012) to show the development between the base year for the targets of the “Energiewende” and the latest year which is statistically available.

The ODYSSEE database offers the choice of several energy units for the calculation of energy efficiency indicators. In our analysis we will use the unit “Joule” (J).

Table 8-2: Choice of energy efficiency indicators for the monitoring of the “Energiewende”

Sector	EE-related targets of the “Energiewende”	EE indicators which directly refer to the EE target	Additional EE indicators to explain the development towards the targets
Overall Economy	Primary energy consumption	Total primary energy consumption -actual -temperature-corrected	Primary energy intensity -actual -temperature--corrected Decomposition of primary energy consumption
	Final energy productivity (defined as GDP / final energy consumption)	Final energy intensity, i.e. the reciprocal of the productivity -actual -temperature corrected	Final energy consumption (total and by sector) Global ODEX Decomposition of final energy consumption
	Gross electricity consumption	Total electricity consumption	Electricity intensity
Households	Heating requirement	Final energy consumption for space heating -actual -temperature-corrected	Unit consumption per dwelling (temperature-corrected) Unit consumption for electricity per dwelling
	Primary energy demand Building renovation rate		Unit consumption for space heating per dwelling (temperature-corrected) Unit consumption for space heating per m2 (temperature-corrected) ODEX Households Decomposition of residential energy consumption
Transport	Final energy consumption in transport	Final energy consumption of the transport sector	Final energy consumption by transport mode Unit consumption of passenger and freight traffic Kilometres for passenger and freight traffic ODEX Transport Decomposition of transport energy consumption
Industry	No specific target	-	Final energy intensity of manufacturing -actual -at constant structure Unit consumption of energy-intensive products (steel, cement, paper) ODEX Industry Decomposition of industrial energy consumption
Tertiary / Services	No specific target	-	Energy intensity of services (temperature-corrected) Unit consumption per employee (temperature-corrected) Decomposition of service energy consumption

8.4 Results

In the following paragraphs, the energy efficiency indicators described in Table 8-2 are calculated for Germany and analysed with regard to the targets of the “Energiewende”. All indicators have been calculated based on the tools provided by the ODYSSEE database.⁷⁶

8.4.1 Indicators for the overall economy

Total energy consumption

The overall energy efficiency targets of the German “Energiewende” refer to primary energy and gross electricity consumption. In addition, Germany has a productivity target which is based on final energy (see **Fehler! Verweisquelle konnte nicht gefunden werden.**)⁷⁷. Between 2000 and 2012, primary energy consumption (not temperature-corrected) fell from 14,401 PJ to 13,757 PJ, i.e. by 4.5%. Between 2008 and 2012, i.e. compared to the reference year of the target, the decrease amounted to 4.3%, i.e. was in the same order of magnitude (Figure 8-1). This is, however, only a little more than one fifth of the decrease which is required to achieve the 20% reduction target in 2020. The decrease in final energy consumption was considerably smaller, amounting to 2.6% over the whole period. Between 2008 and 2012 it was only 1.1%.

The impact of weather fluctuations on energy consumption is shown by the different development of the actual and the temperature-corrected consumption. Beginning with 2000, all years except 2010 were warmer than the long-term average (in terms of degree days). As a result, the temperature-corrected final energy consumption is higher than the actual consumption except in the cold year 2010. Although the difference is relatively small in most of the years, the temperature-corrected consumption shows the more meaningful trend. Both over the whole period 2000-2012 and from 2008 the consumption decrease based on temperature-corrected data was more pronounced: between 2000 and 2012, primary energy consumption fell by 5.9% (2008-2012: -4.8%), and final energy consumption by 4.8% and 2.1% respectively. Although it seems that the primary energy reduction target is closer when considering temperature-corrected

⁷⁶ <http://www.indicators.odyssee-mure.eu/energy-efficiency-database.html>

⁷⁷ These targets are set without a reference whether or not the values are to be adjusted to normal climate. The official monitoring report (BMW, 2014) shows both an actual and a temperature-corrected development. The distance to the target, however, is only measured with regard to the actual development, i.e. without temperature correction. In this paper, we will calculate both actual and temperature-corrected indicators, in order to analyse the impact of weather fluctuations on energy consumption.

data, a strengthening of the falling trend is necessary to achieve the 20% reduction in the eight remaining years.

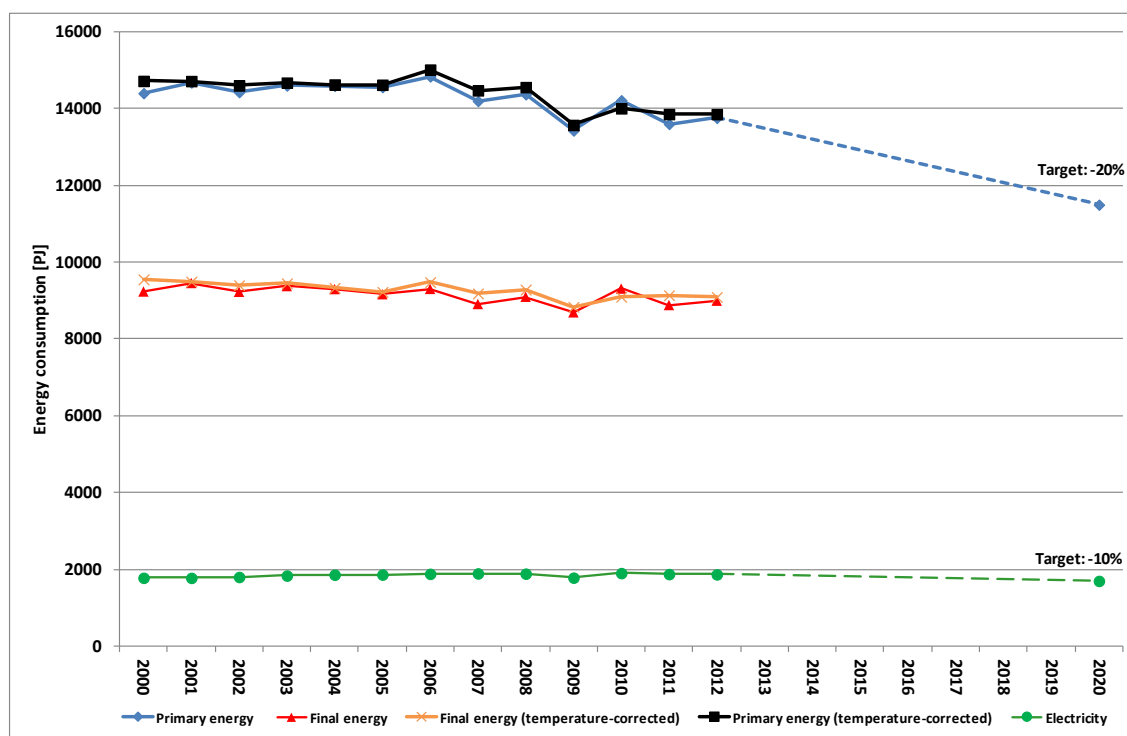


Figure 8-1: Development of primary and final energy consumption 2000-2012

With regard to the composition of final energy consumption by sector, the main sectors, i.e. households, transport and industry, contribute relatively equally with a share of slightly below 30% of total final energy consumption in Germany (

Figure 8-2). There have been no fundamental changes since 2000. The share of industry only slightly increased, by 2 to 3 percentage points, during the last decade which was mainly due to the relatively high industrial growth since 2005 (except the recession year 2009).

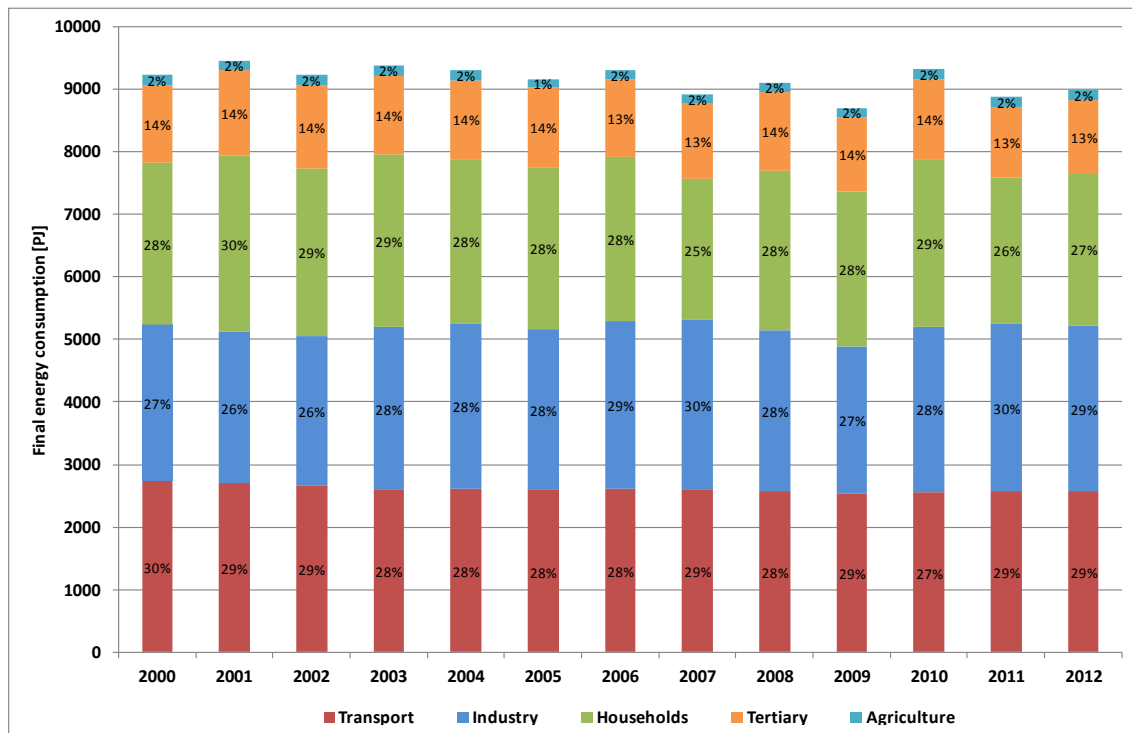


Figure 8-2: Final energy consumption by sector 2000-2012

Energy intensity

There are two general indicators which are often used to characterise the overall energy efficiency of a country from an economic viewpoint: the primary energy intensity and the final energy intensity, i. e. the ratio between primary or final energy consumption and gross domestic product (GDP). The reverse of this ratio, which is called “energy productivity”, is one of the targets of the German “Energiewende” (Table 8-1). The effects of economic growth, as measured by GDP, are removed from this indicator as are weather fluctuations in case of temperature-corrected intensities which are the more meaningful ratios.

Since 2000, actual primary energy intensity in Germany fell by 1.5% per year on average (by 1.6% with temperature correction). The decrease in final energy intensity, as required by the “Energiewende” target, was less pronounced in this period with an annual improvement amounting to 1.3% or 1.5% based on temperature-corrected data (Table 8-3). When only looking at the development from 2008, the starting year of the target, the decrease in final energy intensity was even less pronounced than over the whole period; it fell by only 0.9% per year or 1.2% with temperature correction. The period 2008-2012 was characterised by strong fluctuations in the economic development due to the financial and economic crisis in 2008/2009 and the subsequent revival

of the economy which also had an impact on energy intensity. In 2009, the main year of the economic crisis, final energy intensity even began to increase, i.e. showing a worsening of energy productivity, which was mainly caused by developments in the industrial sector (see Section 8.4.4). As a result, an even stronger annual improvement of around 2.6% (see Löschel et al., 2014, p. Z-9) is required to achieve the German 2020 target in the remaining years. Over the whole period 2000-2012, the decrease in final electricity intensity was less pronounced than for final energy. But in contrast to final energy, it sped up in the period 2008-2012.

Primary energy intensity showed a more favourable development during these years; the decrease from 2008 was even stronger than over the whole period (Table 8-3). This was, however, only due to changes in the power sector (especially the rising share of renewable energies), which will be further analysed below.

Table 8-3: Development of primary and final energy intensity in the periods 2000-2012 and 2008-2012

Indicator [change in % per year]	Period		Target
	2000 - 2012	2008 - 2012	2008 - 2020
Primary energy intensity	-1.5%	-1.7%	
Primary energy intensity (temperature-corrected)	-1.6%	-1.9%	
Final energy intensity	-1.3%	-0.9%	Final energy productivity: +2.1% per year (eqv. to an intensity drop by -2.1%)
Final energy intensity (temperature-corrected)	-1.5%	-1.2%	
Final electricity intensity	-0.7%	-0.9%	

ODEX indicator

Although the overall energy intensities described above already take into account the impact of short-term weather fluctuations and changes in activities, the meaningfulness of aggregate energy intensities in capturing energy efficiency is limited by many structural effects within or across the different energy consumption sectors (e.g. sector or product structure in the industrial and tertiary sectors) and several comfort effects (e.g. larger living area per household, higher room temperature, larger appliances). In addition, energy intensities which are based on monetary activities at a highly aggregated level (i.e. total GDP or added value of a sector) only give a limited understanding of the pure energy efficiency developments. In order to improve the meaningfulness of such ratios, the use of activities measured in physical units (e.g. production in tons in manufacturing or per kilometre driven in transport) is widely recommended (see e.g. Farla et

al., 1998; Farla and Blok, 2000a,b; Neelis et al., 2007). In our paper, we will take into account these effects at the sectoral level by using indicators which are calculated based on activities measured in physical terms. This will be described in the following sections.

In addition, ODYSSEE provides a re-aggregated energy efficiency indicator (the so-called ODEX) at the level of final energy consumption, which takes into account both short-term fluctuations as well as some structural effects (especially changes in the shares of sectors or industrial branches in total economic output) and behavioural changes (such as higher room temperature or user habits). Since the ODEX is originally calculated at the sectoral level and largely based on ratios using physical instead of monetary activities (for the calculation of the ODEX see Appendix A), it is a more suitable indicator to evaluate pure energy efficiency trends than energy intensities calculated at an aggregate level.

The development of the ODEX indicator in Germany in the period 2000-2012 is shown in Figure 8-3. In the year 2012, the global ODEX in Germany amounted to 88 which represents a 12% improvement of the overall energy efficiency since the base year 2000, or 1% per year on average. This is around one third lower than the decrease in the (temperature corrected) final energy intensity during that period (see Table 8-3). That indicates the development of total final energy intensity was still influenced by some external factors not primarily attributable to energy efficiency which are removed from the ODEX. From 2008, the global ODEX in Germany stagnated and only improved again from 2011. In the period 2008 to 2012, the energy efficiency improvement at the level of the whole economy was cut by half to an average of around 0.5% per year. The stagnation of the global ODEX between 2008 and 2010 was caused by the reversal in development of energy efficiency in industry. During these years the industrial ODEX showed an increase, i.e. a worsening of energy efficiency, by around 1.4% per year, whereas the transport and household ODEX further improved, though at a slightly slower rate. This trend in industry is due to the fact that during an industrial recession the energy consumed per unit of production tends to increase. This reflects the fact that process energy does not decrease in proportion to activity (as the efficiency of equipment drops when not used at full capacity) and other energy uses (e.g. heating and lighting of the premises) remain roughly constant.

A more detailed analysis of the development of the ODEX at the level of final energy consumption sectors will be given in the following sections.

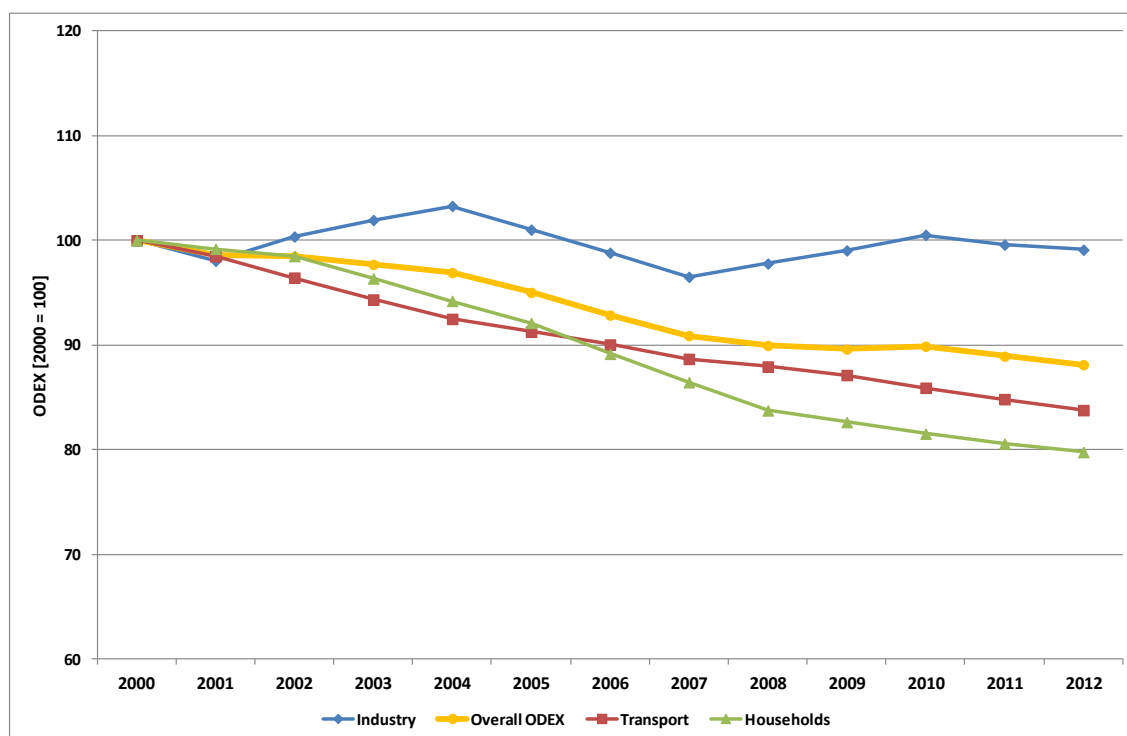


Figure 8-3: Development of the energy efficiency index ODEX in Germany for the overall economy and by sector for the period 2000-2012

Decomposition of final energy consumption

As described above, the ODEX measures the impact of energy efficiency gains (or losses) at the level of the overall economy. Other factors influencing final energy consumption which are not primarily attributable to energy efficiency are removed. In order to show the impact of these external factors on the variation of the total final energy consumption and to relate it to energy efficiency trends as measured by the ODEX, a new indicator was separated out from the ODYSSEE databases. It breaks down the variation of total final energy consumption over a given period into various components to analyse their influence on the aggregate (for a detailed description of this indicator see Appendix A).

The variation of final energy consumption is split into the following explanatory factors, which are calculated at the level of the energy consumption sector and totalled to provide a result for the overall economy:

- an activity effect due to an increase in an activity measured in economic or – as far as possible - physical units
- structural effects due to several changes in the structure of the economy
- a demographic effect due to changes in the number of inhabitants or households

- a so-called “lifestyle effect” due to an increase in comfort and in the number of appliances in a private household as a result of a growing income
- an energy efficiency effect as measured with the ODEX
- weather fluctuations which are taken into account for the household and tertiary sector
- other effects which are defined differently in the sectors and totalled; they mainly include behavioural changes and comfort effects in the household sector, changes in the value of products in industry, changes in labour productivity in the tertiary sector and the impact of statistical differences especially in the transport sector (see also Appendix A).

Figure 8-4 shows the decomposition of total final energy consumption in Germany for the periods 2000-2012 and 2008-2012.

During the period 2000-2012, total final energy consumption in Germany decreased by almost 240 PJ. The activity, demographic and lifestyle effects as well as the weather fluctuations contributed to a total increase in final energy consumption by around 1,570 PJ. These were, however, compensated for by the energy savings achieved through a considerable improvement in energy efficiency as measured by the ODEX and, to a lesser extent, some structural changes and other effects which also caused decreasing energy consumption over the period 2000-2012. The main drivers of the energy consumption variations were the growth of economic activity on the one hand and the reversal effect of the energy efficiency improvements in all final energy consumption sectors which were calculated from the ODEX and resulted in annual energy savings of around 120 PJ between 2000 and 2012 (see Figure 8-4).

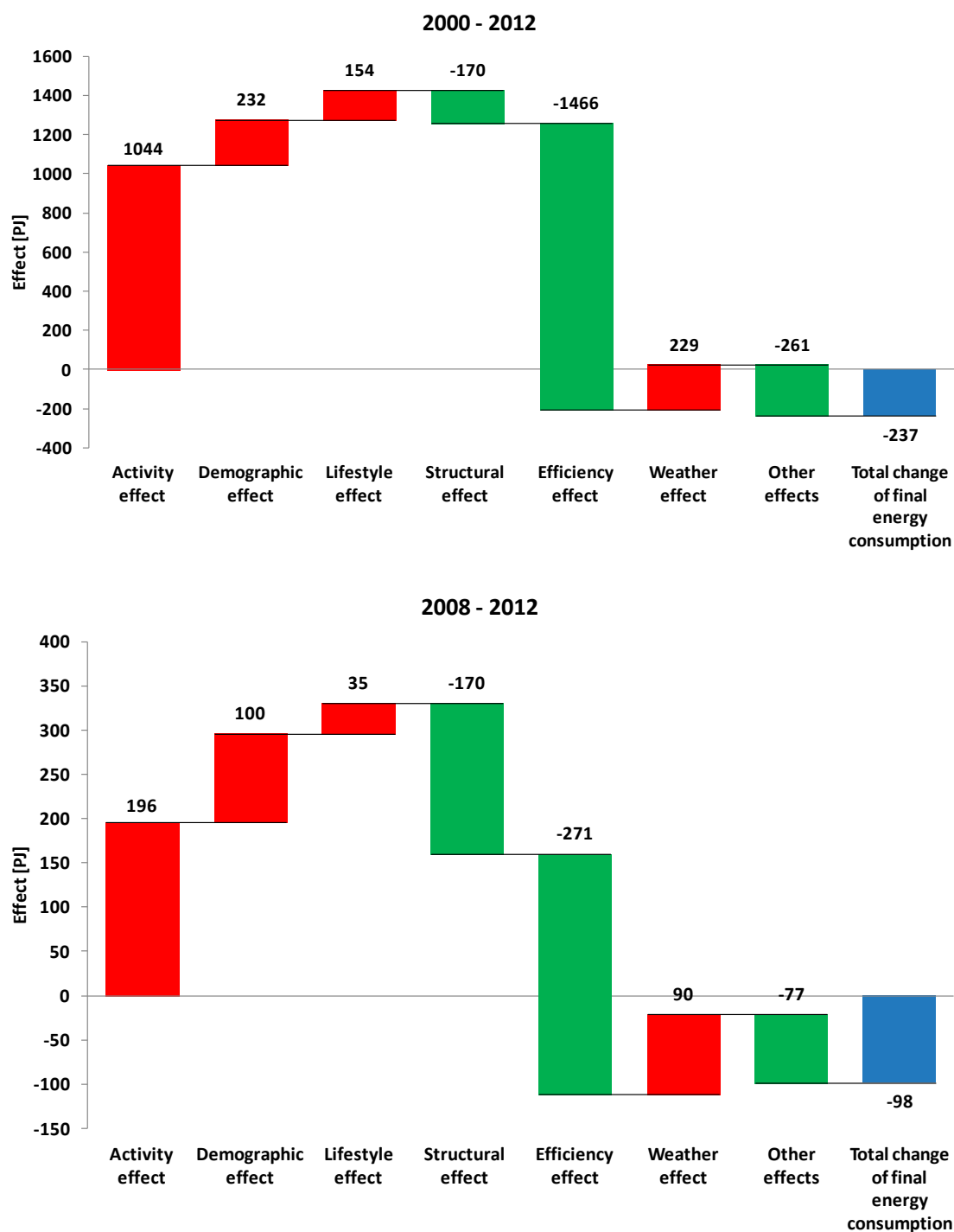


Figure 8-4: Decomposition of final energy consumption for the periods 2000-2012 and 2008-2012

When looking solely at the period 2008-2012, i.e. starting with the base year of the “Energiewende” target, the general direction of the effects is the same as for the whole period under review. However, the impact of the two main drivers of activity (increasing

effect) and energy efficiency (decreasing effect) was almost halved each year. On the other hand, structural effects, i.e. structural changes within the economy towards less energy-intensive sectors, were strongly negative leading to an even larger reduction of final energy consumption between 2008 and 2012 than over the whole period (around 25 PJ per year compared to almost 20 PJ).

As already stated above, the variation in total final energy consumption in a given time period was at first calculated at the sectoral level and then summed up for the total economy. Therefore, in the following Sections 8.4.2 to 8.4.5 we will analyse the developments in the different sectors more deeply.

Decomposition of primary energy consumption

The variation of primary energy consumption analysed here is the sum of the variation of final energy consumption, the variation of the net consumption of the power sector, and the variation in the consumption of other transformations (incl. non-energy uses). The variation of the net consumption of the power sector is further decomposed into three underlying effects, which contribute to the total change (see also Appendix A):

- the effect of “electricity penetration” measuring the impact of increased electricity consumption in terms of additional losses in power generation,
- the impact of changes in the “efficiency of thermal power plants” and
- the impact of changes in the “power mix“, i.e. the shares of renewable energies, nuclear energy and thermal power plants in total power production.

In the following, we base our analysis on temperature-corrected data. As Figure 8-5 shows, the (temperature-corrected) primary energy consumption of Germany decreased by 864 PJ (or almost 6%) in the time period from 2000 to 2012 and by 703 PJ (4.8%) from 2008 to 2012. Changes in the power mix had the greatest effect on this development in both periods (primarily the switching to renewable energy sources). It accounted for a reduction of 507 PJ from the year 2000 and 269 PJ from 2008. Changes in demand reduced primary energy consumption by 238 PJ in the period 2000-2012 and by around 100 PJ from 2008-2012. Compared to these effects, the contribution from changes in the efficiency of the thermal power plant and other transformational changes to the total reduction in primary energy consumption was relatively small. The increase in electricity penetration slowed this development down by 225 PJ in the period 2000 – 2012. However, in the period 2008-2012 a slightly reducing effect of 52 PJ was observed. Overall the analysis of primary energy consumption shows that most of Germany’s efforts to reduce its primary energy consumption, by pushing the development of renewable energies, pay off. These efforts were slowed down however, by contradicting effects like the growing consumption of electricity.

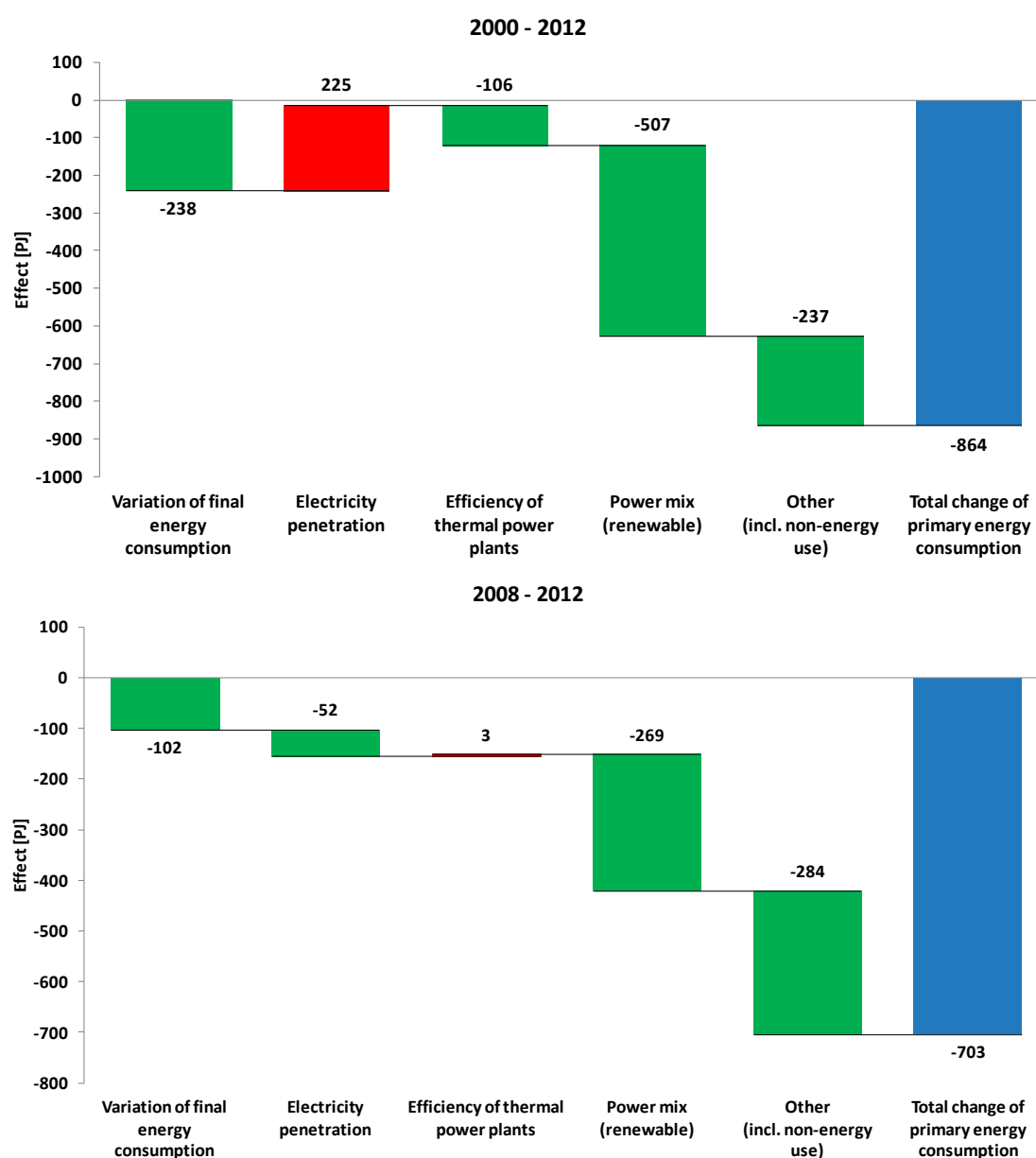


Figure 8-5: Decomposition of primary energy consumption for the periods 2000-2012 and 2008-2012

8.4.2 Indicators for the household sector

In the German energy concept, the household sector is addressed through targets for buildings (Figure 8-6). Although the building targets comprise both residential and non-residential buildings, the current monitoring of the “Energiewende” primarily focuses on energy consumption for space heating in private households (BMWi, 2014). The ODYSSEE database also follows this sectoral approach, not least because of the gaps in statistical data for non-residential buildings.

Total consumption for space heating

Energy consumption for space heating in residential buildings generally decreased in the last decade. In a few years however, it was interrupted by consumption increases (Figure 8-6). This was partly due to weather fluctuations, which are an important influencing factor for this part of energy consumption, but even the temperature-corrected curve, which is steadier than the uncorrected curve, shows some jumps especially in the mid 2000s⁷⁸. Over the whole period 2000-2012, the temperature-corrected energy consumption for space heating in residential buildings decreased by around 450 PJ or 20%. This is in line with the target for the building stock, which also predicts a reduction in heating requirements up to 2020. There is also a relatively continuous decline since 2008, the base year of the overall energy consumption targets. Therefore, we can conclude that if the general trend of the period 2000-2012 (based on temperature-corrected consumption values) can be maintained Germany is likely to achieve its 2020 target for the building sector.

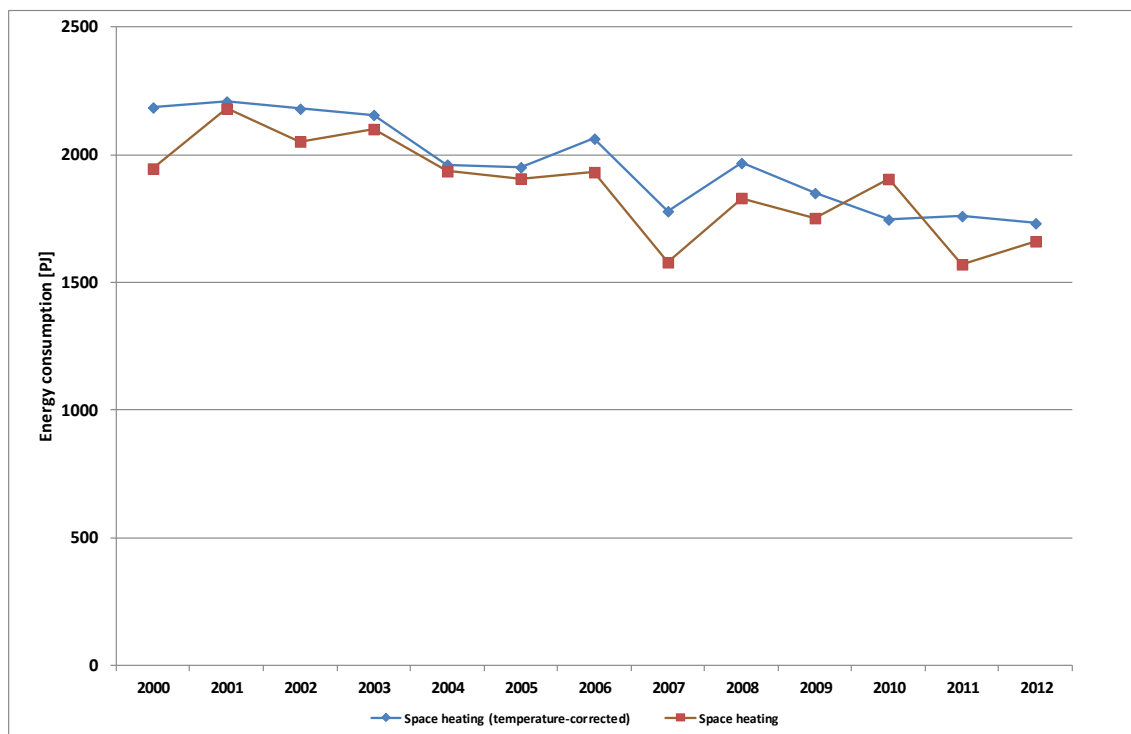


Figure 8-6: Total consumption for space heating in residential buildings 2000-2012

⁷⁸ A sharp decline, in particular in the consumption of mineral oil and to some extent also in the consumption of gas, has been noted in the national energy balances (AGEB, 2013) for the year 2007. This is partly explained by variations in stocks. But a recording error may be suspected, too, since survey data do not confirm this sharp decrease.

Unit consumption

We calculate unit consumption both for total energy and electricity consumption of private households and for space heating alone. Energy consumption is related to physical factors (number of dwellings or square metre) and the total energy consumption and space heating figures are temperature-corrected, to remove the effect of weather fluctuations. Total unit consumption generally follows the development of unit consumption of space heating (Figure 8-7), which represents about 70% of total household energy consumption in Germany⁷⁹. Whereas total unit consumption and unit consumption for space heating declined over the period, electricity consumption per dwelling remained quite static. After an increase to the mid 2000s, this ratio slightly decreased by around 1% per year from 2005.

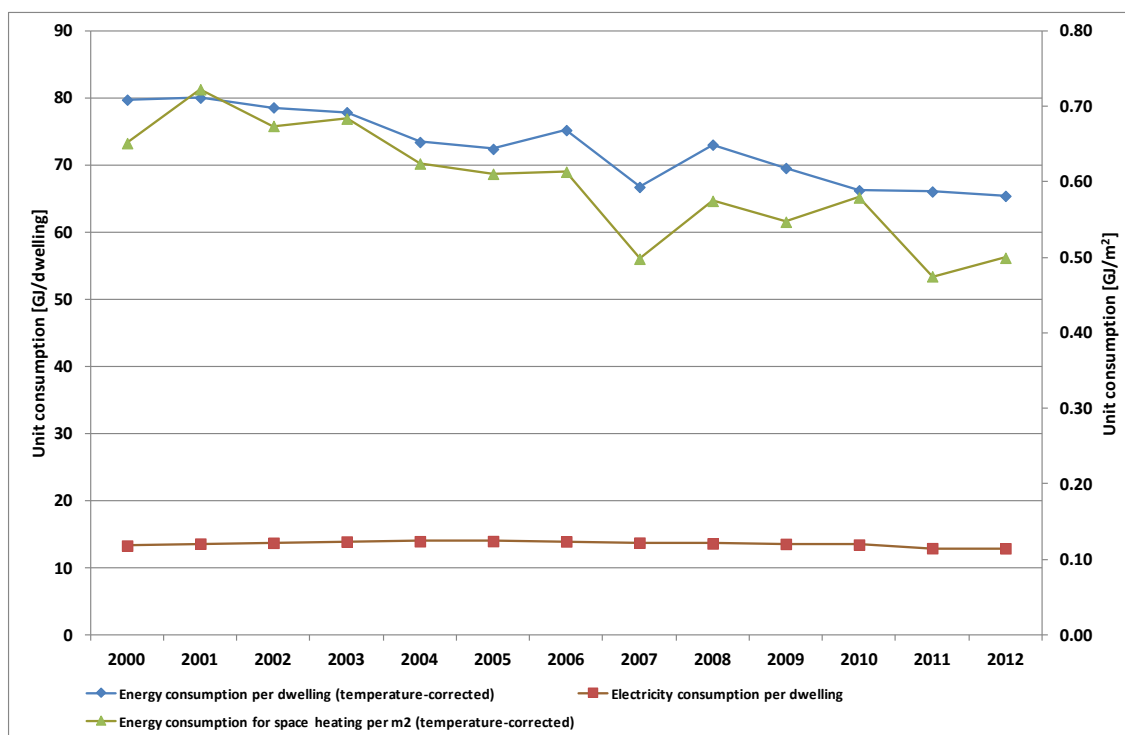


Figure 8-7: Unit consumption for space heating in households 2000-2012

Although the impact of the activity drivers (i.e. number of dwellings or square metre) and weather fluctuations are removed from the unit consumption indicator of private households in ODYSSEE, it is still influenced by several factors, which partly compen-

⁷⁹ In the ODYSSEE database, the following end uses are distinguished in the household sector (respective share in total household energy consumption in Germany in 2012): space heating (68%), water heating (15%), cooking (4%), electrical appliances (11%), lighting (2%).

sate for each other: fuel substitution, higher energy efficiencies due to thermal regulations, changes in dwelling size or heating system (trend to central heating), changes in the share of single and multi-family dwellings and last but not least behavioural factors (e. g. a trend to higher indoor temperature or a more intensive use of electrical appliances and lamps).

ODEX indicator

The calculation of the household ODEX is also affected by the behavioural factors listed above, which play an important role in the household sector and often counteract the energy efficiency gains as measured by the ODEX. In order to remove these influences, the calculation of the household ODEX was revised to calculate a "technical ODEX", which separates technical and behavioural trends (see Enerdata, 2010 and Appendix A).

For the household sector, the ODEX is calculated at the level of eight end-uses or appliances: heating, water heating, cooking and five large appliances (refrigerators, freezers, washing machines, dishwashers, TVs). Between 2000 and 2012, the technical ODEX in the household sector as a whole decreased by 20%, which represents an average energy efficiency improvement of 1.7% per year (Figure 8-8). As in the case of unit consumption, the development of the total household ODEX is strongly influenced by space heating, which is responsible for around 70% of total energy consumption (AGEB, 2014). With around 23% or 1.9% per year, the energy efficiency improvement for heating was even more pronounced than that for the total. However, in the period 2008-2012, it slowed down to 1.2% per year on average. The efficiency improvements of the five large appliances also contributed considerably to the total energy efficiency gains in the household sector, whereas the improvement for water heating and cooking was less pronounced.

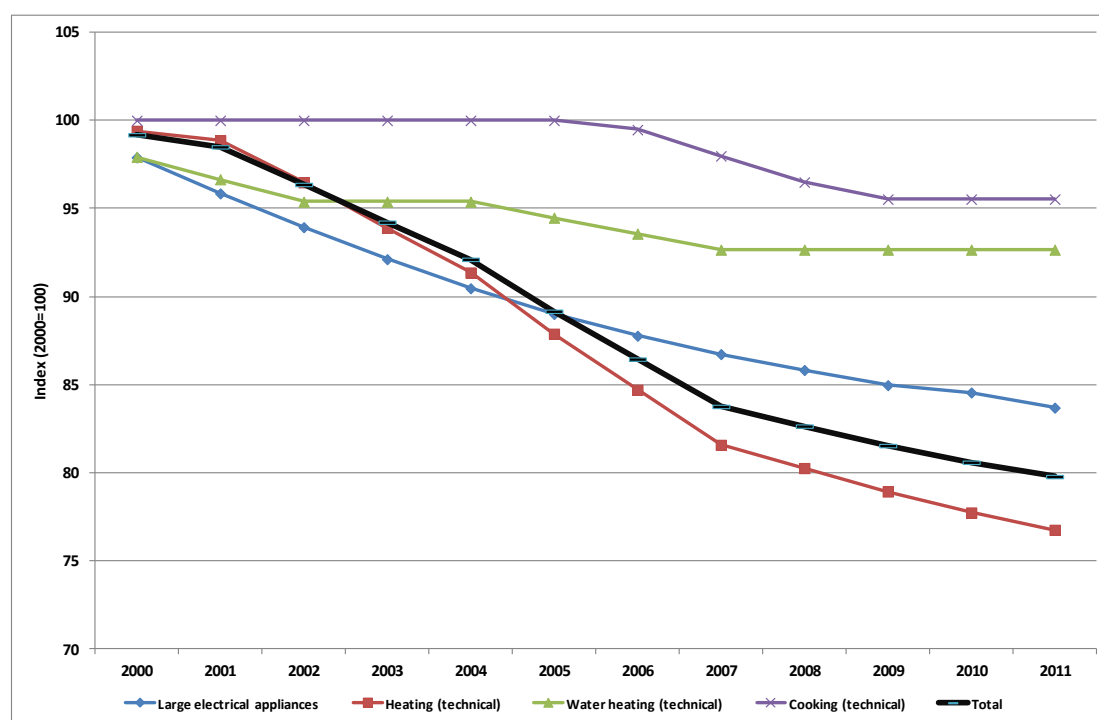


Figure 8-8: Development of the energy efficiency index ODEX in the household sector for the period 2000-2012

Decomposition of household energy consumption

Between 2000 and 2012, total energy consumption in the household sector decreased by around 150 PJ or 13 PJ per year. This decrease was mainly due to the energy efficiency improvement which was observed during this period, measured by the technical household ODEX (Figure 8-9). The increasing number of dwellings (demographic effect) and living space (lifestyle effect) and the weather fluctuations caused energy consumption to increase which was not, however, fully compensated for by the impact of energy efficiency. It was “other effects” which contributed to a reduction of energy consumption in Germany in both periods and became even more important in the period 2008-2012. These “other effects” were primarily behavioural changes (e.g. changing indoor temperature or changed intensity of use of electrical appliances or lamps), which were separated from the energy efficiency improvement measured by the ODEX. In this period, they contributed, along with the energy efficiency improvements, to the total decrease in household final energy consumption of around 130 PJ or 32 PJ per year.⁸⁰

⁸⁰ Why the “other effects” are so pronounced in the period 2008-2012 cannot be fully explained by the decomposition method applied here. The effect is calculated as a residual (see Appendix A) and can therefore also include the impact of changes in the underlying statistical database (see Section 8.3.2 and Appendix B).

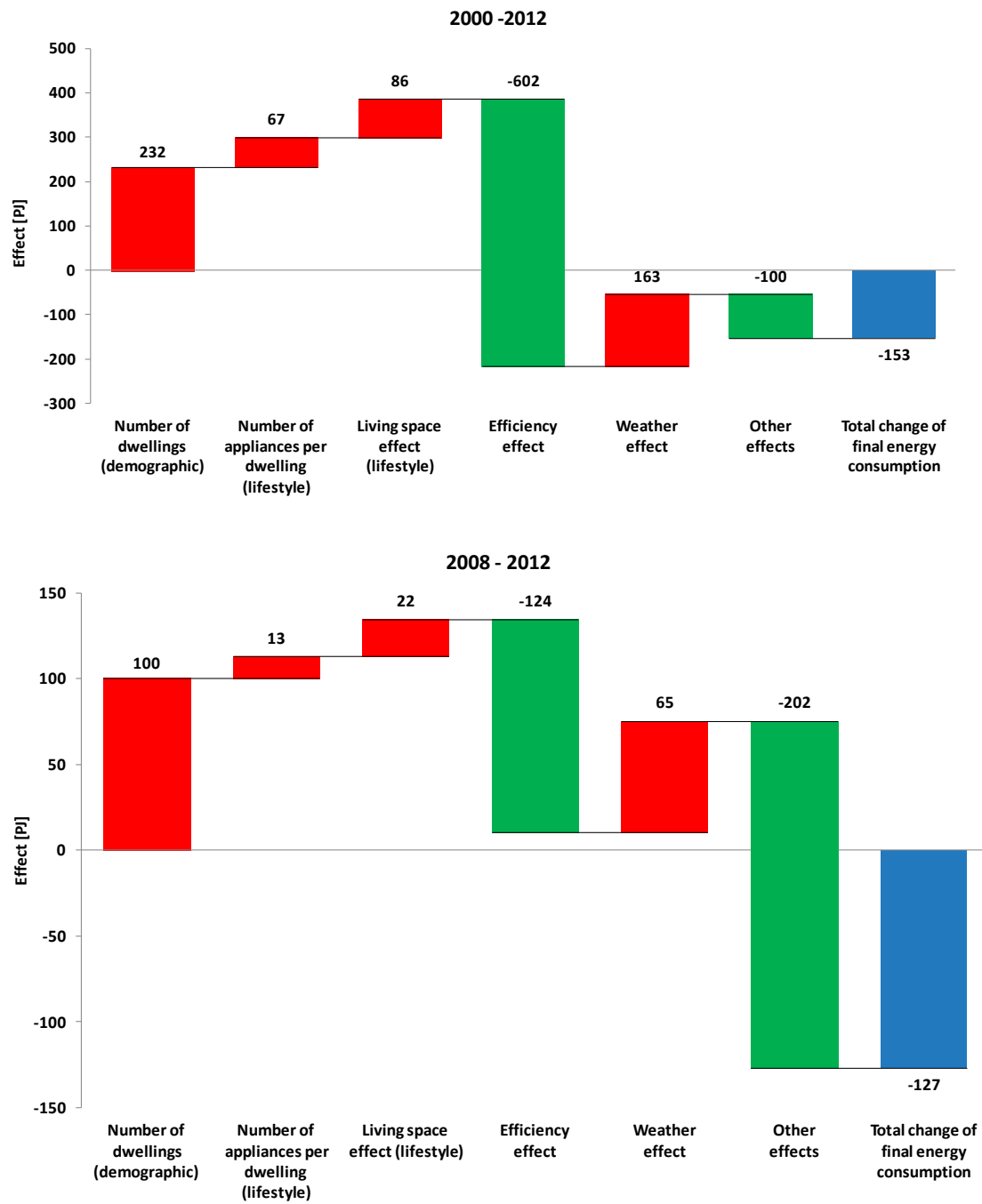


Figure 8-9: Decomposition of final energy consumption in the household sector for the periods 2000-2012 and 2008-2012

8.4.3 Indicators for the transport sector

Total energy consumption

Between 2000 and 2012, total energy consumption in the transport sector decreased by around 6.5% from 2,751 to 2,571 PJ. Compared to 2005, the base year for the transport energy consumption reduction target of 10%, consumption was almost at the same level as in 2012 (Figure 8-10). This means that there is still a considerable gap to close to meet the 2020 reduction target of 10% compared to 2005.

In contrast to road and rail transport, energy consumption for air transport (international and domestic) strongly increased especially between 2004 and 2008 (Figure 8-10). This can particularly be explained by the relatively strong growth of GDP by 2.2% per year during that period and also by the increasing market entry of low-cost carriers. In the following years, a consumption decrease could be observed during the economic recession, but consumption started to grow again in 2011. The share of air transport in total transport energy consumption increased from 11% in 2000 to 14.4% in 2012.

Nevertheless, with a share of more than 80%, road transport still dominates energy consumption of this sector in Germany. Therefore, the main focus of our analysis is on this mode of travel. Road energy consumption widely follows the trend of total consumption, it only lies slightly below (Figure 8-10). Around 70% of energy consumption on roads is by cars and 30% by trucks and light duty vehicles.

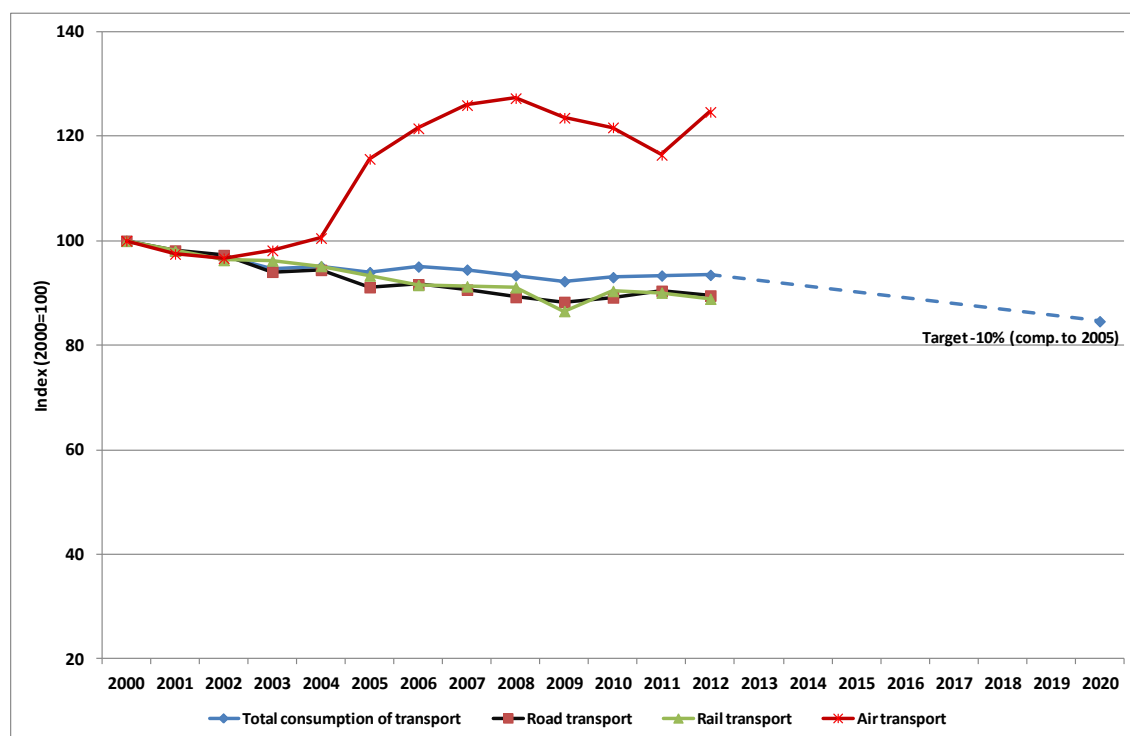


Figure 8-10: Final energy consumption of transport by modes 2000-2012

Unit consumption and traffic kilometres

The development of total energy consumption of road transport in the period 2000-2012 was influenced by two opposite trends: the rising number of passenger-kilometres for cars and ton-kilometres for trucks, and the decreasing unit consumption of these vehicle types (Figure 8-11). For freight transport, this trend was only interrupted in the recession year 2009. In this year there was a decline in the freight kilometres and an increase in unit consumption, both caused by the economic recession.

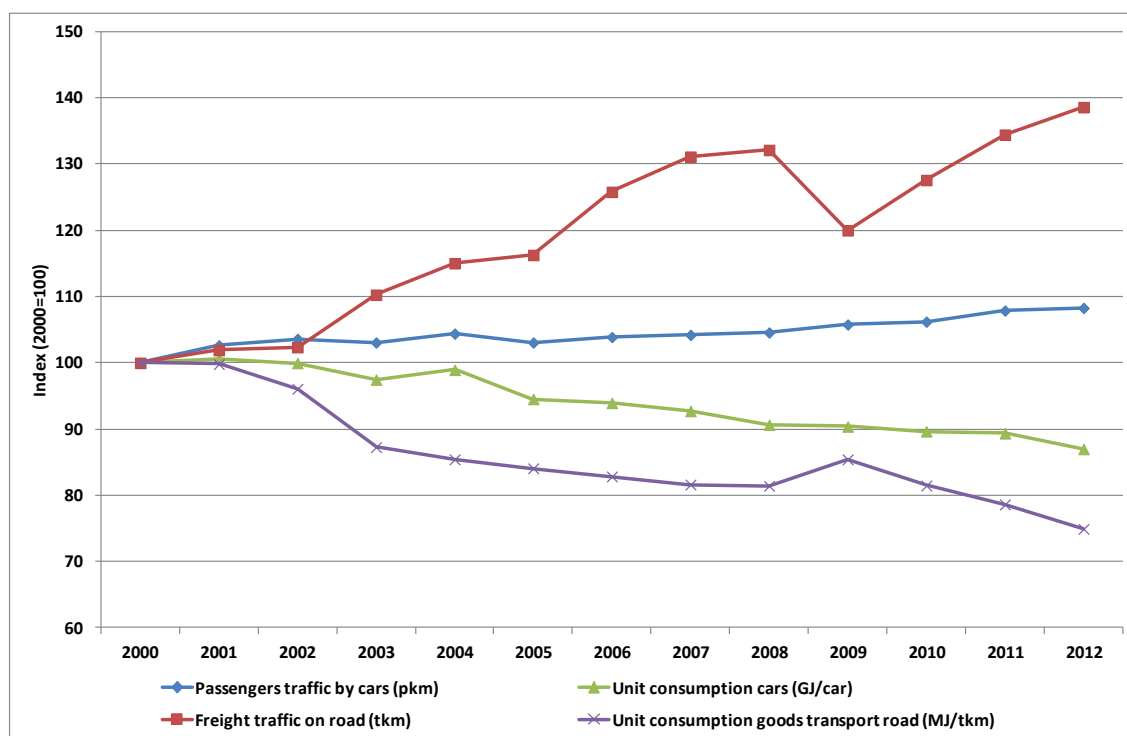


Figure 8-11: Unit consumption and traffic kilometres of passenger and freight transport 2000-2012

ODEX indicator

The energy efficiency progress in the transport sector is measured by the aggregated energy efficiency index (ODEX), which is calculated at the level of seven transport modes or vehicle types: cars, trucks/light duty vehicles, motorcycles, buses, rail, water and domestic air transport (Figure 8-12). The calculation is based on the unit consumption indices for these modes.

In 2012, the energy efficiency index of transport improved by 25% compared to 2000. Efficiency improvements in the car stock as a consequence of the penetration of new, more efficient cars (measured by a specific consumption in l/km) including a continuous trend to diesel cars, contributed steadily to this development. Since 2009, however, the energy efficiency improvement for cars has slowed down considerably. The energy efficiency index for trucks and light duty vehicles also contributed to energy efficiency gains in transport, especially over the period 2001-2006. Between 2007 and 2009, the ODEX for trucks increased, which represents a worsening of energy efficiency during the economic crisis. The contribution of the other transport modes (air, train, buses, motor cycles) is less important due to their relatively small shares in consumption. Air

transport showed a considerable increase in the ODEX, i.e. a worsening of energy efficiency since 2006.

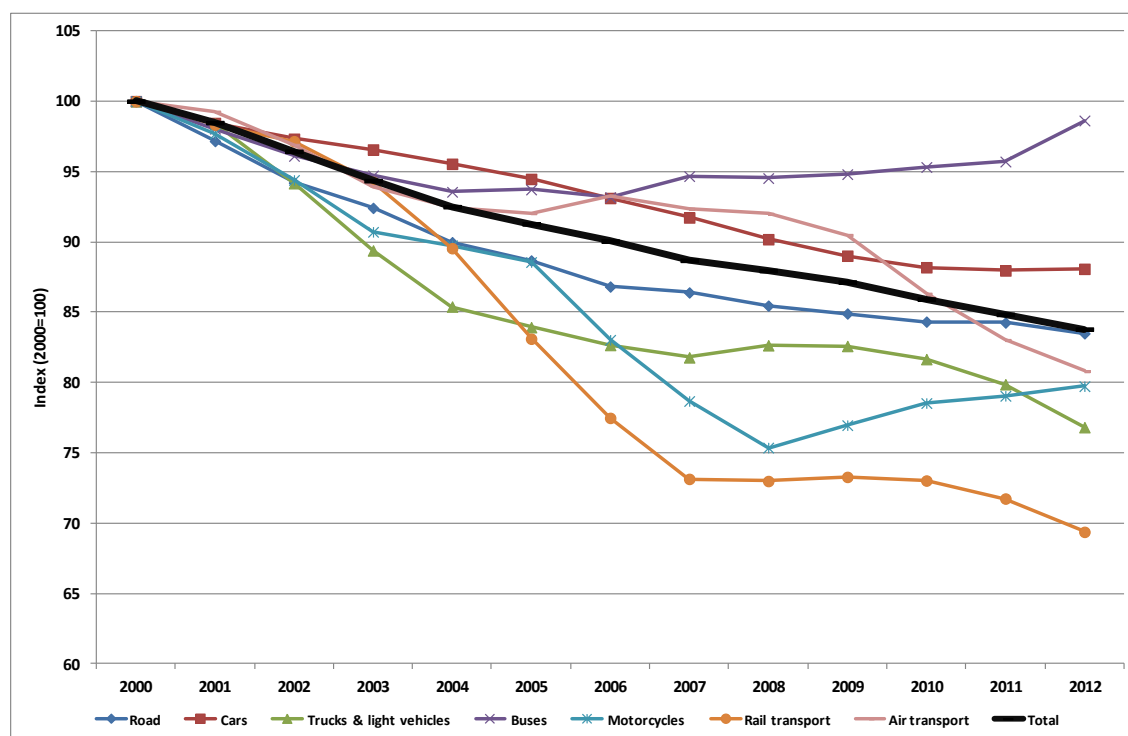


Figure 8-12: Development of the energy efficiency index ODEX in the transport sector for the period 2000 and 2012

Decomposition of transport energy consumption

The decomposition of transport energy consumption is mainly aimed at road transport, which is still by far the dominant transport mode in Germany. Therefore, the analysis is here done without air transport. As already stated above, the variation of transport energy consumption is dominated by an increasing traffic of passenger and goods (activity effect) which contributed to an increase in energy consumption by around 300 PJ in the period 2000-2012 (Figure 8-13). This effect was compensated for by an energy efficiency improvement, resulting in a total decrease of transport energy consumption by around 250 PJ or 21 PJ per year. Modal shift, i.e. changes in the distribution of each mode in total passenger and goods traffic, had a comparatively small impact on transport energy consumption between 2000 and 2012 and slightly increased consumption. In the period 2005-2012, the direction of the impacts was the same as in the whole period under review. The energy efficiency improvement has, however, slowed down from around 66 PJ to 37 PJ per year on average since 2005. As a result, total energy consumption only decreased slightly during that period (-41 PJ). This again suggests that there is still a considerable gap to close to meet the 2020 transport target. Since

the development of transport energy consumption is strongly dominated by the activity and energy efficiency effects, the main starting points for closing the gap are a reduction in the traffic and/or an improvement of energy efficiency.

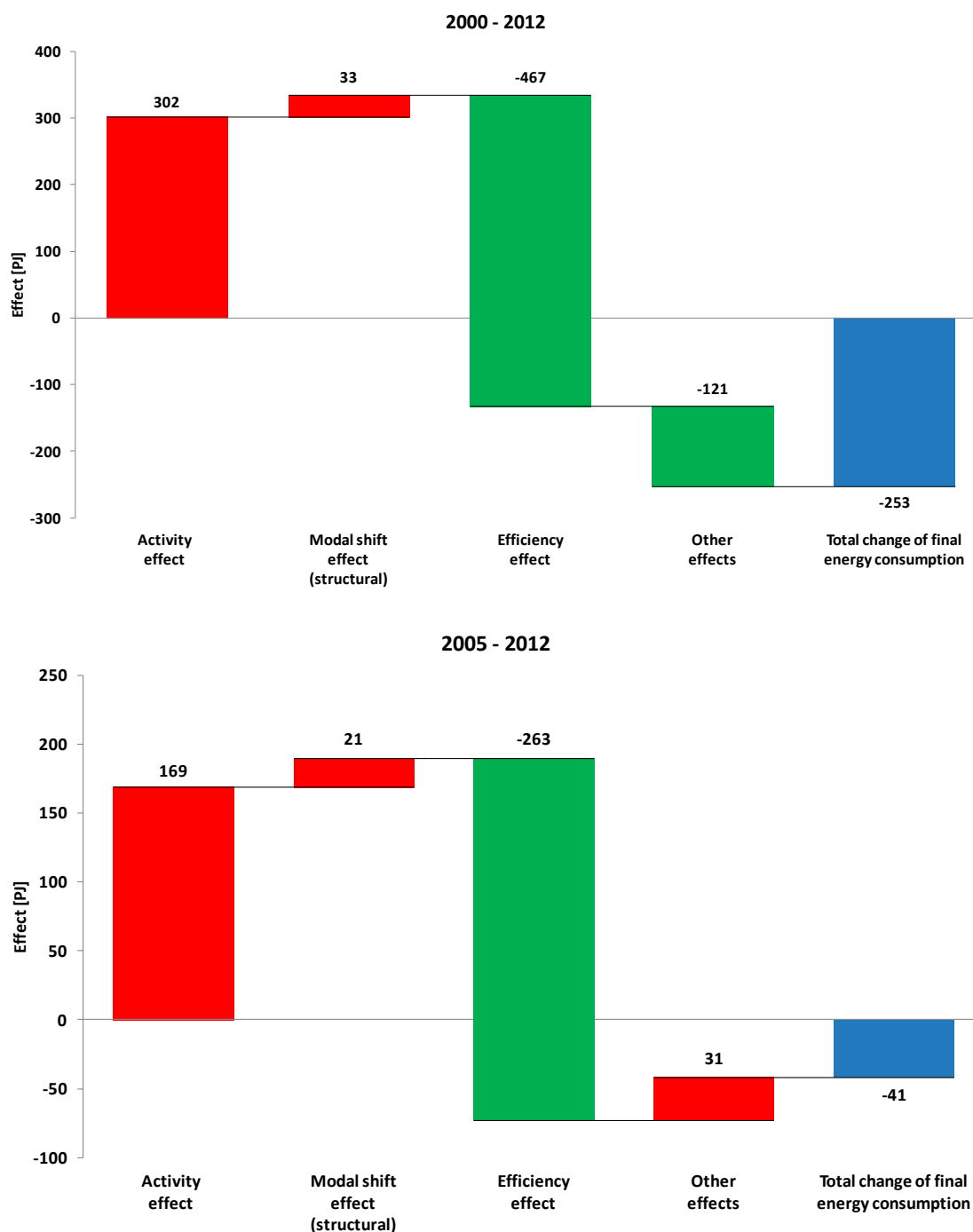


Figure 8-13: Decomposition of final energy consumption in transport (without air transport) for the periods 2000-2012 and 2005-2012

8.4.4 Indicators for industry and manufacturing

Although there is no specific energy efficiency target for the industrial sector in Germany, this sector contributes to the overall targets in total final energy consumption with a current share of around 30% (Figure 8-2). Therefore, we will also need to take a more detailed look at the development of energy consumption and energy efficiency in industry. Our analysis will mainly focus on manufacturing industry, which contributes around 97% of total energy consumption of industry⁸¹ in Germany.

Energy intensity and unit consumption

Energy intensity is an aggregate indicator which is often used to describe the development of energy efficiency in industry. Between 2000 and 2012, energy intensity of manufacturing decreased by 0.8% per year on average. When taking only the period 2008-2012 into account, the decrease slowed down to 0.1% per year. This means that the contribution of industry to the final energy productivity target of the “Energiewende” was below the average of the overall economy in both periods (see Table 8-3).

As already stated above, the development of energy intensity does not only reflect energy efficiency improvements; structural changes within manufacturing (i.e. changing shares of the more or less energy-intensive branches in total industrial output), may also have an important influence. This is shown by the energy intensity calculated within a constant structure of manufacturing. The intensity at constant structure better reflects the predominantly technically induced efficiency changes in manufacturing since the impact of structural changes are removed, using a Divisia index (see Appendix A). In the period 2000-2008, i.e. before the economic recession, the decrease of the actual energy intensity of manufacturing by around 1.6% per year has almost equally been influenced by energy efficiency improvements and structural changes towards less energy-intensive branches (Figure 8-14). In the following period from 2008-2012, this trend changed completely. Whereas the intensity-reducing impact of structural changes more than doubled compared to the period before, there was no energy efficiency progress at all, but energy intensity at constant structure increased by 1.7% per year. As already stated above (see Section 8.4.1), this increasing trend of energy intensity was mainly caused by the economic recession. It reflects the fact that process energy does not decrease in proportion to activity (as the efficiency of equipment drops

⁸¹ Industry is defined in ODYSSEE as manufacturing industry, mining, water processing and construction. The branches are defined in accordance with the statistical classification of economic activities in the European Community (NACE, Rev. 2, 2008).
http://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC

when not used at full capacity) and other energy uses (e.g. heating and lighting of the premises) remain roughly constant.

As a result, however, there was no energy efficiency progress in manufacturing over the whole period 2000-2012, but a slight increase in the intensity at constant structure by 0.1% per year (Figure 8-14). This means that the observed decrease in the actual energy intensity by 1.1% per year was primarily caused by structural changes within manufacturing towards less energy-intensive branches and not by energy efficiency gains.

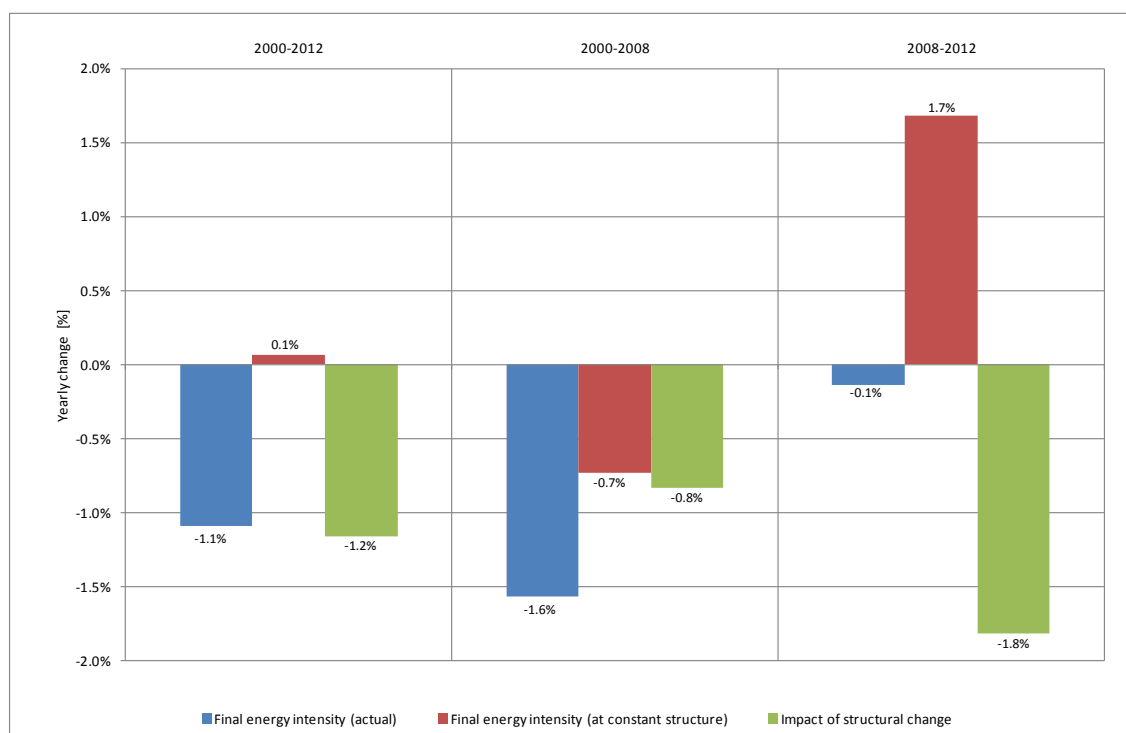


Figure 8-14: Change of energy intensity in manufacturing in the periods 2000-2012, 2000-2008 and 2008-2012

The meaningfulness of final energy intensity of manufacturing is further restricted by the fact that it is calculated based on added value, i.e. activity calculated in monetary units. The use of physical factors is widely advocated, since they better reflect the energy efficiency development (see e.g. Worrell et al., 1997; Farla and Blok, 2000b; Neelis et al., 2007; Salta et al., 2009). Therefore, we calculate – in addition to energy intensities – unit consumption indicators (defined as energy consumption per ton) for some energy-intensive products in manufacturing (see Figure 8-15).

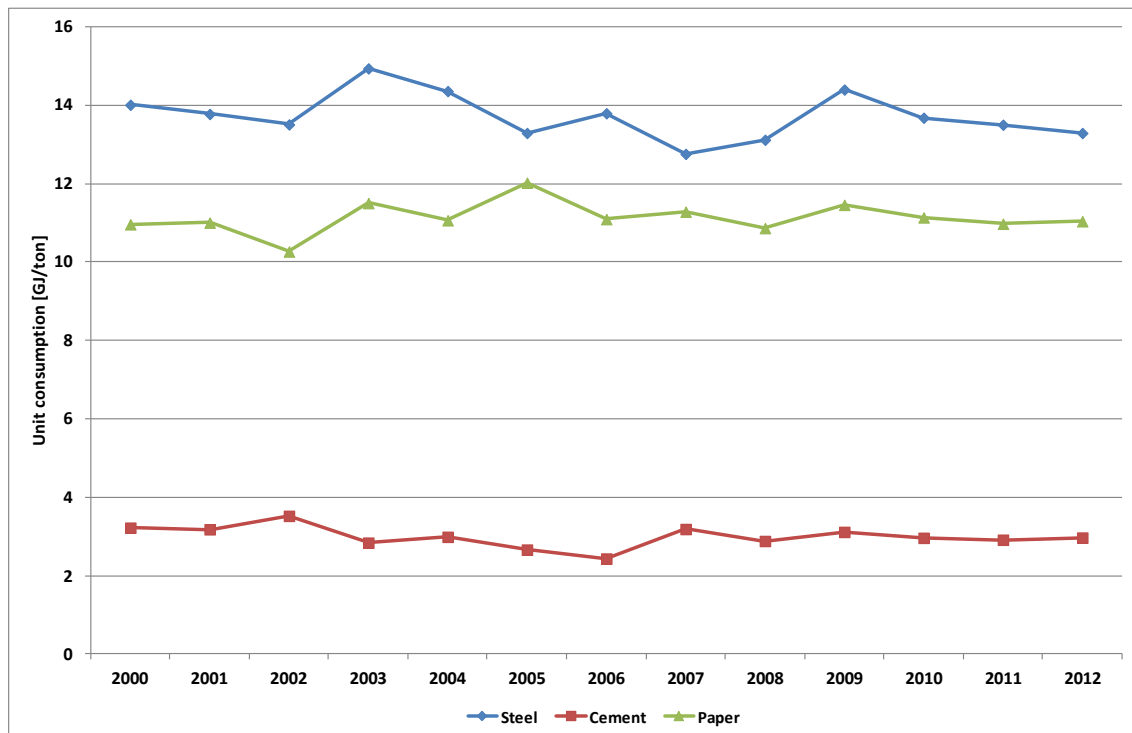


Figure 8-15: Unit consumption of energy-intensive products 2000-2012

Over the whole period 2000-2012, unit consumption of the selected products (crude steel, pulp and paper, cement) did not change significantly. In fact, in some years an increase was observed, especially in the case of steel and paper, and this was mainly linked to business cycles. The trend in unit consumption confirms the observation of rather modest or no energy efficiency improvement in industry which was already shown by the intensity indicator. This was also a reversal of the trend during the 1990s, when both energy intensity and unit consumption of energy-intensive products considerably decreased and a clear improvement in energy efficiency was observed (see Schломann and Eichhammer, 2012).

ODEX indicator

In addition to the energy intensity at constant structure and the unit consumption of energy-intensive products, the efficiency progress in the industrial sector is also measured with the ODEX. It measures the efficiency development at the level of 10 industrial branches, and aggregates this development to the whole sector (Figure 8-16). For the energy-intensive products (cement, steel, paper), the calculation is based on unit consumption per ton. For the other branches, the energy used per production index is used instead of added value, in order to exclude the impact of a changing value of products from the ODEX. This impact, which is not primarily attributable to energy efficiency, is then separated in the decomposition analysis (see Figure 8-17).

Over the whole period 2000 to 2012, the total ODEX for manufacturing remains almost constant, with the total improvement amounting to less than 1%. The development within the 10 industrial branches, however, varied significantly, both between the branches and over the whole period under review (Figure 8-16). There were some branches with a considerable energy efficiency progress (e.g. non-ferrous metals, cement, machinery, transport vehicles), and others with an increasing ODEX, i.e. a worsening of energy efficiency (e.g. paper, non-metallic minerals, chemicals, food). Since the second half of the 2000s, the increasing trend of the ODEX has strengthened in several branches.

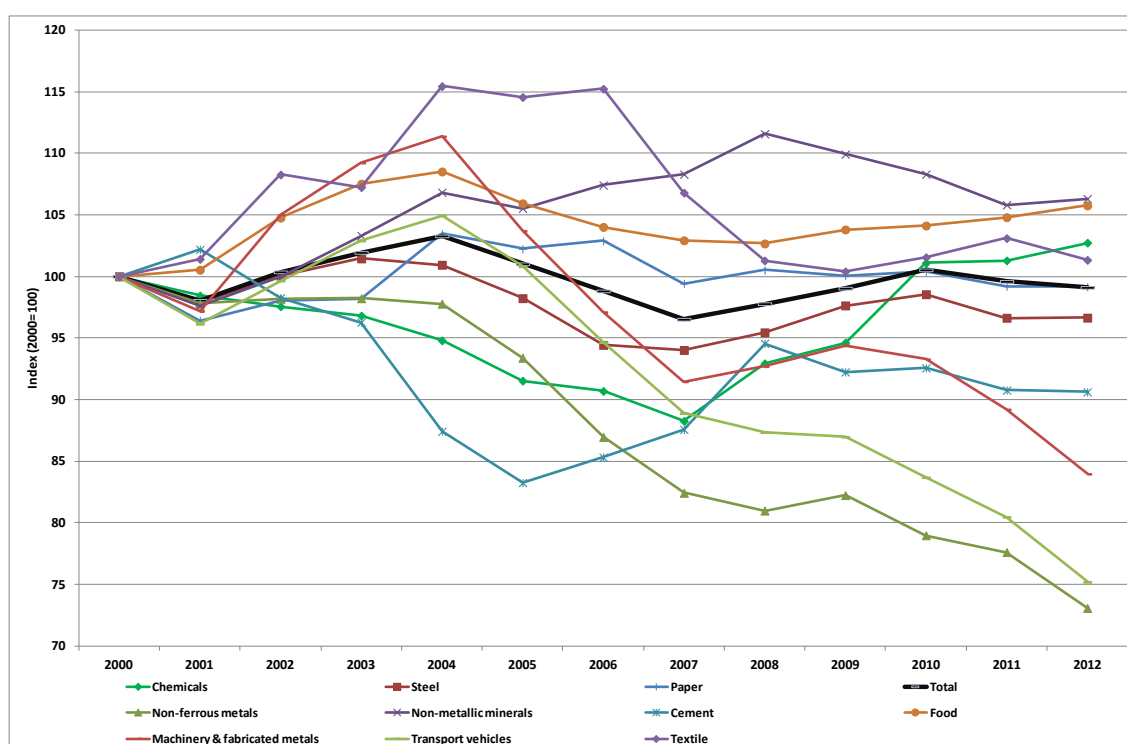


Figure 8-16: Development of the energy efficiency index ODEX in manufacturing for the period 2000-2012

Decomposition of energy consumption of manufacturing industry

The decomposition of energy consumption confirms the minimal progress in energy efficiency which was achieved in manufacturing industry over the period 2000-2012. The activity effect, i.e. the industrial growth, had an increasing impact on energy consumption, whereas structural changes towards less energy-intensive branches caused a significant reduction (Figure 8-17). In the period 2008-2012, the decreasing impact of structural change was further strengthened, whereas the energy efficiency impact caused negative energy savings, i.e. an increase in energy consumption. Changes in the “value of the product”, which is measured through the ratio of added value to

physical production or the production index respectively, also caused a slight increase in industrial energy consumption. As a result of these effects, total energy consumption in industry slightly increased in both periods (Figure 8-17). As already explained in Section 8.4.1, this trend in industry is due to the fact that during an industrial recession, the energy consumed per unit of production tends to increase as process energy does not decrease in proportional to activity (as the efficiency of equipment drops when not used at full capacity) and as the other energy uses (e.g. for heating and lighting of the premises) remains roughly constant.

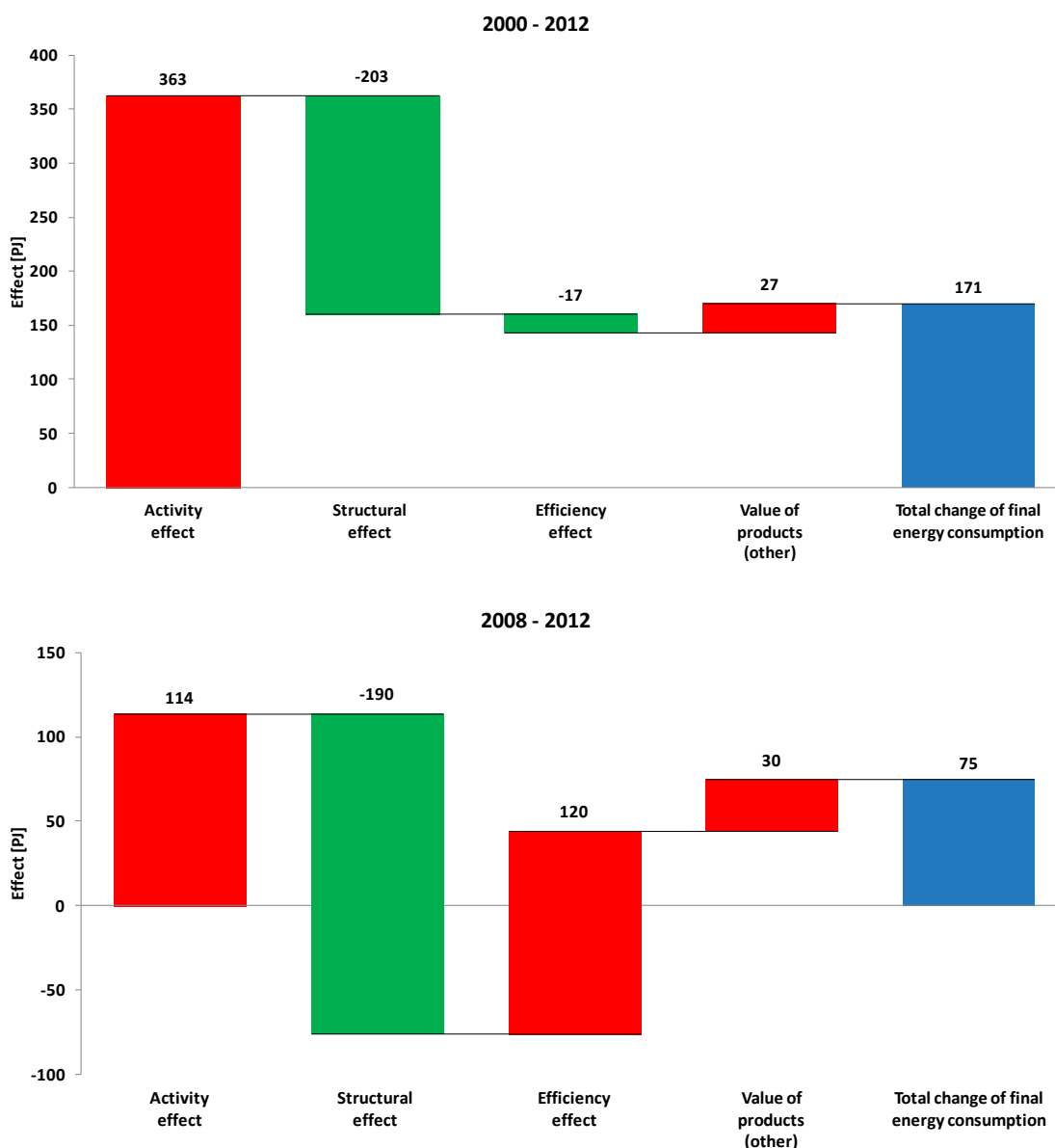


Figure 8-17: Decomposition of final energy consumption in industry for the periods 2000-2012 and 2008-2012

8.4.5 Indicators for the tertiary and service sector

Total energy consumption

The German energy balance (AGEB, 2013) only shows energy consumption for the total tertiary sector, defined here as private and public services, agriculture, construction industries and military. In 2012, energy consumption of this aggregate amounted to 1,397 PJ which is around 15% of total final energy consumption in Germany (Figure 8-2). The main focus of the ODYSSEE database is on energy consumption of the service sector only, including private and public services. For Germany, energy consumption data for this aggregate are available from a regular survey (see Section 8.3.2 and Appendix B). In 2012, energy consumption of the service sector amounted to 1,149 PJ, i.e. around 80% of total consumption of the tertiary sector as defined in the German energy balance.

The number of indicators, which are calculated for the service sector in ODYSSEE, is smaller than for the other final energy consumption sectors. This is due to data gaps at the level of end-uses and sub-sectors in most of the EU countries (see Section 8.3.2). In the following, some energy intensity and unit consumption indicators as well as a decomposed indicator are calculated for Germany.

Energy intensities and unit consumption

Over the whole period, both the energy intensity of services per unit of added value and unit consumption per employee (both temperature-corrected) show a decreasing trend, with a few periods of stagnation especially during the mid 2000s (Figure 8-18). Electricity intensity, on the other hand, was relatively stable and even increased between 2008 and 2010, i.e. in the years of the recession and the following revival of the economy. This is the same trend also observed in industry and transport (see Sections 8.4.3 and 8.4.4).

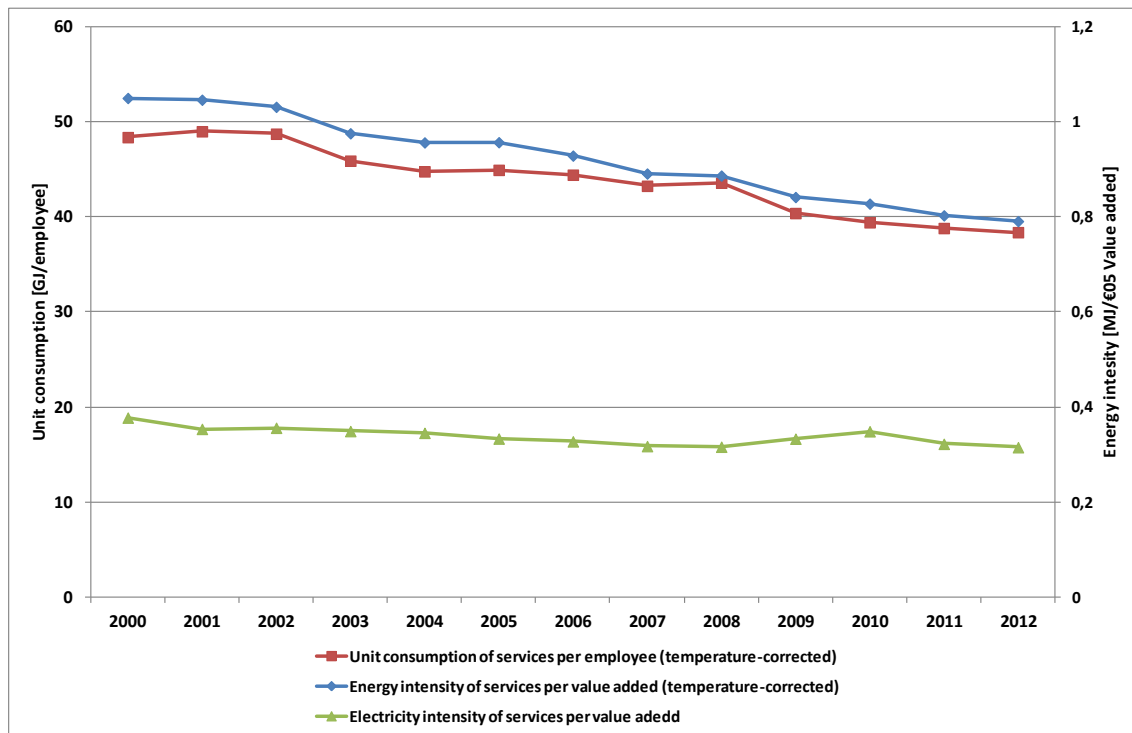


Figure 8-18: Energy intensity and unit consumption in the service sector

Decomposition of energy consumption of services

The decomposition of energy consumption in the service sector is shown in Figure 8-19. In both periods, total final energy consumption decreased by around 80 PJ. The activity effect, which is measured by changes in value added, contributed to an increase in energy consumption. Due to the recession, it was less pronounced in the period from 2008. Weather fluctuations also contributed to an increasing consumption. The decrease in total consumption was mainly caused by the efficiency effect, which counteracted the increasing effect of the other factors in both periods. Over the whole period, the productivity effect, which measures the change in the ratio of added value to employment, also had a reducing impact on energy consumption. In the period 2008-2012 however, the direction of this impact changed.

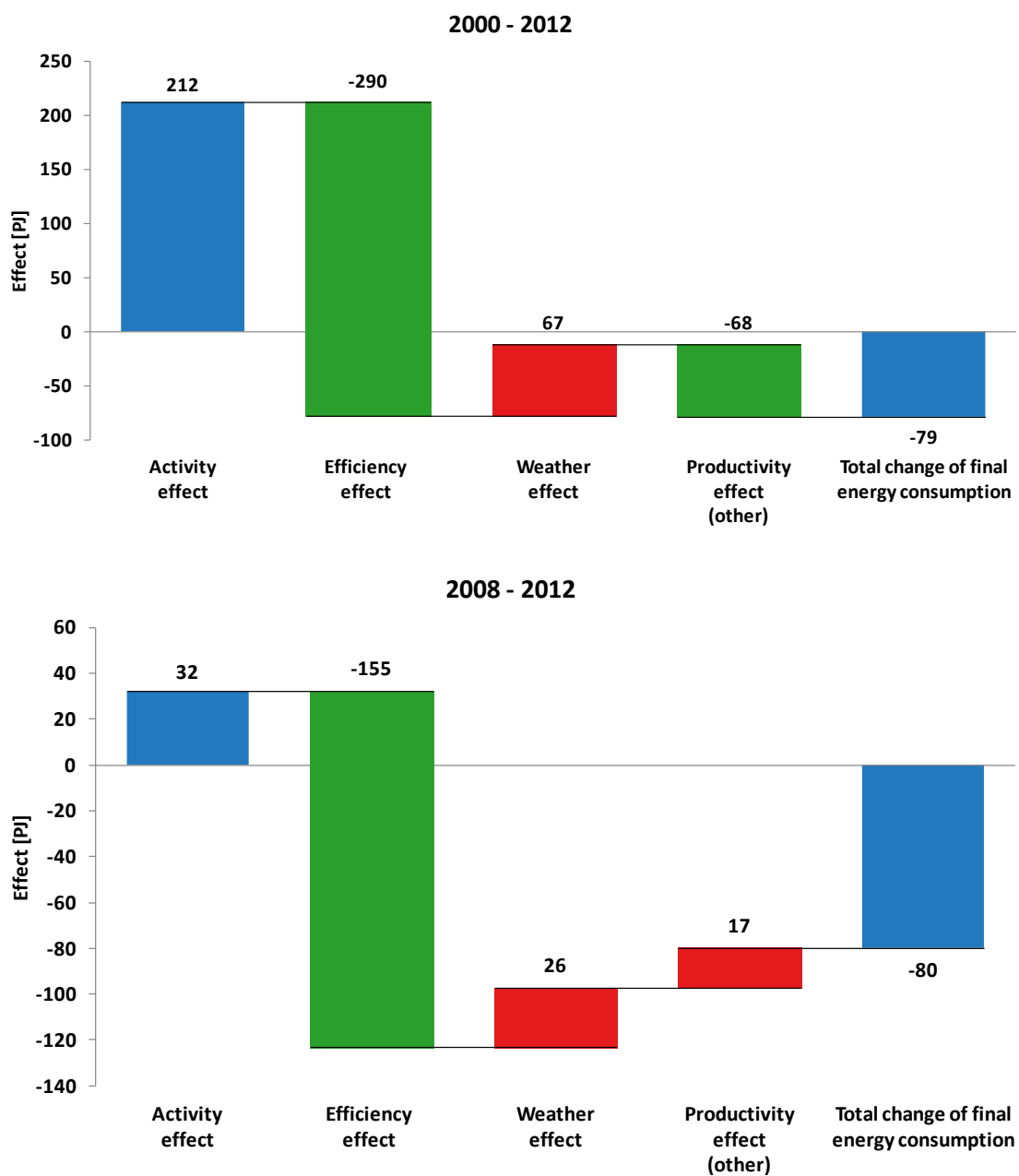


Figure 8-19: Decomposition of final energy consumption in the service sector for the periods 2000-2012 and 2008-2012

8.5 Discussion

8.5.1 Discussion of results

In the frame of the “Energiewende”, Germany has decided on targets for an absolute reduction of energy consumption and an improvement of energy efficiency. We used several types of energy efficiency indicators to monitor the progress achieved towards these targets. First we showed that there is still a considerable gap to close to meet the overall targets, which are the reduction of primary energy consumption by 20% and of electricity consumption by 10% by 2020 (both compared to 2008) and an improvement in energy intensity by 2.1% per year (Table 8-4).

The gap becomes smaller when using temperature-corrected data for the monitoring of the targets, which are in any case more meaningful. A strengthening of the current trend is necessary for all overall targets, but especially for the final productivity and the electricity reductions targets. In the period 2008-2012, the temperature-corrected final energy intensity only improved by 1.2% per year on average (Table 8-4). In order to achieve the target of 2.1% per year, an even stronger improvement of around 2.6% (Löschel et al., 2014, p. Z-9) is required in the remaining years. During the last twelve years, total final electricity consumption in Germany has increased by 5%. Although a slight decrease by 1% in the period 2008-2012 is observed, i.e. compared to the reference year of the target, this trend needs to be strengthened to reach the 10% reduction target. This is even more imperative since recent energy forecasts for Germany show a slightly increasing trend for electricity consumption up to 2030 in a reference scenario without additional policy efforts (German government, 2013)⁸².

⁸² The main reasons for this development are additional electricity uses e.g. electric mobility (which is also a target of the “Energiewende”) and heat pumps in buildings which counteract electricity efficiency improvements.

Table 8-4: Reflection of our results at the targets of the „Energiewende“

Sector	EE-related target for 2020	ODYSSEE indicator	Results 2000-2012	Results 2008-2012
Overall Economy	Primary energy consumption: -20% (comp. to 2008)	Primary energy consumption		
		-actual	-4.5%	-4.3%
		-temperature-corrected	-5.9%	-4.8%
	Final energy productivity : +2.1%/year (eqv. to a respective decrease in energy intensity)	Final energy intensity		
-actual		-1.3%/year	-0.9%/year	
-temperature-corrected		-1.5%/year	-1.2%/year	
	Overall ODEX	-11.9% or -1.0%/year	-1.8% or -0.5%/year	
	Gross electricity consumption: -10% (comp. to 2008)	Total electricity consumption	+5.0%	-1.0%
Households	Heating requirement: -20% (base year not specified)	Final energy consumption for space heating		
		-actual	-14.6%	-12.0%
		-temperature-corrected	-20.8%	-9.3%
		ODEX households	-20.2% or -1.7%/year	-4.0% or -1.0%/year
Transport	Final energy consumption in transport sector -10% (comp. to 2005)	Final energy consumption of transport	-6.5%	-0.6% (2005-2012)
		ODEX transport	-16.2% or -1.4%/year	7.5% or -1.1%/year (2005-2012)
Industry	No specific target	Final energy intensity of manufacturing		
		-actual	-0.8%/year	-0.1%/year
		-at constant structure	+0.4%/year	+1.7%/year
		ODEX industry	-0.9% or -0.1%/year	+1.3% or +0.3%/year
Tertiary/ Services	No specific target	Energy intensity of services (temperature-corrected)	-2.3%/year	-2.8%/year
		Unit consumption of services per employee (temperature-corrected)	-1.9%/year	-1.3%/year

At the level of primary energy consumption, the progress towards the targets is more pronounced than in the case of final energy. Nevertheless, the (temperature-corrected) reduction in primary energy consumption by almost 5% since 2008 (Table 8-4) also needs to be accelerated in order to achieve the 15% reduction required in the remaining eight years. This is even more important since our analysis shows that most of the reduction achieved since 2000 and especially since 2008, was due to the increasing share of renewable energies in the power mix, and not primarily a result of energy efficiency gains at the level of final energy or in the power sector.

By applying energy efficiency indicators, from which external factors not primarily attributable to energy efficiency have been removed, we have also shown that the energy efficiency progress slowed down in the period 2008-2012 compared to the whole period under review. This is true for both total final energy and the final energy consumption sectors. We mainly used the energy efficiency index ODEX to measure the pure energy efficiency progress at the level of the total economy and the main energy consumption sectors. At the level of the whole economy, the progress in energy efficiency has exactly halved since 2008 (from 1% per year to 0.5% per year; see Table 8-4). This was largely as a result of the reversed development of energy efficiency in industry. In the period 2008-2012, the industrial ODEX showed an increase of 0.3% per year. Although this trend was mainly an effect of the industrial recession⁸³, our analysis also showed very slow progress in energy efficiency in industry since the year 2000. The observed decrease in the final energy intensity of the industrial sector by 0.8% per year was in fact only caused by structural changes and not by an energy efficiency improvement. In the household and transport sector, the ODEX still improved by around 1% per year, which was, however, a lower rate than over the whole period (Table 8-4). A similar trend could be observed for unit consumption per employee in the service sector, which improved by 1.3% per year in the period 2008-2012 compared to 1.9% per year over the whole period under review.

8.5.2 Discussion of methodology

Although our analysis gives more insight into the factors behind the development of overall primary and final energy consumption and energy intensity, such a top-down monitoring approach, which is based on statistical data at a relatively highly aggregated level, also has its limits. There are two types of restrictions, which have to be tackled in a different way. On the one hand, there are limits due to data gaps and methodological problems which can be handled by a further improvement of the statistical data and the calculation method. On the other hand, there are limits of principal in using a top-down monitoring approach, which can only be addressed by the use of additional methods.

For statistic-based top-down indicators, detailed, complete, timely and reliable statistics are essential to monitor the energy situation at a country level (IEA 2005, 2014b). The data demands generally grow with a higher degree of disaggregation of the analysis. In our German case study, the main data gaps, which also limit the meaningfulness of the respective indicators, are noted for buildings (especially cooling) and electrical appli-

⁸³ In times of decreasing industrial production, the energy consumed per unit of production tends to increase as energy consumption does not decrease proportionally to the activity.

ances (Löschel et al., 2014; BMWi, 2011). An improvement of these data is strongly recommended. Another problem of top-down indicators, which makes regular and current monitoring difficult, is the long delay encountered in supplying the statistical data for a specific year. Depending on the type of data, the time delay lies between 0.5 and 2 years in Germany (BMWi, 2011). In order to bridge this data gap, there are initial attempts in the ODYSSEE database to develop short-term indicators based on energy intensities or unit consumption as a proxy for energy savings (Boonekamp, 2012).

There is also a question around the reliability and ability to replicate such breakdown analyses. For example, for the household sector the ODYSSEE decomposition tool estimates that other factors such as behavioural changes related to indoor temperatures and appliance use contributed about 14% to the total reduction observed in the period 2000-2012 (excluding weather influence; see Figure 8-9). Similar analysis by Galvin and Sunnikka-Blank (forthcoming) concludes that more than 45% of the reduction of space heating energy consumption in the household sector in the period 2000-2011 was the result of behavioural changes such as skilful heating behaviour and lower indoor temperatures. It is unclear as to why the results of the ODYSSEE tool and the estimates by Galvin and Sunnikka-Blank differ to such an extent but this highlights the uncertainties involved in top-down analyses. However, our analysis also shows a strengthening of behavioural influences on household energy consumption in the period 2008-2012, which may support the observations from Galvin and Sunnikka-Blank (forthcoming).

In order to measure the pure energy efficiency progress from which external factors such as weather, activity, structural changes or behaviour have been removed, we make use of the energy efficiency index ODEX. The data demands of this indicator are, however, relatively high, compared to simple energy intensities or unit consumption ratios. This is due to the fact that the ODEX is calculated at the level of each sector and then re-aggregated for the whole economy. This may hinder a broader use of this indicator in official monitoring processes as it is implemented for the German “Energiewende”. Though the ODYSSEE database provides the necessary data for Germany and all other EU Member States, so that in principle the ODEX could be used for a parallel monitoring of national or EU-wide energy efficiency targets (e.g. under the EED).

The ODEX indicator is, however, also discussed in literature from a methodological point of view. Cahill and O’Gallachoir (2010) refer to the fact that the ODEX uses physical activity data for the analysis of energy consumption rather than added value. They argue that this makes a comparison with other methods of analysis, especially for the industrial sector which relies on added value (see overviews in Ang, 1995 and 2004), more difficult. They present a new analysis method called VALDEX which is based on the existing ODEX methodology, but uses value added data instead of physi-

cal output data. Other authors recommend the use of activities measured in physical instead of monetary units for the calculation of energy efficiency indicators, especially in the manufacturing industry (see e.g. Worrell et al., 1997; Farla et al., 1998; Farla and Blok, 2000a, b; Neelis et al., 2007; Salta et al., 2009). They argue that this contributes to a better understanding of energy efficiency developments. We see the ODEX in this line of argument and assess the use of physical instead of monetary outputs as a methodological advantage of the ODEX compared to other methods of analysis.

Pérez-Lombard et al. (2013) take up some general methodological problems in the construction of energy efficiency indicators, which have also been discussed by Patterson (1996). They particularly refer to value judgement (i.e. the assessment of the amount and quality of service output to which the energy input is related), the quality of the energy input, boundary definition, and the problems of aggregation of energy efficiency gains calculated at the level of sectors or end-uses. All these methodological issues also concern the energy efficiency indicators which we applied in our paper. They are all addressed in the ODYSSEE database in a certain way, as it is described in Appendix A in detail. In their paper, Pérez-Lombard et al. (2013, p. 251) propose a sequence of actions to tackle these problems in an ordered fashion: (i) setting the service quality, (ii) identifying aggregation levels on the efficiency pyramid, (iii) defining a magnitude for consumption measurement and (iv) choosing a suitable magnitude to quantify the service provided. We think that our indicator approach is not far from these recommendations.

Even if the impacts of activity, structural, behavioural, weather and other external factors can be analytically separated from the actual energy efficiency development, it is still not possible to determine at this level whether the change in energy efficiency is induced by policy instruments, or by autonomous or price-driven improvements in energy technologies. For more advanced corrections of price or economic influences as well as the influence of technology progress, predominantly econometric approaches are used which involve a regression analysis based on a pure energy efficiency indicator (see e.g. Schüle et al., 2011; Thomas et al., 2012). These econometric approaches, however, have not gained general acceptance for target monitoring up to now, which is mainly due to the lack of long enough time series for this kind of analysis and the relatively demanding methodological approach.

Another key characteristic of purely top-down monitoring approaches is the lack of a direct relationship between the effect of a specific policy instrument and the energy efficiency indicator. This limits their use if the monitoring also aims to evaluate individual policy instruments or programmes. This fundamental shortcoming, making energy efficiency indicator approaches unsuitable for estimating policy impacts, was demonstrated,

for example, by Horowitz (2008). He advocates the use of other additional methods, i.e. statistical and engineering models, in order to evaluate such policies. By applying top-down indicators calculated at the level of end-uses (as they are provided in ODYSSEE for space heating or electrical appliances or specific transport modes), it is possible to map the influence of policy instruments (e.g. for space heating or electrical appliances). It is however, usually the impact of a bundle of instruments which is being applied to a specific end-use which is then measured (e.g. regulatory and financial support instruments). Nevertheless, a complementary use of so-called bottom-up methods, accumulating energy savings for individual final consumers or pieces of equipment, is necessary (for a detailed description of these methods see, for example, Thomas et al., 2012).

8.6 Conclusions

In this paper, we studied in detail the energy efficiency developments in Germany at the level of the overall economy and all final energy consumption sectors for the period 2000-2012. We made use of the energy efficiency indicator toolbox that we have developed within the ODYSSEE database in recent years and applied these indicators to the targets of the German “Energiewende”.

First of all, we found that there is still a considerable gap to close to meet the overall targets, which can only be achieved by a considerable strengthening of the progress in energy efficiency for all final energy consumption sectors. This is, however, made more complicated by our second finding, namely that such progress slowed down in the period 2008-2012, i.e. since the base year of most of the German energy efficiency targets.

We found, in particular, a very slow improvement in energy efficiency in the industrial sector during the last decade. Without a significant contribution from this sector, which is responsible for around 30% of final energy consumption in Germany, it will be very difficult to close the existing gap in the remaining years. We also found a wide gap between the absolute energy reduction targets for electricity and transport consumption required, and the reduction which had already been achieved in 2012, compared to respective base year for the targets. Therefore, a further reduction of electricity consumption will be necessary in all sectors. For the transport sector, we demonstrated through our decomposition analysis, that the development of transport energy consumption is strongly dominated by the opposite impacts of an (increasing) activity effect and the (decreasing) energy efficiency effect. Therefore, apart from a further strengthening of the progress in energy efficiency, policies to reduce traffic activity could also help close the gap.

Based on these findings we conclude that our analysis gives deeper insight into the factors behind the development of overall primary and final energy consumption com-

pared to highly aggregated indicators as they are e.g. applied in the official monitoring of the German “Energiewende”. This also provides suitable starting points for new energy efficiency policies which are necessary to achieve the targets. Attention should especially be focused to those sectors and end-uses, where a very slow progress of energy efficiency could be observed during the last years or where the gap to the target is most pronounced. According to our results, these are in particular the industrial and transport sectors and electricity consumption. In this way, our approach can complement the official monitoring process of the German “Energiewende” with regard to an in-depth analysis of the factors influencing the development of energy consumption. Since both monitoring approaches use generally the same data sources (see Section 8.3.2), the results are widely compatible.

We also discussed general weaknesses and limitations of top-down monitoring approaches, which rely on factor decomposition and are based on statistical data. These can only partly be handled by a further improvement of the statistical data and the calculation method. Additionally, top-down indicators have to be completed by other methods in order to correct them for price influences as well as the influence of technology progress and to establish a direct link between an indicator and a policy instrument. The methods to be applied are econometric approaches, engineering models or the bottom-up measurement of the energy efficiency progress. However, all these alternative methods have their own drawbacks. Therefore, despite its limitations, we think that top-down approaches are at least a useful calibration of the bottom-up evaluation of policy instruments.

Acknowledgements

This paper is primarily based on the research project “ODYSSEE-MURE”⁸⁴ supported by Intelligent Energy Europe. We would especially like to thank the representatives from EACI and all partners of the ODYSSEE-MURE network for the fruitful discussions during the longstanding work on the project. And we thank the coordinator of the project, Didier Bosseboeuf from ADEME, France, for the very successful coordination and further development of the project during the last 20 years. We would additionally like to thank Prof. Dr. Kornelis Blok, who gave the initial impetus for this paper, for his helpful comments, as well as Helen Colyer for the proofreading.

84 <http://www.odyssee-mure.eu/>

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Appendix A: Detailed description of the calculation of indicators in the ODYSSEE database

Ratios at constant structure

Intensity at constant structure, which is calculated at the level of industry, reflects the variation of the energy intensity assuming a constant structure of added value, between the various branches or sub-branches, for a reference year, so as to leave out the influence of structural changes. Changes in this intensity at constant structure result from variations in the sectoral intensities

For the calculation, the Divisia method is applied on a yearly basis and splits the growth rate of the intensity between year t and t-1 into two components. The first one measures the influence of structural changes, and the second one measures the influence of changes in the sectoral intensities.

Calculation of the Divisia index:

$$\ln\left(\frac{ie_t}{ie_{t-1}}\right) = \sum_i w_i \ln\frac{s_i}{s_{t-1}} + \sum_i w_i \ln\frac{ie_i}{ie_{t-1}}$$

$$w_i = \text{energy consumption weight} = E_i / E$$

The variation of the intensity over a period can be expressed in index (I) as follows :

$$I = I_s \times I_e$$

Ie: index of sectoral intensity effect, which represents the index of the intensity at constant structure.

Is: index of structural effect which represents the variation of the intensity due to structural changes.

$$I_e = \exp\left(\sum_t \sum_i w_i \ln\frac{ie_i}{ie_{t-1}}\right) \times 100 \quad I_s = \exp\left(\sum_t \sum_i w_i \ln\frac{s_i}{s_{t-1}}\right) \times 100$$

Re-aggregated energy efficiency index (ODEX)

The ODEX is an index developed for the ODYSSEE-MURE project for an advanced measurement of the energy efficiency progress by sector and for the whole economy of a country. For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress.

Chosen indicators for the calculation of the ODEX for industry:

- 4 main branches: chemicals, food, textile & leather and equipment goods;
- 3 energy intensive branches: steel, cement and pulp & paper

- 3 residual branches: other primary metals (i.e. primary metals minus steel), other non-metallic minerals (i.e. non-metallic mineral minus cement) and other pulp, paper and printing (i.e. mainly printing).

The unit consumption is expressed in terms of energy used per ton produced for energy intensive products (steel, cement and paper) and in terms of energy used related to the production index for the other branches.

Indicators used for the calculations of ODEX for transport are:

- passenger transport by car: energy consumption per 100 km
- passenger transport by rail: energy consumption per passenger-km
- freight transport: specific energy consumption per ton-km
- air transport: energy consumption per passenger
- buses and motorcycles: energy consumption per vehicle

For households, the calculation is carried out based on three end-uses and five large appliances (refrigerators, freezers, washing machines, dishwashers and TVs):

- unit consumption for space heating per m² at normal climate
- unit consumption for water heating per dwelling
- unit consumption for cooking per dwelling
- specific electricity consumption per large appliance

These selected indicators are measured in physical units to provide the best “proxy” of energy efficiency progress from a policy evaluation viewpoint. The usage of indices allows the combination of different units for a given sector. The weight used to calculate the weighted aggregate is the share of each sub-sector of the total energy consumption of the superordinated sector. The variation of the weighted index of the unit consumption between year t-1 and t is defined as follows:

$$\frac{I_{t-1}}{I_t} = \sum_i EC_{i,t} * \left(\frac{IUC_{i,t}}{IUC_{i,t-1}} \right)$$

with:

IUC_i: unit consumption index of sub-sector i

EC_i: share of energy consumption of sub-sector i

To get the index value of year t the inverse value of $\frac{I_{t-1}}{I_t}$ is calculated.

The unit consumption index for each year t is calculated using this formula:

$$IUC_{i,t} = \frac{UC_{i,t}}{UC_{i,t_0}} * 100$$

with:

IUC_i: unit consumption index of sub-sector or end-use i in year t

UC_i: unit consumption of sub-sector or end-use i

The ODEX indicators represent a better proxy for assessing energy efficiency trends at an aggregate level than the traditional energy intensities, as structural changes and other factors not related to energy efficiency are removed.

The trends observed for some sectors or end-uses can result in strong fluctuations in the ODEX. Such fluctuations can be linked to various factors: imperfect climatic corrections (especially with warm winters), behavioral factors, influence of business cycles or imperfection of statistics, especially for the last year considered. To reduce those fluctuations the ODEX is calculated as the arithmetic mean of the years t^{-1} , t and t^{+1} .

Methodology of decomposition

The decomposition of the change of final and primary energy consumption used in this paper shows various effects on the total change of energy consumption per sector. These are aggregated for the decomposition of the whole economy. We use the year t^{-1} as the base year (moving base year) for decomposition.

Industry

The total change of final energy consumption for industry is analysed into four effects: *activity effect*, *structural effect*, *efficiency effect* and *other effects*, while the latter consists of the residual. The effects are defined by the following formulae:

Activity effect:

$$EQ_{t/t_0} = \Delta VA_{t/t_0} * \left(\frac{C_{t_0}}{VA_{t_0}} \right)$$

with:

EQ: Activity effect, VA: added value of manufacturing,

t: year t (end year),

t_0 : year 0 (base year),

C: energy consumption

This effect represents the impact of changing economic activity (value added) of the sector industry on the final energy consumption.

Structural effect:

$$SE_{t/t_0} = \Delta C_{f,t/t_0} - \Delta C_{t/t_0}$$

with:

$C_f = IE_{ct} * VA_t$, the fictive consumption based on the energy intensity with an assumed constant structure of the sector industry (IE_{ct}),

C: energy consumption,

VA: value added at constant prices

t: year t (end year),

t_0 : year 0 (base year)

Hence, the structural effect shows the impact of changes in the sector industry to or from more energy intensive branches.

The calculation of the *energy efficiency effect*, which shows the change of final energy consumption due to efficiency progress, is based on the ODEX using the following formula:

$$ESI = C_t * \left(\left(\frac{100}{ODEX} \right) - 1 \right)$$

with:

C_t : Energy consumption

ODEX: Energy savings measured by ODEX

The last effect – *Other effects* – consists of the residual and contains effects which cannot be directly attributed to a cause. It is calculated by subtraction of all other effects from the total change of final energy consumption of the sub-sector under consideration.

Transport

The variation of final energy consumption of the sector transport is analysed into four effects which show the impacts of *activity*, *modal shift*, *efficiency* and the residual *other effects*, which is the difference, calculated as in the sector industry.

The *activity effect* of transport shows the impact of changes in passenger and freight traffic and is calculated as the sum of the activity effects of using both the following formulae:

$$\text{Passenger:} \quad EQT_{t/t_0} = \sum_{i=0}^n (\Delta pkm_{n,t/t_0} * CU_{n,t_0})$$

$$\text{Freight:} \quad EQT_{t/t_0} = \sum_{i=0}^m (\Delta tkm_{m,t/t_0} * CU_{m,t_0})$$

with:

EQT: activity effect

CU: energy consumption per passenger-km or ton-km

t: year t (end year),

t₀: year 0 (base year)

n,m: mode of transport

pkm, tkm: passenger-km or ton-km by mode

The *efficiency effect*, which represents the impact of changes in energy consumption per passenger-km or ton-km in the sector transport, is calculated as the sum of these formulae:

$$\text{Passenger:} \quad EST_{t/t_0} = \sum_{i=0}^n (\Delta CU_{n,t/t_0} * pkm_{n,t})$$

$$\text{Freight:} \quad EST_{t/t_0} = \sum_{i=0}^m (\Delta CU_{m,t/t_0} * tkm_{m,t})$$

with:

EST: efficiency effect

CU: energy consumption per passenger-km or ton-km

t: year t (end year),

t₀: year 0 (base year)

n,m: mode of transport

pkm, tkm: passenger-km or ton-km by mode

The *modal shift effect*, corresponds to the difference between the sum of savings of each mode for passenger and freight respectively and the aggregate savings calculated directly for passenger or goods as a whole. This effect represents the change of final energy consumption due to changes in other modes of transport compared to the base year. As with the activity and efficiency effect it is calculated for passenger and freight transport separately and summed up for total transport:

$$\text{Passenger:} \quad MST_{t/t_0} = EST - (\Delta CU_{t/t_0} * pkm_t)$$

$$\text{Freight:} \quad MST_{t/t_0} = EST - (\Delta CU_{t/t_0} * tkm_t)$$

with:

MST: modal shift effect

EST: efficiency effect

CU: energy consumption per passenger-km or ton-km

t: year t (end year),

pkm, tkm: passenger-km or ton-km by mode

The modal shift effect is attributed to the total structural effect in the aggregated decomposition.

Households

The decomposition of final energy consumption in the sector households results in five effects. These are *demographic effect*, *lifestyle effect*, *efficiency effect*, *weather effect* and the residual labelled as *other effects* or *behavioural effect*. The lifestyle effect, which is shown in the aggregated decomposition, consists of two underlying effects: change of the number of appliances per dwelling and living space per dwelling. These are shown separately in the analysis for the household sector.

The demographic effect shows the changes in final energy consumption due to the change of the number of dwellings and is calculated as the variation of the number of dwellings multiplied with the energy consumption per dwelling in the base year t_0 :

$$DEH_{t/t_0} = \Delta NOD_{t/t_0} * CU_t$$

with:

DEH: demographic effect

NOD: number of dwellings

CU: energy consumption per dwelling with temperature correction

t: year t (end year)

The two effects forming the lifestyle effect in the aggregated decomposition are number of appliances per dwelling and living space. These are calculated in a similar way to the demographic effect:

$$NAH_{t/t_0} = \Delta NOA_{t/t_0} * CU_t$$

and

$$LSH_{t/t_0} = \Delta SOD_{t/t_0} * CU_t$$

with:

NAH: number of appliances effect

NOA: number of appliances per dwelling

LSH: living space per dwelling effect

SOD: size of dwelling in m²

CU: energy consumption per appliance or per m² with temperature correction

t: year t (end year)

The efficiency effect is calculated based on the ODEX for households, which includes the efficiency progress of these underlying indicators:

- unit consumption for space heating per m² at normal climate
- unit consumption for water heating per dwelling
- unit consumption for cooking per dwelling
- specific electricity consumption per large appliance

It is calculated by the following formula:

$$ESH = C_t * \left(\frac{100}{ODEX} - 1 \right)$$

with:

ESH: efficiency effect

C: energy consumption

ODEX: ODEX for households

The weather effect, which represents the influence of the changes in temperature (difference in the number of degrees days) on the variation of final energy consumption of households, is calculated by

$$WEH_{t/t_0} = -\left((CC_t - CC_{t_0}) - (C_t - C_{t_0})\right)$$

with:

WEH: weather effect

CC: temperature corrected energy consumption

C: energy consumption

t: year t (end year),

t₀: year 0 (base year)

The last effect labelled as other effects is calculated by subtracting the sum of all other effects of households from the total variation of final energy consumption of the sector.

Tertiary / Services

For the tertiary and service sectors the change of final energy consumption is analysed into four effects: *activity effect*, *efficiency effect*, *weather effect*, and the residual *other effects*.

The activity effect in the tertiary sector, which shows the influence of changes in added value generated in this sector, is measured by the variation of the added value multiplied by the energy intensity by branch:

$$EQT_{t/t_0} = \sum_{i=0}^n \Delta VA_{i,t/t_0} * I_{i,t/t_0}$$

with:

EQT: activity effect

VA_i: value added of branch i

I_i: energy intensity of branch i

t: year t (end year),

t₀: year 0 (base year)

The effect of changes of energy efficiency on the final consumption is calculated by multiplying the number of employees by the variation of unit consumption per employee by branch.

$$ESH_{t/t_0} = \sum_{i=0}^n \Delta CU_{i,t/t_0} * EMP_{i,t}$$

with:

ESH: efficiency effect

CU_i: energy consumption per employee in branch i

EMP_i: number of employees of branch i

t: year t (end year),

t₀: year 0 (base year)

Influences of the variation in weather are represented in the weather effect, which is calculated in the same way as the sector households using this formula:

$$WET_{t/t_0} = - \left((CC_t - CC_{t_0}) - (C_t - C_{t_0}) \right)$$

with:

WET: weather effect

CC: temperature corrected energy consumption

C: energy consumption

t: year t (end year),

t₀: year 0 (base year)

The residual other effects is calculated as the difference of total variation of final energy consumption of the sector tertiary and the sum of all other effects.

Aggregated breakdown of final energy consumption

The shown effects of the aggregated breakdown of the total change of final energy consumption are summed up from corresponding effects of the underlying sectors as shown in the matrix below.

Table 8-5: Aggregation of sectoral effects

Effect	Industry	Households	Transport	Tertiary/Services
Activity effect	X		X	X
Demographic effect		X		
Lifestyle effect		living space + number of appli- ances per dwell- ing		
Structural effect	X		Modal shift effect	
Efficiency effect	X	X	X	X
Weather effect		X		X
Other effects	X	X	X	X

Breakdown of primary energy consumption

The variation of primary energy consumption between year t and t^{-1} is the sum of the variation of final energy consumption, the variation of the net consumption of the power sector, the variation in the consumption of other transformations and the variation in the consumption for non energy uses. Total effects for the whole period from year t_0 to t are calculated by summation of the effects for the years in between.

The net consumption of the power sector is defined as the primary energy input minus the output of generated electricity and heat.

The variation of the net consumption of the power sector is analysed into three underlying effects, which contribute to the total change:

- Electricity penetration
- Efficiency of thermal power plants
- Power mix

Other influences such as the consumption for non-energy uses, which are not attributed to a certain effect are labeled as other effects.

While the effect “variation of final energy consumption” is the difference between final energy consumption of year t and t^{-1} , the other three effects are calculated based on a second analysis regarding the variation of the net consumption of the power generation sector. Here the factor “efficiency of thermal power plants” measures the impact of the change of primary energy per unit of electricity produced compared to the previous year and summed up for the time period in question.

The effect “electricity penetration” measures the impact of increased electricity consumption in terms of additional losses in power generation assuming constant efficiency of thermal power generation and constant power mix; it is calculated as a residual as the difference between the sum of all other effects regarding the power generation sector and the total change of consumption for power generation.

Appendix B: Data sources for Germany in ODYSSEE⁸⁵

Data in ODYSSEE	Data source for Germany	Classification of data source*
Overall economy		
GDP, added value, private consumption	Federal Statistical Office (2014), National Accounts	A
Population	Federal Statistical Office (2013a), Statistical Yearbook	A
Primary and final energy consumption by sector	National energy balances (AGEB 2013)	A
Electricity generation by energy carriers	AGEB 2013; BMU 2013	A
Degree days	Based on Deutscher Wetterdienst (DWD)	B
Tertiary sector		
Value added/employment by sub-sectors	Federal Statistical Office (2014), National Accounts	A
Floor area by subsector	Regular surveys on energy consumption in the tertiary sector (Fraunhofer ISI et al. 2014; Schlomann et al., 2014)	B
Energy consumption by end-uses and subsectors		
Household sector		
Number of households and dwellings, floor area	Federal Statistical Office (2013a), Statistical Yearbook	A
Stock and sales of electrical appliances	ZVEI/GfK (2013)	B
Energy consumption by end-uses	National end-use balances (AGEB 2014)	A
Specific consumption of electrical appliances	Stock model data (Prognos, internal information)	B
Industry		
Value added by industrial branches	Federal Statistical Office (2014), National Accounts	A
Production index	Federal Statistical Office (2013a), Statistical Yearbook	A
Physical production	Statistics of industrial associations	B
Energy consumption by branches	National energy balances (AGEB 2013); Federal Statistical Office (2013b)	A
Transport		
Stock of cars and kilometres for passenger and freight traffic	Verkehr in Zahlen (DIW Berlin and BMVBS 2014)	A
Energy consumption by sub-sectors	National energy balances (AGEB 2013)	A
Energy consumption by vehicle types	Verkehr in Zahlen (DIW Berlin and BMVBS 2014)	A

* A = Official Statistics (Statistics/surveys by national Statistical Offices, Eurostat/IEA, Ministries; model estimations used as official statistics; data "stamped" by ministries)

B = Surveys/modelling estimates by research institutes, universities, consultants, industrial associations

C = Estimate / expert guess

⁸⁵ For a more detailed description of the statistical database for Germany in ODYSSEE also see Schlomann and Eichhammer, 2012.

9 Summary and conclusions

9.1 Introduction and scope

Energy efficiency (EE) is widely acknowledged as the most important strategy for achieving global energy and climate targets. Apart from its contribution to the reduction of energy consumption and energy-related greenhouse gas emissions (GHG), improving energy efficiency can deliver a range of co-benefits to the economy and society. These comprise e.g. macro-economic impacts as e.g. an increase in GDP and employment, the improvement of competitiveness at the national or company level, or an increase in energy security by the reduction of energy imports.

But in spite of the widely undisputed role of energy efficiency as a corner stone of worldwide and European energy and climate policy, there are indications that energy efficiency policy is still insufficiently anchored both in the EU and many Member States as well as at an international level. For example, although the EU is on track to achieve its GHG and RES targets, there is evidence that it may not be fully on track to meet its 2020 energy savings target of 20% compared to a baseline development (EEA, 2013; Harmsen et al., 2014; Fraunhofer ISI et al. 2014). In addition, there are still quite divergent opinions on the definition and monitoring of a target for energy efficiency, which became apparent again during the discussion process on a new 2030 framework for the European energy and climate policy. This means that in spite of a long history of profound research on the issue of definition and measurement of energy efficiency, clear definitions and common rules for the measuring are still missing (Patterson, 1996; Pérez-Lombard et al., 2013).

This thesis focuses on the question how to create more favourable preconditions for a better anchoring of energy efficiency policy in international and national energy and climate policy. The central research question for this thesis is:

What is necessary for the design of effective energy efficiency policies?

In order to answer this overall research question, the following sub questions were defined:

1. What are the fundamental aspects for measuring energy efficiency in a political context?
2. How does energy efficiency fit a target architecture aimed at multiple objectives for climate and energy?
3. What role can energy efficiency potentials play in the process of target setting and policy design?

4. Which key elements should be taken into account for the design of effective energy efficiency policies?
5. How can the perspective of specific actors and target groups be considered in the policy design?
6. What methods are appropriate to evaluate the effectiveness of EE policy instruments?
7. What methods are appropriate to measure the progress made towards EE targets and what factors should be taken into account?

With these sub questions in mind, we aim to determine the key factors which should be taken into account for an effective design of energy efficiency policies. The sub questions have been discussed in one or more of the previous chapters 2 to 8 of this thesis (see the explanations concerning the link between the sub questions and the different chapters in section 1.3).

9.2 Summary of the results

This section presents and discusses the main results we found with regard to the sub-questions and to the central research question of this thesis.

1. *What are the fundamental aspects for measuring energy efficiency in a political context?*

In **Chapter 2**, we examine basic aspects of the ongoing discussion on the definition and measurement of energy efficiency. In particular, we refer to the formulation of the baseline and to the accounting method used for the measurement of energy efficiency, where we still see a considerable lack of clarification in spite of the previous research in this field. We show that there are many definitions and approaches used for measuring energy efficiency in a political context, each with its own merit and usefulness. We find that a difference by a factor of 10 or more between various meaningful definitions of energy efficiency improvement is easily achievable. Measuring energy efficiency improvement, hence, presents a considerably larger methodological challenge which has implications in the policy sphere both in terms of target formulation and in terms of communication of targets and achievements across the policy sphere, including to the general public and non-specialist policy makers such as parliamentarians who have to decide on legislative piecework based on rather complex methodologies.

On the one hand, we identify so-called “top-down” methods considering energy efficiency at a highly aggregated level by country or economic sector, based on aggregated statistical data. Compared to these, “bottom-up” methods start by calculating individual energy savings for one final consumer or one piece of equipment and then

accumulate them. We found that both top-down and bottom-up methods contain a series of “adjustment settings” which can strongly influence the degree to which energy efficiency gains are achieved. Top-down methods are particularly concerned with correcting energy efficiency indicators for external influences which are not primarily attributable to changes in energy efficiency (e.g. weather, activity, structure or behaviour). Bottom-up methods, on the other hand, deal with effects that can strongly influence the impact of an EE policy, but which are not always corrected. Examples include (i) the double-counting of energy savings due to the interaction of policies, (ii) the problem of non-compliance which is especially important for regulatory policies as well as multiplier effects enhancing the impact of a policy in other areas not directly concerned by the policy, and (iii) free-rider effects being impacts that would have occurred without an EE policy. We particularly identified missing data as major problem for a widespread use of methods for correction. We conclude that a sufficient amount of data availability is a prerequisite for all approaches for monitoring energy efficiency and must be taken into account for each decision on a specific monitoring process in good time. Examples cited in this thesis show that the financial means necessary to carry out specific monitoring processes are limited. This is especially critical when the monitoring process is an important element in the success of the instrument itself.

Our results also indicate that precise rigorous definitions should be used for formulating and monitoring energy efficiency targets in a political context, to ensure that exactly the same understanding of a target is achieved. In order to avoid the use of loopholes, which exist due to unclear definitions and measurement approaches, a common and widely accepted understanding of some basic rules is necessary. These should at least cover central issues such as the choice of the baseline and the accounting method which are crucial to evaluate the impacts of energy efficiency policies. The rules surrounding the measure also need to be as precise as possible. Comparability of the measurement approaches is necessary in order to ensure similar efforts are made, or at least that the efforts made are transparent. Otherwise a target, which seems to be ambitious at first sight, can turn out to be a ‘paper tiger’ which will not contribute to achieving targets in the field of energy and climate policy.

However, rigorous definitions alone may not be sufficient, given the fact that the policy sphere (including the general public) are not composed primarily of “mathematicians”. This implies that targets should best be formulated in simple terms. This was e.g. reflected in the move from the formulation of an energy saving target in the Energy Service Directive 2006/32/EC towards an absolute energy consumption in the Energy Efficiency Directive 2012/27/EU, which has the benefit of simplicity but presents other caveats (see below). This is the more important when energy efficiency targets interact with other targets, e.g. with greenhouse gas emission targets, which will be discussed

in the next sub-question below. However, there has also been a learning process, at least with the policy makers involved in the formulation of these two Directives for energy efficiency, which has allowed spreading out more widely the knowledge on these methodologies though there are apparent limits to the communication of complex targets.

Since Chapter 2 also serves as a general methodological foundation for this thesis, we return to some of the results when addressing further sub-questions.

2. How does energy efficiency fit a target architecture aimed at multiple objectives for climate and energy?

In **Chapter 3** we analyse what lessons can be learned from the EU 2020 system of climate and energy targets and how a new 2030 framework can be coherently designed.

The 2020 target system of the EU consists of three headline targets for greenhouse gas emissions (GHG), renewable energy sources (RES) and energy efficiency (EE). Our main finding is that this target system lost its coherence when the economy took an unexpected deviation from baseline projections, as the EE target is an absolute energy consumption target compared to a baseline. We derive a coherent reference target system for the EU in 2030 based on an ambitious setting of EE and RES targets, which would generate at least 50% or even 55% or 60% GHG emission reductions in 2030 (compared to 1990). We show that setting an ambitious EE target of 41% for 2030, which corresponds to a full realisation of all cost-effective sectoral EE potentials (comprising industry, private households, tertiary sector and transport), is consistent with a much more ambitious GHG targets than the currently debated reduction of 40%. We also found that a GHG target as the only headline target will not exploit all cost-effective EE potentials, unless it is formulated very ambitiously, i.e. with an order of magnitude of at least 50% or even 55 or 60%.

An agreement of such ambitious GHG targets is, however, unlikely since GHG targets are threatened by the lowest-level ambition world-wide, as they constitute the lowest common denominator at international level. Therefore, we think that ambitious GHG emission reductions can be more realistically achieved by the setting of ambitious EE targets. These targets can be justified by the cost-effectiveness of the EE potential and additionally by the macro-economic co-benefits of energy efficiency as increases in GDP, and employment, or an improvement of the competitiveness.

With regard to the target formulation we conclude that dynamic elements should be part of the design of a target system from the start or a periodic target adaptation

should at least be foreseen. This is particularly the case for absolute EE targets. Targets which are formulated as intensity or savings targets are likely to be less sensitive to changes in the economic framework conditions, but cannot guarantee that consumption would indeed be lowered in absolute terms. EE targets formulated in intensity terms can also be influenced by structural changes, though in the past these effects were not overly important. Saving targets, due to the strong interaction with baseline definitions, are not easily communicated, as they imply quite complex methodologies which makes them more easily manipulated, which is a fear by part of the policy sphere.

3. What role can energy efficiency potentials play in the process of target setting and policy design?

In Chapters 3, 4 and 5 of this thesis, we discuss the role of (economic) EE potentials in the context of EE policy from different perspectives. In Chapter 3, we derive a coherent target system for 2030 from a bottom-up assessment of energy efficiency potentials. In Chapter 4, we use a bottom-up stock modelling approach to calculate the technological improvement potentials to reduce electricity consumption for information and communication technologies (ICTs). Finally, in Chapter 5 we look at energy efficiency potentials with regard to the implementation of a new group of market-oriented EE policy instruments such as energy efficiency obligations (EEOs).

The main result of our analysis is that energy efficiency potentials could become a key element for the formulation of an effective EE policy strategy based on strong analytic grounds. From our analysis in **Chapter 3** we conclude that more ambitious GHG emissions reductions are to be expected when starting with an assessment of what is possible in terms of EE (and RES) potentials. The GHG target can then be derived from this. In **Chapter 4**, we refer to a specific end-use, i.e. electricity consumption for information and communications technologies. By applying a bottom-up stock model for information and communications technologies (ICT) and consumer electronics (CE), we show that there is a high technological improvement potential to reduce electricity consumption for information. This can at least slow down the expected consumption increase for this end-use or even stabilise consumption in the medium and long-term. However, whether these saving potentials will be exploited depends on the EE policies introduced by countries to stimulate the uptake of very efficient products and network solutions.

Finally, in **Chapter 5** we make use of energy efficiency potentials in order to design and evaluate new market-oriented EE policies such as EEOs, taking Germany as an example. An EEO is the obligation of a particular group of actors (usually energy sup-

plier or network companies) to meet an energy-saving target by delivering a certain amount of energy-savings within a specific period. The potentials are calculated using a bottom-up simulation model for the main final energy consumption sectors (private households, industry and tertiary sector). The models are first used to derive a realistic energy-saving target to be achieved by the new instruments up to 2020. The cumulative annual final energy savings for Germany from such cost-effective EE potential is estimated to be 343 TWh by 2020⁸⁶. This is almost 15% of total final energy consumption in Germany in the year 2012. From this we derive three energy saving targets to be achieved by the EE instruments. We distinguish between three levels of ambition, amounting to 343 TWh, 228 TWh and 114 TWh respectively. Secondly, we use the EE potentials in a quantitative evaluation of the suitability of the new instruments to meet these targets. Our evaluation shows that none of the instruments alone can exploit the full cost-effective energy saving potential, i.e. to achieve the prescribed EE target at the highest level; a mix of instruments is necessary.

Suitable models are a prerequisite for the use of EE potentials for the design of EE targets and policies. These generate a reliable quantification of the EE potentials and their costs at the detailed level of energy consumption sectors and end-uses. The bottom-up simulation models we used to calculate the EE potentials in Chapters 3, 4 and 5 largely fulfill this condition. The EE potentials are calculated for the sectors of buildings, electrical household devices and cross-cutting technologies in the household and tertiary sector (with a sub-model for ICTs), industry (distinguishing processes subject to the EU Emission Trading Scheme from processes not subject to the ETS) and transport.⁸⁷ These models are fundamentally set up to be dynamic, i.e. they take into account cost reductions through technological progress and broader market penetration through efficiency technologies. They include a huge number of energy saving options in all sectors based on empirical evidence and cover both the European Union as a whole and all Member States individually. Therefore, they can both be applied to an analysis for the total EU (as we did in Chapter 3) and for national case studies (as we did for Germany in Chapters 4 and 5).

Important in this context is also the notion of “economic potentials”. The policy sphere frequently requests that the EE measures to be taken are economic. Therefore it is very important to define the conditions under which measures appear as economic.

⁸⁶ Without transport sector and the energy consumption falling under the EU emission trading system (EU-ETS).

⁸⁷ Though the transport sector is partly excluded from the scope of general regulations in the field of EE (as for example EED or the former ESD) and from cross-cutting instruments as e.g. EEOs.

Frequently this is linked to the definition of discount rates for energy efficiency measures. A variety of well-known EU studies (e.g. the regular projections of the EU Commission such as EC, 2013) rely on discount rates that may reach 17-18% in the residential sector, as they are supposed to reflect barriers to energy efficiency. However, these barriers frequently are non-economic in nature (see for example the more detailed discussion in Chapter 7 on barriers in the tertiary sector in Germany) and can be overcome with non-economic policy instruments (for example by labels providing information on the most efficient appliances, by instruments to overcome split incentives for rented houses etc.). It is therefore not appropriate to reflect all kinds of barriers in financial terms (though there are certainly also economic barriers to be dealt with). Defining the economic terms of the analytical scenarios to define potentials is therefore of uttermost importance.

4. Which key factors should be taken into account for the design of effective energy efficiency policies?

In **Chapter 5**, we perform a cost-benefit analysis on the introduction of new EE policy instruments such as an energy efficiency obligation system (EEO) or an energy efficiency fund, and compare it to the expansion and improvement of the existing set of EE instruments. This is in line with Article 7 of the EED, which either demands for the introduction of an EEO in order to achieve the 1.5% energy saving target or for alternative policy measures provided that the same EE target is achieved. For our analysis, we use the example of Germany.

Making use of the methodological discussion in **Chapter 2**, we first of all identify the following key elements which have to be decided before performing a comparable cost-benefit analysis of EE policy instrument in order to guarantee direct comparability:

- specification of the scope which should be addressed by the instrument in terms of fuels sources, sectors and end-uses
- the choice of the baseline which is of particular importance; i.e. only energy-savings that exceed a certain standard defined by the baseline should be accounted for
- the principle of additionality which means that the energy-savings should exceed an autonomous development which would in any case occur either due to the general technical progress or due to existing EE policies setting minimum efficiency standards
- the precise definition of the method for accounting energy savings under an EEO or a similar policy instrument; this is a precondition for an effective design of a new energy policy since we found that the accounted energy savings for the same EE measure can vary significantly, depending on the concrete accounting method applied

Another key feature of the design of effective energy policies is the perspective of actors and target groups. This will be discussed in detail in the next sub-question below.

With a multi-criteria approach we then evaluate the strengths and weaknesses of the EE policy instruments under review. First we make a semi-quantitative assessment of the suitability of the instruments to reach the prescribed targets, which were derived from the cost-effective EE potential (see sub-question 4). We then add a qualitative evaluation of the following criteria (also see Section 1.2): (i) cost of the instruments, (ii) market conformity and impacts on competitiveness and the market of energy services, (iii) distributional and structural effects as well as effects on the energy price trends, (iv) interaction of policy instruments, and (v) political acceptance by the different groups affected by a policy and scope for refinancing, i.e. how policy instruments may differ in terms of their funding.

As we already concluded, none of the EE instruments considered in our study can individually achieve the prescribed high energy efficiency targets. These targets can only be achieved by the implementation of a suitable mix of policy instruments. This is mainly due to the suitability of the instruments to overcome different barriers to energy efficiency and thus to exploit the cost-effective EE potential. The mix of instruments that is actually chosen can only be decided at the political level after careful consideration and weighting of the various evaluation criteria. The results of such an analysis can, however, form the analytical foundation for political decisions. A key requirement is that the combination of instruments, which is finally chosen, fits the existing instrument landscape. From our point of view, the possibility of state budget-independence component of the funding of energy efficiency in particular supports a supplementary deployment of new market-oriented instruments such as an EEO as part of the future mix of policy instruments in Germany.

5. How can the perspective of specific actors and target groups be considered in the policy design?

The perspective of actors and target groups is another key feature of the design of effective energy policies needed to remove the existing barriers to energy efficiency deployment (see Section 1.1). We showed the importance and specifics of the actor perspective and how it could be taken into account in the concrete policy design in two different cases.

In **Chapter 6**, we have a deeper look at the retailers, who play an important role in the implementation of many product labelling regulations, yet sometimes fail to comply with these regulations. In order to understand a retailer's (lack of) compliance with product label regulations, we first develop a theoretical framework that encompasses instru-

mental and normative motives. We then test this framework in the energy label context through a large-scale empirical study covering 1,314 retail stores in all 27 EU countries. We use two separate sets of data collected at the store level: a compliance audit (providing the percentage of correctly labelled appliances for each store) and a standardised survey of store managers. The results show that both instrumental factors (especially fear of sanctions) and normative factors (internalisation of regulation and social norms) help explain retailer compliance with product label regulations. Our results have implications for policy makers as well as retail management. Policy makers can use the results to fine tune labelling programs. Our results show for instance that perceived effort to paste the labels on the appliances has much less impact than originally supposed. Instead, we demonstrate the importance of regular checks through regulatory institutions, as well as the impact of consumer pressure. Consumer education programs, bringing attention to the labels, may be useful, not only directly, by heightening consumer awareness, but indirectly by putting pressure on retailers. The results are also potentially useful for retailers, helping management understand why their employees do or do not follow regulations. Based on our analysis, we can advise retail management to implement regular internal checks of regulation compliance; furthermore, our results show that store managers are more respectful of regulation when they are convinced by it. Training programs aimed at developing acceptance of a regulation by store employees may help curb non-compliance and therefore avoid possible sanctions or fines.

In **Chapter 7**, we empirically explore factors driving the adoption of energy management procedures and of other low cost energy-saving measures in the so-called tertiary sector (mainly comprising public and private services, trade, commerce and some small industries). Our statistical analysis relies on more than 1500 observations from a recent representative survey in Germany, largely of small and medium enterprises (SMEs). By focusing on low cost measures our analysis adds to the empirical evidence on factors driving adoption of this type of energy efficiency measure. The findings suggest that such adoption is closely related to organisational factors and split incentives. In contrast, an implementation of low-cost measures appears to be only weakly related to electricity prices. Also, there is no differentiation across sectors. Thus, efficient policy making for these measures would involve a generic rather than a sector-specific design.

More specifically, our findings suggest that the landlord-tenant dilemma holds true for energy management and low-cost energy efficiency measures in the tertiary sector in Germany. Measures are often physically linked to the buildings infrastructure, such as automatic lighting systems or metering systems, and may thus be affected by the landlord-tenant dilemma.

Arguably, organisational culture and social factors such as the social prestige of CEOs or companies may be more important than financial incentives in the decision to adopt low-cost energy efficiency measures. These factors could be strengthened by policies and programs addressing social mechanisms and the “green image” of a company (e.g. energy efficiency awards). This could also raise the awareness of top management of energy costs. Successful examples of this kind of program are, for example, regionally or locally-organised learning networks of companies as they have been established in Switzerland and Germany. The main elements of these networks are (i) the implementation of energy management systems together with energy audits, (ii) common target setting for energy efficiency performance, and (iii) a scientific monitoring and evaluation of the process.

6. What methods are appropriate to evaluate the effectiveness of EE policy instruments?

Instruments can typically be evaluated both as individual instruments and in their combination with other instruments. For both applications there is increasing need as instruments like EEO require the determination of impacts even at the level of individual actions, while – due to the increasing number of policies – interactions between instruments get more and more important. Individual instruments can then frequently only be separated with quite some additional efforts, while it may be possible to determine the combined impacts of policy with more certainty. For example separating standards and labels for appliances or cars requires considerable effort, while the combined effect can quite well be established through the evolution of appliance or car labels. This research question focuses on individual instruments, though frequently evaluating bundles of measures is also helpful for the evaluation of individual instruments.

In **Chapter 2**, we discuss a broad range of top-down and bottom-up methods for the monitoring and evaluation of EE targets and policies (see the description of these methods in Figure 1-3 and Table 2-1). We show that each method has its drawbacks, limiting its suitability, depending on the actual monitoring or evaluation purpose. One principle limitation of top-down methods is that the link between the development of the indicator and a specific policy instrument or programme is missing. Therefore, in order to evaluate the impact of individual policy instruments, pure bottom-up methods have to be applied which start from calculating individual energy savings and add these up. Nevertheless, top-down indicators are well suited to evaluate certain bundles of measures (including rebound or free-rider effects) and may therefore be applied to control the evaluations carried out for individual instruments. Due to their use of policy or programme-specific data, bottom-up methods have the advantage of being able to establish a reference to a specific policy instrument or a saving programme and so

cause-and-effect relationships can be quantified. On the other hand, these methods usually involve more effort in data collection and processing. The “ideal” bottom-up method directly measures the respective object or case; this is, however, also by far the most complex and costly method. The effort of data collection can be reduced by using existing measurement data (e.g. from energy consumption invoices), as well as by relying on technical impact assessments and the use of standardised values. Nevertheless, these bottom-up approaches will mainly be applied where an EE measure-specific accounting of energy savings is necessary for a policy instrument (e.g. for EEOs, which we have studied in **Chapter 5**). Altogether our results show that the availability of sufficient and reliable data is a precondition for the monitoring and evaluation of energy efficiency policies. This is both true for top-down and bottom-up methods. Therefore some effort for data gathering is necessary and appropriate in order to ensure the effectiveness of EE policies.

Other types of methods are the econometric approaches. These have a top-down character since they are usually based on aggregate data from statistics or surveys. These approaches are commonly used for evaluations of individual energy efficiency policies where the effort of pure bottom-up approaches is deemed to be too high. In contrast to pure top-down methods based on EE indicators, econometric methods can establish a direct link to a policy instrument, provided that sufficient data are available for applying statistical regression analysis or even a multivariate statistical analysis. In **Chapters 6** and **7**, we apply econometric methods to two actual EE policy instruments, i.e. the labelling of energy-using products and the introduction of energy management systems in small and medium-sized companies. This is, however, only possible because we can rely on comprehensive survey data, which confirms again the important role of sufficient data for all monitoring and evaluation methods.

In conclusion, frequently it is necessary, to rely on one specific method for the evaluation of an instrument though applying different methods, in particular top-down and bottom-up methods in combination may best be suited to control the results achieved with one single method.

7. What methods are appropriate to measure the progress made towards the targets and what factors should be taken into account?

Our last sub-question is similar to the previous one, but turns the focus from policy instruments back to the targets. This puts a stronger focus on packages of measures rather than individual instruments. We again base our analysis on the methodological foundations in **Chapter 2**, where we describe and discuss the range of top-down and bottom-up methods for monitoring and evaluation. In **Chapter 8**, we then analyse the

possibilities and limits of top-down methods as tools for the regular monitoring of EE targets. We refer to the targets of the German “Energiewende” and calculate and discuss several energy efficiency indicators for Germany at the level of both the overall economy and the main energy consumption sectors. We made use of the energy efficiency indicator toolbox that we have developed within the ODYSSEE database⁸⁸ in recent years and found that there is still a considerable gap to close in order to achieve the overall energy efficiency targets in Germany by 2020. We also showed that the energy efficiency progress slowed down in the period 2008-2012, i.e. compared to the base year 2008 of most of the German energy efficiency targets and found that progress in energy efficiency in the industrial sector during the last decade has been particularly slow. We conclude that energy efficiency improvement has to speed up considerably in order to achieve the targets in the remaining years up to 2020. Although the use of energy efficiency indicators is limited by data constraints and methodological problems such as the definition of economic output and energy input, boundary definition, or the aggregation of energy efficiency gains calculated at the level of sectors or end-uses these indicators give deeper insight into the factors determining energy consumption. They can therefore complement the official monitoring process of the German “Energiewende” which only relies on highly aggregated indicators for energy efficiency. These indicators also provide suitable starting points for new energy efficiency policies which are necessary to close the gap towards the targets. Attention should especially be focused to those sectors and end-uses, where a very slow progress of energy efficiency could be observed since 2000 and especially during the last years since 2008. According to our results, these are in particular the industrial sector and electricity consumption, where the gap to the target is rather pronounced. Finally, top-down approaches are a useful calibration of the bottom-up evaluation of policy instruments, as it was discussed in the previous sub question.

After having summarized the main findings for the sub questions, we now return to the central research question of this thesis:

What is necessary for the design of effective energy efficiency policies?

In order to answer this overall question, we once again refer to the conceptual framework of this thesis (Figure 9-1), which we developed in Section 1.3. Here we embed the design of EE policy instruments in the broader framework of energy efficiency policy which comprises the setting of EE targets and their achievement through successful energy efficiency policies, and which must be monitored and evaluated.

⁸⁸ <http://www.odyssee-mure.eu/>

Energy efficiency targets are an important driver for the introduction of new EE policies and for the improvement of those already existing. We identify (cost-effective) energy efficiency potentials as a suitable foundation for the derivation of these targets. We show further, that potentials also have an important role for a comparable assessment of different instrument options.

We found that in spite of a long history of profound research, clear definitions and common rules for the measuring of energy efficiency are still missing. This can strongly weaken the achievement of EE targets and present a strong barrier to the communication of targets and target achievement, especially in target systems based on a larger number of individual targets such as the 2020 target system of the EU. Increasingly, energy efficiency targets are anchored in more general target systems and lead to interactions between the different targets. Simplicity argues for as few targets as possible (which would argue in favour of a unique GHG target rather than individual targets for energy efficiency, for renewable and for GHG). However, care has to be taken that through oversimplification individual objectives are not sufficiently reflected in the targets. Simplicity of the target formulation is an important but not the only argument to take into account. We therefore conclude that precise rigorous definitions should be used for setting and monitoring energy efficiency targets in a political context, if exactly the same understanding of target is to be achieved. In order to hinder the use of existing loopholes due to unclear definitions and measurement approaches, a common and widely accepted understanding of some basic rules at least for the accounting method and the choice of the baseline is necessary. This also concerns concrete EE policy instruments, which are – as e.g. energy efficiency obligation schemes or voluntary energy efficiency networks – designed based on an EE target which has to be achieved.

For the monitoring and evaluation of EE targets and policies we analyse a broad set of methods all of which have drawbacks limiting their use for monitoring and evaluation purposes. The choice of a suitable and meaningful method for the monitoring and evaluation of EE targets and policies is therefore crucial within an effective policy design. This needs be considered at the start of the process in order to ensure that the necessary data are available or that activities are initiated to obtain the necessary data. This thesis identified the availability of proper data as a pre-requisite for a widespread use of meaningful methods for monitoring and evaluation.

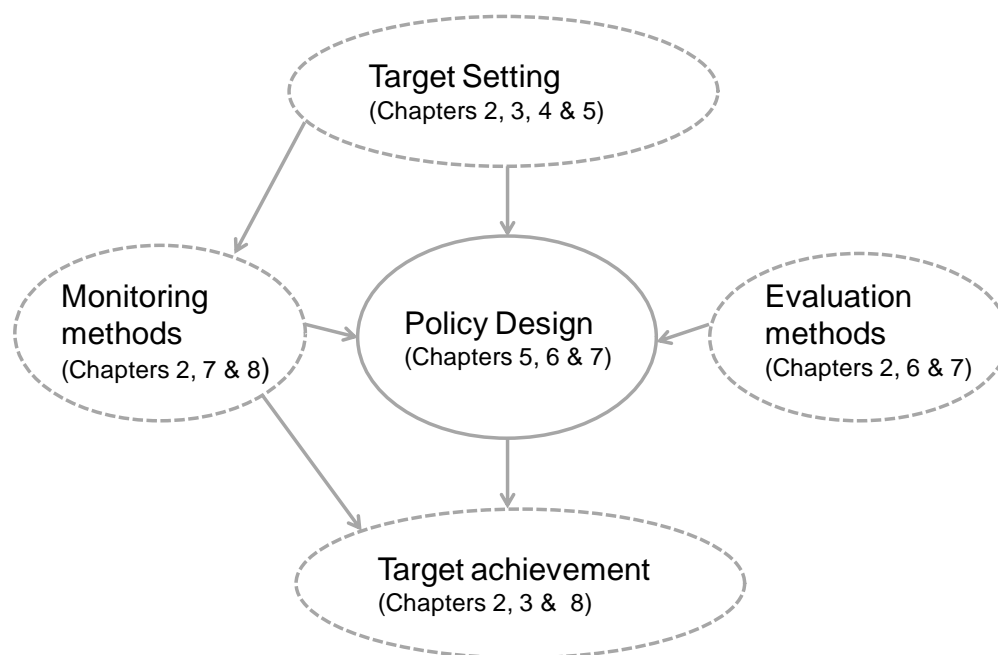


Figure 9-1: Conceptual framework of the thesis

Looking at the policy design in the narrower sense, as it is at the centre of our conceptual framework, a significant result of this thesis is that ambitious EE targets will not usually be achieved through one single policy instrument, but that a mix of different instruments is necessary. This is mainly due to the different suitability of the instruments to overcome barriers to energy efficiency and thus to exploit the cost-effective EE potential. In order to design a policy mix which is suitable for exploiting the whole cost-effective EE potential and thus to achieving ambitious EE targets, we recommend the adoption of a multi-criteria semi-quantitative approach. Apart from the suitability of the instruments to overcome barriers and thus to achieve a certain amount of energy savings, an array of further evaluation criteria should be considered. Alongside cost aspects, political considerations play an important part in many sectors. These include (i) the strategic view of the development of an energy services market, (ii) the question of refinancing of the market and competitive compatibility and, (iii) the political enforceability of instruments and the complexity of the instrument mix that arises.

An effective policy design also requires broad consideration of the perspectives of the different actors and target groups. In this thesis, we exemplify this for retailers and SMEs. For the design of an effective bundle of instruments, however, which simultaneously addresses all major obstacles, the whole chain of relevant actors and target groups in the product cycle must be considered.

9.3 Conclusions and recommendations

In this thesis, we found several indications that there is still the need for a better anchoring of energy efficiency policy within international and national energy and climate policy. This applies to both the general framework of target setting and monitoring and the design of energy efficiency policies in order to achieve these targets. We identified the following key elements for the design of a more effective EE policy:

- The setting of an ambitious and mandatory energy efficiency target (anchored in a more general and coherent target frame) which is derived from cost-effective energy efficiency potentials.
- The regular monitoring of the progress toward the targets using suitable monitoring methods and based on precise definitions of EE measuring.
- A sufficient availability of necessary statistical and measure-related data being a prerequisite for all monitoring approaches of energy efficiency.
- The design of suitable bundles of EE policy instruments which simultaneously reduce major obstacles hindering the exploitation of cost-effective EE potentials.
- The consideration of all relevant actors and targets groups in the product cycle of energy efficiency and making use of the specific motivations of these groups.
- The adoption of a multi-criteria approach for the design of the policy mix which takes into account both quantitative and qualitative criteria.
- Evaluation method and process of individual instruments (frequently based on bottom-up or econometric methods) which is well embedded into “control” evaluation methods for the bundle of measures, to which the individual instrument belongs to and which may be based on top-down methods (taking automatically into account issues such free-rider or multiplier effects), which otherwise are difficult to establish. Combining methods in such a manner is certainly a further field of research.

We think that the current moment is a good time for the application of at least some of these findings in actual energy efficiency policy. At the European level, the full implementation of the Energy Efficiency Directive (EED) demands further increase in the energy efficiency progress and the implementation of new or at least comprehensively improved EE policy instruments. The new framework for EU energy and climate policies up until 2030 would allow the introduction of an ambitious and binding energy efficiency target. The interaction of this target with other targets, e.g. for renewables and GHG emissions need to be carefully considered in the target design. Germany, which is the by far biggest energy consumer in the EU, has decided on a fundamental transition of its energy system (the so-called “Energiewende”), which will not be possible without a considerable increase in energy efficiency compared to the slow progress in the period 2008-2012 (see Chapter 8). In the Coalition Agreement of the new govern-

ment from December 2013, a “National Action Plan Energy Efficiency” was announced which has to be agreed before the end of 2014. Such a plan would offer the option of implementing a more effective EE policy in Germany and thus also contribute to the achievement of European EE targets.

There is another reason why we think that time is favourable for a better anchoring of energy efficiency policy within international and national energy and climate policy. This is the growing importance of the so-called co-benefits of energy efficiency in political and public discussion. These comprise, for example, (i) macro-economic impacts such as an increase in GDP and employment, (ii) the improvement of competitiveness at the national or company level, and (iii) an increase in energy security through the reduction of energy imports. These co-benefits can be an additional justification for the setting of ambitious EE targets and the design of effective EE policies. We have addressed these co-benefits in this thesis several times, but we have not comprehensively analysed or discussed them. There are already some studies investigated these impacts more deeply at the international level (e.g. IEA, 2012, 2014), at the level of the EU (e.g. Cambridge Econometrics, 2013) or in some Member States as e.g. Germany (Fraunhofer ISI, 2009; Lehr et al., 2012). Nevertheless, we still see the need for further research especially with regard to a systematic quantification of these co-benefits of energy efficiency in evaluations of policy instruments.

Another issue not fully covered with our methodological approach is the question of a suitable distribution of the European-wide or international targets among States (so-called burden sharing, or better effort sharing, as for energy efficiency there is a financial benefit at the end), taking into account the differences in national context. We could only consider a differentiation by sector since we derived the target from sectoral EE potentials. Further research is also needed here.

The last topic we want to mention is the financing of EE policies. We briefly addressed this issue in Chapter 5 as one of the criteria to be taken into account for the design of a suitable mix of EE policy instruments. High upfront investments are required to substantially increase energy savings in the European Union (see Wesselink et al., 2011), especially in the building sector. This means that ensuring the financing of EE investment by public finance, and especially by activating more private capital, will be one of the key challenges of a more ambitious energy efficiency policy in the years to come. The development of new business models for energy efficiency investment is likely to be part of this and also requires further research.

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Samenvatting en conclusies

Introductie en scope

Verbetering van de energie-efficiëntie (EE) is algemeen erkend als de belangrijkste strategie voor het bereiken van wereldwijde energie- en klimaatdoelstellingen. Behalve bijdragen aan de reductie van energiegebruik en energiegerelateerde broeikasgasemissies, levert de verbetering van de energie-efficiëntie ook verschillende additionele voordelen op voor economie en samenleving. Deze omvatten o.a. macro-economische invloeden zoals een toename in BNP en werkgelegenheid, verbetering van het concurrentievermogen op nationaal of bedrijfsniveau, of een toename in energievoorzieningszekerheid door middel van het reduceren van energie-import.

Ondanks de algemeen onbetwiste rol van energie-efficiëntie als een hoeksteen van de wereldwijde en Europese energie- en klimaatbeleid, zijn er indicaties dat energie-efficiëntie nog steeds onvoldoende is verankerd in zowel de EU en zijn lidstaten als ook daarbuiten. Ter illustratie, hoewel de EU op koers ligt om zijn broeikasgasemissie en hernieuwbare-energie doelstellingen te halen, is het duidelijk dat de EU niet volledig op koers ligt om haar energie besparingsdoelstelling voor 2020, namelijk een reductie van 20% in vergelijking met een referentie-ontwikkeling, te halen (EEA, 2013; Harmsen et al., 2014; Fraunhofer ISI et al. 2014). Daarnaast zijn er nog steeds uiteenlopende meningen met betrekking tot het definiëren en monitoren van de doelstellingen voor energie-efficiëntie, wat wederom duidelijk werd tijdens de discussie betreffende een nieuwe opzet van het Europese energie- en klimaatbeleid gericht op het jaar 2030. Dit geeft aan dat ondanks een lange historie van diepgaand onderzoek naar de definitie en meting van energie-efficiëntie, heldere definities en algemene regels voor meting nog steeds ontbreken (Patterson, 1996; Pérez-Lombard et al., 2013).

Dit proefschrift concentreert zich op de vraag hoe gunstigere randvoorwaarden gecreëerd kunnen worden voor een betere verankering van het energie efficiëntiebeleid in het internationale en nationale energie- en klimaatbeleid. De centrale onderzoeksvraag van dit proefschrift is:

Wat is noodzakelijk voor het ontwikkelen van effectief energie-efficiëntiebeleid?

Om deze globale onderzoeksvraag te kunnen beantwoorden zijn de volgende deelvragen gedefinieerd:

1. Wat zijn de fundamentele aspecten van het meten van energie-efficiëntie in een politieke context?
2. Hoe past energie-efficiëntie binnen een raamwerk van meerdere doelstellingen voor klimaat en energie?
3. Welke rol kunnen energie-efficiëntiepotentiëlen spelen in het proces van het vaststellen van doelstellingen en beleidsontwerp?
4. Met welke belangrijke elementen moet men rekening houden bij het ontwerp van beleid gericht op energie-efficiëntieverbetering?
5. Hoe kan het perspectief van specifieke actoren en doelgroepen in beschouwing worden genomen bij het beleidsontwerp?
6. Welke methodes zijn geschikt voor de evaluatie van de effectiviteit van EE beleid instrumenten?
7. Welke methodes zijn geschikt voor het meten van de gemaakte vooruitgang bij het bereiken van de energie-efficiëntiedoelen en met welke factoren moet hierbij rekening worden gehouden?

Met deze deelvragen in gedachten, richten wij ons op het vaststellen van sleutelfactoren waar rekening mee gehouden dient te worden voor een effectief ontwerp van energie-efficiëntiebeleid. De deelvragen zijn besproken in één of meerdere van de voorgaande hoofdstukken 2 tot 8 van dit proefschrift (zie de toelichtingen met betrekking tot de link tussen de subvragen en de verschillende hoofdstukken in sectie 1.3)

Samenvatting van de resultaten

Deze sectie presenteert en bespreekt de belangrijkste resultaten die wij gevonden hebben met betrekking tot de deelonderzoeksvragen en de centrale onderzoeksvraag van dit proefschrift.

1. *Wat zijn de fundamentele aspecten van het meten van energie-efficiëntie in een politieke context?*

In **hoofdstuk 2**, onderzoeken wij de basisaspecten van de doorgaande discussie over de definitie en het meten van energie-efficiëntie. In het bijzonder doelen wij op het formuleren van een referentie-ontwikkeling en aan de berekeningsmethode gebruikt voor de meting van de energie-efficiëntie, waar wij nog een tekort aan helderheid zien, ondanks voortgaand onderzoek op dit gebied. Wij laten zien dat er vele definities en wijze van benadering gebruikt worden voor het meten van energie-efficiëntie in een

politieke context, elk met zijn eigen voordelen en bruikbaarheid. Wij hebben gevonden dat een verschil van een factor van 10 of meer tussen verschillende betekenisvolle definities van energie-efficiëntieverbetering voor kan komen. Daardoor vormt het meten van energie-efficiëntie verbetering een aanzienlijke methodologische uitdaging welke implicaties heeft in het beleidsdomein, zowel wat betreft formulering van de doelstelling als wat betreft communicatie van doelen en realisatie van de doelen, ook richting het grote publiek en niet-gespecialiseerde beleidsmakers zoals parlementariërs die besluiten moeten nemen over stukken wetgeving gebaseerd op tamelijk ingewikkelde rekenmethoden.

Eenzijds, identificeren wij zogenoemde “top-down” methodes gericht op de energie-efficiëntie op een hoog aggregatieniveau per land of economische sector, en gebaseerd op geaggregeerde statistische data. “Bottom-up” methodes, daarentegen, starten met de berekening van de individuele energiebesparing van één finale gebruiker of één specifiek apparaat om deze vervolgens te accumuleren. Wij hebben vastgesteld dat zowel top-down als bottom-up methodes een serie correctiemethodes bevatten die de mate waarin energie-efficiëntiewinst bereikt wordt beïnvloeden. Top-down methodes in het bijzonder hebben te maken met correctiemethodes voor externe invloeden welke niet primair toe te schrijven zijn aan veranderingen in de energie-efficiëntie (bijv. het weer, activiteitsniveau, structuur of gedrag). Bottom-up methodes, anderzijds, hebben te maken met effecten die sterk de impact van een energie-efficiëntiebeleid kunnen beïnvloeden, maar waarvoor niet altijd gecorrigeerd wordt. Voorbeelden zijn o.a. (i) dubbeltelling van energiebesparing door de interactie van beleidsinstrumenten, (ii) het probleem van niet-naleving van regelgeving welke vooral van belang is voor normstellend beleid als ook voor multiplicatie-effecten die de impact van beleid versterken in andere gebieden, en (iii) free-rider effecten van beleid welke ook zouden hebben plaatsgevonden zonder een energie-efficiëntiebeleid. In het bijzonder identificeren wij ontbrekende gegevens als belangrijk probleem voor de brede toepassing van correctiemethodes. Wij concluderen dat een toereikend kwantiteit van beschikbare data een voorwaarde is voor alle vormen van monitoring van de energie-efficiëntie en dat daar nadrukkelijk rekening mee gehouden dient te worden bij de keuze voor een specifieke monitoringsmethode. Voorbeelden geciteerd in dit proefschrift illustreren dat de noodzakelijke financiële middelen voor uitvoering van specifieke monitoringsmethoden beperkt zijn, in het bijzonder wanneer het monitoringsproces in hoge mate het succes van het instrument zelf bepaalt..

Onze resultaten laten ook zien dat nauwkeurig vastgelegde definities gebruikt dienen te worden voor de formulering en monitoring van energie-efficiëntiedoelen in een politieke context, om te verzekeren dat alle betrokkenen hetzelfde begrip krijgen van

het doel. Ten einde het gebruik van mazen in de wetgeving te vermijden, welke bestaan vanwege onduidelijke definities en meetmethodes, is het noodzakelijk een gemeenschappelijk en breed geaccepteerd begrip van een paar basisregels te hebben. Deze zouden op zijn minst een aantal centrale onderwerpen moeten beslaan zoals de keus van de referentie en de rekenmethodes die cruciaal zijn voor de evaluatie van het effect van energie-efficiëntiebeleid. De regels rondom de maatregel moeten ook zo precies mogelijk te zijn. Vergelijkbaarheid van de meetmethodes is noodzakelijk om te garanderen dat overal vergelijkbare inspanningen gemaakt moeten worden, of op zijn minst dat de inspanningen transparant gemaakt worden. Anders zal een doelstelling, welk op het eerste gezicht ambitieus lijkt een “papieren tijger” blijken, wat niet zal bijdragen aan het behalen van doelstellingen in het domein van energie- en klimaatbeleid.

Echter, nauwkeurige definities alleen zijn mogelijk niet toereikend, gegeven het feit dat de beleidsomgeving (inclusief het grote publiek) grotendeels niet zal zijn samengesteld uit “wiskundigen”. Dit betekent dat doelen het liefst in eenvoudige termen geformuleerd moeten worden. Dit was ondermeer de reden voor de verschuiving van de formulering van de energiebesparingsdoelstelling in de Energy Service Directive 2006/32/EC naar een absolute energiegebruiksdoelstelling in de Energy Efficiency Directive 2012/27/EU, welke het voordeel van eenvoud heeft maar ook weer nieuwe beperkingen heeft (zie hieronder). Dit is nog belangrijker wanneer energie-efficiëntiedoelen interactie hebben met andere doelen, bijv. met broeikasgasemissiedoelstellingen, welke besproken zullen worden in de volgende deelonderzoeksvraag hieronder. Echter, er is ook een leerproces geweest, tenminste bij de beleidsmakers betrokken bij het formuleren van deze twee Directives voor energie-efficiëntie, welk ook gezorgd heeft voor een bredere verspreiding van de kennis van deze methoden, ondanks dat er kennelijk grenzen zijn aan de communiceerbaarheid van complexe doelen

Daar hoofdstuk 2 ook dient als een algemene methodologische basis voor dit proefschrift, zullen wij terugkomen op een aantal van de resultaten als de verdere deelonderzoeksvragen behandeld worden.

2. Hoe past energie-efficiëntie binnen een raamwerk van meerdere doelstellingen voor klimaat en energie?

In **hoofdstuk 3** analyseren wij welke lessen men kan leren van het pakket van klimaat- en energiedoelstellingen voor 2020 en hoe een samenhangend raamwerk voor 2030 ontwikkeld kan worden.

Het 2020 doelstellingensysteem van de EU bestaat uit drie hoofddoelstellingen: voor broeikasgasemissie (greenhouse gas emissions; GHG), duurzame energiebronnen en

energie-efficiëntie (EE). Onze hoofdbevinding is dat het doelstellingensysteem zijn samenhang is kwijtgeraakt toen de economie een onverwachte afwijking kreeg ten opzichte van het referentiescenario, daar de EE-doelstelling een absolute energiegebruiksdoelstelling is ten opzichte van de referentie. Wij construeren een coherent doelstellingensysteem voor de EU in 2030 gebaseerd op een ambitieuze vaststelling van doelen voor EE en duurzame energie, welke 50% of zelfs 55% of 60% broeikasgasemissiereductie in 2030 kunnen genereren (ten opzichte van 1990). Wij laten zien dat een ambitieuze EE doelstelling van 41% voor 2030, welke correspondeert met een volledige realisatie van alle kosteneffectieve sectorale EE-potentiëlen (voor industrie, huishoudens, tertiaire sector en transport), consistent is met een ambitieuzere doelstelling voor de broeikasgasemissiereductie dan de nu voorgestelde reductie van 40%. Wij hebben ook gevonden dat een emissiereductiedoelstelling voor broeikasgassen als enige hoofddoelstelling niet zal leiden tot realisatie van alle kosteneffectieve EE-potentiëlen, tenzij deze zeer ambitieus geformuleerd is, i.c. een reductie ten opzichte van 1990 van op zijn minst 50% of zelfs 55% of 60%.

Een overeenkomst over een dergelijk ambitieuze broeikasgasemissiedoelstelling is echter zeer onwaarschijnlijk, gegeven het lage ambitieniveau wereldwijd. Daarom denken wij dat ambitieuze broeikasgasemissiereducties op meer realistische wijze bereikt kunnen worden door te beginnen met ambitieuze EE-doelstellingen. Deze doelstellingen kunnen gerechtvaardigd worden door de kosteneffectiviteit van het EE-potentieel en in aanvulling daarop door de macro-economische positieve neven-effecten van energie-efficiëntie zoals een toename in BNP en werkgelegenheid, of een verbetering van het concurrentievermogen.

Met betrekking tot de formulering van de doelstellingen concluderen wij dat dynamische elementen vanaf het begin onderdeel van het ontwerp van een doelstellingensysteem moeten zijn of dat men op zijn minst bedacht moet zijn op een periodieke bijstelling van de doelstellingen. In het bijzonder is dit het geval voor absolute EE-doelstellingen. Doelstellingen welke geformuleerd zijn als intensiteit- of besparingsdoelstellingen zijn waarschijnlijk minder gevoelig voor verandering in de economische omstandigheden maar kunnen niet garanderen dat het energiegebruik verlaagd wordt in absolute zin. EE-doelstellingen geformuleerd in termen van intensiteit kunnen ook beïnvloed worden door structurele veranderingen, hoewel in het verleden deze effecten niet van groot belang waren. Door de sterke interactie met het referentieniveau zijn besparingsdoelstellingen niet gemakkelijk te communiceren: de methodes zijn vrij complex en daardoor gemakkelijker te manipuleren, wat door een deel van de beleidsmakers als een nadeel gezien wordt.

3. Welke rol kunnen energie-efficiëntiepotentiëlen innemen in het proces van het vaststellen van doelstellingen en beleidsontwerp?

In de hoofdstukken 3, 4 en 5 van dit proefschrift, bediscussiëren wij vanuit verschillende perspectieven de rol van (economische) EE-potentiëlen in de context van EE-beleid.

In hoofdstuk 3, ontwikkelen wij een coherent doelstellingensysteem voor 2030 vanuit een bottom-up-analyse van energie-efficiëntiepotentiëlen. In hoofdstuk 4, gebruiken wij een bottom-up voorraadmodel om de technologische verbeteringspotentiëlen voor reductie van het elektriciteitsverbruik voor informatie- en communicatietechnologie (ICT) te berekenen. Tot slot kijken wij in hoofdstuk 5 naar de energie-efficiëntiepotentiëlen die gerealiseerd kunnen worden door de implementatie van een nieuwe groep van marktgeoriënteerde EE beleidsinstrumenten zoals energie-efficiëntieverplichtingen (energy efficiency obligations; EEO).

Het belangrijkste resultaat van onze analyse is dat energie-efficiëntiepotentiëlen een belangrijke analytische basis zouden kunnen vormen voor de formulering van een effectieve EE-beleidsstrategie. Vanuit onze analyse in **hoofdstuk 3** concluderen wij dat verdergaande broeikasgasemissiereducties verwacht mogen worden wanneer er begonnen wordt met een raming van wat mogelijk is in termen van EE- (en duurzame energie-) potentiëlen. De broeikasgasemissiedoelstelling kan hier dan van afgeleid worden. In **hoofdstuk 4** behandelen wij aan een specifiek eindverbruik, i.c. elektriciteitsverbruik voor informatie- en communicatietechnologie. Door het toepassen van een bottom-up voorraadmodel voor informatie- en communicatietechnologie (ICT) en consumentenelektronica (CE), laten wij zien dat er een hoog technologisch verbeteringspotentieel is voor reductie van het elektriciteitsverbruik in deze categorieën. Dit kan op zijn minst leiden tot een vertraging van de verwachte verbruikstoename of zelfs het verbruik op midden en lange termijn stabiliseren. Echter, of deze besparingspotentiëlen gerealiseerd zullen worden is afhankelijk van het EE-beleid dat landen gaan introduceren ter stimulering van de snelle adoptie van zeer efficiënte producten en netwerkoplossingen.

Ten slotte, in **hoofdstuk 5** maken wij gebruik van energie-efficiëntiepotentiëlen voor het ontwerpen en evalueren van nieuw marktgeoriënteerd EE-beleid zoals EEO's, met Duitsland als voorbeeld. Een EEO is een verplichting voor een bepaalde groep actoren (meestal energieleveranciers of netwerkbedrijven) om een energiesbesparingsdoelstelling te realiseren door het genereren van een bepaalde hoeveelheid energiebesparing in een specifieke periode. Deze potentiëlen worden berekend door middel van een bottom-up simulatiemodel voor de belangrijkste eindverbruikssectoren (huishoudens, industrie en tertiaire sector). Deze modellen worden eerst gebruikt voor

het afleiden van een realistische energiebesparingsdoelstelling die tot en met 2020 behaald dient te worden met de nieuwe instrumenten. De cumulatieve jaarlijkse energiebesparingen voor Duitsland van dit kosteneffectieve EE potentieel wordt geschat op 343 TWh per 2020⁸⁹. Dit is bijna 15% van het totale finale energieverbruik in Duitsland in het jaar 2012. Hieruit leiden wij drie energiebesparingsdoelstellingen af die bereikt dienen te worden door de EE-beleidsinstrumenten. Wij onderscheiden drie ambitieniveau's, resulterend in besparingen van respectievelijk 343 TWh, 228 TWh en 114 TWh. Ten tweede, maken wij gebruik van de EE-potentiëlen in een kwantitatieve evaluatie van de toepasbaarheid van de nieuwe instrumenten om deze doelstellingen te halen. Onze evaluatie laat zien dat met geen van deze instrumenten zelfstandig het volledige kosteneffectieve energiebesparingspotentieel kan worden gerealiseerd, i.c. voor het bereiken van de voorgeschreven EE doelstelling op het hoogste niveau is een mix van instrumenten is noodzakelijk.

Geschikte modellen zijn een voorwaarde om EE-potentiëlen te gebruiken voor het ontwerp van EE-doelstellingen en -beleid. Deze genereren een betrouwbare kwantificering van de EE-potentiëlen en de kosten op een gedetailleerd niveau van energieverbruikssectoren. De bottom-up simulatiemodellen die wij gebruikt hebben voor het berekenen van de EE-potentiëlen in hoofdstuk 3, 4 en 5 voldoen grotendeels aan deze voorwaarde. De EE-potentiëlen zijn berekend voor de sectoren gebouwen, elektronische huishoudelijke apparatuur en generieke technologieën in huishoudens en de tertiaire sector (met een submodel voor ICT), industrie (onderscheid makend tussen processen onderhevig aan het EU emissiehandelssysteem en processen die buiten dit systeem vallen) en transport⁹⁰. Deze modellen zijn dynamisch opgezet, i.c. zij houden rekening met kostenreductie ten gevolge van technologische vooruitgang en toenemende marktpenetratie van efficiënte technologie. Zij omvatten een enorm aantal energiebesparingsopties in alle sectoren gebaseerd op empirisch gegevens en beslaan zowel de Europese Unie als geheel als alle lidstaten afzonderlijk. Daardoor kunnen beiden toegepast worden in een analyse voor de totale EU (zoals wij gedaan hebben in hoofdstuk 3) en voor nationale case studies (zoals wij gedaan hebben voor Duitsland in de hoofdstukken 4 en 5).

Belangrijk in deze context is ook de notie van "economische potentiëlen". Beleidsmakers verlangen vaak dat EE-maatregelen die genomen moeten worden

⁸⁹ Zonder de transportsector en het energiegebruik dat onder het EU emissiehandelssysteem (EU-ETS) valt.

⁹⁰ Hoewel de transportsector gedeeltelijk uitgesloten is van de regels vastgesteld op het gebied van EE (bijvoorbeeld EED of de voormalige ESD) en van generieke instrumenten zoals de EEO's.

economisch zijn. Daardoor is het van groot belang de te definiëren wat men onder “economisch” verstaat. Regelmatig wordt dit verbonden aan de vaststelling van de rentevoet die wordt gebruikt bij de kosten-batenanalyse van energie-efficiëntie maatregelen. Diverse bekende EU-studies (bijv. de reguliere scenario's van de Europese Commissie zoals EC, 2013) gebruiken rentevoeten tot 17-18% in de huishoudelijke sector, aangezien het de bedoeling is dat ze barrières voor energie-efficiëntie simuleren. Echter, vaak zijn deze barrières niet-economisch van karakter (zie als voorbeeld de discussie in hoofdstuk 7 over barrières in de tertiaire sector in Duitsland) en kunnen ze overwonnen worden met niet-economische beleidsinstrumenten (bijvoorbeeld de inzet van labels die informatie verstrekken over de meest efficiënte apparatuur, door instrumenten die split incentives overwinnen voor huurhuizen etc.). Het is daardoor niet passend alle soorten barrières te vertalen in financiële termen (hoewel er ook zeker economische barrières zijn die aangepakt moeten worden). Definitie van het begrip “economisch” binnen de analytische scenario's is daarom van groot belang om energiebesparingspotentiëlen correct te bepalen.

4. Met welke belangrijke elementen moet men rekening houden bij het ontwerp van beleid gericht op energie-efficiëntieverbetering??

In **hoofdstuk 5**, hebben wij een kosten-batenanalyse uitgevoerd van de introductie van nieuwe EE-beleidsinstrumenten zoals een energie-efficiëntieverplichting (EEO) of een energie-efficiëntiefonds. We vergelijken deze met de uitbreiding en verbetering van de bestaande EE-instrumenten. Dit is in lijn met Artikel 7 van de Energy Efficiency Directive, welke òf de introductie van een EEO vereist gericht op de realisatie van een energiebesparingsdoelstelling van 1,5% per jaar òf alternatieve beleidsmaatregelen waarmee dezelfde EE-doelstelling wordt gerealiseerd. Voor onze analyse gebruiken wij de situatie in Duitsland als voorbeeld.

Gebruik makend van de methodologische discussie in **hoofdstuk 2**, identificeren wij de volgende belangrijke keuzes die gemaakt moeten worden vóór uitvoering van een vergelijkende kostenbaten analyse van EE-beleidsinstrumenten opdat een goede vergelijking mogelijk is:

- specificatie van de omvang van het energiegebruik dat door de instrumenten beïnvloed dient te worden, in termen van brandstoffen, sectoren en eindgebruikscategorieën
- de keuze van de referentie-ontwikkeling is van bijzonder belang; i.c. alleen energiebesparing die een bepaald niveau (gedefinieerd door de referentie-ontwikkeling) overschrijdt, zou in rekening gebracht moeten worden

- het principe van de additionaliteit, wat betekent dat de energiebesparing verder gaat dan de autonome ontwikkeling die ook zonder beleid zou plaatsvinden, bijv. door algemene technologisch verbetering of door reeds bestaand EE-beleid
- de precieze definitie van de methode voor berekening van energiebesparing onder een EEO of een vergelijkbaar beleidsinstrument; dit is een voorwaarde voor een effectief ontwerp van nieuw energiebesparingsbeleid. Wij hebben immers gevonden dat de berekende energiebesparing voor een gegeven EE-maatregel enorm kan variëren, afhankelijk van de rekenmethode die wordt gebruikt
- een ander invalshoek bij het ontwerp van effectief energiebesparingsbeleid is het perspectief van actoren en doelgroepen. Dit zal in detail besproken worden in de volgende subvraag hieronder.

Met een multi-criteria aanpak evalueren wij de sterktes en zwaktes van de verschillende EE-beleidsinstrumenten. Eerst maken wij een semikwantitatieve beoordeling van de toepasbaarheid van de instrumenten om de voorgeschreven doelen, zoals die afgeleid zijn van het kosteneffectieve EE-potentieel (zie subvraag 4), te halen. Dan voegen wij een kwalitatieve evaluatie van de volgende criteria toe (zie ook sectie 1.2): (i) kosten van de instrumenten, (ii) marktconformiteit en invloed op het concurrentievermogen en op de markt voor energiediensten, (iii) verdelings- en structurele effecten en invloed op de ontwikkeling van energieprijzen, (iv) interactie van beleidsinstrumenten, en (v) politieke acceptatie door de verschillende doelgroepen van het beleid alsmede de vraag hoe de beleidsinstrumenten verschillen in termen van hun financiering.

Zoals wij al geconcludeerd hadden, kunnen met geen van de EE-beleidsinstrumenten afzonderlijk de hoge energie-efficiëntiedoelstellingen gehaald worden. Deze doelstellingen kunnen alleen bereikt worden door het invoeren van een geschikte mix van beleidsinstrumenten. Dit hangt voornamelijk samen met de toepasbaarheid van de instrumenten voor het overwinnen van verschillende barrières voor energie-efficiëntie. De mix van instrumenten die daadwerkelijk wordt gekozen is uiteindelijk een politieke keuze, na zorgvuldige overweging en weging van de verscheidene evaluatiecriteria. De resultaten van zo'n analyse kan echter wel de analytische onderbouwing vormen voor politieke besluiten. Een sleutelvoorwaarde is dat de combinatie van instrumenten welke uiteindelijk gekozen wordt, past binnen het bestaande pakket aan beleidsinstrumenten. Naar onze mening is de mogelijkheid om energiebesparing onafhankelijk van het overheidsbudget te financieren, een goede reden voor de aanvullende inzet van nieuwe marktgeoriënteerde instrumenten zoals een EEO.

5. Hoe kan het perspectief van specifieke actoren en doelgroepen in beschouwing worden genomen bij het beleidsontwerp?

Het perspectief van actoren en doelgroepen is een ander belangrijke invalshoek bij het ontwerp van effectief energiebeleid dat nodig is voor het uit de weg ruimen van de barrières voor energie-efficiëntie (zie sectie 1.1). Wij hebben het belang en de bijzonderheden laten zien van het actor-perspectief en hoe er rekening mee gehouden kan worden in een concreet beleidsontwerp in twee verschillende cases.

In **hoofdstuk 6**, kijken wij speciaal naar detailhandelaren die een belangrijke rol spelen bij de implementatie van labeling van producten, maar hierin soms tekort schieten. Om te begrijpen waarom een verkoper (niet) voldoet aan de eisen voor labeling, ontwikkelen wij eerst een theoretisch raamwerk dat rekening houdt met instrumentele en normatieve motieven. Vervolgens testen wij dit raamwerk in de context van het energielabel door middel van een grootschalige empirische studie in 1.314 winkels in alle toenmalige 27 EU-landen. Wij hebben twee afzonderlijke datasets verzameld op winkelniveau: een audit van de naleving (verschafft het percentage van correct gelabelde apparatuur voor elke winkel) en een gestandaardiseerde enquête onder winkelmanagers. De resultaten laten zien dat zowel instrumentale factoren (voornamelijk vrees voor sancties) en normatieve factoren (internalisering van regelgeving en sociale normen) helpen om de naleving van de eisen voor productlabeling te verklaren. Onze resultaten hebben implicaties voor beleidsmakers alsook voor het management in de detailhandel. Beleidsmakers kunnen de resultaten gebruiken voor preciezere afstelling van de labelingprogramma's. Onze resultaten laten bijvoorbeeld zien dat de moeite die het kost om de labels op de apparatuur te plaatsen veel geringer is dan in eerste instantie werd verondersteld. Wij laten het belang zien van regelmatige controles en van de druk die consumenten uitoefenen. Programma's die de aandacht van consumenten op de labels vestigen kunnen behulpzaam zijn, niet alleen omdat zij het bewustzijn van consumenten verhogen, maar ook indirect doordat zij druk uitoefenen op detailhandelaren. De resultaten kunnen ook nuttig te zijn voor detailhandelaren, zij helpen het management te begrijpen waarom hun werknemers wel of juist niet de regels volgen. Gebaseerd op onze analyse kunnen wij het detailhandelmanagement adviseren regelmatige interne controles te implementeren; tevens laten onze resultaten zien dat winkelmanagers meer geneigd zijn om de eisen na te leven als zij overtuigd zijn van het nut. Trainingsprogramma's gericht op ontwikkeling van acceptatie van de reglementen door winkelpersoneel kan helpen niet-naleving te beperken en daardoor mogelijke sancties of boetes te vermijden.

In **hoofdstuk 7**, verkennen wij empirisch de drijvende krachten voor het implementeren van energiemangement en andere energiebesparingsmaatregelen met lage kosten in de zogeheten tertiaire sector (voornamelijk bestaand uit publieke en private diensten, handel en commercie en sommige kleine industrieën). Onze statistische analyse is gebaseerd op meer dan 1500 observaties in een representatieve enquête in Duitsland, grotendeels bij het midden- en kleinbedrijf. Door te concentreren op goedkope maatregelen draagt ons onderzoek bij aan de empirisch inzicht in de factoren die de adoptie van dit type energie-efficiënte maatregelen beïnvloeden. De bevindingen suggereren dat de adoptie in belangrijke mate bepaald wordt door organisatorische factoren en split incentives. De implementatie van goedkope maatregelen lijkt daarentegen nauwelijks afhankelijk te zijn van de elektriciteit prijzen. Er is geen differentiatie tussen de sectoren. Efficiënt beleid voor deze maatregelen zou daarom bij voorkeur een generiek in plaats van een sectorspecifiek karakter moeten hebben.

Onze bevindingen suggereren dat het huurder-verhuurder dilemma een rol speelt bij het al dan niet implementeren van energiemangement en andere goedkope energie-efficiëntie maatregelen in de tertiaire sector in Duitsland. Maatregelen zijn vaak fysiek gekoppeld aan gebouwen, zoals automatische verlichtingssystemen of energie-monitoringsystemen en kunnen daardoor beïnvloed worden door het huurder-verhuurder dilemma.

De cultuur in de organisatie en sociale factoren zoals het aanzien van bedrijven of van de directeurs van de bedrijven zijn mogelijk van groter belang dan de financiële stimulansen in de beslissing om goedkope energie-efficiëntie maatregelen te nemen. Deze factoren kunnen versterkt worden door programma's die sociale mechanismes en het "groene imago" van een bedrijf aanspreken (bijv. het instellen van prijzen voor energie-efficiëntie). Dit kan ook het bewustzijn van het topmanagement met betrekking tot energiekosten verhogen. Succesvolle voorbeelden van dit soort programma's zijn bijvoorbeeld regionale of lokaal georganiseerde leernetwerken van bedrijven zoals deze gevestigd zijn in Zwitserland en Duitsland. De belangrijkste elementen van de netwerken zijn (i) de implementatie van energiemangementsystemen tezamen met energie audits, (ii) gemeenschappelijke doelstellingen voor de prestaties op het gebied van energie-efficiëntie, en (iii) monitoring en evaluatie van het proces.

6. Welke methodes zijn geschikt voor de evaluatie van de effectiviteit van EE-beleidsinstrumenten?

Beleidsinstrumenten kunnen individueel geëvalueerd worden alsook in combinatie met andere instrumenten. Aan beide vormen is een toenemende behoefte. Instrumenten zoals de energie-efficiëntieverplichting (EEO) hebben zelfs als vereiste de vaststelling

van het besparingseffect op het niveau van individuele acties, terwijl – door het toenemende aantallen beleidsmaatregelen – interactie tussen instrumenten steeds belangrijker wordt. Individuele instrumenten kunnen dan vaak alleen geëvalueerd worden met veel additionele inspanning, terwijl de gezamenlijke impact van het beleid met meer zekerheid vastgesteld kan worden. Bijvoorbeeld, het scheiden van het effect energie-efficiëntiestandaarden en energielabeling voor elektrische apparaten of auto's vereist aanzienlijke inspanning, terwijl het gecombineerde effect zeer goed vastgesteld kan worden door de ontwikkeling van de verkopen in de verschillende labelklassen te volgen. Deze onderzoeksvraag richt zich op individuele instrumenten, hoewel frequente evaluatie van maatregelenpakketten ook behulpzaam kan zijn voor de evaluatie van individuele instrumenten.

In **hoofdstuk 2**, bespreken wij een breed scala aan top-down en bottom-up methodes voor de monitoring en evaluatie van EE-doelstellingen en beleidsinstrumenten (zie de beschrijving van deze methodes in figuur 1-3 en tabel 2-1). Wij laten zien dat elke methode zijn nadelen heeft, wat de toepasbaarheid beperkt, afhankelijk van de gewenste monitoring- of evaluatiefunctie. Eén principiële beperking van van top-down methodes is dat de koppeling tussen de ontwikkeling van de indicator en een specifiek beleidsinstrument of programma ontbreekt. Om te kunnen evalueren wat de impact van individuele beleidsinstrumenten is moeten daarom bottom-up methodes toegepast worden die beginnen met de berekening van de individuele energiebesparingen en deze vervolgens optellen. Desalniettemin zijn top-down indicatoren wel geschikt voor de evaluatie van maatregelenpakketten (inclusief rebound- en free-ridereffecten) en kunnen daardoor toegepast worden ter controle van de evaluaties van de individuele instrumenten. Door het gebruik van beleidsspecifieke data, hebben bottom-up methodes het voordeel in dat ze gekoppeld zijn aan een specifiek beleidsinstrument of een besparingsprogramma en zo oorzaak-en-gevolg relaties gekwantificeerd kunnen worden. Aan de andere kant brengen deze methodes met zich mee dat er meer inspanningen nodig is voor dataverzameling en -verwerking. De “ideale” bottom-up methode meet direct het object; dit is daarom echter ook veruit de meest complexe en dure methode. De inspanning voor dataverzameling kan gereduceerd worden door gebruik te maken van bestaande datasets (bijv. energierekeningen), alsook door te gebruik te maken van technische impact assessments en het gebruik van standaardwaarden. Desalniettemin, deze bottom-up benaderingen zullen voornamelijk toegepast worden daar waar een maatregelspecifieke bepaling van de energiebesparing noodzakelijk is voor een beleidsinstrument (bijv. voor de EEO's, welk wij bestudeerd hebben in **hoofdstuk 5**). Alles wel beschouwd, onze resultaten laten zien dat de beschikbaarheid van voldoende en betrouwbare data een voorwaarde is voor het monitoren en de evaluatie van energie-efficiëntiebeleid. Dit geldt zowel voor

top-down en bottom-up methodes. Daardoor is een zekere mate van inspanning voor dataverzameling noodzakelijk en terecht om de effectiviteit van EE-beleidsinstrumenten te garanderen.

Een andere categorie methodes zijn de econometrische benaderingen. Deze hebben een top-down karakter daar zij meestal gebaseerd zijn op geaggregeerde data uit statistieken en enquêtes. Deze benaderingen worden in het algemeen gebruikt voor evaluaties van individuele energie-efficiëntiebeleidsinstrumenten als de kosten van bottom-up benaderingen te hoog worden gevonden. In tegenstelling tot top-down methodes gebaseerd op EE-indicatoren, kunnen econometrische methodes een directe link vaststellen met een beleidsinstrument, mits er voldoende data beschikbaar zijn voor het toepassen van statistische regressie-analyse of zelfs een multivariabele statistische analyse. In de **hoofdstukken 6 en 7**, passen wij econometrische methodes toe op twee bestaande EE-beleidsinstrumenten, i.c. de labeling van energiegebruikende producten en de introductie van energiemanagementsystemen in midden- en kleinbedrijven. Dit is echter alleen mogelijk omdat wij de beschikking hebben over uitgebreide enquêteresultaten. Hieruit blijkt opnieuw het belang van voldoende data voor alle monitoring- en evaluatiemethodes.

Concluderend: het is vaak noodzakelijk om één specifieke methode voor de evaluatie van een instrument te gebruiken. Het toepassen van verschillende methodes, in het bijzonder top-down en bottom-up methodes gecombineerd, zijn vooral geschikt is voor het controleren van de resultaten behaald met één enkele methode.

7. Welke methodes zijn geschikt voor het meten van de gemaakte vooruitgang bij het bereiken van de energie-efficiëntiedoelen en met welke factoren moet hierbij rekening worden gehouden?

Onze laatste deelvraag is vergelijkbaar met de voorgaande, maar richt de focus weer op de doelstellingen. Dit betekent een sterkere concentratie op pakketten van maatregelen in tegenstelling tot individuele instrumenten. Opnieuw baseren wij onze analyse op de methodologische basis in **hoofdstuk 2**, waar wij de verscheidenheid beschrijven van top-down en bottom-up methodes voor monitoring en evaluatie. In **hoofdstuk 8** analyseren wij dan de mogelijkheden en beperkingen van top-down methodes als gereedschap voor het regelmatig monitoren van EE-doelstellingen. Wij refereren naar de doelstellingen van de Duitse “Energiewende” en berekenen en bediscussiëren verschillende energie-efficiëntie-indicatoren voor Duitsland zowel voor de complete economie als voor de belangrijkste energieverbruikssectoren. Wij hebben gebruik gemaakt van het gereedschap aan energie-efficiëntie-indicatoren dat wij in de

afgelopen jaren hebben ontwikkeld binnen de ODYSSEE database⁹¹. We stellen vast dat er nog steeds een aanzienlijk gat te dichten is om de globale energie-efficiëntiedoelstellingen in Duitsland per 2020 te halen. Wij laten ook zien dat de vooruitgang van de energie-efficiëntie verminderd is in de periode 2008-2012 vergeleken met de periode daarvoor. In het bijzonder vonden we dat de vooruitgang van de energie-efficiëntie in de industriële sector gedurende het laatste decennium traag is geweest. Wij concluderen dat de energie-efficiëntieverbetering aanzienlijk moet versnellen opdat de doelstellingen bereikt worden in de resterende jaren tot 2020. Hoewel het gebruik van energie-efficiëntie-indicatoren gelimiteerd is door databeperkingen en methodologische problemen geven deze indicatoren dieper inzicht in de factoren die het energieverbruik bepalen. Zij kunnen daardoor complementair zijn aan het officiële monitoringsproces van de Duitse “Energiewende” dat alleen gebruik maakt van zeer geaggregeerde indicatoren voor de energie-efficiëntie. Onze EE-indicatoren zijn ook uitgangspunt bij het ontwikkelen van nieuwe energie-efficiëntie beleid dat noodzakelijk is om het gat te dichten richting de doelstellingen. De aandacht zou in het bijzonder gericht moeten worden op de sectoren en eindgebruikscategorieën, waar een zeer langzame voortgang van energie-efficiëntie gezien werd sinds 2000 en vooral gedurende de laatste jaren vanaf 2008. Volgens onze resultaten zijn het in het bijzonder de industriële sector en het elektriciteitsverbruik, waar de afstand tot de doelstelling redelijk geprononceerd is. Tenslotte, top-down benaderingen zijn een bruikbare calibratie van de bottom-up-evaluatie van beleidsinstrumenten, zoals besproken in de voorgaande deelvraag.

Nadat we de bevindingen van de deelvragen hebben samengevat keren wij nu terug naar de centrale onderzoeksvraag van dit proefschrift:

Wat is noodzakelijk voor het ontwikkelen van effectief energie efficiëntie beleid?

Om deze algemene vraag te kunnen beantwoorden, refereren wij nogmaals aan het conceptueel raamwerk van dit proefschrift (figuur 9-1), welk wij ontwikkelden in sectie 1.3. Hierbij plaatsen wij het ontwerp van EE-beleidsinstrumenten in het bredere raamwerk van energie-efficiëntiebeleid welk bestaat uit het vaststellen van EE-doelstellingen en hun realisatie via succesvol energie-efficiëntiebeleid dat vervolgens gemonitord en geëvalueerd moeten worden.

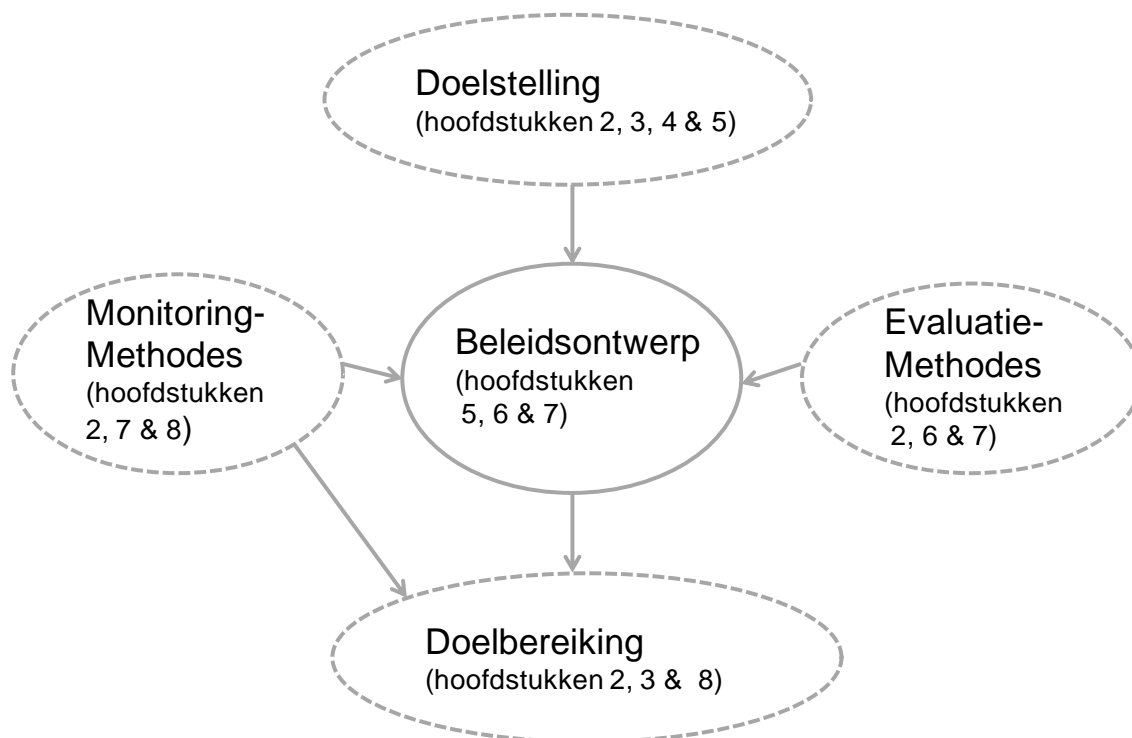
Energie-efficiëntiedoelstellingen zijn een belangrijke drijver voor de introductie van nieuw EE-beleid en voor de verbetering van het bestaande. Wij identificeren (kosteneffectieve) energie-efficiëntiepotentiëlen als geschikte basis voor het afleiden

91 <http://www.odyssee-mure.eu/>

van deze doelstellingen. Wij laten verder zien dat deze potentiële ook een belangrijke rol kunnen spelen bij de vergelijkende beoordeling van verschillende instrumentopties.

Wij hebben gevonden dat, ondanks een lange historie van onderzoek, duidelijke definities en algemene regels voor het meten van energie-efficiëntie nog steeds ontbreken. Dit kan het bereiken van EE-doelstellingen sterk verzwakken en vormt een sterke barrière voor de communicatie van doelstellingen en doelbereiking, in het bijzonder in een doelstellingensystemen gebaseerd op een aantal individuele doelstellingen zoals in het 2020 doelstellingensysteem van de EU. In toenemende mate zijn energie-efficiëntiedoelstellingen verankerd in meer algemene doelstellingensystemen en dit leidt tot interactie tussen de verschillende doelstellingen. Eenvoud pleit er voor om zo min mogelijk doelstellingen te hebben (wat pleit ten gunste van een enkele broeikasgasemissiedoelstelling liever dan individuele doelstellingen voor energie-efficiëntie, voor duurzame energie en voor broeikasgasemissies). Eenvoud van doelstellingen is een belangrijk maar niet het enige argument waar rekening mee gehouden moet worden. Daarom concluderen wij dat preciese definities gebruikt zouden moeten worden voor het vaststellen en monitoren van energie-efficiëntiedoelstellingen om een gemeenschappelijk begrip van de betekenis van de doelstelling te bereiken. Om mazen in de wetgeving vanwege onduidelijke definities en monitoringmethoden te voorkomen, is het noodzakelijk een algemeen toepasbaar en breed geaccepteerd begrip van een aantal basisregels te hebben, op zijn minst voor de rekenmethode en de keuze van het referentieniveau. Dit heeft ook betrekking op concrete EE-beleidsinstrumenten – zoals energie-efficiëntieverplichtingen of vrijwillige energie-efficiëntienetwerken – die worden ontworpen om een EE-doelstelling te bereiken.

Voor de monitoring en evaluatie van EE-doelstellingen en -beleid analyseerden wij een breed scala van methodes die allen nadelen hebben die hun toepasbaarheid voor monitoring- en evaluatiedoeleinden beperkt. De keuze van een geschikte en zinvolle methode voor de monitoring en evaluatie van EE-doelstellingen en beleidsinstrumenten is daardoor cruciaal binnen een effectief beleidsontwerp. Dit moet in overweging worden genomen in het begin van het proces om te verzekeren dat de benodigde data beschikbaar zijn of dat acties ondernomen worden om de benodigde data te verkrijgen. Dit proefschrift heeft de beschikbaarheid van correcte data geïdentificeerd als een voorwaarde voor het gebruik van zinvolle methodes voor monitoring en evaluatie.



Figuur 9-1: Conceptueel raamwerk van dit proefschrift

Kijkend naar het beleidsontwerp in de beperktere betekenis, zoals in de kern van ons conceptuele raamwerk, is een belangrijk resultaat van dit proefschrift dat ambitieuze EE-doelstellingen in het algemeen niet behaald zullen worden via één enkel beleidsinstrument, maar dat een mix van verschillende instrumenten noodzakelijk is. Dit is voornamelijk omdat verschillende beleidsinstrumenten geschikt zijn om verschillende barrières voor energie-efficiëntie uit de weg te ruimen en op die manier het kosteneffectieve EE-potentieel te realiseren. Voor het ontwerpen van een beleidsmix die geschikt is om het gehele kosteneffectieve EE-potentieel te realiseren bevelen wij het gebruik van een semikwantitatieve multi-criteria benadering aan. Los van de toepasbaarheid van de instrumenten om barrières te overwinnen en dus een zekere hoeveelheid energiebesparing te behalen, moet een aantal andere evaluatiecriteria in beschouwing worden genomen. Naast financiële aspecten, spelen politieke overwegingen een belangrijke rol in veel sectoren. Deze behelzen onder meer (i) de strategische visie op de ontwikkeling van de energiedienstenmarkt, (ii) de vraag naar de financiering van de energiebesparingsinvesteringen en de invloed op het concurrentievermogen en, (iii) de afdwingbaarheid van de beleidsinstrumenten en de complexiteit van de instrumentenmix die ontstaat.

Een effectief beleidsontwerp vergt ook een uitgebreidere beschouwing van de perspectieven van de verschillende actoren en doelgroepen. In dit proefschrift

belichten wij dit voor de detailhandelaren en het MKB. Voor het ontwerp van een effectief pakket van instrumenten, dat simultaan alle voornaamste obstakels aanpakt, moet de hele keten van relevante actoren en doelgroepen in de productcyclus in beschouwing genomen worden.

Conclusies en aanbevelingen

In dit proefschrift vonden wij verschillende indicaties dat er nog steeds behoefte is aan een betere verankering van het energie-efficiëntiebeleid binnen het internationale en nationale energie- en klimaatbeleid. Dit betreft het algemene raamwerk van doelen stellen en monitoring evenals het ontwerpen van energie-efficiëntiebeleidsinstrumenten gericht op realisatie van deze doelen. Wij identificeren de volgende sleutelementen voor het ontwerp van een meer effectief EE-beleid:

- Het stellen van een ambitieuze en verplichtende energie-efficiëntiedoelstelling (verankerd in een meer algemeen en samenhangend doelstellingenraamwerk) die is afgeleid van kosteneffectieve energie-efficiëntiepotentiëlen.
- Het regelmatig monitoren van de voortgang richting de realisatie van de doestellingen, gebruikmakend van geschikte monitoringmethodes en gebaseerd op precieze definities van EE.
- Een voldoende beschikbaarheid van de benodigde statistische en beleidsmaatregel gerelateerde data als voorwaarde voor alle monitoringbenaderingen van energie-efficiëntie.
- Het ontwerp van een geschikte pakket van EE-beleidsinstrumenten die simultaan de belangrijkste obstakels uit de weg ruimen die exploitatie van de kosteneffectieve EE-potentiëlen verhinderen.
- Het in beschouwing nemen van alle relevante actoren en doelgroepen in de productcyclus van energie-efficiëntie en gebruikmakend van de specifieke motivaties van deze groepen.
- Het gebruik van een multicriteria benadering voor het ontwerp van de beleidsmix welke rekening houdt met zowel kwantitatieve als kwalitatieve criteria.
- Evaluatiemethode en -proces van individuele instrumenten (gebaseerd op bottom-up of econometrische methodes) welk goed geworteld zijn in "controle" evaluatie methodes voor het pakket van maatregelen, waartoe het individuele instrument behoort en welk gebaseerd kan zijn op top-down methodes (automatisch rekening houdend met zaken zoals free-rider- en multiplicatie-effecten welk anderzijds moeilijk vast te stellen zijn). Het combineren van deze methodes is beslist verder onderzoek waard.

Wij denken dat het nu een goed tijdstip is voor toepassing van op zijn minst een aantal van deze bevindingen in het energie-efficiëntiebeleid. Op Europees niveau vereist de

volledige realisatie van de doelen van de Energy Efficiency Directive (EED) de implementatie van nieuwe of op zijn minst sterk verbeterde EE-beleidsinstrumenten. Het nieuwe raamwerk voor het EU energie- en klimaatbeleid tot 2030 biedt de mogelijkheid voor de introductie van een ambitieuze en bindende energie-efficiëntiedoelstelling. De interactie van deze doelstelling met andere doelstellingen, bijvoorbeeld voor duurzame energie en broeikasgasemissies moet zorgvuldig ingepast worden in het beleidsontwerp. Duitsland, dat veruit de grootste energieverbruiker is in de EU, heeft besloten tot een fundamentele transitie van zijn energiesysteem (de zogenoemde “Energiewende”), welk niet mogelijk zal zijn zonder een aanzienlijke toename in energie-efficiëntie in vergelijking met de langzame voortgang in de periode 2008-2012 (zie hoofdstuk 8). In het Regeerakkoord van de nieuwe regering van december 2013, was een “Nationaal plan van aanpak energie-efficiëntie” aangekondigd dat goedgekeurd dient te zijn voor het einde van 2014. Zo’n plan biedt de mogelijkheid om een effectiever EE-beleid in Duitsland te implementeren en daarmee bij te dragen aan het behalen van de Europese EE-doelstellingen.

Er is een andere reden waarom wij denken dat de tijd gunstig is voor een betere verankering van het energie-efficiëntiebeleid binnen het internationale en nationale energie- en klimaatbeleid. Dit is het groeiend belang van de zogenoemde co-benefits van energie-efficiëntie in de politieke en publieke discussie. Deze beslaan, bijvoorbeeld, (i) macro-economische effecten zoals een toename in BNP en werkgelegenheid, (ii) de verbetering van het concurrentievermogen op nationaal of bedrijfsniveau, en (iii) een toename in energievoorzieningszekerheid door reductie van de energie-import. Deze co-benefits kunnen een additionele rechtvaardiging zijn voor het stellen van ambitieuze EE-doelstellingen en ambitieus EE-beleid. Wij hebben deze co-benefits verschillende malen aangehaald in dit proefschrift, maar wij hebben deze niet uitgebreid geanalyseerd of besproken. Er zijn al een aantal studies die deze effecten diepgaander onderzoeken op een internationaal niveau (e.g. IEA, 2012, 2014), op Europees niveau (e.g. Cambridge Econometrics, 2013) of in sommige lidstaten zoals Duitsland (Fraunhofer ISI, 2009; Lehr et al., 2012). Toch zien wij nog steeds de behoefte aan verder onderzoek, voornamelijk met betrekking tot een systematische kwantificering van deze co-benefits van energie-efficiëntie in evaluaties van beleidsinstrumenten.

Een ander onderwerp dat niet volledig behandeld is met onze methodologische benadering is de vraag of een geschikte verdeling van de EU-brede of international doelstellingen tussen landen (zogenoemde lastenverdeling, of beter inspanningsverdeling, daar er voor energie-efficiëntie uiteindelijk een financieel voordeel is), rekening houdt met de verschillen in nationaal context. Wij konden alleen een

differentiatie per sector in beschouwing nemen, omdat wij onze doelstelling afgeleid hebben van de sectorale EE potentiëlen. Verder onderzoek is ook hier nodig.

Het laatste onderwerp wat wij willen benoemen is de financiering van EE-beleid. We halen kort dit onderwerp aan in hoofdstuk 5 als één van de criteria waar rekening mee gehouden dient te worden voor het ontwerp van een geschikte mix van EE-beleidsinstrumenten. Hoge vooruit gemaakte investeringen zijn noodzakelijk voor een substantiële toename van het tempo van energiebesparing in de Europese Unie (zie Wesselink et al., 2011), vooral in de gebouwde omgeving. Dus het verzekeren van de financiering van EE-investeringen door publieke financiering, en vooral door het activeren van meer private kapitaal, zal een van de belangrijkste uitdagingen van een ambitieuzer energie-efficiëntiebeleid zijn in de komende jaren. De ontwikkeling van nieuwe business modellen voor energie-efficiëntie-investeringen zal hiervan hoogstwaarschijnlijk een onderdeel zijn en ook dit behoeft verdere onderzoek.

Acknowledgements

The writing of this thesis alongside my full-time work as a researcher at Fraunhofer ISI and my numerous family responsibilities has been a true challenge for me. That I have finally succeeded is largely due to the motivation I received from my supervisor and my co-supervisor who never lost faith in me.

I would particularly like to thank my supervisor Prof. Dr. Kornelis Blok for his continuous support during the writing period of this thesis. Its development would not have been possible without his constructive criticism and the fresh impetus he gave to my thinking and writing. I am also very grateful to my co-supervisor Wolfgang Eichhammer who provided numerous creative ideas and always spurred me to finalise the thesis under very difficult circumstances. Thank you for taking the time to discuss issues with me and provide me with valuable comments despite your own tremendous work load.

I also want to thank all my colleagues at Fraunhofer ISI for providing a creative working atmosphere generating valuable discussions and ideas which considerably enriched this thesis. In particular, I want to thank Eberhard Jochem who was the initial inspiration for my research into “energy efficiency” when I joined Fraunhofer ISI many years ago. My special thanks also go to my colleagues Joachim Schleich, Clemens Rohde and Patrick Plötz and all the other co-authors of the papers for sharing their experiences in conducting theoretical and empirical research and in the writing of scientific articles. I am also grateful to my colleague Matthias Reuter who covered much of my daily scientific work, especially during the last year, giving me more time to write this thesis.

I am grateful to my fellow members on the board of the European Council for an Energy Efficient Economy (eceee) for providing inspirational discussions on the topic of “energy efficiency”. Similar thanks go to all my colleagues in the ODYSSEE-MURE network, especially Didier Bosseboeuf, Bruno Lapillonne, and Stefano Faberi for their stimulating discussions on energy efficiency indicators and policies during the 20 years in which we have collaborated.

I also wish to thank my colleagues, particularly Kurt Roth, at Fraunhofer CSI in Cambridge M.A.. Many of the ideas for the papers were developed during my research visit there in autumn 2011.

I am very grateful to my colleague Brigitte Kallfaß for her very valuable support in giving all the papers and the final publication an attractive layout. This thesis also profited very much from the linguistic expertise of Gillian Bowman-Köhler, Helen Colyer and Vanessa Dolbé-Raffler. And I would also like to thank Stephanie English and Kornelis Blok for writing the Dutch summary.

Curriculum vitae

Barbara Schlomann studied economics and energy economics at the universities of Freiburg i.Br. and Cologne. In 1987, she joined the Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe, Germany, where she works as a senior scientist and project manager. From 2008 to 2011, head of business unit Energy Efficiency in the Competence Center Energy Policy and Energy Systems, since 2012 head of business unit Energy Policy in the Competence Center Energy Policy and Energy Markets. Her current research focus and publications are mainly in the area of national and international energy policy. They comprise the analysis of energy consumption in all final consumption sectors, the development and analysis of energy efficiency indicators, the monitoring of energy consumption in private households and the tertiary sectors, projections of energy consumption and the design and evaluation of energy policies. From 1990 to 1998, she also gave lectures in economics. Since 2011, she is a member of the Board of the “European Council for an Energy Efficient Economy” (eceee).

Selected Publications

- Diekmann, J.; Eichhammer, W.; Neubert, A.; Rieke, H., Schlomann, B.; Ziesing, H.-J. (1999): Energie-Effizienz-Indikatoren. Statistische Grundlagen, theoretische Fundierung und Orientierungsbasis für die politische Praxis. Heidelberg: Physica. ISBN 3-7908-1243-9.
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Energy efficiency is widely acknowledged as the most important strategy for achieving global energy and climate targets. This thesis focuses on the question how to create more favourable preconditions for an effective anchoring of energy efficiency policy in energy and climate policy. The design of energy efficiency policies is analyzed in the frame of the setting of energy efficiency targets and the monitoring and evaluation of their success.

The Fraunhofer ISI analyzes the framework conditions for innovations. We explore the short- and long-term developments of innovation processes and the societal impacts of new technologies and services. On this basis, we provide our clients from industry, politics and science with policy recommendations and perspectives for key decisions. Our expertise lies in a broad scientific competence as well as an inter-disciplinary and systemic research approach.



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