Living up to expectations? Monitoring the effects of ecodesign and energy labelling in Germany

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Abstract

Ecodesign and Energy Labelling are policies based on extensive ex ante impact assessment. Preparatory studies project potential savings for each product group. Impact assessments re-estimate them for concrete regulatory alternatives. The bulky "Ecodesign Impact Accounting" harmonized all this data in order to provide a comparative assessment of energy savings (VHK 2015). However, retrospective accounts of what has actually been achieved are much scarcer. The authors of the paper have been involved in a study for the German Ministry of the Economy, trying to pinpoint national level savings that can be associated with Ecodesign and Labelling for six product groups (boilers, water heaters, light sources, electric motors, household cold appliances, and ventilation units). Ecodesign (ECO) scenarios have been compared to Business as Usual (BAU) scenarios, using national sales and energy consumption data wherever possible. This provides more reliable insights than before, especially for those product groups that have been regulated for some years so that actual market developments could be taken into account. The assessment suggests considerable savings in ECO as compared to BAU. However, they are consistently smaller than what could be expected if the EU-wide Ecodesign Impact Accounting figures had been scaled down for Germany. Also, ECO vs. BAU savings do not always mean that total energy consumption decreases over time. The paper discusses possible reasons for the differences between national and EU savings, and suggests future policy avenues to deal with the increase in total energy consumption.

Introduction

Controversial as they are, Ecodesign and Energy Labelling are among the EU's flagship policies for fighting climate change and reaching its energy saving goals. When announcing the new Ecodesign Working Plan in November 2016, Vice President Katainen stressed that these policies so far had helped to save the equivalent of the annual energy consumption of Italy, and further measures would render additional savings the size of the annual energy consumption of Sweden (EU COM 2016a,b). Such figures are the result of an extensive process of ex-ante evaluation. Before a product group is subject to an Ecodesign or Energy Labelling measure, a preparatory study is conducted. This assesses the product group's potential future energy consumption and improvement options. Scenarios are constructed for different regulatory options and potential savings are projected for each of the scenarios. Before a concrete proposal for a regulation is drafted, Commission staff conduct an additional impact assessment estimating the expected savings from the specific policy options that are being considered by the Commission. In 2015, the final report of an extensive Ecodesign Impact Accounting was published (VHK 2015)[1]. It uses harmonized data from preparatory studies and impact assessments to compare Ecodesign and Energy Labelling scenarios to Business as Usual scenarios for 33 product groups.

However, all these estimates, along with several independent studies (Ballu et al 2010, Elsland et al 2010, Irrek et al 2010, Molenbroek et al 2012, Smith et al 2016) are ex-ante projections based on hypothetical scenarios. To date, the authors are not aware of any retrospective study that uses actual sales or performance data to evaluate the effects of Ecodesign or En-

1. In 2016, a revision was published which could not be considered in this work.

ergy Labelling. Two studies by Topten Europe (Michel et al. 2014, 2015) have monitored the actual market for white goods and TVs, but not attempted to isolate the effects of Ecodesign and Energy Labelling. The present study is a first attempt at partly closing this gap on a national level for Germany. It spans six product groups: three groups that have only recently been regulated (boilers, water heaters and air conditioning) and three others with a longer history of regulation (electric motors, household refrigerators and freezers, household lighting). After a short overview of the project background and research questions, the methodology is described. Core results are then presented and discussed, dealing with three main topics: expected savings, comparison of national savings to EU level projections, and development of total energy consumption. Finally, conclusions are presented.

Project background and research questions

The German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie, BMWi) commissioned a project in 2015 entitled "Scientific analysis of the development of energy consumption and measures to improve product-related energy efficiency". Its aim is to provide scientific background to inform product-related energy efficiency policies. The main contractor is ifeu - Institut für Energie- und Umweltforschung Heidelberg (Institute for Energy and Environmental Research), with Öko-Institut e.V. as a subcontractor. The goal of Work Package 3 is to assess the national savings from Ecodesign and Energy Labelling for various product groups. For the assessment, the six product groups with the highest projected energy savings in 2020 (according to the Ecodesign Impact Accounting) have been chosen. Table 1 gives an overview of the product groups, regulations, and estimated European savings according to the Impact Accounting. The entry into force date is not necessarily identical with the date from which the requirements apply: some requirements only apply after a transition period, and there may be several stages.

For boilers, water heaters and ventilation, the regulations were about to enter into force at the time the assessment was conducted. It was therefore an ex ante assessment, like the estimates cited above. However, actual national sales, stock, and energy consumption data was used in order to model the savings on a national level (see for details section "Individual product groups"). For three other product groups – electric motors, light sources and household refrigerators and freezers –, the regulations had been in force for some time when the assessment was conducted. For lamps and household refrigeration appliances, that means that the assessment could be based on retrospective observations of real market developments. For electric motors, unfortunately no such data was available so that the assessment had to be based on a pro-rated share of European level data.

Methodology

PARAMETERS AND CONVERSION FACTORS

The work was intended to estimate the annual savings of primary energy and CO_2 emissions in the German appliance stock for target years of 2020 and 2030. To enable a comparison with the findings from the Ecodesign Impact Accounting, the same primary energy factors and emission factors were used as in Kemna et al 2014. The factors are shown for key years in Table 2.[2]

SCENARIOS

Savings were modelled as difference between a "business as usual" (BAU) scenario in which the latest Ecodesign or Energy Labelling measures would not have been adopted, and an Ecodesign (ECO) scenario with these measures in force. Both scenarios are based on time series of empirical data. Depending on data availability and the effective date of the measures, the time series have been extrapolated into the future from different points in time. Figure 1 illustrates the moment when extrapolation begins for each of the product groups and scenarios.

INDIVIDUAL PRODUCT GROUPS

In this section, we describe the data, assumptions and calculation methods used for the individual product groups in order to adapt to data limitations, information restrictions, and specific features of the product groups.

Boilers

For boilers, the following data sources were used (Table 3[3]).

Both the ECO and BAU scenario were constructed from assumptions from 2015 on. A sensitivity scenario was calculated for the ECO scenario to account for possible errors in the estimation of future market shares. Table 4[4, 5] shows the assumptions that were made for the ECO and BAU scenarios.

Water heaters

The data sources in Table 5 were used for water heaters.

Both the ECO and BAU scenario were constructed from assumptions from 2015 on. A sensitivity scenario was calculated for the ECO scenario to account for possible errors in the estimation of future market shares. The assumptions made for the ECO and BAU scenarios are shown in Table 6.

Light sources

For light sources, the sources in Table 7[6, 7] were used.

2. We are aware of the inconsistencies that arise from the use of a constant primary energy factor for electricity on the one hand, and an emission factor that evolves over time, on the other. Still, we chose to remain with the (politically decided) constant primary energy factor that has been used in the EU Ecodesign context so far in order to allow comparability of our findings with EU projections.

3. Average energy consumption per type is kept constant and only shares of types vary.

4. ECO – Main scenario: Industry sources expect that manufacturers will try to achieve 86 % efficiency in low temperature boilers to keep them on the market; also gas-fired combi-boilers in low temperature mode remain legal.

5. ECO – Main scenario: In Germany, condensing boilers already had a 68 % market share in 2014, low temperature technologies only a 19 % share, 16 % of which were gas.

6. German sales data according to GfK are on average 5 % of EU sales data according to VHK, while Germany's share of the EU population 2015 is 16 %, and its share of the EU GDP 2015 is 20 %, according to Eurostat. In addition, if GfK's sales data are applied considering the lamp lifetimes, they suggest a total number of only 7 lamps per household in 2005 and 16 lamps in 2013, while EU average is 26 lamps in 2006 and 30 in 2013. Data has further been found to support that the number of lamps per household in Germany is in the range of 30 lamps per household.

7. Energy consumption data: Three independent sources were found suggesting an average value of 1.5 hours of operation time per day. As this would add up to ~550 hours per annum, the VhK values were assumed sufficient, allowing the incorporation of differing daily operation times for different light source types.

Table 1. Overview of Ecodesign and Energy Labelling regulations.

Lot/Product group	Ecodesign Regulation		Energy Labelling Regulation		Savings (EU-28, Primary Energy, TWh/a)	
	No.	in force since	No.	in force since	2020	2030
ENER 1: Boilers	813/2013	26.09.2015	811/2013	26.09.2015	465	763
ENER 2: Water heaters	814/2013	26.09.2015	812/2013	26.09.2015	176	291
ENER 8/9/19: Light sources	244/2009; 245/2009	01.09.2009; 13.04.2010	874/2012	01.09.2013	282	356
ENER 10: Electric motors	640/2009	16.06.2011	none	none	351	521
ENER 13: Household refrigerators + freezers	643/2009	01.07.2010	1060/2010	30.11.2011	167	217
ENER 21 / ENTR 6: Ventilation units	1253/2014	01.01.2016	1254/2014	01.01.2016	115	212

Table 2. Conversion factors used in the assessment.

	2010	2020	2030
Primary energy factor			
Heating oil	1.1	1.1	1.1
Natural gas	1.1	1.1	1.1
Electricity	2.5	2.5	2.5
CO_2 emission factor (g/kWh)			
Heating oil	270	270	270
Natural gas	198	198	198
Electricity	410	380	340

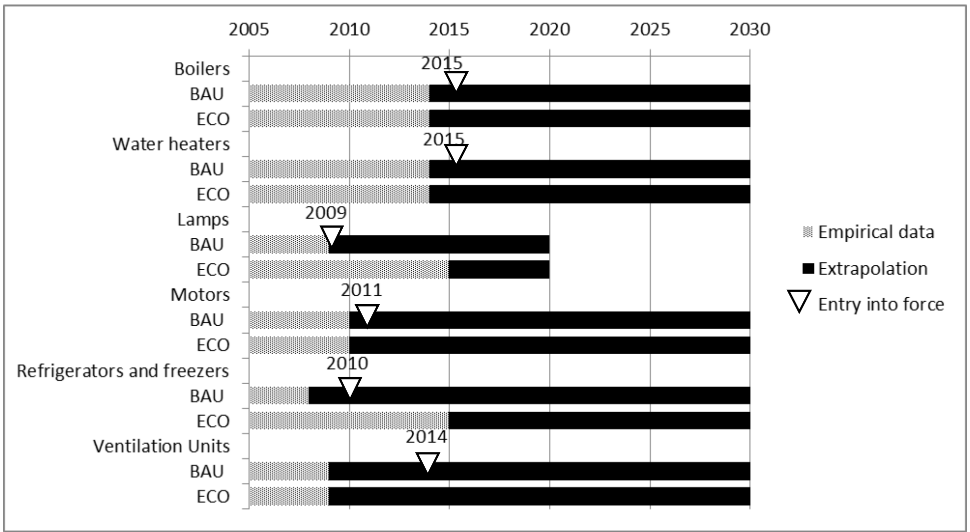

Figure 1. Cut-off dates for the use of empirical data vs. entry into force date for product groups.

Table 3. Data sources – boilers.

Sales data	National sales data up to the year 2014: BDH Marktentwicklung 2004–2014
Stock data	National stock data up to the year 2014 from BDH Anlagenbestand 2014; BDEW 2015, and personal confidential communication
Energy consump-tion data	Average energy consumption for each type of boiler, calculated from total energy consumption for heating purposes per energy carrier (according to BMWi 2015) and stock of the different boiler types

Table 4. Scenario assumptions – boilers.

BAU	Until 2021, sales of low temperature boilers drop by 5 % per year; with condensing boilers being sold instead. Heat pump sales increase by 2 % per year between 2016 and 2020 because of improved support schemes. Total sales increase slightly from 2016 on. Starting from 2021, only 50 % of discharged low temperature boilers are replaced by condensing boilers, and 40% are replaced by heat pumps. The rest are dismantled, or replaced by solar thermal installations, pellets, or CHP which is not quantified here. Total sales drop slightly.
ECO – Main scenario	The regulations take effect in October 2015. Sales of low temperature technologies drop by 50 % per year. Sales of condensing technologies, in turn, rise by 2 % yearly, from 2021 on by 1 %. Heat pump sales rise by 5 % yearly up to 2020, then by 2.5 %. Total sales rise slightly because of increased replacement of old installations.
ECO – Sensitivity	The regulations take effect in October 2015. Sales of low temperature technologies drop by 80 % per year. Sales of condensing technologies, in turn, rise by 2.5 % yearly, from 2021 on by 0.5 %, because low temperature technologies will have virtually disappeared from the market by that time. All other assumptions are the same as in the main scenario.

Table 5. Data sources – water heaters.

Sales data	National sales data up to the year 2014 from BRG Building Solutions 2015
Stock data	National stock data up to the year 2014 from BRG Building Solutions 2015; for solar heat: BDH, BSW
Energy consumption data	Average energy consumption for each type of water heater, calculated from total energy consumption for hot water per energy carrier (according to BMWi 2015) and stock of the different water heater types

Table 6. Scenario assumptions – water heaters.

BAU	Sales of low temperature technologies drop by 5 % per year while sales of condensing technologies increase by 2,5 %. Sales of solar thermal systems increase by 4,200 installations per year (VHK 2007). Heat pump sales increase by 2,5 % per year from 2016 on because of improved support schemes.
ECO – Main scenario	The regulations take effect in Oct 2015. As a result, sales of electric storage heaters drop by 5 % p.a, mainly replaced by electric instantaneous heaters whose sales increase by 1 % p.a. Sales of low temperature technologies drop by 50 % p.a. In turn, sales of condensing technologies rise by 2,5 % p.a. and heat pump sales by 5 % p.a until 2020, and by 10 % p.a. from 2021. Solar heat systems sales rise by 6,300 units p.a. (1.5 times the BAU number), from 2021 on by 8400 units p.a. (twice the BAU number). Total sales of dedicated water heaters decline in favor of combined space heating and hot water systems.
ECO – Sensitivity	The regulations take effect in Oct 2015. Sales of electric storage heaters drop by 10 % p.a. Until 2020, 70 % of them are replaced by electric instantaneous heaters, 10 % by heat pumps and 5 % by solar thermal systems; the rest are not replaced because of a trend towards combined systems for space heating and hot water. Sales of gas instantaneous water heaters are constant. Sales of low temperature technologies drop, as in the main scenario, by 50 % p.a. 50 % of them are replaced by condensing technologies and 40 % by solar heat (the rest is not replaced). Total sales of dedicated water heaters decline in favor of combined systems for space heating and hot water.

Table 7. Data sources – Light sources.

Sales data	National sales data for 2005–2015 have been purchased from GfK for the following lamp types: General Lighting Service (GLS), Halogen, Compact Fluorescent Lamps (CFL), Linear Fluorescent Lamps (LFL) and Light Emitting Diodes (LED). However, this data does not cover the full German market. A correction factor was therefore applied. Sales before 2005 are calculated using shares of EU sales in order to determine the correct number of lamps to be phased out each year (see below).
Stock data	EU stock data for 2005 was used from VITO and VHK (2015). German stock for the different lamp types was calculated as share of EU stock, under the assumption that the total number of lamps per household is the same as the EU average (which was 26 lamps in 2006). Furthermore, it was assumed that the national stock shares of the different lamp types are equivalent to their sales shares (which are known). Development of the stock was calculated as described in the scenarios.
Energy consumption data	A weighted wattage average for each lamp type was calculated based on GfK data for the lamp types mentioned above. Annual energy consumption was calculated based on annual operating times used by VhK, which ranged between 450 and 700 hours per annum, depending on light source type.

Table 8. Scenario assumptions – Light sources.

BAU	Stock develops from 2005 on as follows: GLS are replaced after 2 years, halogen lamps after 3 years, CFLs after 12 years, LFLs after 17 years. LEDs are not replaced during the period assessed. Sales develop as follows: Without Ecodesign, GLS are not phased out; their sales drop by 10 % in 2009, then each year by a smaller number, stabilizing their share around 2020 (with sales dropping around 0,13 % as compared to 2019). Based on the expected changes in the RoHS Directive it is assumed that CFLs as well as LFLs of the T5 and T8 type will be phased out after July 2018. LED sales rise more moderately (first by 10 %, then less). The rest of the GLS, CFL and LFL are replaced by halogens which increase their share accordingly. In 2020, sales are about 44 % GLS, 40 % halogen, 1 % LFL and 15 % LED.
ECO	Replacement times are the same as in the BAU scenario. The projected development of the sales is as follows: Due to Ecodesign and Energy Labelling, all GLS >60 lm are phased out on 1.9.2012. However, it is observed that sales continue at much lower rates and is assumed that regulation loopholes (special purpose lamps) are to some degree exploited. Therefore, GLS sales drop by 10 % each year after a sharp rise in 2009. With respect to RoHS, the same assumptions apply as in the BAU scenario with the respective effects on CFL and LFL. Halogen lamps are phased out between 1.9.2016 and 1.9.2018, but remaining stocks are expected to remain in circulation for are sold some years after. The missing lamps are replaced by LEDs. In 2020, sales are about 6 % GLS, 4 % halogen, 1 % LFL and 88 % LED.

Table 9. Data sources – motors.

Sales data	EU sales data for 1990 and 2010 from VHK 2015, multiplied by the German share of the EU Gross Domestic Product (GDP) 2015 (Eurostat) for each of the following years (the latter taken from Eurostat for the years 2010–2014 and held constant after that). The VHK data dates back to the Lot 11 preparatory study for 2008.
Stock data	EU stock data for 1990 and 2010 from VHK 2015, multiplied by the German share of the EU GDP 2015 (Eurostat) for each of the following years (the latter taken from Eurostat for the years 2010–2014 and held constant after that). The VHK data dates back to the Lot 11 preparatory study for 2008.
Energy consumption data	EU calculations for total energy consumption of electric motors for 1990 and 2010 from VHK 2015, multiplied by the German share of the EU GDP for each of the following years (the latter taken from Eurostat for the years 2010–2014 and held constant after that). The VHK data dates back to the Lot 11 preparatory study for 2008.

Table 10. Scenario assumptions – motors.

BAU	The efficiency of newly sold motors rises from 71,9 % in 2010 to 81,1 % in 2030. The efficiency of all motors in stock rises from 71,4 % (2010) to 80,5 % (2030).
ECO	The efficiency of newly sold motors rises from 71,9 % in 2010 to 96,1 % in 2030, of which 10 % are due to variable speed drives. The efficiency of all motors in stock rises from 71,4 % (2010) to 95,9 % (2030).

The scenarios were only calculated until 2020 with the understanding that the uncertainty of various factors would impact on the accuracy of the projections between 2020 and 2030 (real lifetime of LEDs, new lighting trends, new luminaire types with integrated LEDs which cannot be replaced independently and where it is unclear how to factor them in relation to LED lamps). The BAU scenario was constructed using the empirical sales data and the calculated stock data up to 2008, followed by a hypothetical projection for the different lamp types under the assumption that the Ecodesign and Energy Labelling measures had not taken effect. For the ECO scenario, empirical data was used up to 2015, followed by a projection. The assumptions in Table 8 were made.

Electric motors

For electric motors, the data sources in Table 9 were used.

BAU and ECO scenarios were constructed as hypothetical scenarios. Because of the similar composition of the German motor stock to the EU average stock, the same assumptions were used as in VHK 2015 (Table 10).

Household refrigerators and freezers

For household refrigerators and freezers, the data sources in Table 11[8] were used.

8. A lifetime of 15 years was assumed, so that each year the appliances purchased 15 years ago go out of stock. As sales data is only available from 2005 on, information about the performance of the appliances that go out of stock is only available from 2020 on. However, it was assumed that the appliances that go out of stock can be neglected until 2025: Until then, they are the same in both BAU and ECO scenario and therefore do not change the difference between scenarios. Only from 2025 on the more efficient products purchased in 2010 in the ECO scenario begin to go out of stock.

Table 11. Data sources – Cold appliances.

Sales data	National sales data for household refrigerators and freezers per size class and energy efficiency class for the years 2005 to 2015 have been purchased from GfK. The data gives good market coverage.
Stock data	No baseline for the national refrigerator and freezer stock, differentiated according to efficiency classes, was available. Therefore, savings in the stock were calculated as follows: for each year and both scenarios, the difference between the energy consumption of newly purchased appliances (energy $consumption_{new}$) and the energy consumption of the appliances that go out of stock (energy $consumption_{old}$) was calculated. This difference was considered the change in energy consumption (savings or additional consumption) in that year and scenario. Savings were calculated as difference between "BAU" annual changes and "ECO" annual changes. $Savings_{year}$ = Annual $change_{BAU}$ (energy $consumption_{new, BAU}$ –-energy $consumption_{old, BAU}$) – Annual $change_{ECO}$ (energy $consumption_{new, ECO}$ –-energy $consumption_{old, ECO}$) To calculate the savings in the whole stock in 2020 and 2030, these savings were added up for each year from the base year up to the target year (as the changes in stock effectuated in each year remain effective in the following years).
Energy consumption data	National data on annual energy consumption of household refrigerators and freezers per size class and energy efficiency class for the years 2005 to 2015 haven been purchased from GfK.

Table 12. Scenario assumptions – Cold appliances.

BAU (Main scenario)	**Refrigerators:** Average annual energy consumption per appliance and efficiency class is constant from 2010 on because the threshold values for the classes remain constant so there is no incentive to improve within a class. Sales shares develop under the condition that class A remains legal and class A+++ is not introduced. We supposed that A++ (most efficient appliances on the market) share increases steadily. Shares of A appliances (least efficient) decrease quickly until 2015 and drain off slowly until 2025. Sales of A+ appliances increase as they replace A, and decrease from 2016 on in favour of A++. Shares in 2020 are: 49 % A++, 45 % A+, and 6 % A. In 2030 they are: 64 % A++, and 36 % A+. As total sales increased between 2005 and 2015 by 3 % per year on average, it was supposed that this trend continues until 2020. After that, the increase goes down to 2 % between 2021 and 2025, and 1 % between 2026 and 2030. **Freezers**: Assumptions on the average energy consumption per class and the development of the sales shares for each class were analogous to those for refrigerators. They result in the following sales shares: In 2020, 46 % A++, 52 % A+ and 2 % A, in 2030: 63 % A++, and 37 % A+. As total sales increased between 2010 and 2015 by 3,3,1,5, and 1 % respectively, it was supposed that sales increase by 2 % annually until 2023, and by 1 % after that.
ECO – Main scenario	**Refrigerators:** Ecodesign and Energy Labelling measures take effect in 2010. The average annual energy consumption per appliance and efficiency class is constant from 2010 on because the threshold values for the classes remain constant so there is no incentive to improve within a class. Shares of A+++-appliances increase constantly as they are the most efficient appliances on the market. A+ shares decrease from 2015 on, as they are the least efficient appliances, and reach zero by 2022. Shares of A++ sales increase until 2022 as they replace A+, and decrease from 2022 on. Sales shares in 2020 are: 35 % A+++, 64 % A++, 1 % A+. In 2030 they are: 63 % A+++, and 37 % A++. Total sales develop as in the BAU scenario. **Freezers**: Assumptions on the average energy consumption per class and the development of the sales shares for each class were analogous to those for refrigerators. They result in the following sales shares: In 2020, 32 % A+++ and 68 % A++, in 2030: 62 % A+++, and 38 % A++. The development of total sales was as in the BAU scenario.
Sensitivity	Total sales were reduced for both BAU and ECO, and replacement of old appliances was accelerated. **Refrigerators:** Instead of rising by 3 %, 2 % and 1 % for five years each from 2016 on, total sales rise by 3 % and 2 % for three years each, then the increase stabilizes at 1 % per year. In addition, some old appliances are replaced before they reach their technical end of life. This also means that the total number of appliances per household rises more slowly. **Freezers:** Instead of rising by 2 % for seven years from 2016 on, and then by 1 %, total sales only increase by 1 % per year. In addition, some old appliances are replaced before they reach their technical end of life. This also means that the total number of appliances per household rises more slowly.

For the BAU scenario, empirical data was used until 2008. 2009 data was not used because sales already reflected an anticipation of the expected Ecodesign and Energy Labelling measures. Instead, an average between 2008 and 2010 was constructed. From 2010, a hypothetical scenario was constructed under the assumption that the Ecodesign and Energy Labelling measures had not taken effect.

For the ECO scenario, empirical data was used until 2015; a hypothetical scenario was calculated from then on. As it seemed that increases in total sales might be overestimated, a sensitivity scenario with reduced total sales was also calculated for both BAU and ECO. The assumptions in Table 12 were made.

Ventilation units

Ventilation units already save energy as compared to natural ventilation. They do consume electricity, but overcompensate this consumption with savings of space heat. Two types have been considered: with and without heat recovery. Ventilation units with heat recovery save even more energy than those withou because they conserve more space heat. Additional benefits from ecodesign arise from two sources: improved electrical efficiency and increase of the share of ventilation units with heat recovery. The data sources in Table 13 have been used.

Both ECO and BAU scenario use empirical data until 2014 and projection from then on. With respect to the relative improvements, they use the same assumptions as the Ecodesign Impact Accounting. However, the start of the ECO scenario has been postponed: in line with the real developments, the measures started to take effect in 2016 and not before 2015, as in the Impact Accounting. The assumptions are shown in Table 14.

DATA QUALITY

In sum, it becomes clear that data quality and level of detail are different for the different product groups. For light sources and cold appliances, empirical national sales data could be used that spans several years after Ecodesign and Energy Labelling measures became effective. This allows monitoring their real effects (while the construction of both scenarios after 2015, and thus the calculation of savings remain hypothetical). However, market coverage of the data is much better for cold appliances than for light sources. For boilers, water heaters and ventilation units, projections had to be made for both the ECO and BAU scenario. Recent empirical national sales, stock data and energy consumption data could be used as a basis for these projections, which provides for more accuracy than could be achieved by using EU average data. The data base for electric motors is the weakest. Projections had to be made on the basis of average EU data from the Ecodesign Impact Accounting, which in turn dates back to preparatory studies from 2008. No specific national circumstances could be taken into account.

Results and discussion

NATIONAL PRIMARY ENERGY SAVINGS

Table 15 shows the calculated primary energy savings of the ECO scenario as compared to BAU for the various product groups. Electric motors stand out as the product group with by far the highest savings. However, this finding is to be interpreted with much caution as the methodology for the assessment of motors differs from the methodology for all other product groups. It was the only product group where no national data

Table 13. Data sources – ventilation units.

Sales data	National sales data until 2014 from BDH2013/2014; Hörer & Händel 2013; IWO 2013
Stock data	National data on 2009 stock from IWU 2013; share of ventilation units with heat recovery for 2010 from IWO 2013. National data on replacement of old installations until 2013 from Kaup and Kampeis 2014
Energy consumption data	National data on average electricity consumption and energy gain through heat recovery per installation until 2013: Rivière et al. 2009, Kaup and Kampeis 2014.

Table 14. Scenario assumptions – ventilation units.

BAU	2009 stock was 937,090, 91 % of which without heat recovery. Sales of new installations rise between 2010 and 2014 from 25,000 to 53,000 p.a., then by 12 % p.a. until 2020. Afterwards, the yearly increase slows down by one percentage point p.a. until it reaches 2 % in 2030. Assuming a lifetime of 15 years, every year 6.4 % of the installations are replaced. That means that until 2030, the number of installations that go out of stock is identical in ECO and BAU. The share of units with heat recovery rises from 67 % in 2010 to 80 % in 2014 and then stays constant. Between 2010 and 2030, energy consumption per unit rises from 85 to 107 kWh for those without heat recovery and from 5,349 to 7,979 kWh for those with heat recovery; at the same time the energy gain through heat recovery rises from 100,000 to 141,000 kWh per installation.
ECO	Assumptions on stock and total sales are the same as in the BAU scenario. Measures take effect in 2016. In line with the Ecodesign Impact Accounting (VHK 2015) it is assumed that the measures lead to 1 % electricity savings through improved efficiency and 1 % heat energy savings through a higher share of installations with heat recovery. Up to 2030, the savings increase to 19 % electricity and 16 % heat.

was available and the assessment was based on the results of the Ecodesign Impact Accounting, with a downscaling factor for Germany. This may have led to important distortions, as will be explained below.

In total, primary energy savings in 2020 are 31–32 TWh/a, even excluding electric motors, and in 2030 they amount to around 88–93 TWh/a (excluding motors and household lamps). These are significant savings. Total primary energy consumption in Germany in 2015 for all sectors including industry, transport, commercial sector and households was 3,692 TWh/a, meaning that these individual policies for 5 product groups save the equivalent of 1–3 % of total national energy consumption. In other terms, it saves, in 2020, the equivalent of the 2014 primary energy consumption of Cyprus or Albania and in 2030 that of Bosnia and Herzegovina.

Electric motors are likely to have a very important share of energy savings, even if it is not as high as the table suggests. Other important product groups are boilers and light sources. The results suggest that, controversial as it was, the "ban" of GLS light bulbs has been an overwhelming success, speeding up the market penetration of LEDs to a degree that had previously been inconceivable.

COMPARISON OF NATIONAL AND EU SAVINGS

It is instructive to compare those savings to the figures that result if one calculates the hypothetical share for Germany, based on the findings of the Ecodesign Impact Accounting for the EU-28, and using either Germanys share of the EU 28's population or its GDP as a scaling factor. The results are presented in Table 16. Electric motors are not considered as database and assumptions are virtually the same so there is no basis for comparison.

With the exception of ventilation units in 2030, calculated national savings are consistently lower than theoretical shares of EU-28 savings, by a factor 2.2 to 15 for GDP and 1.7 to 11.6 for population. There are several possible explanations. First, national assessments might have been too conservative. The speed of stock replacement or the efficiency of new appliances

Table 15. Primary energy savings ECO vs. BAU (TWh/a).

	Primary energy savings (TWh/a)		CO_2 emission savings (1000 t/a)	
	2020	2030	2020	2030
Boilers – Main scenario	11.0	22	2,162.5	4,456.5
Boilers – Sensitivity	12.7	24.1	2,499.5	4,858.9
Water heaters – Main scenario	5.0	27.7	768.5	4,006.7
Water heaters – Sensitivity	4.4	21	676.9	3,055.0
Light sources	9.6	n/a	1,457.8	n/a
Electric motors	73.9	109.6	11,200.0	15,000.0
Refrigerators and freezers – Main scenario	2.3	5.1	365.0	763.0
Refrigerators and freezers – Sensitivity	2.3	4.9	364.0	730.0
Ventilation Units	3.1	38.1	600.0	6,600.0
Total (main scenario)	**104.90**	**202.50**	**16,553.80**	**90,226.20**
Total (sensitivity)	**106.00**	**197.70**	**16,798.20**	**89,643.90**
Total w/o motors (main scenario)	**31.00**	**92.90**	**5,353.80**	**75,226.20**
Total w/o motors (sensitivity)	**32.10**	**88.10**	**5,598.20**	**74,643.90**

Table 16. Comparison of assessed national savings and calculated German shares of EU-28 savings.

	2020			2030		
	Calculated	EU-28 share (GDP)	EU-28 share (pop.)	Calculated	EU-28 share (GDP)	EU-28 share (pop.)
Boilers – Main scenario	11.0	95.9	74.3	22	157.3	121.9
Boilers – Sensitivity	12.7	95.9	74.3	24.1	157.3	121.9
Water heaters – Main scenario	5.0	36.3	28.1	27.7	60.0	46.5
Water heaters – Sensitivity	4.4	36.3	28.1	21	60.0	46.5
Light sources	9.6	58.1	45.0	n/a	73.4	56.9
Refrigerators and freezers – Main scenario	2.3	34.4	26.7	5.1	44.7	34.7
Refrigerators and freezers – Sensitivity	2.3	34.4	26.7	4.9	44.7	34.7
Ventilation Units	3.1	23.7	18.4	38.1	43.7	33.9

might have been underestimated, or efficiency of the existing stock or autonomous technical development might have been overestimated. (Wrong estimations of total sales are not likely to affect the results because they apply to both scenarios. However, they greatly affect total energy consumption and rebound effects, as will be discussed below). This is however an unlikely explanation, for the following reasons:

- Speed of stock replacement: Stock replacement rates were based on the average technical lifetime of the products. Experience shows that big installations such as boilers or water heaters, but also cold appliances in households, are unlikely to be replaced before the end of their technical lifetime (unless in case of a major renovation). Efficiency increases are not sufficient to stimulate early replacement. For cold appliances a sensitivity scenario with a higher replacement rate was calculated which did not impact the results much. For lamps, we assume that GLS and halogen lamps are rarely replaced before the end of their technical lifetime, given the very controversial public reactions to the Ecodesign measure.
- Efficiency of new appliances: For boilers and water heaters, it is difficult to predict which technologies they will be replaced by. Therefore, sensitivity scenarios have been calculated that account for this uncertainty and are included in Table 15 and Table 16. For light sources, availability of alternative, less efficient technologies is limited due to RoHS and older Ecodesign rules. For cold appliances, availability of less efficient appliances is also limited, and high shares of highly efficient technologies have been assumed for the ECO case (Table 12). Finally, for ventilation units, assumptions for the development of their relative efficiency are the same as in the EU assessment.
- Actual energy consumption of stock: For boilers, water heaters, light sources and ventilation units, fairly reliable information of the actual energy consumption of the existing stock was available. For light sources, a problem might be that only the wattage of the different types is known well, but operating time might be longer than assumed. However, the consultation of various independent sources suggests that our estimates of operation time are fairly accurate, possible rebound effects aside (see footnote 7). Even if this is doubled (doubling the savings), there is still an important gap between national calculated savings and EU share. For refrigerators and freezers, no stock data was available so that this did not impact the results.
- Autonomous technical development: This was judged very conservatively. For lamps, cold appliances, boilers and water heaters, energy consumption per lamp type, energy class resp. type of installation were held constant. For ventilation units, the same assumptions as in the Impact Accounting were used.

A second possible explanation is that EU figures are overestimated. This is indeed part of the story. The BAU scenario in the Ecodesign Impact accounting is a scenario without any Ecodesign and Energy Labelling measures, , while the BAU scenario in the present article is a scenario that generally takes into account all measures taken before the latest Ecodesign and Energy Labelling regulation. This makes a difference for product groups such as lamps, refrigerators and electric motors, where early measures were in place (see section "scenarios"). However, it is not expected to impact the assessment for boilers, dedicated water heaters and ventilation units.

Furthermore, the Authors of the Ecodesign Impact Accounting mention some caveats when interpreting the figures (VHK 2015, p. 41). First, the database is incomplete and often outdated. The accounting is based on preparatory studies that date back up to 2007 and use data that may be several years older. While this may lead to both over- or underestimations, other factors point clearly to a possible overestimation: The Accounting is based on the scenarios in the preparatory studies or Impact Assessments. Those differ from the final regulation that is in many cases less stringent. Furthermore, it was assumed that the measures are fully implemented and there is full compliance. What the authors do not mention is that they also do not always take into account delays in the policy process. While the exact assumed starting date for the future regulations is not stated, differences in the expected energy consumption for the ECO and BAU scenario in 2010 and 2015 suggest that for boilers measures have been assumed to take effect before 2010 (the actual starting date was 2015) and for dedicated water heaters and ventilation units before 2015 (actually in 2015 and 2016).

Finally, apart from methodological reasons, there are probably important substantial reasons for the difference between the national and EU savings. The most important one is that the German appliance stock was already more efficient than the EU average in the baseline scenario, so that the measures do not yield as much additional savings. Data for cold appliances and boilers underpins this interpretation.

Figure 2a shows a comparison of the average annual energy consumption of newly sold household refrigerators for Germany and EU average. German values are consistently about 50 kWh/a lower. Figure 2b shows the technology shares of newly sold boilers for space heating in 2014. Condensing technologies had 68 % market share. This is probably somewhat more than the EU average although recent data is not available. For 2010, the penetration in Germany was already close to 70 % while EU-16 average was about 60 % (BRG data as reported by Centrotec (2014, p. 28)). In 2009, EU-27 average was 59 % (BRG data as reported by van Elburg et al. 2011, Table 31).

As new appliances are probably already relatively efficient in Germany, further gains are rather to be expected from changes in appliance ownership or accelerated replacement of the existing stock, as will be discussed below.

TOTAL ENERGY CONSUMPTION

The savings in the ECO as compared to BAU scenario do not necessarily mean that the energy use reduces over time. Figure 3 shows the projection of total energy consumption in the appliance stock for the ECO scenario. Energy use per year for boilers, water heaters and light sources are shown on the left scale, motors and ventilation units on the right. For ventilation, energy consumption is negative because they help to conserve heat. While energy consumption for motors is more or less constant, and there are slight decreases for water heaters and ventilation units and a sharp decrease for lighting, total energy consumption of boilers increases again after an initial drop. As

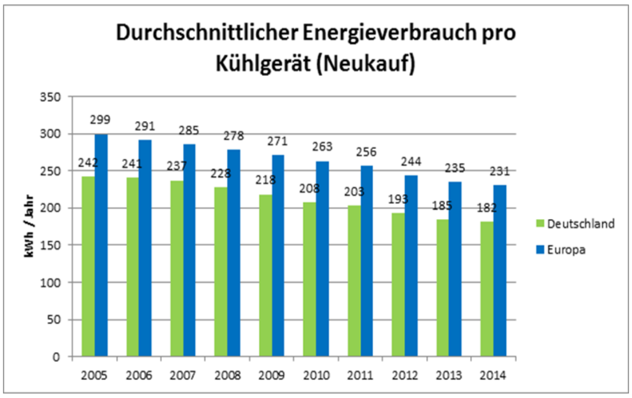

Figure 2a. Average annual energy consumption of new refrigerators, Germany vs. EU-27.

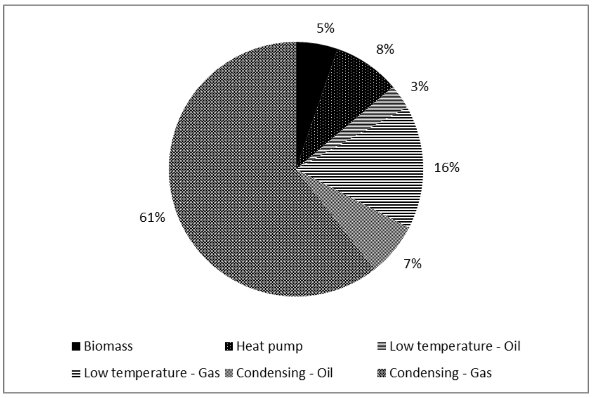

Figure 2b. Technology shares of new boilers for space heating, Germany 2014.

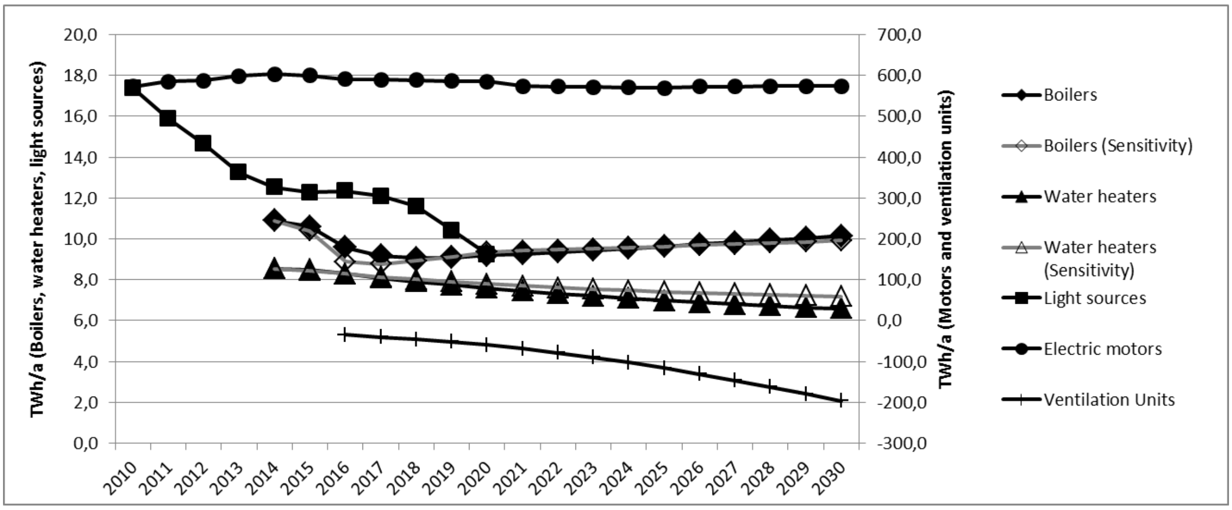

Figure 3. Total primary energy consumption in the ECO scenario for selected product groups.

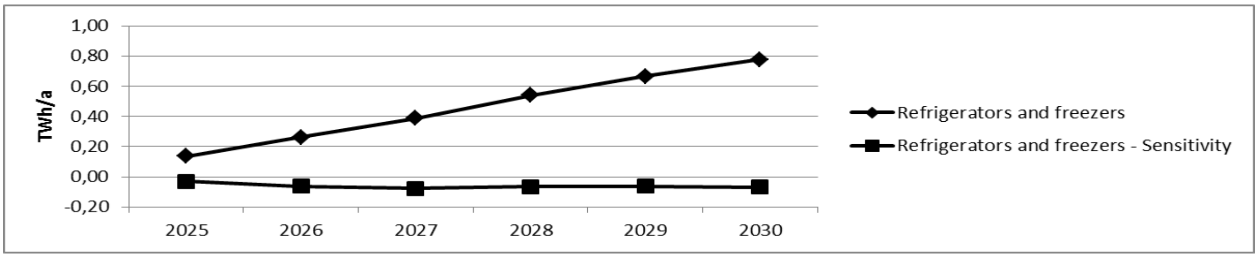

Figure 4. Changes in total primary energy consumption for cold appliances.

building insulation is expected to improve, this might be due to increasing per capita living space.

The projection for refrigerators and freezers is especially illuminating. No stock data is available for this product group. However, Figure 4 shows the projected annual changes in energy consumption of the stock in the ECO scenario. For 2025 to 2030, these can be calculated as the difference between the energy consumption of the new appliances and the consumption of those that are discarded.

A considerable difference between the main scenario and the sensitivity analysis becomes visible. As described in Table 12, the main scenario extrapolates (for both BAU and ECO) existing trends of increasing sales and assumes that appliances are only replaced after 15 years, leading to an increasing number of appliances per household. This leads to increased total energy consumption even in the ECO scenario. In the sensitivity scenario, sales increases level out quickly, and some old appliances are replaced earlier.[9] This scenario leads to energy savings not only in comparison to a BAU scenario but also over time.

9. From a lifecycle point of view, replacement of old refrigerators is ecologically beneficial after about 10-year lifetime.

Conclusions

In this paper, we present scenario analyses conducted to determine national energy savings in Germany from Ecodesign and Energy Labelling for six product groups. For five product groups, national sales, stock, and energy consumption data could be used, and for two product groups, retrospective data about the development after the introduction of Ecodesign and Labelling measures is available as well. The analysis shows robust savings, which are however consistently lower than could be expected if the EU-28 projections were pro-rated to Germany. Besides probable overestimations on EU level, it also becomes clear that in the baseline scenario new appliances sold in Germany are already rather efficient. However, increasing sales and the relatively high consumption of old appliances persisting in the stock mean that total energy consumption for product groups such as boilers and cold appliances continue to increase. This suggests the following conclusions for EU and national policies:

- To reap the full benefits of Ecodesign and Energy Labelling measures, they should be implemented in a timely fashion.
- Furthermore, market surveillance is crucial to ensure compliance.
- Ecodesign and Energy Labelling measures could be even more stringent. For example, the break-even point (level of ambition at which the average life cycle costs of BAU equals the average life cycled costs of products regulated under Ecodesign) instead of the Lowest Life Cycle Cost point (point of ambition which renders the lowest life cycle costs) could be used as a reference point for designing requirements.
- On a national level, policies should focus on energy consumption of the whole stock instead of efficiency of new appliances only. There are two main possible approaches:
  - Policies should aim at accelerated stock turnover through supporting the replacement of old inefficient appliances where it is recommended from a life cycle resource consumption perspective. This could be beneficial especially for boilers and cold appliances, but also storage water heaters.
  - In line with a "sufficiency policy" (Fischer and Grießhammer 2013; Heyen and Fischer 2013; Zahrnt and Schneidewind 2013), policymakers could start to address the number and size of appliances in households. There are possible low-intrusive policies, e.g. to address the parallel running of multiple, not fully used cold appliances by means of energy advice, or offer free disposal of such appliances. More ambitious policies, e.g. in urban planning, could start to address the problem of ever-increasing per capita living space, which leads, among other things, to increasing heat energy demand.

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