Assessing the impact of the EU Ecodesign Directive on a member state level

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Abstract
The Ecodesign Directive (EDD) is a key instrument of the EU's energy policy framework and is expected to have a substantial impact on energy efficiency and energy demand in the European economy.

We have conducted a model-based ex-ante assessment of the energy savings induced by the EDD until 2020 and 2030 for the sectors industry, tertiary and households. We first screened the regulations and lots (i.e. product-groups) to finally quantify 16 individual lots in detail. We use bottom-up models that have a very high level of technological detail, which allows simulating the EDD on the level of individual member states and lots (e.g. in the industrial sector, we simulate the electricity demand for electric motors in each member state).

We calculate two scenarios: a baseline scenario without the EDD and a scenario with the current EDD implementation.

The scenario analysis is preceded by an assessment of implementing measures (mostly regulations) for all lots.. We use information from the regulations and further calibrate the models to data from preparatory studies. The macro-economic framework data is calibrated to the most recent official EU projections from 2013.

The results show a strong impact from the EDD. The potential savings from the evaluated lots amounts to about 225 TWh/a of electricity (and about 30 TWh of other fuels) by 2030, which equals roughly 8 % of current EU28 electricity demand. Furthermore, the results allow comparison of the impact by country, lot and year. The major share of the savings results from appliances and lighting in the residential sector, while the importance of individual sectors varies substantially among countries. The calculations only consider implemented regulations for 16 lots. Including additional lots for where regulations are not yet in force, would considerably increase the potential savings – particularly in the industrial sector where only a few regulations are implemented so far. On the other hand, we did assume full compliance and excluded rebound effects. Both, non-compliance and rebound effects could diminish the calculated saving potential.

Introduction
The EU Ecodesign Directive (EDD) (European Commission 2009) is a key instrument in the European policy-mix for energy efficiency improvement. It provides a frame for the implementation of minimum requirements and labelling of energy-related products on the EU market. Only products with a certain market volume and a substantial potential to reduce the environmental impact are relevant for the EDD. The standard-setting process begins with a preparatory study to assess the potentials and costs of possible standards for individual product groups (technical EDD term is lots). It is followed by a consultation process, which involves all stakeholders, and finally an impact assessment. The final outcome is mostly a regulation (termed implementing measure) that sets minimum energy performance standards (MEPS) for the related products of a lot (alternatively self-regulation by industry is also possible). The entire process typically takes a few years per lot while several lots are treated simultaneously. By September 2014 a total of 28 regulations were adopted, 14 further lots still in the consultation process and 7 preparatory studies still in work

(see Table 1).[1] The impact on energy demand is expected to be huge, particularly for electricity consumption, whereas the broad scope of the Directive is a huge challenge for impact assessments.

Impact assessments of the EDD so far mostly consider individual segments like sectors, technologies, countries or lots. Although, the preparatory studies and the impact assessments related to the individual lots[2] provide an ex-ante estimation of energy savings, these savings do not consider interaction effects between lots, often use different assumptions and do not provide results by country.

A few official evaluations have been conducted for the European Commission and assessed the impact of several lots. An early assessment from 2010 (Ökopol et al. 2010) provides an overview of the energy savings estimated in the individual preparatory studies and lot-specific impact assessments. Including additional correction factors (for double counting, rebound effects, etc.) that have not been considered in the preparatory studies, they also calculate energy savings by lot and by country. As a result, the energy saving potentials calculated are lower than those in the preparatory studies. Another report (CLASP 2013) focused on additional savings analysing the case existing regulations would be tightened and additional tiers implemented in the coming years. They analyzed seven lots and found an additional energy saving potential of 40–70 TWh/a for the EU by 2030.

A comprehensive assessment of the EDD on the EU tertiary sector is conducted by Bertoldi and Atanasiu (2011). They calculate EU-wide savings per implementing measure based on a combination of a survey used to estimate electricity demand by end-use and a review of implementing measures and preparatory studies.

Another study, (Elsland et al. 2014a) focused on the lots addressing heating systems (Space heaters (lot 1), water heaters (lot 2), solid fuel boilers (lot 15) and local space heaters (lot 20)) and used a bottom-up approach to estimate the long-term savings for the EU. Using a model-based approach they explicitly consider interaction effects between the four lots analyzed.

Jakob et al. (2013) calculated the impact of the EDD until 2035 on the electricity demand of the tertiary sector. They conducted a country-specific bottom-up estimation for all European countries. The inclusion of Ecodesign MEPS, however, has been done in a rather generic manner based on alternative assumptions on least lifecycle cost calculations instead of including the specific requirements of the individual regulations into the model.

Other studies address the total residential sector in Germany (Elsland et al. 2013) and in the European Union (Braungardt et al. 2014) also using a bottom-up simulation model. From a methodological point of view, these two studies come closest to our approach as they are also using the same model.

Given these segmented analysis, we have conducted a broad model-based ex-ante assessment of the impact of the EDD until 2020 and 2030 for all relevant sectors (industry, tertiary and households). We use bottom-up models that have a very high level of technological detail, which allows simulating the EDD on the level of individual member states and lots. As all MEPS are included into one consistent model framework, interaction effects lots are accounted for.

Methodology

ECODESIGN-DIRECTIVE AND SELECTION OF LOTS

The number of individual lots considered in the EDD has been increasing continuously in recent years (with currently more than 30 lots often containing several technologies/appliances). The progress of those lots varies heavily, as can be seen in Table 1. While for some lots regulations are already adopted, for other lots, the impact assessments have not yet been finished. The preparatory studies, however, are finalized for nearly all lots. The table also shows the importance of each lot by sector, distinguishing industry, tertiary and residential sectors. The importance is measured as share of the respective electricity/fuels demand of each sector. E.g. simple set-top boxes account for 1–5 % of electricity demand in the residential sector (upper left corner of table).

Given the huge amount of lots, we have to focus the bottom-up assessment on the most important combinations of lots and sectors. Sector/lot combinations marked with an "x" are included in our analysis. The decision to include a lot has mostly been driven by its importance in terms of energy demand, but also considers aspects like data availability, which is always a challenging aspect for a country specific bottom-up assessment. Clearly, including additional sector/lot combinations into the assessment would increase the resulting saving potential.

SCENARIO DEFINITION

The scenario analysis is based on the study Fraunhofer ISI et al. (2014) conducted for the European Commission, which evaluates the progress of alternative policy scenarios towards the EU targets for energy efficiency until 2020 (and gives an outlook until 2030). Our analysis takes the scenario "Baseline with early action" from this study as a basis. This scenario includes policy measures that have been implemented at the latest in 2013 (mostly EU, but also important national policies)[3]. The consideration of policies beyond the EDD is important, as overlap between policies need to be considered, e.g. additional energy savings of MEPS are lower, when labelling is in place already, or when energy taxes have already increased the market share of efficient appliances.

In order to assess the impact of the EDD, we calculate two variants of this scenario: One includes all implementing measures that have been implemented until 2013 and the other excludes all implementing measures. All other variables (policy instruments, economic framework) remain unchanged. The savings of the EDD can be calculated as the difference in energy demand between the two scenario-variants assuming full compliance.

The main economic framework conditions (energy wholesale prices, GDP, population) are calibrated to the most recent official EU energy outlook (European Commission 2014).

1. An overview of the current progress of the EDD is among others provided by the eceee (http://www.eceee.org/ecodesign) or Ökopol (http://www.eup-network.de).

2. See the reports available at: https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp.

3. In total, the scenario falls short by 2–3 % of the 20 % energy efficiency target under the assumed economic development.

Table 1. Overview of Ecodesign lots ("x" indicates sector/lot combinations included in this analysis) (last update September 2014).

Product Groups	Preparatory Study Completed	Regulation (Enforced from)	Impact Assessment	Sector allocation		
				Industry	Services	Household
Lot- Simple Set Top Boxes	yes	25.01.2010	published			x
Lot 1 Boiler and Combi-boiler	yes	02.08.2013	published	x	x	x
Lot 2 Water Heater/Boiler	yes	02.08.2013	published		x	x
Lot 3 PCs and Computer Monitors	yes	26.06.2013	published		x	x
Lot 4 Imaging Devices	yes		published			
Lot 5 Consumer Electronic: Television	yes	07.01.2010	published			x
Lot 6 Standby and (off-mode) Losses	yes	07.01.2010	published			
Lot 7 External Power Supply Units	yes	27.4.2010	published			
Lot 8 Office Lighting	yes	13.4.2010		x	x	
Lot 9 Street Lighting	yes	13.4.2010		x	x	
Lot 10 Air Conditioner	yes	30.03.2013	published			x
Lot 10 Small Fans	yes	30.03.2013	published			
Lot 10 Ventilation Systems	yes					
Lot 11 Electric Motors (0,75kW - 200kW)	yes	27.01.2009	published	x		
Lot 11 Circulation Pumps	yes	01.01.2013	published	x	x	
Lot 11 Fans	yes	01.01.2013	published	x		
Lot 11 Water Pumps	yes	01.01.2013	published	x		
Lot 12 Commercial Refrigerator- and Freezers	yes					
Lot 13 Household Refrigerators and Freezers	yes	01.07.2010	published			x
Lot 14 Household Dishwashers	yes	01.12.2011	published			x
Lot 14 Household Washing Machines	yes	01.12.2011	published			x
Lot 15 Small Plants combusting Solid Fuels	yes					
Lot 16 Clothes Dryer	yes	03.10.2012	published			x
Lot 17 Vacuum Cleaner	yes	08.07.2013	published			
Lot 18 Complex Set top boxes	yes	voluntary	published			
Lot 19 Household Lighting: non-directional	yes	01.09.2009	published		x	x
Lot 19 Household Lamps. "Reflector Lamps"	yes	01.01.2013	published		x	x
Lot 20 Local Room Heating Products	yes					
Lot 21 Central Heating Products	yes					
Lot 22 Household and Commercial Ovens	yes	20.02.2014				
Lot 23 Hobs and Grills	yes	20.02.2014				
Lot 24 Washing Machines, Dryers Commercial	yes					
Lot 25 Coffee Machines for non-Commercial Purposes	yes					
Lot 26 Linked-up Standby-Losses	yes	22.08.2013				
ENTR Imaging Systems in Medicine	no					
ENTR Lot 1 Refrigerators and Freezers	yes					
ENTR Lot 2 Transformers	yes	21.05.2014	draft			
ENTR Lot 3 Devices for Sound and Image Processing	yes					
ENTR Lot 4 Combustion Plants and Ovens	yes					
ENTR Lot 5 Machine Tools	yes					
ENTR Lot 6 AC and Ventilation Systems > 12kW	yes					

Relevance
Very high (>10%)
High (5-10%)
Medium (1-5%)
Low (<1%)
Per definition excluded
No data

Based on these main drivers, the relevant energy service drivers (e.g. energy end-use prices, number of appliances, floor area) were calculated. The assumed international fuel prices are displayed in Table 2.

THE BOTTOM-UP MODELS USED

We use two bottom-up models for our assessment: FORECAST and INVERT-ee/lab. For both models, the following methodological key aspects are defined:

- The EDD does not affect the lifecycle of technologies or appliances, i.e. the natural rate of stock turnover is not affected – no early replacement takes place.
- We assume perfect compliance with the standards and implementation of regulations according to plan.
- A possible rebound effect is not considered.

INVERT-ee/lab

Lots 1 and 2 are related to the stock of heating and hot water systems. For the evaluation of the EDD impact in this sector, we applied the model Invert/EE-Lab. Invert/EE-Lab is a dynamic bottom-up simulation tool that evaluates the effects of different promotion schemes (in particular different settings of economic and regulatory incentives) on the total energy demand, energy carrier mix, CO_2 reductions and costs for space heating,

Table 2. International Fuel prices (in €'10 per boe-barrel of oil equivalent).

	2010	2015	2020	2025	2030
Oil	60,0	86,0	88,5	89,2	93,1
Gas	37,9	53,8	61,5	58,9	64,5
Coal	16,0	22,0	22,6	23,7	24,0

Source: (European Commission 2014).

cooling and hot water preparations in buildings. Furthermore, Invert/EE-Lab is designed to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviours, etc.) and their respective impact on future trends of energy demand and mix of renewable as well as conventional energy sources on a national and regional level. More information is available at www.invert.at, in the publication section of www.entranze.eu or in Kranzl et al. (2013) or Müller (2012).

The basic idea of the model is to (1) describe the building stock, heating, cooling and hot water systems at a highly disaggregated level, (2) calculate related energy needs and delivered energy, (3) determine reinvestment cycles and new investment of building components and technologies, and (4) simulate the decisions of various agents (i.e. owner types) in cases where an investment decision is due for a specific building segment. The core of the tool is a myopic, multinominal logit approach, which optimizes objectives of "agents" under imperfect information conditions and thus represents the decision maker concerning building related decisions. As "agents" e.g. owner occupier, private landlords, community of owners (joint-ownership), and housing association can be distinguished.

Coverage and data structure

The model Invert/EE-Lab up to now has been applied in all countries of EU-28 (+ Serbia). A representation of the implemented data of the building stock is given at www.entranze.eu.

Invert/EE-Lab covers residential and non-residential buildings. Industrial buildings are excluded (as far as they are not included in the official statistics of office or other non-residential buildings). The level of detail, the number of construction periods etc. depends on the data availability and structure of national statistics. We take into account data from Eurostat, national building statistics, national statistics on various economic sectors for non-residential buildings, BPIE data hub, and Odyssee, which are summarized in the ENTRANZE database (www.entranze.eu).

As efficiency technologies, Invert/EE-Lab models the uptake of different levels of renovation measures (country specific) and the diffusion of efficient heating and hot water systems.

Outputs from Invert/EE-Lab

Standard outputs from the Invert/EE-Lab on an annual basis are:

- Installation of heating and hot water systems by energy carrier and technology (number of buildings, number of dwellings supplied)
- Refurbishment measures by level of refurbishment (number of buildings, number of dwellings)
- Total delivered energy by energy carriers and building categories (GWh)
- Total energy need by building categories (GWh)
- Policy programme costs, e.g. support volume for investment subsidies (M€)
- Total investment (M€)

Moreover, Invert/EE-Lab offers the possibility to derive more detailed and other type of result evaluations as well. Based on the needs of the policy processes we will have to discuss which other type of evaluations of the result data set might be required.

Application of Invert/EE-Lab for evaluation of Lots 1 and 2 of the EDD:

The technology database of Invert/EE-Lab includes several options for every heating system with different efficiency values. The efficiencies of those technologies, which would not fulfil the corresponding requirement according to the EDD, were increased in order to meet the standards.

The impact-assessment of the EDD with Invert/EE-Lab is driven by the following three elements:

- Efficiency improvement of new installations due to MEPS from the EDD implementationHeating system replacement rate and new installation of relevant technologies: The heating system exchange rate is driven by the average lifetime of heating systems as well as the vintage structure of existing systems. Moreover, the installation in the relevant systems is also driven by policies and/or economic conditions for other heating systems (e.g. district heating).
- Building renovation activities and development of useful energy demand for space heating.

FORECAST[4]

The FORECAST modelling platform aims to develop long-term scenarios for future energy demand of individual countries and world regions until 2050. It is based on a bottom-up modelling approach considering the dynamics of technologies and socio-economic drivers. The model allows investigation of various research questions related to energy demand including scenarios for the future demand of individual energy carriers like electricity or natural gas, calculating energy saving potentials and the impact on greenhouse gas (GHG)

4. See also http://www.forecast-model.eu/.

emissions as well as abatement cost curves and ex-ante policy impact assessments.

The FORECAST platform comprises four individual modules, each representing one sector according to the Eurostat (or national) energy balances: industry, services/tertiary, residential and others (agriculture and transport). While all sector modules follow a similar bottom-up methodology, they also consider the particularities of each sector like technology structure, heterogeneity of actors and data availability.

Each sector requires specific activity data such as industrial production in the industry sector and the number of households in the residential sector. Furthermore, end-consumer energy prices play an important role in each sector and are distinguished by energy carrier. The third group of input data, the technology characterisation also reflects the data availability of individual sectors. While in the industry and tertiary sectors the model works with so-called energy-efficiency measures (EEMs) (e.g. see Jakob et al. 2012; Fleiter et al. 2012; Fleiter et al. 2010), which represent all kinds of actions that reduce specific energy consumption. In the residential sector the stock of alternative appliances and the market share of different efficiency classes is explicitly modelled (Elsland et al. 2014b). In all cases, energy savings can be calculated and traced back to technological dynamics including cost considerations.

The inclusion of technologies in the simulation model directly affects how MEPS (and consequently the implementing measures of the EDD) are modelled. For electric appliances a stock model approach can be used, which distinguishes individual efficiency levels and restricts new market entrants in a given year by the defined MEPS. This has for example been done in Elsland et al. (2013) in a case study for Germany. For the tertiary and industry sector, data availability does not allow such a detailed modelling of the technology stock. Instead, the approach used considers exogenous diffusion boundaries. MEPS result in the choice of a higher minimum diffusion boundary (Jakob et al. 2013; Fleiter et al. 2011).

DEFINITION OF STANDARDS

In following, an overview of the assumptions by lot and sector is given. The analysis is based on the efficiency requirements as outlined in the regulations – we do assume full compliance in the calculation. Most regulations are designed in a progressive way, i.e. the minimum threshold is increasing over the years.

The following assumptions are taken for selected lots:

- The analysis regarding **Lot 1 boilers and combi-boilers** builds on the regulation No 813/2013 (European Commission 2013) in particular regarding efficiency requirements for the two steps 2015 and 2017. Moreover, in line with the regulation, the technological scope focused on space heaters and combination heaters based on natural gas, heating oil and electricity. The preparatory study for Lot 1 (Kemna et al. 2007) included solar thermal and heat pump technologies as BAT but stated that "All in all, the heat pump and solar technologies are an interesting option with a large saving potential and should be promoted whenever and wherever possible. As such they should therefore have their place in the highest ranks of a labelling scheme. However, the uncertainties (and the costs) of the option should be taken into account, making the technology – as yet – not ripe for EU-wide mandatory measures." Thus, these technologies have not been implemented in regulation No 813/2013 and our assessment.
- Correspondingly, for **Lot 2 water heaters** we implemented the regulation No 814/2013 (European Commission 2013), for water heaters and hot water storage tanks based on natural gas, heating oil and electricity in the model.
- **Lot 8 and lot 9:** office and street lighting: requirements are defined for fluorescent lamps without integrated ballast, of high intensity discharge lamps, and of ballasts and luminaires able to operate such lamps (European Commission 2009). Applications for these lams are in public street lighting, commercial lighting and the industry sector. A number of lamp and luminaire types and applications are exempted from the regulation.
- **Lot 11 electric motors:** electric motors are defined as three-phase 50 Hz or 50/60 Hz, squirrel cage induction motors (European Commission 2009), which is the most common type of motor used in industry. The scope includes electric motors with a rated power between 0.75 and 375 kW. Also certain applications (e.g. brake motors, motors operating in liquids or motors completely integrated into products) are excluded from the regulation according to an amendment in 2014. The motor efficiency classes are aligned to the international IEC standards. The standards from 2015/2017 also require the use of variable speed drives.
- **Lot 11 circulators:** For tier 1 i.e. from 1st January 2013, glandless standalone circulators, excluding those specifically designed for primary circuits of solar thermal systems and of heat pumps, should have an Energy Efficiency Index (EEI) of not more than 0.27, as mandated in Annex 1 part 1(1) of the regulation EC/641/2009 (European Commission 2009). For tier 2 i.e. from 1st January 2015, glandless standalone circulators and glandless circulators integrated in products shall have an EEI of not more than 0.23, as mandated in Annex 1 part 1(2) of the regulation EC/641/2009 (European Commission 2009).
- Lot 11 **ventilation** fans: Ecodesign requirements for axial, centrifugal forward curved and centrifugal radial bladed, centrifugal backward curved with housing, centrifugal backward curved without housing, mixed flow and cross flow fans have been set out for tier 1 i.e. from 1st January 2013 and for tier 2 i.e. from 1st January 2015 (European Commission 2011).
- **Lot 11 water Pumps:** Ecodesign requirements for end suction own bearing, end suction close coupled, end suction close coupled inline, vertical multistage and the submersible multistage pumps have been set out for tier 1, i.e. 1st January 2013, and for tier 2, i.e. 1st January (European Commission 2012).

Results

Below, the results of the simulation runs are discussed beginning with a broad overview of the impact by lot, country and sector followed by selected insights into the industrial, buildings and residential sectors with a focus on major uncertainties of the analysis.

Table 3. Overview of MEPS assumptions by lot and sector as defined in the model calculations.

Product group	Industry	Residential sector	Tertiary sector
Lot 1: boilers and combi-boilers	Tier 1: 2015 Tier 2: 2017	Tier 1: 2015 Tier 2: 2017	Tier 1: 2015 Tier 2: 2017
Lot 2: water heaters and hot water storage tanks	Tier 1: 2015 Tier 2: 2017	Tier 1: 2015 Tier 2: 2017	Tier 1: 2015 Tier 2: 2017
Lot 3: PCs and monitors	–	Tier 1:2014	Tier 1:2014
Lot 5: Televisions	–	Tier 1: 2010 Tier 2: 2012	–
Lot 8: Office lighting	Tier 1	–	Tier 1
Lot 9: Street lighting	Tier 1	–	Tier 1
Lot 10: Room air conditioning	–	Tier 1: 2013 Tier 2:2014	–
Lot 11: electric motors	IE2 motors: 2011 IE3 motors: 2015/2017 VSDs: 2015/2017	–	–
Lot 11: water pumps	Tier 1: 2013 Tier 2: 2015	–	–
Lot 11: circulators	Tier 1: 2013 Tier 2: 2015	–	Tier 1: 2013 Tier 2: 2015
Lot 11: fans	Tier 1: 2013 Tier 2: 2015	–	–
Lot 13: Domestic refrigerators and freezers	–	EEI ≤ 55 from 2010 EEI ≤ 44 from 2012 EEI ≤ 42 from 2014	–
Lot 14: Domestic washing machines, domestic dishwashers	–	Washing machines: EEI ≤ 68 in 2011 EEI ≤ 59 in 2013 Dishwashers: EEI ≤ 80 from 2011 EEI ≤ 71 from 2013 EEI ≤ 63 from 2016	–
Lot 16: Loundry dryers	–	EEI ≤ 85 from 2013 EEI ≤ 76 from 2015	–
Lot 18: Simple set-top boxes, complex set top boxes	–	Tier 1: 2010 Tier 2: 2012	–
Lot 19: Domestic lighting	–	EEI ≤ 80 from 2010–2013 depending on technology EEI ≤ 60 from 2016	–

OVERVIEW

Figure 1 shows the savings in 2030 by country and sector. Overall for the EU28, 57.4 % of the EDD savings would come from the residential sector, 28 % from the tertiary sector and 14.7 % from the industry. Differences among countries are observed in terms of total energy saved but also in terms of distribution of the savings across sectors. E.g. Greece and Portugal show very high savings in the residential sector, while other countries like for example Sweden and Finland have the highest share in the industrial sector (mainly affected by the high share of the paper industry, which uses high amounts of electricity in pumping systems). In total, the residential sector accounts for the major share of the savings with more than 50 % in 18 countries. The country-specific results have to be interpreted with caution, as data availability is not very good for all countries. In case, some information (e.g. market shares) was not available for a particular country, values from neighbouring or "similar" countries were taken. Using this approach might be imprecise for individual countries, but it does not result in a general underestimation or overestimation of the total saving potential (data gaps do not lower the potential).

Looking at the impact by lot for the EU28 in 2020 and 2030 (Figure 2) reveals huge differences between the individual lots. Especially lots in the residential sector show high savings potential (e.g. lot 13: refrigerators and freezers, lot 14: washing machines and dishwashers, lot 19: domestic lighting). The lots in the industrial sector show considerably lower savings, e.g. related to electric motors, pumps and fans. This difference results from the fact that industrial energy efficiency potentials are strongly related to system optimization. Efficiency potentials via replacement of individual components, e.g. electric motors, often experience only low remaining potentials, where a few percentage points is considered a lot. On the contrary, differences between efficiency classes in household appliances often amount to 10–20 %.

The savings of lot 1: boilers and combi-boilers mostly relate to fuels (e.g. natural gas or fuel oil). To properly compare them to the other lots would require all electricity savings to be converted to primary energy (rough estimate: multiplication with a factor of 3 t account for losses in electricity generation). The saving potential of boilers compared to other lots would seem even smaller. One might expect that the impact of boilers should be higher due to the high relevance of space heating on the overall energy consumption. Compared to other lots, the remaining (relative) efficiency improvements from replacing boilers are substantially lower than e.g. in electric appliances like refrigerators or lamps. Still, the impact of the EDD is expected to be moderated according to our estimations. Below, in the section "buildings" some related aspects, uncertainties and reasons for these results are discussed.

For the year 2030, Table 4 shows the savings potential by lot and by sector. Empty cells are either not quantified (due to low expected potential) or excluded from the regulation, as summarized in Table 1. Some combinations of lots and sub-sectors are assessed as a bundle, due to model and data restrictions.

The total savings potential of all lots and sectors amounts to about 254 TWh of which roughly 225 TWh is electricity, which equals to roughly 8 % of current EU electricity demand of 2,800 TWh in 2012.

INDUSTRY

Adopted EDD regulations addressing the industrial sector are mostly related to electric motors and motor systems. They are summarized within lot 11 addressing the technologies electric motors, water pumps, circulators and fans. The model FORECAST-Industry considers these technologies in the frame of so called cross-cutting technologies (CCT). Electricity demand of these CCT is calculated as a share of industry's total electricity demand per sub-sector and country. Figure 3 shows the resulting electricity demand per CCT by country. In most countries the share of industrial electricity demand consumed by electric motor systems accounts for about 65–75 %.

Based on the electricity demand per CCT (and its projection) the resulting savings are calculated. For lot 11 they are disaggregated by CCT and saving option in Table 5 for the EU28. The impact of lot 11 "electric motors" is distinguished into standards for IE2 motors, IE3 motors and the requirement to install a variable speed drive (VSD). Standards for water pumps and circulators are both included in the impact for tier 1 and tier 2 standards for pumps. The results show that from the total savings of about 30 TWh, roughly 50 % are related to standards for electric motors (including VSDs). The other 50 % come from standards for fans and pumps. The motor standards are further disaggregated by motor size (i.e. installed power) distinguishing three size classes: below 10 kW, 10–70 kW and above 70 kW. The results show that the class "below 10 kW" accounts for more than 50 % of the savings related to electric motors (excluding VSDs). This effect can be explained by the fact that

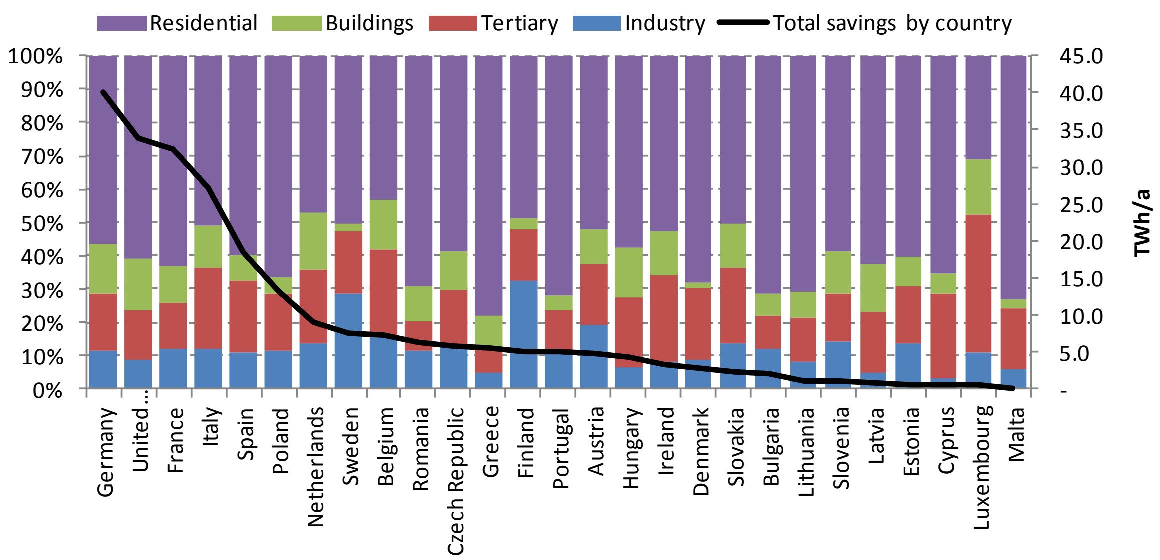

Figure 1. Total final energy savings by country [secondary axis: TWh/a] and as share by sector [primary axis: % of total savings] in 2030.

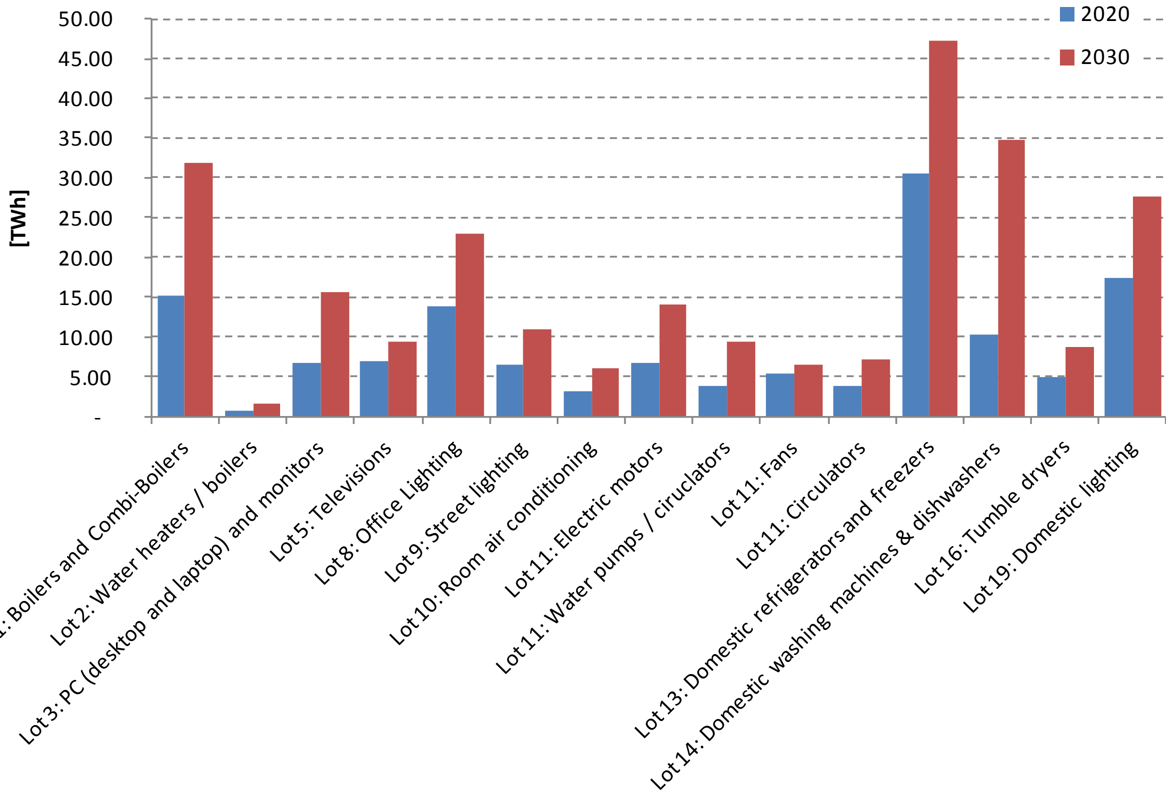

Figure 2. Final energy savings by lot for EU28 (lot 1 & 2: fuels and electricity; all others: only electricity).

Table 4. Energy savings by lot and sector for EU28 in 2030 [TWh] (lot 1 & 2: fuels and electricity; all others: only electricity).

<table>
<tr><th>Lot</th><th>Industry</th><th>Tertiary</th><th>Residential</th><th>Total</th></tr>
<tr><td>Lot 1: Boilers and Combi-Boilers</td><td rowspan="2">5.2</td><td colspan="2">26.7</td><td>32.0</td></tr>
<tr><td>Lot 2: Water heaters / boilers</td><td colspan="2">1.5</td><td>1.5</td></tr>
<tr><td>Lot 3: PC (desktop and laptop) and monitors</td><td>-</td><td>3.8</td><td>11.8</td><td>15.7</td></tr>
<tr><td>Lot 5: Televisions</td><td>-</td><td>-</td><td>9.4</td><td>9.4</td></tr>
<tr><td>Lot 8: Office Lighting</td><td rowspan="2">2.2</td><td>20.8</td><td>-</td><td>23.0</td></tr>
<tr><td>Lot 9: Street lighting</td><td>11.0</td><td>-</td><td>11.0</td></tr>
<tr><td>Lot 10: Room air conditioning</td><td>-</td><td>-</td><td>6.1</td><td>6.1</td></tr>
<tr><td>Lot 11: Electric motors</td><td>14.0</td><td>-</td><td>-</td><td>14.0</td></tr>
<tr><td>Lot 11: Water pumps / ciruclators</td><td>9.4</td><td>-</td><td>-</td><td>9.4</td></tr>
<tr><td>Lot 11: Fans</td><td>6.4</td><td>-</td><td>-</td><td>6.4</td></tr>
<tr><td>Lot 11: Circulators</td><td>-</td><td>7.1</td><td>-</td><td>7.1</td></tr>
<tr><td>Lot 13: Domestic refrigerators and freezers</td><td>-</td><td>-</td><td>47.2</td><td>47.2</td></tr>
<tr><td>Lot 14: Domestic washing machines & dishwashers</td><td>-</td><td>-</td><td>34.9</td><td>34.9</td></tr>
<tr><td>Lot 16: Tumble dryers</td><td>-</td><td>-</td><td>8.8</td><td>8.8</td></tr>
<tr><td>Lot 19: Domestic lighting</td><td>-</td><td>-</td><td>27.6</td><td>27.6</td></tr>
<tr><td>Total</td><td>37.2</td><td>71.0</td><td>145.7</td><td>253.9</td></tr>
</table>

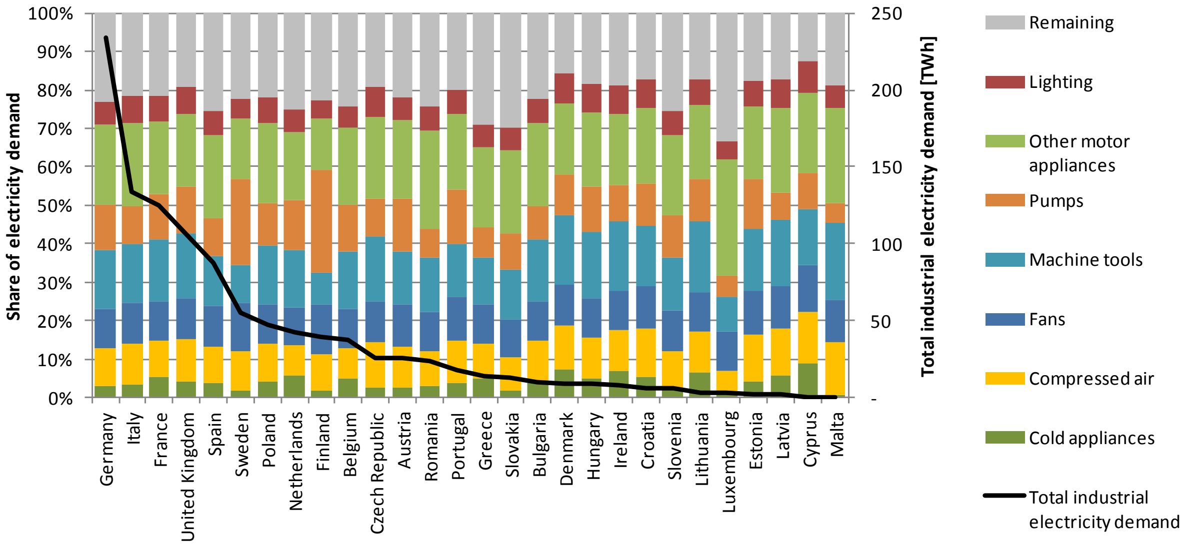

Figure 3. Electricity demand by cross-cutting technology (CCT) and country in 2010 as share of total industrial electricity demand [primary axis in %] and total electricity demand for industry by country [secondary axis: TWh/year].

Table 5. Energy savings in industry by saving option and technology for EU28 in 2030 [TWh/a].

Saving option	cold appliances	compressed air	fans	pumps	other motor appliances	Total
IE2 Motors with 10 to 70 kW	0,10	0,24	0,27	0,29	0,49	1,38
IE2 Motors with above 70 kW	0,07	0,18	0,20	0,21	0,35	1,01
IE2 Motors with less than 10 kW	0,23	0,57	0,63	0,69	1,20	3,32
IE3 Motors with 10 to 70 kW	0,05	0,13	0,15	0,16	0,27	0,77
IE3 Motors with above 70 kW	0,05	0,11	0,13	0,13	0,23	0,64
IE3 Motors with less than 10 kW	0,07	0,19	0,21	0,23	0,40	1,11
Variable Speed Drive with 10 to 70 kW	0,10	0,06	0,57	0,73	0,67	2,13
Variable Speed Drive with above 70 kW	0,09	0,04	0,43	0,71	0,67	1,94
Variable Speed Drive with less than 10 kW	0,13	0,06	0,44	0,45	0,61	1,68
MEP tier 1	-	-	2,95	6,95	-	9,90
MEP tier 2	-	-	3,48	2,45	-	5,93
Total	0,89	1,57	9,45	13,00	4,90	29,80

larger motors typically have already (before EDD regulations) higher levels of efficiency, while particularly small motors often have poor efficiencies. Consequently, the remaining saving potential is higher for smaller motors. However this does not apply for VSD, where 70 % of the energy savings would come from VSD above 10 kW.

These results are sensitive to the assumptions taken and also subject to several uncertainties. Among those is the efficiency (and its development over time) of the base technologies. Country differences in efficiencies are unknown for most technologies. In this case, we assumed EU average values.

BUILDINGS

The results indicated above in Figure 1 and Figure 2 are mainly driven by three variables, all of them are related to some uncertainty. In the following, we discuss some of these uncertainties and how they could affect the results.

1. Efficiency improvement of new installations due to MEPS from the EDD implementation
2. The efficiency improvement is driven by two elements:
   - Compliance with the directive and additional other drivers for the efficiency. Besides compliance problems and difficulties to implement effective monitoring and control mechanisms, we know that the efficiency of heating and hot water systems may also be strongly affected by the installation, specific conditions, heat supply temperature levels in the building etc. These factors are not addressed in the EDD since the EDD focuses on the product itself, not the use of the product or the complex aspects how this product is integrated in the overall energy system of a building.

- Efficiency of technologies in the reference scenario. There are huge uncertainties about the seasonal efficiencies of heating and hot water systems in real-life. Moreover, even the average values of systems currently on the market are not available. Thus, we refer to the technology database derived in the frame of the project ENTRANZE (www.entranze.eu).

Combining these two elements and points results in a range of 2–4 % (depending on technologies and Lots) efficiency improvement in new installations due to the EDD (i.e. new installations are 2–4 % more efficient due to the EDD framework compared to the reference scenario without EDD). Due to the arguments raised above, in particular due to the impact of real-life installation conditions, we estimate that these values are optimistic and could be lower in reality.

3. Heating system exchange rate and new installation of relevant technologies. As explained above in the "methodology" section, the heating system exchange rate depends on the vintage structure of the heating system stock and lifetime. There are considerable uncertainties regarding these issues. In our analysis, we implemented the data collected in the project ENTRANZE (www.entranze.eu).

The building renovation activities of course also have an impact on the useful energy demand of buildings, but also on the full load hour and partial load operation time of heaters. The renovation activities are based on the scenario defined above in the methodology section. With a more ambitious scenario regarding thermal renovation activities of the building envelope, the absolute impact of the EDD would be lower as well, since the covered energy demand basis would be decrease. In our analysis, we assumed that increasing renovation activities of the building envelope would not lead to increasing rate of heating system replacement. However, this might also be a matter of further research. The resulting share of space heating for which space heating systems are being replaced is shown in Figure 4.

RESIDENTIAL APPLIANCES

For residential electricity use, the EED covers the most important end-uses and therefore has a strong impact on residential electricity consumption. For most end-uses, the EED acts in combination with the energy label, where the EED "pushes" the lower end of the market and energy labelling "pulls" the higher end. As both measures act in a complementing but overlapping way on the market for residential appliances, the effects of the EED may be slightly overestimated in this study. The energy savings achieved through the EED for residential appliances depend on a variety of factors that are subject to uncertainties including the level of compliance and behavioural aspects such as the rebound effect. Furthermore, the estimated savings depend on the assumptions regarding the average lifetime of the appliances. Figure 5 illustrates the effect of the EED on the stock turnover by displaying the share of washing machines with different energy efficiency index (EEI) in the baseline scenario and the EED scenario.

Conclusions

In the above analysis, we assessed the additional impact of the Ecodesign-Directive (EDD) on final energy demand in the EU28 and calculated saving potentials by country, lot and sector until 2020 and 2030. The analysis is based on a detailed bottom-up simulation using the models FORECAST and INVERT-ee/lab. The impact of the EDD is calculated as the difference between two scenarios: one excluding the EDD and one including the implementing measures already in force (both scenarios consider other implemented policies similarly). Due to the high number of lots, we focus on those combinations of lots and sectors for which the highest saving potentials are expected (also taking into account data availability). The macroeconomic framework is in line with recent EU forecasts (European Commission 2014).

The results show a substantial impact on electricity demand. By 2030 a savings potential of 225 TWh electricity demand per year is calculated, which equals about 8 % of total EU28 annual electricity demand in 2012. Adding additional lots, for which implementing measures have not yet been enforced or includ-

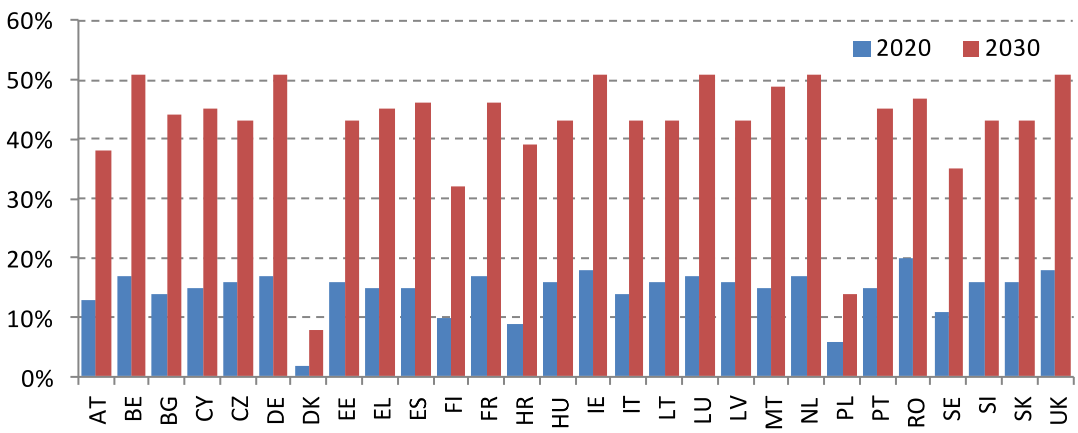

Figure 4. Share of space heating energy demand of replaced heating systems beginning in 2015.

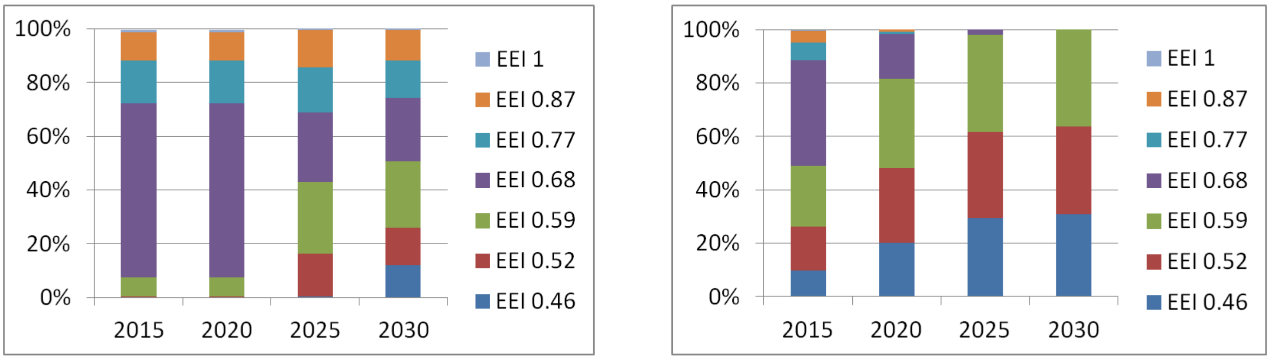

Figure 5. Share of washing machines by energy efficiency index (EEI) in the EU-28 in the Scenario without EED (left) and with EED (right).

ing more ambitious standards to existing regulations would further increase this potential as for example shown by CLASP (2013) for selected lots.

The results by lot and country show how unevenly the impact is distributed. Not only the total saving potential, but also the importance of individual sectors varies strongly by country. The lots with the highest impact are from the field of residential appliances, whereas industry-related lots mostly have a lower savings potential. One major reason for this difference is that many components have only limited remaining energy efficiency potentials in industry (e.g. electric motors < 5 %), while many appliances in the residential sector still show huge differences between the efficiency classes of often more than 10 % . This existing potential in households can be explained by a low importance of energy cost. Furthermore, in industry, system optimization is much more important than in the residential sector, but more difficult to address with standards.

While in general, the detailed disaggregation of energy demand into individual technologies and appliances as well as the stock-model approach used in the bottom-up models is a good basis for such an assessment, there are uncertainties remaining, mostly resulting from the input data and scenario assumptions. Often, the standards defined in the regulations are very detailed and distinguish numerous sub-technologies that have to be aggregated to fit into the models. Also the current market share of efficiency classes is not known for all appliances and countries. For a more detailed country-specific analysis of results, more empirical data needs to be gathered, also from country-specific sources. The counterfactual (i.e. the reference scenario) is uncertain: How fast efficient technologies would diffuse through the market without the EDD is a critical, yet uncertain assumptions and empirical observations are not always available for the past (e.g. mostly in the industrial sector the available technology-specific data is scarce). While overlaps with other policy instruments were considered in the analysis, this is particularly critical for labelling, which is difficult to separate from MEPS when allocating the effects to individual policies. In total, these mentioned uncertainties require a cautious interpretation of the calculated results.

Besides improving these data issues, sensitivity analysis could help to better understand the importance of the mentioned sources of uncertainty. From a methodological point of view, future research on the inclusion of the rebound effect into such an analysis could further improve the value of policy recommendations.

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