Ex-ante estimation of the EU Ecodesign Directive's impact on the long-term electricity demand of the tertiary sector

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Abstract

Ex-ante evaluation is important to effectively design policy measures. The paper addresses the electricity demand of the tertiary sector in Europe which is one of most strongly growing. On the EU-level, a number of policies are implemented to improve energy efficiency also in the tertiary sector. Among such measures are the recently adopted Energy Efficiency Directive, the Ecodesign Directive (EDD) and the Energy Performance of Buildings Directive (EPBD).

In this paper, we aim to analyse the impact of such and additional policies using comparative scenario analysis. Different scenarios are characterized by different levels of policy measures and programmes. Being one of the most important policy options for electricity demand, we will particularly focus on the EDD and its impact. For the scenario analysis, we use the techno-economic bottom-up model FORECAST. The model differentiates between 29 countries, 8 sub-sectors and 15 building and user related energy-services such as lighting in buildings, street lighting, electric heating, ventilation and cooling, refrigeration, cooking, laundry, ICT devices and data centres with servers. Electricity demand is obtained through physical drivers and specific energy consumption indicators. The latter consist of technical information such as installed power, energy demand per unit of driver, and utilisation rates such as full load hours. Energy-efficiency measures aim at reducing both installed power and utilization rates and cover technologies and practices. As the model also considers growing drivers it allows developing a comprehensive picture of the net electricity demand development. Among such drivers is the number of employees or the floor area, or more specific energy service drivers such as equipment or diffusion rates (e.g. share of cooled floor area, no. of computers per employee).

Results show that electricity demand in the EU tertiary sector will continue to grow in the coming years. However, the policies currently implemented and foreseen for implementation will mitigate this effect to a large extent and demand tends to stabilize in the long term, particularly if the EDD is consequently implemented and enforced based on the least lifecycle cost approach and if it is accompanied by additional soft policies to address energy-efficiency measures (EEMs), such as system optimization or behavioural measures. Moreover energy services not covered by the EDD should be included in the future.

Introduction

Between 1990 and 2010 electricity demand of the tertiary sector in the EU27 has been increasing by about 93 %. As compared to the other sectors the tertiary sector shows the most dynamic development over these past twenty years (Figure 1). For comparison, total EU27 electricity demand increased by "only" 32 % over the same period. With a demand of 834 TWh in 2010, the tertiary sector has reached the same level of electricity demand as the residential sector and even demand in the industry sector is only 20 % higher. These figures reflect a growing relevance of the tertiary sector, which has increased from a share of 20 % of electricity demand in 1990 to a share of 29 % in 2010, mainly at the cost of the industry sector, which depicts a decreasing share. A strongly rising demand in the tertiary sector cannot only be observed for the EU27 as a whole, but also for all individual member states. Here, Denmark, Sweden, UK,

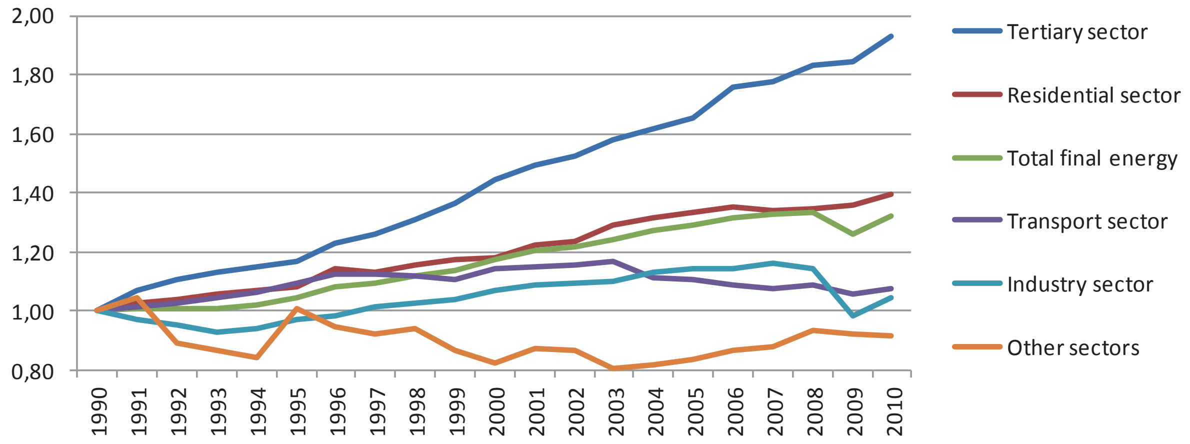

Figure 1. Development of electricity demand by sector in the EU27 as an index (1990=1) (Source: Eurostat).

Austria and Latvia exhibit the lowest growth ranging between 26 % and 37 %, whereas countries such as Czech Republic, Ireland, Portugal, Slovakia, Slovenia and Spain show a growth of more than 200 % over the time period from 1990 to 2010.

As it is expected that electricity demand of the tertiary sector will continue to be increasing in the future, policy measures to curb demand are becoming more and more relevant for this sector. A number of policies are already implemented, many of which are driven by EU legislation. Although, these policies are mostly not directly addressing the tertiary sector, they cover parts of it. The recently adopted EU Energy Efficiency Directive (Directive 2012/27/EU) – and to a certain extend also its predecessor, the Energy Service Directive (Directive 2006/32/EC) – requires member states among others to support energy audits for SMEs and to set energy-efficiency standards for public procurement rules. Many of the SMEs are allocated to the tertiary sector. Such policies are mostly based on incentives and provision of information. As such they might be summarized under the term soft policies – opposed to technical codes and standards. Such a set of regulative policy measures is currently being implemented in the frame of the EU Ecodesign Directive (Directive 2009/125/EC) (EDD), which provides a frame to adopt minimum energy performance standards (MEPS) for energy-using as well as energy-related products. MEPS (or alternative measures) are defined by product type and implemented via individual so called implementing measures, mostly regulations. The EDD is expected to have a substantial impact on energy demand and for many products MEPS were already adopted in form of a regulation in recent years, of which several are relevant for the tertiary sector. Among those are the product groups office, domestic and street lighting, electric motors, circulators and fans.

Thus, knowledge about the potential impact of energy-efficiency policies to mitigate electricity demand of the tertiary sector is crucial. Most studies assessing policy measures are focusing on single countries and for relatively new policies such as the EDD, only few impact assessments are available so far. One of the most comprehensive assessments of the impact 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. The calculated saving potentials, however, are based on the diverse methodological approaches from the individual preparatory studies and they do not take the dynamic development of the tertiary sector into account – at least not systematically.

Here, we aim to suggest another approach. We use a bottom-up model for the ex-ante assessment of the impact of energy-efficiency policies on the EU tertiary sector. We aim to consider EU-wide policies such as the EDD, but also the mix of soft policies such as energy audits, labelling and information programs.

The paper is organized as follows. We begin with a description of the methodology and the modelling approach in the following chapter, before we describe the definition of the scenarios calculated. Finally, we present and discuss the results and conclude.

Methodology

We use the model FORECAST-Tertiary to assess the policy impact. The model has been developed and extended in recent years in a number of studies. Jakob et al. (2012) extended the static bottom-up model of Fleiter et al. (2010) to present the coherent bottom-up model FORECAST-Tertiary which allows for simulating the electricity demand of the tertiary sector of the EU27+2 up to 2035 by country, by 8 sub-sectors, and by 14 end uses including lighting, electric heating, ventilation and cooling, refrigeration, cooking, data centres with servers and others. With this model the impact of novel technologies and other EEMs (e.g. organizational measures) as elements of energy efficiency policies can be estimated, particularly by comparing different scenarios. FORECAST-Tertiary is based on the concept of energy-efficiency measures (EEMs), which represent individual options that improve energy efficiency when diffusing through the equipment stock. Examples are fluorescent lamps, reduction of stand-by losses or changed user behaviour. Consequently, policies are modelled by adjusting the dynamics and the level of diffusion of such EEMs, depending on general and technology specific economic parameters.

Basically the model adopts a bottom-up methodology which consists of a "sum product" of global drivers such as the number of employees or floor area, specific energy service drivers (specific equipment or diffusion rates, e.g. share of cooled floor area, number of computers per employee) and specific energy consumption indicators. The latter consist of technical data on the end-uses such as installed power per unit of driver. Energy services and their techno-economic description represent a key element of the modelling approach. We consider the EDD in the model by relating the product groups of the EDD to individual EEMs as defined in the model. In this section, we describe the calculation of saving potentials, the technology structure and definition and finally focus on the relation to the product groups. For a more detailed description of the modelling approach we refer to Fleiter et al. (2010) and Jakob et al. (2012).

This approach brings a number of advantages. Techno-economic data from the EDD preparatory studies (and other sources) can be used to estimate model parameters. Thus, our assumptions are in line with the preparatory studies, but the method used is similar for all products and ensures good comparability. The model considers the dynamic development of the key drivers of this sector's energy demand, which are the number of employees, the floor area, energy prices as well as product specific drivers such as the number of computers per employee in a particular sub-sector. Thus, our approach does not only calculate energy savings per product group, it also puts them into the broader frame of the tertiary sector and its dynamics of energy demand. And, finally, the impact of policies modelled can be broken down to individual countries, sub-sectors or energy services.

SECTOR DEFINITION

The tertiary sector, also referred to as the service or commercial sector, covers all the economic sectors not part of the primary economic sector (agriculture, forestry, fishery etc.) or the secondary economic sector (industry). Hence, the tertiary sector comprises the NACE sub-sectors G to S (NACE rev. 2.0). We differentiate between Trade (G), Hotel and restaurant (I), Traffic and data transmission (H, J), Finance (K), Health (Q), Education (P), Public administration (O), Other services (L, M, N, R, S), see Table 1 in Fleiter et al. (2010). Electricity demand of the tertiary sector includes both, building-related energy use of these sub-sectors and other energy use such as street lighting, ventilation of tunnels, public transport infrastructure and others. An exception is the sub-sector "Traffic and data transmission," where the transportation energy for trains, subways, trams etc. is – as is usual in energy economic analysis – not accounted for in the tertiary sector, but in the transportation sector.

CALCULATION APPROACH

Electricity demand of a given year is determined as the product of the specific energy demand per unit of driver (e.g. number of computers, floor area cooled / ventilated, etc.) multiplied by the quantity of the given driver. The driver is further decomposed down into an energy service driver *D* (e.g. computers per employee, share of floor area ventilated/ cooled, etc.) and a global driver *G* (e.g. floor area or employees). The specific electricity demand is calculated as the product of installed (full load) power *P* and the annual utilisation rate *U* (annual full load hour equivalent). A schematic representation of the model structure is given in Jakob et al. (2012). As is usually the case in bottom-up simulation models its dynamics is driven by time dependent input variables. In the case of FORECAST-Tertiary, dynamics is implemented by three sets of variables:

1. The dynamics of the global quantity structure *G* depends on general economic structural changes (number of employees by sub-sector) and on specific indicators (e.g. floor area per employee).
2. The dynamics of the energy service drivers *D* such as the diffusion of cooled floor area is modeled by diffusion curves whose parameters depend on the past development, the sector and the energy service considered.
3. Specific energy demand varies over time due to the diffusion of new technologies and/or energy-efficiency options (EEMs). The dynamics of the specific energy demand is modeled by constant initial starting values from which the relative impact of EEMs, are subtracted. EEMs may reduce either the installed power, the utilisation rate, or both. This allows for a more realistic consideration of the Ecodesign Directive's implementing measures (which often only address the installed power) and of other EEM (e.g. operational measures). EEMs diffuse into the building stock and the economic sub-sectors according to specific diffusion rates *DR*.

Thus, the modelling approach is formally described by the following equation:

$$\mathrm{T_t} = \sum_{C=1}^{n}\sum_{S=1}^{l}\sum_{\mathrm{E}=1}^{\mathrm{k}} \mathrm{G_{C,S,t}} \cdot \mathrm{D_{C,S,E,t}} \cdot \mathrm{P_{C,S,E}} \cdot \prod_{EEM=1}^{x} (1 - DR_{\mathrm{C,S,E,EEM,t}} \cdot P_{\mathrm{C,S,E,EEM}}) \cdot \mathrm{U_{C,S,E}} \cdot \prod_{EEM=1}^{x} (1 - DR_{\mathrm{C,S,E,EEM,t}} \cdot U_{\mathrm{C,S,E,EEM}})$$

With

T	total bottom-up electricity demand of the tertiary sector [kWh]
$G_{C,S}$	global driver [# of employee, m^2]
$D_{C,S,E}$	energy service driver [unit depends on energy service]
$U_{C,S,E}$	utilisation rate (annual full load hours) [h/a]
$P_{C,S,E}$	installed power per unit of driver [W/unit of driver]
$\Delta P_{C,S,E,\,EEM}$	relative reduction of installed power by energy-efficiency option EEO [%]
$\Delta U_{C,S,E,\,EEM}$	relative reduction of utilisation rate by energy-efficiency option EEO [%]
$DR_{c,S,E,EEM,t}$	Diffusion rate [% of energy service driver]

Indices:

C	country, n = 29
S	sub-sector, l = 8
E	energy service, k = 13
EEM	energy-efficiency option, x=1 to 3

ENERGY SERVICE DRIVER AND TECHNOLOGY DATA

Several energy services are defined for each of the sub-sectors representing distinct appliances as well as building-related and other technologies. Most energy service drivers (D) are related to both a global driver G and energy service driver D, some of them, (such as street lighting or cooking), are only related to an energy service driver D (see Table 2 in Fleiter et al. (2010) for all the energy services considered in the model). These energy drivers represent a diffusion curve, penetration or ownership rate of the respective technology in each of the sub-sectors and each country. Energy service drivers vary over time, depending by the type of energy service driver and/or by country.

Typical examples of energy service drivers (D) are for example the share of ventilated floor area and/or with space cooling, the number and type of information and communication (ICT) devices per employee (e.g. personal computers) (see Fleiter et al. 2010 for details). Each energy service in each sector is characterized by a specific energy demand. These specific demand values are the product of the installed power P of a technology and its utilisation in full-load hours per year, U. These values are explicitly differentiated between sub-sectors, countries and, whenever possible, implicitly between new and existing buildings and between already installed systems and those that are retrofitted. Based on the calculation scheme, the total bottom-up energy demand for the tertiary sector T can be calculated and differentiated by either sub-sector or energy service.

ADJUSTING MODEL PARAMETERS AND MODEL VALIDATION

The individual energy services are mostly calibrated to data from the EDD preparatory studies. Beyond this, detailed statistical information about electricity demand in the tertiary is scarce, particularly for individual energy services (Bertoldi and Atanasiu 2011). On a European level electricity demand is only available for the tertiary sector as a whole from Eurostat and only a few studies have assessed the shares of different end-uses; these show differing results together with a high degree of uncertainty (Bertoldi et al. (2009), Bertoldi et al. (2006), De Almeida et al. (2006). Studies on a national level are often not comparable due to different definitions and system boundaries (Schlomann et al. 2008, Abreu et al. 2007). Still, wherever possible, we have considered the various sources available.

In total, the sum of the bottom-up electricity demand per country shows a good match to the Eurostat energy balances. All larger countries are within a range of ±10 % and only a few smaller countries are overestimated (Romania) or underestimated (Norway and Sweden) (Fleiter et al. (2010). For a bottom-up model this is a very good match, even more when considering the low availability of empirical data.

SIMULATION OF THE ECODESIGN DIRECTIVE (EDD)

Challenges

The simulation of the EDD in a bottom-up model faces a number of advantages (see above), but also a number of challenges.

First, the product groups are unequally advanced in the process towards implementing measures (see Table 1). At the time of this study (end of 2012) 8 product groups were finalized resulting in implementing measures, which state very precisely how the product group will be regulated. For additional 9 product groups the preparatory study was finished, which provides techno-economic information on the products as well as a proposal for a future regulation via an implementing measure. For the remaining six product groups the preparatory study is still in progress and information is very scarce.

Second, the number of product groups covered under the EDD is growing continuously and the products addressed become more and more heterogeneous. Such niches are often not covered by bottom-up models, as they typically focus on the most relevant energy services.

Third, while the design of the current implementing measures is known, the measures will probably be updated over the modelling time period (which in this case goes up to 2035). This imposes a considerable uncertainty on the modelling, as technologies and products change dynamically over time and might require new or adapted regulation.

Fourth, the definition and scope of the product groups are often more specific (e.g. certain power ranges) than the definition of energy services in a bottom-up model.

In order to simulate the impact of the EDD, the following steps are considered:

1. Allocation of product groups/implementing measures to energy services in the model.
2. Integration of standards based on implementing measures or preparatory studies into the model in the form of EEMs.
3. Definition of scenarios and baseline.

Allocation of product groups to energy services

An overview of the product groups considered is given in Table 1. For most product groups, preparatory studies are available, which are a good source for techno-economic data and model calibration. The table also shows the allocation of energy services and product groups. Some of the product groups have a narrower scope than the energy services in the model have, while others match very well with the energy services (e.g. refrigeration, street lighting). Thus, in the former case, several product groups are allocated to one energy service. For example, the three product groups for office lighting, domestic lighting for directional and non-directional lamps do all refer to the energy service lighting, but differ by type of technology used. Thus, in the model we consider them within one bundled energy service named "lighting".

Product groups of the EDD lots cover about 80 % of the electricity demand of the tertiary sector – based on the modelled bottom-up demand per energy service (Table 1). Note however that this does not imply that the EDD covers 80 % of the potential measures or of the existing energy-efficiency potentials.

Integration of standards based on implementing measures or preparatory studies into the model in the form of EEMs

Every preparatory study mentioned in Table 1 describes many possible saving options for many different use types (e.g. office lamps, directional lamps, etc.). For these saving options the preparatory studies specify whether the saving is addressing the installed power, the operating or full load hours, or both. Moreover initial investment costs or add-on costs, operating costs and the lifetime of the saving measures are included.

Referring to the standards based on implementing measures or following the EuP's recommendation about the applicable options, we selected and aggregated most of the EuP's saving options into more aggregated bundles of saving options. Then

Table 1. Overview of Ecodesign product groups and relation to energy services included in the model (Electricity demand in the tertiary sector as modelled by FORECAST).

Product group	Preparatory study finished	Regulation (in force from)	Main energy carrier addressed	Modeled in energy service	Electricity demand in tertiary sector in 2010 [TWh]	As share of tertiary sector
Lot 1 Boilers and combiboilers	yes		Fuels/ Electricity	Electric heating	48	6%
Lot 20 Local room heating products	no		Fuels/ Electricity			
Lot 21 Central heating products (hot-air based)	no		Fuels/ Electricity			
Lot 2 Water heaters	yes		Fuels/ Electricity	Hot water	63	8%
Lot 3 PC (Desktops and Laptops) and Computermonitors	yes		Electricity	ICT office		
Lot 6 Standby and off-mode losses	yes	7.1.2010	Electricity			
Lot 26 Networked standby losses	yes		Electricity			
Lot 7 Battery chargers and external power supplies	yes	27.4.2010	Electricity			
ENTR Lot 3 Sound and imaging equipment	yes		Electricity		20	2%
Lot 8 Office lighting	yes	13.4.2010	Electricity	Lighting	237	
Lot 19 Domestic lighting part I "non-directional lamps"	yes	1.9.2009	Electricity			
Lot 19 Domestic lighting part II "directional lamps"	yes		Electricity			28%
Lot 9 Street lighting	yes	13.4.2010	Electricity	Lighting street	31	4%
Lot 11 Electric motors (0,75kW - 200kW)	yes	16.6.2011	Electricity	several*	n.a.	n.a.
Lot 11 Circulators	yes	1.1.2013	Electricity	Heating auxiliaries	45	5%
Lot 11 Fans	yes	1.1.2013	Electricity	Ventilation and AC		
ENTR Lot 6 AC and ventilation systems > 12kW	no		Electricity		100	12%
Lot 12 Commercial refrigerators and freezers	yes		Electricity	Refrigeration		
ENTR Lot 1 Refrigerating and freezing equipment	yes		Electricity		80	10%
Lot 22 Domestic and commercial ovens	no		Fuels/ Electricity	Cooking		
Lot 23 Domestic and commercial hobs and grills	no		Fuels/ Electricity		45	5%
Lot 24 Prof. washing machines, dryers and dishwasher	yes		Electricity	Laundry	12	1%
ENTR Medical imaging equipment	no		Electricity	n.a.	n.a.	n.a.
Total					682	82%

** Electric motors are not modeled as distinct energy service, instead they are integrated in all appliances/energy services that are based on mechanical energy. Among those are refrigeration, ventilation and AC, pumps and circulators.*

taking into account structural differences across the different sub-sectors and countries and other data sources and studies (e.g. Jakob et al. 2010, Schade et al. 2009, Jakob et al. 2006a, b), we built a consistent model data base of techno-economic data and diffusion curves for each of EEM, differentiating by energy service, by sector and by country. Techno-economic data include the saving potential regarding the installed power, the saving potential regarding the utilisation rates (full load hours), operating costs, initial investment costs and EEM lifetime. Two potential diffusion curves that are consistent to these techno-economic data are associated to each of these EEMs: an autonomous diffusion curve and a maximum diffusion curve. Depending on the cost-effectiveness of the EEM (which in term depends on scenario parameters such as discount rates and energy prices) the model selects whether a certain EEM is tapped up to either of the two diffusion curves (or to a level in between).

Scenario definition

We apply scenario analysis and calculate alternative future developments for the electricity demand of the tertiary sector and the impact of the EDD. All scenarios entail a similar development for the activity related drivers like the number of employees, the floor area or the energy-service related drivers like the number of computers per employee. The only parameter changed across scenarios is the diffusion rate of EEMs. An increased diffusion implies a higher saving potential and results in lower electricity demand. Consequently, the scenarios allow concluding on the electricity saving potential available to policies that aim to accelerate the diffusion of EEMs. We calculate the following scenarios (in ascending order with regard to diffusion speed).

- **Frozen efficiency scenario:** in the frozen efficiency scenario there is no further diffusion of EEMs and thus also the specific energy consumption remains on the base year level. This scenario is calculated for purposes of comparison and shows the development of electricity demand if only the scenario drivers change.
- **Autonomous diffusion scenario:** The autonomous diffusion is an exogenous parameter set, which extrapolates the past diffusion rate of EEMs. It captures the effect that, due to manifold barriers, even cost-effective EEMs are often not adopted by firms. Referring to the framework of Sorrell et al. (2004) and to the empirical work of Gruber and Brand (1991), Gillingham et al. (2009), Schleich (2004), Schleich (2009) and Farsi (2010) who identified barriers such as limited access to capital, split incentives between landlords and tenants, failure to recover undepreciated investments on the real-estate market, risk consideration, and behavioural failures (for a recent overview see Fleiter et al. 2012). However, the autonomous diffusion scenario represents a minimum diffusion level regardless of the cost-effectiveness of the EEM. This assumption shall cover the enormous heterogeneity in the tertiary sector and the fact that the turnover of capital stock mostly implies a certain energy-efficiency progress.
- **Least life-cycle cost (LLCC-35) scenario:** Here, we assume that a set of information and incentive based policies, consisting for instance of energy-labelling, energy audits and information campaigns, is implemented. These policies improve the capability of firms to identify, assess and implement EEMs. However, even if a policy framework is in place to accelerate the diffusion of EEMs, it is reasonable to assume that not all cost-effective EEMs will be realized. Furthermore, if ever economic calculus is done, companies often are adopting EEMs with quite short payback periods, typically two to five years, although economic lifetimes of typical EEMs are rather eight to fifteen years. Such decision behaviour is equivalent to a framework of internal rates of return of twenty to ninety percent or more. Hence, similarly to the concept of Decanio and Laitner (1997) we introduce the concept of implicit discount rate in our modelling. EEMs are diffused into the stock of building and companies depending on the cost-effectiveness calculus based on implicit discount rates which implicitly include remaining barriers and risk awareness of investors, building owners, and end users. Referring to findings of Hausman (1979), Houston (1983), and the overview given in Decanio and Laitner (1997) we assume an implicit discount rate of 35 %.
- **Least life-cycle cost (LLCC-5) scenario:** This scenario assumes that all cost-effective EEMs diffuse through the capital stock. We assess cost-effectiveness on the basis of a classical life cycle cost calculation using an engineering-type discount rate of 5 %, which implicitly assumes that all barriers to the diffusion of EEMs are overcome and adopters have perfect information and act rationally on the basis of cost-effectiveness.
- **Least life-cycle cost (LLCC-5/35) scenario:** This scenario represents a combination of the two previous scenarios. Adoption based on least lifecycle cost (discount rate of 5 %) is assumed for all EEMs addressed by a particular lot of the EDD, while for the remaining EEMs a higher discount rate of 35 % is assumed. Of all scenarios considered this scenario represents most closely the potential impact of the EDD, as the implementing measures of the EDD are also selected on a least lifecycle cost calculation. As most implementing measures are defined as MEPS, diffusion of related EEMs no longer depends on the investment choice of consumers and firms, but only on the turnover of the capital stock of the related equipment. Although, certainly not the entire mix of current (soft) policies can be explicitly considered in the model, this is the scenario that comes closest to the current EU policy mix addressing energy-efficiency in the tertiary sector.
- **Technical diffusion scenario:** in this scenario the diffusion rate is exogenous input to the model and does not consider restrictions on the cost-effectiveness of the EEMs and even expensive EEMs diffuse through the capital stock. Still, also the technical diffusion does not imply an “unrealistic” development. We assume that the regular turnover rate of capital stock is not affected, which ultimately limits the diffusion of EEMs, particularly if they replace long-living equipment.

The relation of diffusion paths and related energy-saving potentials are shown in Figure 2. The changes in the diffusion paths across scenarios result in different types of energy saving potentials (ceteris paribus).

Thus, the effect of the EDD can be calculated as the difference between the LLCC-5/35 scenario and the LLCC-35 scenario. As outlined in the foregoing section, not all EEMs included in the model are subject to the EDD and its (potential) implementing measures. Many EEMs in the model represent elements of system optimization, are based on behavioural changes or tend to be more ambitious than the MEPS resulting from the ecodesign process. Consequently, to calculate the impact of the EDD, only a selection of EEMs is considered. For comparison, we calculate additional scenarios like the LLCC-5 scenario and the technical diffusion scenario.

Description of the data

PROJECTION OF GLOBAL DRIVERS: NUMBER OF EMPLOYEES AND FLOOR AREA

As outlined above, most of the energy services are linked to a physical driver G. In most cases this is either the number of employees or the floor area differentiated by sub-sector. All these drivers are derived from exogenous sources (e.g. past trends and macro-economic forecasts) and are specific to some of the sub-sectors.

The number of employees is taken from the past employment figures by sub-sectors and countries (1990 to 2009) contained in the Eurostat database (see Table 2). The quality and completeness of this data set differs considerably between countries. Missing data of 2010 was estimated based on figures of previous years. Floor area is calculated by the number of employees and the indicator floor area per employee. Indicators were derived from the Odyssee database for the countries Denmark, France, Germany, Sweden, UK, and Norway. The indicators are differentiated between countries and between most sub-sectors. For the sub-sectors public administration, traffic and data transmission and other services, they are assumed to be the same. Where data was not available for the start year of the model (2010), it was derived from past trends. The occupied floor area per employee changes over time, differently by country. The indicators are partly based on Jochem et al. (2007), Jochem et al. (2008), partly on the ODYSSEE data base, on various country-specific sources, and on own assumptions. Some other drivers are specific to some of the sectors (e.g. number of guests in the hotel sector).

The future development of the number of employee was derived from econometric estimation and ad hoc regression models based on GDP, gross value added and population projections from various sources.

ASSUMPTIONS ON THE DEVELOPMENT OF ELECTRICITY PRICES

Assumptions on the future development of electricity prices represent one of the key scenario parameters and most important drivers, as they determine the cost-effectiveness of EEMs. 2010 electricity prices are taken from Eurostat. Projections assume a constant but in total very moderate increase in the range of 9 to 21% across all countries. The distribution of electricity prices across EU member states is maintained in 2010 is also more or less maintained in 2035 (see Figure 3).

Results

The results are analyzed in three steps. We begin with the aggregated electricity demand for the EU27, before we show the effect on individual energy services and finally look at differences that emerge between countries.

In the rather hypothetical frozen efficiency scenario which includes no energy-efficiency improvements electricity demand of the tertiary sector would increase by about 50 % up to 2035 (Figure 4). This increase is explained both by an increase of fundamental drivers (number of employee and floor area, see Table 2) and by a further diffusion of energy services

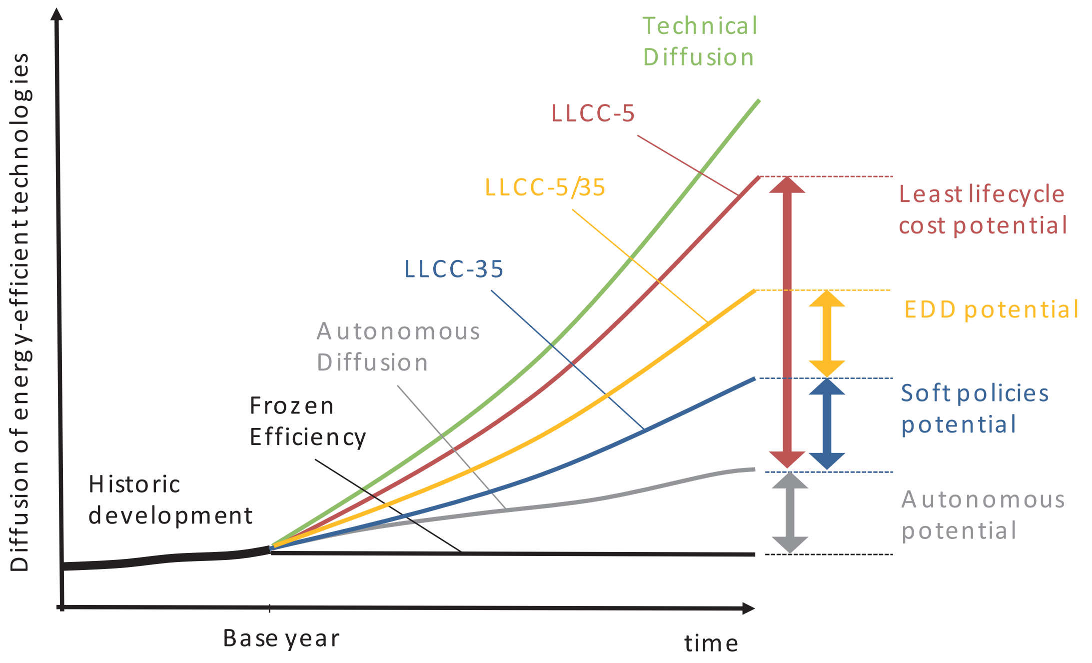

Figure 2. Definition of technology diffusion paths and energy saving potentials.

Table 2. Employees and floor area per sub-sector in the EU27.

	Education	Finance	Health	Hotels, cafes, restaurants	Other services	Public offices	Traffic and data transmission	Wholesale and retail trade	Total
Employees 2000 [1000]	13,368	6,183	17,431	7,459	24,070	14,397	12,449	28,858	124,214
Employees 2010 [1000]	15,609	6,595	22,030	9,540	33,446	15,876	13,696	32,228	149,022
Employees 2020 [1000]	16,013	7,051	24,296	10,167	37,936	17,114	14,640	34,417	161,634
Employees 2035 [1000]	15,674	7,222	26,441	10,879	40,106	17,038	14,994	35,063	167,418
Floor area 2000 [1000 m^2]	845,299	148,993	410,042	324,671	899,784	533,385	449,788	1492,733	5104,696
Floor area 2010 [1000 m^2]	987,994	160,071	526,573	410,093	1245,213	587,568	496,394	1661,160	6075,066
Floor area 2020 [1000 m^2]	1044,259	180,970	616,578	455,977	1494,432	666,131	566,217	1844,334	6868,896
Floor area 2035 [1000 m^2]	1097,953	210,626	762,718	530,297	1778,523	742,560	666,065	2041,230	7829,972

Source: Eurostat, Odyssee, own calculations.

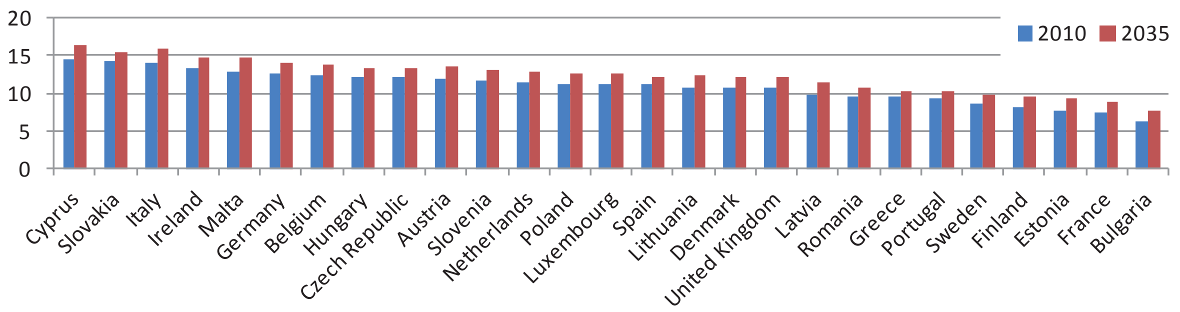

Figure 3. Assumption on electricity prices in 2010 and 2035 (source: Eurostat and own assumptions).

such as ventilation and cooling, ICT services and many more. However, it is more reasonable to assume that at least some EEMs will be diffused, even if there were no policy measures implemented. Such an autonomous diffusion is explained by structural and turnover of equipment stock effects (new appliances and building technology usually is more efficient than existing ones) and by some efficiency activities of the actors in the tertiary sector, albeit on a low level. Nevertheless, as compared to frozen efficiency the demand increase is significantly attenuated to roughly one third (36 %). This result underlines the high relevance of energy-efficiency already in a scenario without policy incentives.

The following three scenarios are all based on economic investment calculus and differ in the (implicit) discount rate assumed.

The impact of the EDD is captured by the scenario LLCC-5/35, in which electricity demand almost stabilizes from 2020 onwards on a level of 874 TWh, which is 5 % higher than demand in 2010. Compared to the autonomous diffusion scenario, the scenario shows a saving potential of about 261 TWh in 2035, assuming that all EEMs addressed by the EDD will diffuse according to their least lifecycle cost (discount rate 5 %) and the remaining EEMs are addressed by other (soft) policies. To calculate the impact of the EDD, however, the autonomous diffusion scenario is not a suitable baseline, because the EDD is only one element in the current policy mix. Instead, the remaining policy mix without EDD should represent the baseline, which is captured by the LLCC-35 scenario (see Figure 2). Accordingly, the calculated savings of the EDD equal about 100 TWh in 2035, or about 9 % of the demand in the autonomous diffusion scenario.

This saving potential, however, is subject to a number of uncertainties. It is an unanswered question how strict the enforcement and monitoring and the resulting compliance of e.g. appliance manufacturers and retail firms will be and how close the implementation of standards follows the least life-cycle cost approach. Further, the baseline, the LLCC-35 scenario, implies a high level of uncertainty. Simulation of firm behaviour, policies and barriers using an implicit discount rate is always a relatively rough approach (see Fleiter et al. 2011) and the quantification of the discount rate used lacks empirical data.

The scenario used as baseline (LLCC-35) assumes that a comprehensive mix of soft policies will overcome most of the information and motivation related barriers. In this scenario, demand increases by about 17 %, which is equal to 980 TWh in 2035. The difference to the autonomous diffusion scenario of 157 TWh is apparent and would certainly require a very comprehensive set of (soft) policies like energy audits and energy management systems.

While this saving potential in the LLCC-5/35 scenario already is substantial, it does not exploit the full potential, as many EEMs are not covered by the EDD, such as system optimization, control measures or operational and behavioural measures. Assuming that other policies would be successful resulting in a least life-cycle cost diffusion of such EEMs as well, the scenario LLCC-5 shows the potential impact. Here, demand falls by an additional 50 TWh until 2035 compared to the scenario LLCC-5/35. However, compared to the year 2010, demand is only about 1 % lower in 2035, mainly because in the short term demand is still increasing until it peaks between 2015 and 2020. Compared to the current EU policy mix, such a scenario can certainly be regarded as rather optimistic.

Finally, the technical diffusion scenario describes the minimum demand that would be achieved by full adoption of EEMs considered in the model without taking costs into account. Such a scenario would exploit additional 140 TWh of electricity savings by 2035 compared to the LLCC-5 scenario. Note that the costs of exploiting this additional potential could still be lower than support for renewable energies on the energy supply side or that higher energy prices could render at least parts of this potential cost-effective as well.

As has been mentioned above, particularly the scenarios based on LLCC are subject to various uncertainties. A very sensitive assumption in this respect is the development of future electricity prices. Here, only very moderate increase has been assumed (+9 to 21 % between 2010 and 2035). Faster increasing electricity prices would move all LLCC-based scenarios closer to the technical diffusion scenario, which in this sense provides the lower boundary, while similarly the autonomous diffusion scenario provides the upper boundary.

Table 3 breaks down the aggregated electricity demand to the contribution of the individual energy services. It can be observed that the dynamics of the individual energy services are different, already in the autonomous diffusion scenario. While the demand for heating even falls from 2010 to 2035, the demand of other energy services increases between 2 % (cooking) and 87 % (ventilation and air-conditioning). Heat pumps are separately modeled and show an even higher growth rate, mainly because demand in the base year 2010 is still on a very low level.

The remaining scenarios are shown as difference to the autonomous diffusion scenario. The effects vary heavily by energy service. For some energy services the EDD is expected to show no effect (same values for LLCC-35 and LLCC-5/35), which has mainly two reasons. Either the EEMs considered are not cost-effective (cooking), or the energy service is out of the scope of the EDD (elevators).

The impact of policies and particularly the EDD not only varies by energy service, but also by country. Figure 5 shows the effect of the LLCC-5/35 scenario as difference to LLCC-35 scenario for the year 2035. The heights of the individual bars represent the saving potential induced by the EDD as share of the electricity demand in the autonomous diffusion scenario in the year 2035. Accordingly, the EDD impact ranges from about 21 % in Portugal to about 5.5 % in the United Kingdom. These large differences between countries result from both the level of electricity prices and the country specific structure of the tertiary sector. The latter is considered in the model in the form of employees and floor area per sub-sector, the diffusion of energy services, which is typically more advanced in countries with higher income and the level of efficiency in the current stock of equipment. For example energy savings related to the energy service ventilation and air-conditioning (AC) are highest in the Mediterranean countries, where AC systems are widely spread already in 2010 but even more in 2035. The efficiency standards, which represent the implementing measures of the EDD, are, however, not differentiated by country.

Furthermore, the results shown in Figure 5 are subject to uncertainty from the baseline used, which is the LLCC-35 scenario. In the following, the impact of the scenario LLCC-5/35 is calculated as difference to the autonomous diffusion scenario (Figure 6). This difference captures the entire effect of the current policy mix (EDD plus other policies). Across the countries, this effect ranges from about 35 % in Cyprus to around 15 % in Estonia. The EU27 average is around 22 % (see Figure 6).

Conclusions

While scenario analysis always contains a certain degree of uncertainty, one can draw the overall conclusion from the scenarios calculated that electricity demand in the EU tertiary sector will probably continue to grow in the coming years. However,

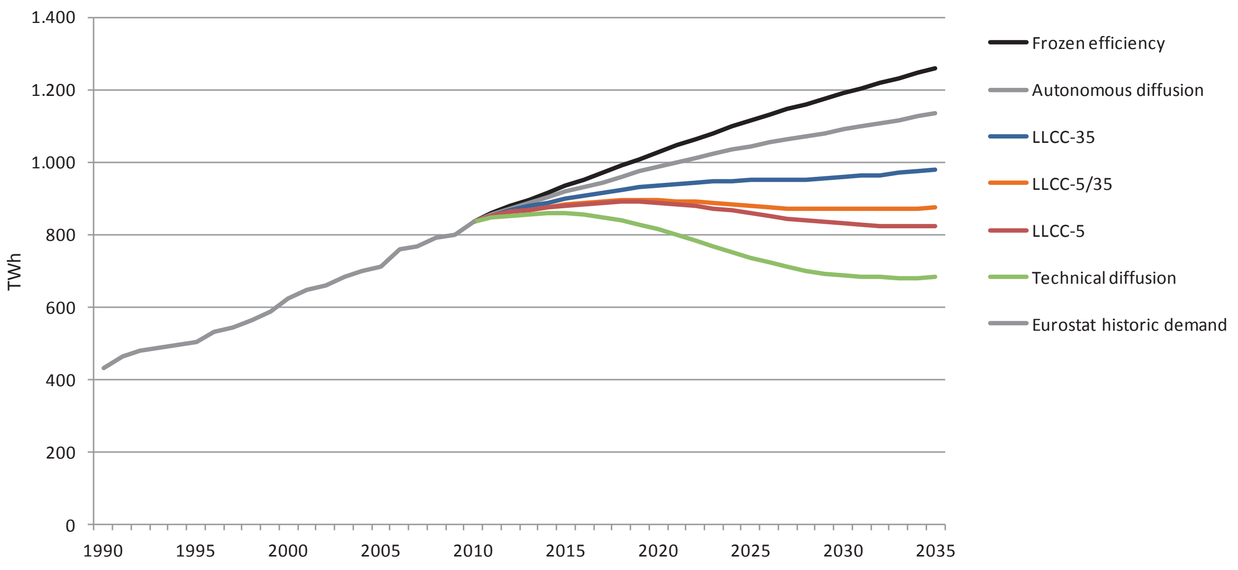

Figure 4. Electricity demand of EU27 between 2010 and 2035 for different scenarios.

Table 3. Electricity demand of the autonomous diffusion scenario in the EU27 and the effect of different policy scenarios in 2035, by energy services.

Energy service	Autonomous diffusion			Saving potential to autonomous diffusion in 2035				EDD potential in 2035*
	2010	2035	Growth 2035/2008	LLCC-35	LLCC-5/35	LLCC-5	Technical diffusion	
Heating auxiliaries	45.2	54.6	21%	0.0	7.5	7.5	16.1	7.5
Cooking	44.9	46.0	2%	5.9	5.9	5.9	13.2	-
Electric heating	48.3	45.7	-5%	1.3	9.7	13.2	17.7	8.4
Elevators	12.4	15.6	26%	2.4	2.4	2.4	2.4	-
Heat pumps	0.6	19.3	3265%	0.0	1.7	1.7	5.2	1.7
Hot water	63.4	85.1	34%	0.0	3.1	3.1	20.3	3.1
ICT data centers	35.0	54.6	56%	10.2	11.0	11.0	11.0	0.8
ICT office	20.1	27.0	34%	4.2	8.2	8.2	8.6	4.0
Laundry	11.6	13.5	17%	n/a	n/a	n/a	n/a	-
Lighting	237.4	261.7	10%	43.0	64.9	80.0	147.1	21.9
Lighting street	31.1	36.1	16%	2.8	14.4	14.4	14.1	11.6
Misc. building technologies	105.1	167.4	59%	21.4	21.4	54.5	64.1	-
Refrigeration	80.0	121.8	52%	39.4	40.1	40.1	45.1	0.7
Ventilation and AC	99.8	186.6	87%	25.0	70.2	70.2	90.0	45.2
Total	834.8	1'135.0	36%	155.5	260.6	312.3	455.1	105.0

** EDD potential = LLCC-5/35 – LLCC-35.*

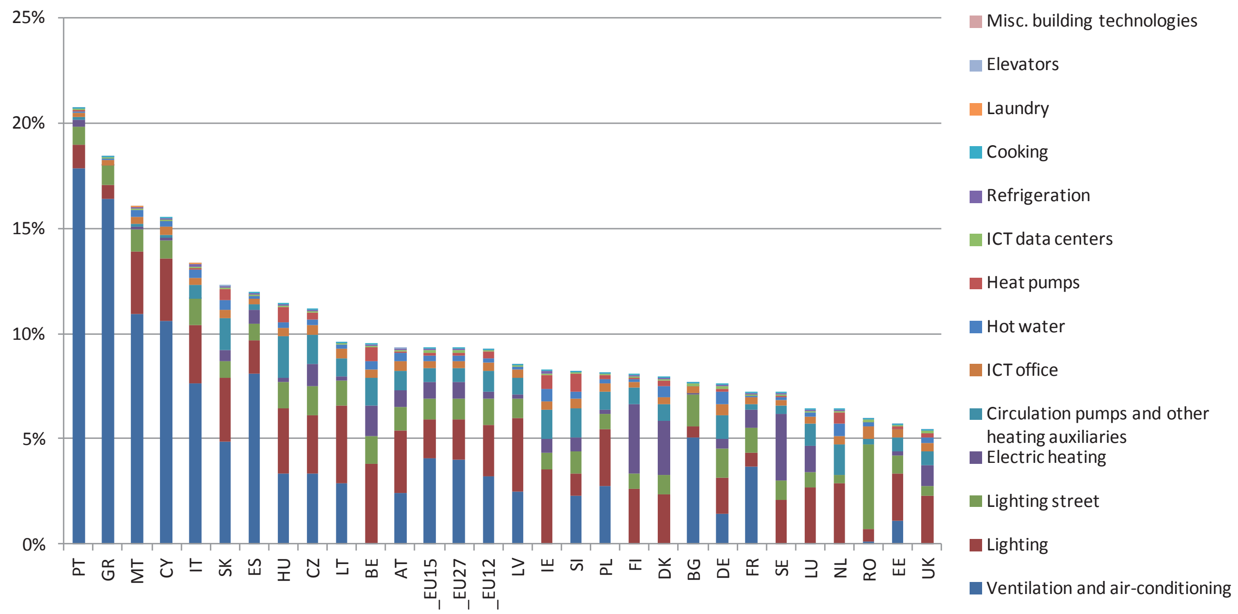

Figure 5. Effect in LLCC-5/35 scenario compared to LLCC-35 scenario as share of autonomous diffusion baseline for 2035 by country.

the policies currently implemented and foreseen for implementation will mitigate this effect to a large extent and demand tends to stabilize in the long term, particularly if the Ecodesign Directive (EDD) is consequently implemented based on the least life-cycle cost (LLCC) approach and if it is accompanied by additional soft policies to address energy-efficiency measures (EEMs), such as system optimization or behavioural measures, and energy services not covered by the EDD and its implementing measures (scenario LLCC-5/35).

If compared to a theoretical scenario in which the intensity of the implemented policies equals an investment decision according to LLCC with a 35 % discount rate (scenario LLCC-35), the EDD results in about 100 TWh additional electricity savings in 2035. If additional policies (energy labelling, energy audits, energy management) of the current policy mix are included, the saving potential is about 260 TWh compared to the autonomous diffusion baseline.

The authors are only aware of only one other study that investigated the aggregated impact of the EDD, which reports electricity savings of 340 TWh (Bertoldi, Atanasiu 2009). The comparison to our results, however, is difficult, as Bertoldi and Atanasiu calculate the savings for the year 2020, aggregate the tertiary and the residential sector, include minimum standards as well as labelling and follow a different methodological approach.

Though it is certainly difficult to consider all country specific differences in such a modelling approach and the country spe-

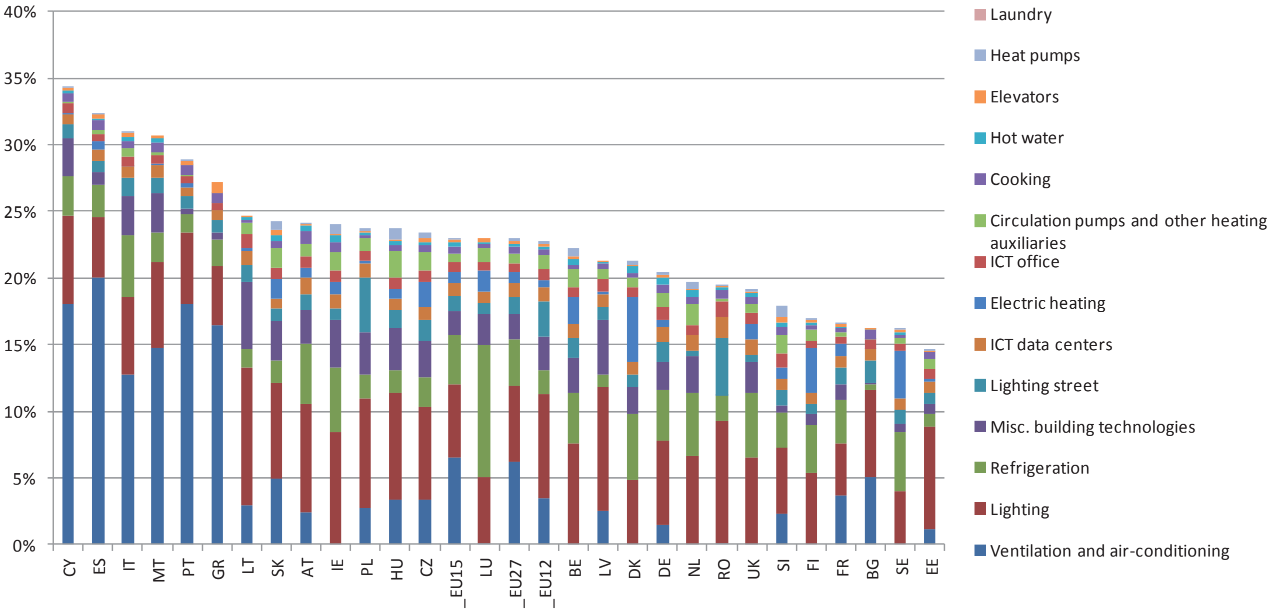

Figure 6. Effect in LLCC-5/35 scenario compared to autonomous diffusion baseline for 2035 by country.

cific results should be interpreted with caution, some country specific conclusions can be drawn. Mainly, the impact of the EDD varies by country and shows a range of 5.5 % to 21 % of the countries' electricity demand in the autonomous diffusion scenario. If additional soft policies are included, the potential impact ranges from 15 to 35 %.

From a methodological point of view, the integrated model-based analysis using FORECAST-tertiary has shown a number of advantages. First of all the dynamics of drivers that is inherently part of the tertiary sector leading to strongly growing electricity demand is taken into account. Secondly, explicitly modelling energy-efficiency measures and their diffusion into the different sub-sector, differentiating by energy-services and countries, makes this model particularly suitable for assessing energy-efficiency policy measures such as those defined in the different EDD lots. Finally, taking into account costs, energy prices and discount rates are explicitly offers the potential to place policy into an economic framework and to conduct cost-benefit analysis.

Note however that at the current stage of model implementation there is still a certain room for improvement. The modelling of the EDD could certainly be more precise, if the plenty of material available from preparatory studies and implementing measures is more systematically integrated in the model. Also, we did not consider a potential future extension of standards nor the adoption of even more ambitious implementing measures or the inclusion of additional energy services. For such a long time horizon, these aspects are relatively likely, although difficult to forecast. Including such assumptions in the model would certainly increase the potential of the EDD more towards the scenario LLCC-5.

Further, our analysis relies heavily on the assessment of life-cycle costs. Costs are, however, difficult to assess and might develop quite dynamic, as particularly for the relatively new equipment and technologies, widespread diffusion will probably result in experience effects and falling costs. To a certain degree, this effect is captured in the specification of EEMs in the model, although not systematically.

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