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Scenarios of energy demand and uptake of renovation activities in the EU commercial building sector

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Executive Summary

The CommONEnergy project aims to "re-conceptualize shopping malls through deep retrofitting, developing a systemic approach made of innovative technologies and solution sets as well as methods and tools to support implementation and to assess their environmental and social impact in a life cycle approach."

The European wholesale and retail sector is the big marketplace of Europe, contributing with around 11% of the EU's GDP [1]. Therefore, sustainability of the retail sector will significantly contribute to reaching the EU environmental and energy goals.

To enable the development of energy saving strategies to address Europe's shopping centres, it is important to understand the energy demand of the sector both now and in the future.
This report:

- analyses energy demand for energy services in different shop types and shopping centres built in different periods;
- calculates the final energy demand of the shopping centre building stock in all EU-28 and Norway;
- models the final total energy demand from 2012 to 2030 according to different potential scenarios for the future.

Analysis
Total final current and future energy demand and CO_2-emissions from Europe's shopping centre's building stock is calculated using a bottom-up building stock modelling approach. The shopping centres are categorised based on the building period, building size and types of shops in the building, and for each category (see chapter 4.1.2.) the energy demand for space heating and cooling, lighting, ventilation, refrigeration and appliances is calculated (see chapter "Energy demand calculation"). The four scenarios were calculated considering different parameters such as thermal renovation of the building envelope, change rate of the lighting, appliances and refrigeration systems as well as new building construction rate. These parameters are influenced by the country specific gross domestic product and its development (GDP), market uptake of the innovative technologies and policy implications. The scenarios reflect these abovementioned parameters and show their impact on the final energy demand and greenhouse gas development: (1) the first scenario is a status quo scenario including moderate energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating; (2) the second scenario includes policies addressing more ambitious measures and control systems for lighting, appliances, refrigeration, ventilation and space heating; (3) the third scenario includes policies addressing higher energy efficiency like in the 2nd scenario and additionally there is a renovation rate obligation for space heating; (4) the fourth scenario includes an external framework condition taking new shopping centre developments into account

considering growing market share of the internet sales. This last scenario is combined with the 1st scenario.

Scenario	Energy efficiency measures	Renovation rate	New building development
1 Status quo Moderate energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating	Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented to reduce specific energy demand by 57%, 49%, 50%, 25%, 26%, respectively	Moderate yearly renovation rate - 1.8% thermal renovation rate reducing space heating and ventilation, 5.5% for lighting, 5.3% for refrigeration and appliances	Linked to GDP scenario (OECD (2016)) from 2012-2030 and historical sales growth resulting in high growth in the mature markets and limited growth in saturated markets
2 Policies for higher efficiency of lighting, appliances, refrigeration, ventilation and space heating and control systems	Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented to reduce specific energy demand by 59%, 53%, 53%, 45%, 36%, respectively	As in the scenario 1	As in the scenario 1
3 Policies for higher energy efficiency like in scenario 2 plus increased renovation rate for space heating	As in the scenario 2	Yearly thermal renovation rate is increased to 3.5% reducing space heating and ventilation	As in the scenario 1
4 Increased internet sales scenario combined with moderate energy efficiency measures	As in the scenario 1	As in the scenario 1	Annual initial sales growth is reduced by 1.5% which reduces the new building construction rate

Findings

Final energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting was 43 TWh in the shopping centre building stock in 2012. The highest energy demand in the shopping centre buildings is in the United Kingdom followed by Germany and Spain. Data on the total energy demand in 2012 for each European country is the starting point for the energy demand development until 2030 in all four scenarios. The share of energy demand is:

Share of energy demand in shopping centres	
Lighting	33%
Space cooling	25%
Appliances	16%
Refrigeration	15%
Ventilation	6%
Space heating	5%

Under scenario 1, 36% of the total energy savings can be achieved by 2030 using moderate energy efficiency measures. The highest reduction (59%) of energy demand from 2012 to 2030 can be achieved by replacing the lighting technologies.
In the scenario 2, which includes higher measures for lighting, appliances, refrigeration, ventilation and space heating and control systems, 45% of the total energy savings can be achieved by 2030. Replacement of lighting also has the highest energy saving potential.+

The figure below shows the change in the final energy demand in the shopping centre building stock from 2012 to 2030 in all four scenarios.

Figure 1 Change in total energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting from 2012 to 2030 in the European countries in different scenarios

Overall, there is a reduction of energy demand in all scenarios in the saturated markets (i.e. Austria, Ireland, Norway, Sweden and the United Kingdom) and energy demand increase in immature markets (i.e. Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia) from 2012 to 2030.

In the *status quo scenario*, the final energy demand increases from 2012 to 2030 in the immature markets. This is due to the increasing number of the new buildings. In saturated markets, total energy demand is decreasing, due to renovation of the existing shopping centre buildings and a low rate of new construction due to the market saturation.

Scenario 2, which includes more ambitious measures, the energy demand reduction from 2012 to 2030 is higher compared to the previous scenario. The final energy demand from 2012 to 2030 will decrease further in saturated market, and in immature markets the increase in energy demand is much lower compared to the status quo scenario.

In scenario 3, which has an increased thermal renovation rate, slightly greater savings are achieved.

In scenario 4, the online market growth reduces shopping centres sales and in turn lowers new construction rates. It is assumed that unsaturated shopping centre markets are less affected by internet sales than saturated markets. In Bulgaria, Lithuania, Poland and Romania, there is still a growing trend in the future energy demand. However, the increase in energy demand is much lower compared to the previous scenarios.

CO_2-emission scenarios have the same trend as the energy demand scenarios. While in the saturated markets CO_2-emissions are going down from 2012 to 2030, in non-mature markets, there is an increase in the total CO_2-emissions in the same period.

Conclusions

1: The energy demand for lighting makes up the highest share on the total final energy demand. The energy demand for lighting in the total shopping centre building stock in EU28 and Norway can be reduced by up to 62% from 2012 to 2030 with policies for ambitious energy efficiency measures and control systems. Improvements and new innovative technologies (LED, control systems) have a high potential to reduce energy demand in the shopping centres.

2: Electricity is the main energy carrier covering energy demand in the European shopping centres. Thus, reduction of the greenhouse gasses is highly dependent on the electricity sector and its decarbonisation.

3: In the transition economies and especially in Bulgaria, Lithuania, Latvia, Poland, Romania and Slovakia there is an exploitable untapped potential for the new shopping centre development. The share of the new buildings built between 2012 and 2030 on the total building floor area in 2030 is above 50%. Consequently, the total energy demand in the shopping centre building stock is growing until 2030 in these markets. There is a need for new and innovative energy efficiency technologies or new green business models to ensure energy efficiency. Building codes and certification schemes to enhancing green branding could play an important role in encouraging investment in energy efficiency measures for the shopping centres.

4: Policy makers can support and guide shopping centres to reduce their energy demand through clear and stable policies which provide long term drivers to increase energy efficiency. Policies addressing shopping centres must pay attention to the complex physical structure of shopping centres and multiple stakeholders (owners, tenants, customers and administration) involved in decision making processes. Policies addressing shopping centres should build on existing and efficient voluntary certification schemes such as BREEAM certification and green leases. Ex-ante evaluations of the impact of policies should be conducted to improve understanding and aid development of successful approaches. A further policy paper providing recommendations to improve European policy is currently being developed.

1. Introduction

The CommONEnergy project aims to "re-conceptualize shopping malls through deep retrofitting, developing a systemic approach made of innovative technologies and solution sets as well as methods and tools to support implementation and to assess their environmental and social impact in a life cycle approach." The project encourages the development of sustainable shopping centres by supporting the energy efficient refurbishment of existing shopping centres and providing knowledge which will foster the efficient planning and design of new shopping centres.

To enable the development of energy saving strategies and recommendations in a framework addressing Europe's shopping centre, there is a need for a comprehensive energy demand analyse and an outlook on future energy demand scenarios.

The potential to reduce energy demand in the shopping centre building stock is strengthened compared with other buildings due to the opportunities to implement cost effective energy saving measures, a very high renovation (redesign) rate and the immaturity of the shopping centre market in many European countries, with expectations for many centres to be built over the next years, which has an impact on the future energy demand.

The non-residential building sector is more heterogeneous and complex compared to the residential sector due to variations in usage pattern, energy intensity and construction techniques. Shopping centre buildings equate this complexity. The main aim of this paper is to calculate final energy demand of the European shopping centre stock until 2030 by defining four different scenarios which address some of the abovementioned barriers. Moreover, the recommendations on how to increase the use of energy efficiency measures and overcome the barriers are derived.

This report aims to

1) analyse energy demand for energy services in different shop types and shopping centres built in different periods;

2) calculate the final energy demand of the shopping centre building stock in all EU-28 and Norway;

3) model the final total energy demand from 2012 to 2030 taking into account new building construction and energy saving while retrofitting the existing building stock.

This report contains the following steps: (I) describing EU shopping centre, its energy consumption and energy efficiency drivers and barriers (II) describing the methodology and the main input data of the shopping centre building stock (III) defining the scenario framework (IV) showing the results on the development of the gross leasable area of the shopping centres and their energy demand and finally (V) deriving conclusions.

2. EU shopping centres: floor area, energy consumption and development

The European wholesale and retail sector is the big marketplace of Europe, contributing with around 11% of the EU's GDP [1]. Therefore, sustainability of the retail sector may significantly contribute to reaching the long-term environmental and energy goals of the EU. Within the retail sector, shopping centres are of interest due to their structural complexity and multi-stakeholders decisional process, to their high potential of energy savings and carbon emissions reduction, as well as to their importance and influence in shopping tendencies and lifestyle.

We have come a long way from medieval markets, Middle Eastern bazars and 18th century arcades to the modern shopping centres we know today. The 1950s, the 1960's and 70's established the shopping centre as the most dominant retail form in Western Europe. By the end of the 1970's they covered a retail space of 25 million m^2. Today, there are 9,263 shopping centres in Europe with over 151 Km2 of gross leasable area (GLA) in the EU28, including Norway (ICSC, 2015). This means 6.7 percent of all retail and wholesale buildings in Europe are shopping centres. The total floor area of the European retail sector is distributed rather unevenly across the continent. As Figure 2 shows, a small number of Member States, namely the UK, Germany, Spain, France Italy, the Netherlands, Poland Sweden make up over 74% of the gross leasable area of the EU28 & Norway. Note that this figure is for shopping centres over 5,000m^2.

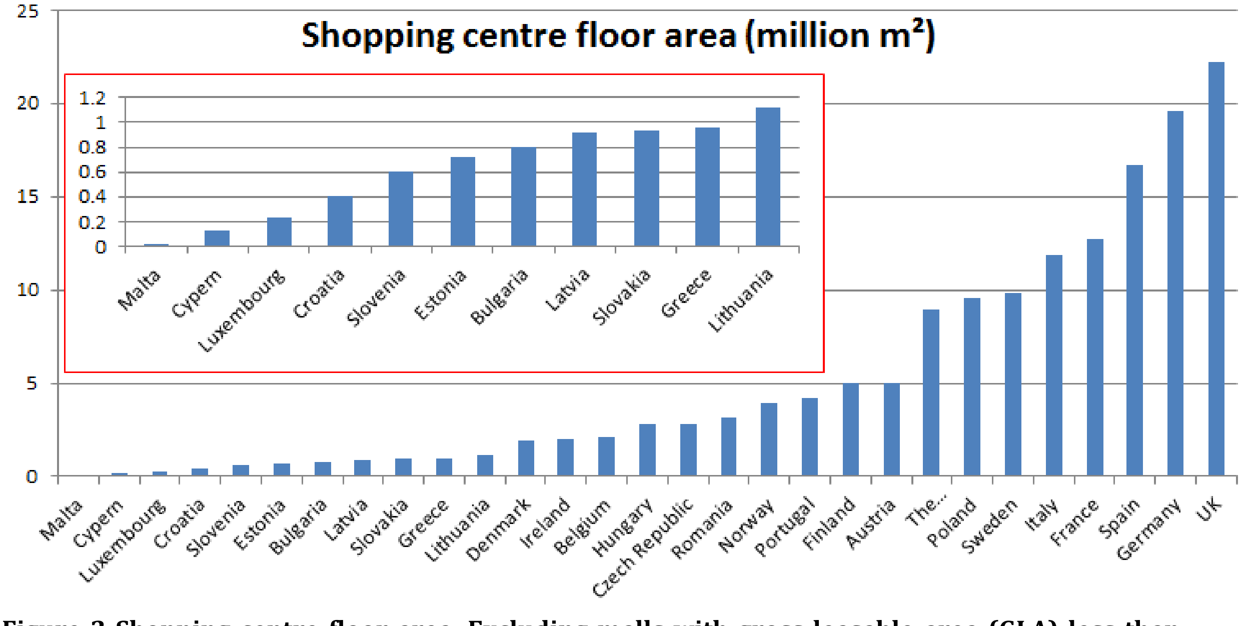

Figure 2 Shopping centre floor area. Excluding malls with gross leasable area (GLA) less than 5,000 m^2 (ICSC, 2015)

European total retail sales in 2014 were worth more than €2.7 trillion, and compared to the total EU GDP in 2014 of €13,920 billion (European Union, 2014), the retail sector in 2014 contributed 19.3% to the EU GDP. The value-added tax from sales in the retail sector, and more specifically in shopping centres, were in 2014 approximately €109.6 billion. According to data from the database of Real Capital Analytics, in 2014 there was an investment of €20.6 billion for shopping centre assets and over half (51.4%) of this investment originated from cross-border sources. Shopping centres accounted for 9.5% of the total European commercial property investments of 2014. The employment impact of the sector is not negligible, since the number of people in Europe whose employment is an extent related to shopping centres is roughly 4.2 million, or 2% of the total workforce (ICSC, 2015).

Shopping centres vary in their functions, typologies, forms and size as well as the (shopping) trip purpose. In order to be able to consider the shopping centre building stock as one segment, a shopping centre definition was defined in an earlier phase of the CommONEnergy project as *"A formation of one or more retail buildings comprising units and 'communal' areas which are planned and managed as a single entity related in its location, size and type of shops to the trade area that it serves. The centre has 1) a retail complex containing several stores or units and 2) a minimum gross leasable area (GLA) of 5,000 m² except some specific types of shopping centres, e.g. market halls."*

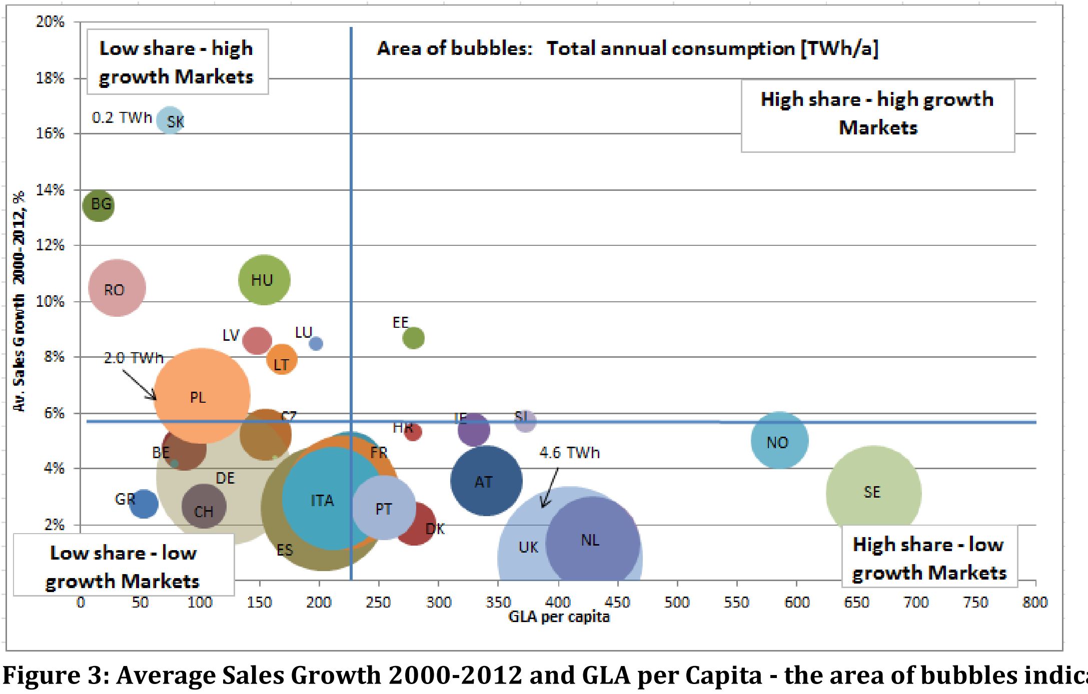

Figure 3: Average Sales Growth 2000-2012 and GLA per Capita - the area of bubbles indicate the total annual energy consumption, blue lines indicate the mean values

The shopping centre building stock is expected to growth especially in the emerging markets, and there is a clear relation between market growth and gross leasable area.

Mature markets usually have low sales growth rates at large GLA per capita. In general, for non-mature markets it is the opposite. This concept is now being extended to energy consumption of shopping centres. Figure 3 is plotting sales growth against GLA per capita. In addition, the bubble size shows the annual energy consumption of shopping centres in TWh per year.

While markets with high sales growth rates are mainly marked by new construction, while refurbishment plays a minor role. This is confirmed by the building age. Redeveloping existing buildings towards energy efficient shopping centres is the main challenge.
Countries with low sales growth rates and high GLA per capita, considered as mature markets, will see only limited activity in relation to the development of new centres. However, these countries, namely Austria, Denmark, Finland, the Netherlands, Ireland, Norway, Portugal, Sweden and the United Kingdom, account for 41.2% of the total energy consumption. As there is a high retrofitting potential, they provide a huge energy saving potential related to the building renovation activities.

The situation in countries with low sales growth rates and low GLA per capita varies from country to country. Moreover, many countries are very close to the average, whether in sales growth or in GLA per capita. This is the case for Czech Republic, France, Italy and Spain. Some others have strict regulations limiting the GLA per capita and others, such as Greece, face difficult economic conditions. Nevertheless, this part accounts for the largest portion of the total energy consumption (45.0%) and offers opportunities for both new constructed shopping centre as well as renovations.

From a more general point of view, it can be concluded that countries with low sales growth – most of them mature markets – offer the highest potential for retrofitting measures in existing shopping centres. These countries account for 86.2% of the total annual energy consumption and offer high potential for energy savings via increasing efficiency. Nevertheless, it is important to spread knowledge about energy efficient and sustainable shopping centres among all countries to avoid previous mistakes in developing markets, such as technological lock-ins and inefficient use of energy.

3. Energy efficiency drivers and barriers in the shopping centres

3.1. Drivers

Retailers are starting to accept that their businesses have environmental impacts and are taking steps to assume responsibility. While some retailers rely on certification, others go beyond and proactively drive change in their value chains, including the retail spaces. Small, cooperative retailers are driving this transition while price-led grocery retailers tend to be laggards. The interaction of retailers with consumers tends to influence the environmental behaviour of the second both through awareness and through better environmental performance along the supply chain (David Styles, 2012). Retailers are realising investments in cost saving technologies and strategies and are promoting them as progress towards their sustainability aims. (BTC, 2012) (Westfield Corporation, 2016) (SES) (Yudelson, 2009) (Redevco , 2016). Such communication and the sustainability plans put forth by retailers has been shown to increase the loyalty of customers (Bolton & Mattila, 2015).

The industry has been willing to implement strategies to build, renovate and operate more energy efficient stores, having cost savings and the factor driving change. Energy costs follow labour costs as the second largest expenditure for retailers (ASHRAE, 2011). Retailers are aware of this reality and have been engaging in own and policy led actions to reduce energy demand (Retail Forum, 2009). In order to increase profit margins and honour their sustainability commitments, including their energy reduction targets, many leading retailers are improving the energy performance of their facilities (Jamieson & Hughes, 2013).

In addition to the drive to cut energy expenditure, energy efficiency is being implemented as part of corporate social responsibility initiatives. Barriers to green consumption have been identified in the literature (Gleim, Smith, Andrews, & Cronin, 2013) and CSR strategies have been developed in order to address these barriers and promote energy efficient behaviour by leading by example. Retailers are using energy management to increase customer loyalty, be more competitive, reduce operating costs and mitigate their impact to their environment. These corporate programmes have an impact on buildings since they set targets, improve the energy efficiency of facilities, and purchase or invest in the installation of renewable energy sources (Jamieson & Hughes, 2013). Furthermore, policy-led actions are targeting major energy consumers of the retail sector, such as grocery stores that require excessive amounts of cooling, through the Retail Forum, an initiative of the European Commission and key European retailers, that is cantered on promoting sustainable consumption and exchange best practices among retailers that reduce their environmental footprint (Retail Forum, 2009). Moreover the JRC (Joint Research Centre) is facilitating the exchange of best environmental management practices in the retail trade sector by identifying key technologies, methods, measures and actions that organisations can use to limit the environmental impact of aspects under their control or aspects that they have an influence on (Schönberger, Galvez Martos , & Styles , 2013).

3.2. Measures to reduce energy consumption

Shopping centres have high energy consumption and therefore high energy costs, so stand to gain the most from ambitious renovation measures. The value of assets can be increased as a proportion of the energy saved, and as such, deep renovations offer both potential savings with realistic pay back periods, and an increase in asset valuation. There are many measures that building owners may undertake to decrease heat losses, improve synergies in the system design, ensure a healthy indoors environment and, in short, deliver a building of high quality.

Windows are key for the level of energy performance, since they are the building element that often has the highest heating transmittance and can create air leakage and thermal bridges where they join with surrounding building elements. Straube (2014) identifies some key solutions to improve thermal performance, including an increase of windows performance, and a limitation of the window to wall ratio. The best available double glazing windows that are gas filled and have fiberglass frames reach very low U values of less than 0.3 $W/m^2{\cdot}K$, and triple glazing is available with U values of less than 0.15 $W/m^2{\cdot}K$. In addition to the high energy performance of windows, installers need to ensure that the thermal resistance of the window frame is aligned with the thermal resistance of the wall, thus avoiding thermal bridges and air leakage. In order to achieve this, frames need to be sealed and be filled with foamed insulation. Straube (2014) also suggests that architects limit the window-to-wall ratio between 20-40%, and reach 50% only when using the best available technology in window performance.

Energy efficiency improvements very often include insulation but focus should also be applied to the **craftsmanship** of installing insulation and upgrading **the building envelope**. Haves, Coffey, & Williams (2008) identified that in the case of Big Box retail typologies insulation resulted in smaller efficiency gains due to the “core-dominated nature of the loads and the diminishing returns from insulation”. Their research shows small improvements in the overall energy performance following an improvement of the thermal characteristics of the building envelope. The US Department of Energy provides an explanation by identifying that the payback period for improving the energy efficiency of the building envelope is more closely correlated to the cost of installation, rather than on the energy performance of the material (US DOE, 2014).

Air leakage and thermal bridging within the assembly of the envelope is related to low payback period (US DOE, 2014). Air leakage through critical components by-passes insulation and renders it ineffective. The ASHRAE (2011) has created a guide on thermal bridges and air leakage with specific consideration and strategies for a number of climate zones. It provides recommendations by targeting the often faulty elements of the envelope, such as junction points. Steel frames for example and concrete junctions are building elements that facilitate the creation of thermal bridges, where heat curves around insulation material. Straube (2014) also identifies solutions and benefits in increasing wall and roof insulation with the purpose to control thermal bridges and secure airtightness. Airtightness, in addition to improving the effect of insulation, also ensures good indoor air quality by reducing water vapour condensation and by improving comfort.

Lighting makes up between 30% and 50% of all energy used in retail stores and it is considered the most cost effective opportunity to improve energy efficiency and increase productivity. For specialised stores the share of energy expenditure for lighting can reach up to 80% (Schönberger, Galvez Martos , & Styles , 2013). The installation of lighting controls, use of natural lighting and investment in advanced technologies such as LEDs can reduce lighting energy expenditure by up to 80% (Fedrizzi & Rogers , 2002) but might not be always adopted due to payback periods of longer than 3 years. Lighting requirements in shopping centres can be as high as 100kWh/m2.y in order to meet basic lighting requirements (i.e. parking spaces) and effect lighting requirements in order to produce a desired effect on products (i.e. attractive colours). Lighting has crucial role in marketing and selling products, and increasing the energy efficiency of lightning must not compromise on the ability of retailers to sell their products. The parameter to control therefore is not energy consumption but lighting power density, or light per unit of power (Schönberger, Galvez Martos , & Styles , 2013). Daylight harvesting and lighting controls are justifiable in low energy buildings and technical measures to improve a retail building's energy consumption should use occupancy and daylight controls for lights and similar equipment (Straube, 2014).

The HVAC systems of shopping centres regulate the various heating, cooling ventilation and air conditioning parameters of the building. As such, they are of high importance to the energy efficiency of the building operations and their optimisation can facilitate important energy savings. Depending on the building occupancy, the presence or not of food retailers and other specialised shops, the HVAC system may prove to be highly complex. Simple solutions include the reuse of waste heat from refrigeration activities and the adjustment of the system according to lighting upgrades (David Styles, 2012). Straube (2014) suggests that ventilation should be separated from heating and cooling operations because big commercial buildings need to move large quantities of hot or cold air, and that creates additional energy requirements for fans. In order to save unnecessary expenses, it is possible to minimise the air movements around a building by creating a separate system for ventilation and dehumidification and another system for heating and cooling.

A dedicated outdoor air ventilation system with a heat exchanger can be an energy saver since it moves air only when ventilation is needed, instead of when heating and cooling needs present themselves.
ASHRAE (2011) also supports the separation of the three functions of heating & cooling, ventilation and dehumidification in order to achieve maximum efficiencies within each component. When these systems are separated, it is suggested (Straube, 2014) that buildings should not over-ventilate (since ventilation needs to be running at low level to remove pollutants), but that they should have a demand controlled ventilation systems and that they should be using heat recovery methods. Energy recovery ventilation technology continues to emerge into the mainstream and can improve the functioning of the HVAC system by reducing the energy demand whole system by 30% (Hastbacka, Dieckmann, & Bouza, 2013).

Retail operations have distinct energy consumption patterns according to the types of products offered and the different concepts of sale. When examining the share of energy consumption used in **refrigeration**, a basic distinction is made between food and non-food retailers, or whether or not shopping centres include a significant share of food retailers. Retailers where food needs preservation use typically 50% of their energy consumption on refrigeration and less than 30% on lighting. HVAC accounts for 15%-20% (Galvez-Martos, Styles, & Schoenberger, 2013). Retailers are aware of their energy expenditure and are taking steps to minimise it by implementing energy efficiency measures in the system of refrigeration, such as using natural refrigerants to reduce greenhouse gas emissions, defining cooling zones in the stores, and covering the refrigeration display with glass lids (Retail Forum, 2009).

Renewable energy in retail
Renewable energy needs to consider alongside energy efficiency, but alternative energy sources should be implemented after measures that minimise the demand and optimise the use of energy. Renewable energy needs to be strongly integrated into the building's energy management system (Tassou, Ge, Hadawey, & Marriott, 2010). In terms of technologies, shopping centres have been using solar thermal tube collectors for hot water; biomass boilers, geothermal heat pumps, cold storage and CHP for heating and cooling needs; and the purchase of renewable energy or generation on site or investment in RES on other sites. (Schönberger, Galvez Martos , & Styles , 2013).
The generation of renewable energy ranges from 5 to 80 kWh/y.m2 of sales area, while retailers usually install PVs or wind turbines but rarely in an integrative manner to the wider building complex of the shopping centre. A better incorporation of renewable energies is being realised on a few lighthouse projects of retailers, where the buildings are nearly zero

energy, meaning they are highly energy efficient, have no air leakages, have an optimally operating HVAC system and cover a significant amount of their energy needs through renewable sources. These projects generate knowledge that should become the norm and strategically applied across all store locations, if retailers are to minimise their environmental impacts (Galvez-Martos, Styles, & Schoenberger, 2013).

3.3. Barriers

The barriers of implementing technical building systems or measures to reduce energy demand in retail environments to be recognised. Primarily, since profitability is the primary objective of shopping centres the attention is on attracting clients and increasing their spending. Cost savings through energy efficiency, while substantial, might not be high on the list of measures due to the lack of consumer demand.

Reducing energy needs might also be perceived negatively if it decreases the thermal comfort, the air quality, or impacts the shopping experience in terms of the presentation of goods.

Another barrier is lack of knowledge. Stakeholders, such as tenants and employees, in shopping centres are unaware of the energy use of their working environments and therefore put little or no effort towards the aim of saving energy. The lack of widespread certification or awareness measures, such as displays of real consumption, prevent potential engagement of various stakeholders in the decision making process of shopping centres.

Financial barriers are also seen in the form of the high upfront costs of installing new technical systems and therefore most owners might opt for the cheaper, lower cost and shallow renovation solutions. However, incentives to move to deep renovations or to even achieve positive energy building status would provide significantly more added benefits.

4. Scenario modelling

The main aim of this section is to calculate the scenarios for the total energy demand development in the EU28 shopping centre building stock from 2012 to 2030. The scenario modelling is carried out using a bottom-up approach by breaking down the shopping centres into segments and by applying the renovation rate and renovation depth as the main drivers for the future energy savings. These two indicators are influenced by different policy measures.

This chapter contains the following steps: (I) defining the scenario framework and the key parameters driving the future energy demand development (II) describing the main input data and disaggregation of the shopping centre into the segments (III) describing the methodology on how calculate specific energy demand for space heating, cooling, lighting, appliances, refrigeration and ventilation (IV) showing the results on the development of the gross leasable area of the shopping centres and their energy demand as well as greenhouse gas emissions scenarios (IV) and finally (V) deriving conclusions.

4.1. Methodology and input data

Total final current and future energy demand as well as CO_2-emissions by 2030 in the shopping centre's building stock is calculated using a bottom-up building stock modelling approach. The shopping centres are categorised based on the building period, building size and types of shops in the building. For each category, the specific energy demand for space heating and cooling, lighting, ventilation, refrigeration and appliances is calculated.

Modelling of the future energy demand and greenhouse gas emissions is based (I) on the development of the shopping centre building stock, taking into account the renovated floor area and new building construction and (II) on the specific energy demand of the installed new technologies for appliances, lighting, refrigeration, space heating and space cooling. Four different scenarios are calculated showing the influence of abovementioned parameters.

The detailed calculation approaches are explained in more detail below.

4.1.1. Scenario framework

The shopping centre sector has been very dynamic in recent years. The growth and market saturation is influenced by different parameters such as demographic development and consumer incomes, cultural preferences, difficulties in obtaining government permits, planning policies and dominant presence of other retail formats (DTZ 2012), (EMEA 2013). We built four different scenarios which reflect these abovementioned parameters and tried to identify their impact on the final energy demand and greenhouse gas development: (1) the first scenario is a status quo scenario including moderate energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating; (2) the second scenario includes policies addressing more ambitious measures and control systems for lighting, appliances, refrigeration, ventilation and space heating; (3) the third scenario includes policies addressing higher energy efficiency like in the 2nd scenario and additionally there is a renovation rate obligation for space heating; (4) the fourth scenario includes an external framework condition taking new shopping centre developments into account considering growing market share of the internet sales. This last scenario is combined with the 1st scenario. Parameters used in all scenarios are summarized in Table 1.

(I) *Status quo scenario*. In general, system component replacement and renovations are more frequent in the wholesale and retail sector than any other sector (Bointner et al, 2014) because a modern design is essential for the excitement of shopping. The market uptake and diffusion of energy efficient technologies are in place in this status quo scenario. Moderate yearly renovation rate of the thermal renovation reducing space heating is 1.8% and the replacement rates of other energy services are as follows: 5.5% for lighting, 5.3% for refrigeration and appliances. Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented which reduce the specific energy demand by 57%, 49%, 50%, 25%, 26%, respectively. New construction is based on shopping centre market sales in the respective country. In general, the lower the market saturation, the more shopping centres will be built and extended.

(II) *Scenario including policies addressing more ambitious measures and control systems for lighting, appliances, refrigeration, ventilation and space heating*. The same replacement rates as in the status quo scenario are applied but energy efficiency measures are more ambitious. Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented which reduce specific energy demand by 59%, 53%, 53%, 45%, 36%, respectively. There are policies triggering investments in higher energy measures and there is the mandatory use of active control systems for lighting, appliances, refrigeration, ventilation, heating, and cooling systems. Building automation according to EN 15232 offer large energy saving potential in wholesale and retail (Siemens, 2016). According to Siemens (2016) 5% additional savings are assumed for lighting, appliances and refrigeration, 13.5% for heating and 27% for ventilation and cooling. These savings are equal to a shift from C (standard case) to B (advanced energy efficiency) class building automation control systems in the wholesale and retail sector.

(III) *Scenario including policies on renovation depth and rate*. This scenario includes the energy efficiency measures and control systems as in the second scenario and additionally there is an obligated renovation rate. On top of technologic and economic solutions as introduced in the previous scenarios, legal obligations to foster energy efficiency could lead to further energy demand reductions. For instance, literature showed that thermal renovation is not always cost-effective in the shopping centres (Haase et al 2015, Bointner et al, 2014). That is why the shopping centres are not willing to invest. These retrofitting solutions, however, provide a huge potential to reduce energy demand and greenhouse gas emissions. In this scenario, the renovation rate obligation is implemented. Yearly renovation rate of thermal renovation reducing space heating is increased by 3.5 %.

(IV) *Scenario considering growing market of the online shopping*. More and more people search and buy goods and services in web shops. This is comfortable, independent from opening hours and location. The online market is growing every year. As a consequence, conventional shopping centres have to re-think their sales strategies. On the other hand, internet sales are not a full substitute to traditional markets but partially complimentary. For instance, customers order/reserve a good in the internet and check the quality, fit, etc. in the shop before making their purchase decision. It can be assumed that unsaturated shopping centre markets are less affected by internet sales than saturated markets, in which shopping centres lose their attractiveness due to the online shopping. This leads to lower footfall, reduced shopping centres sales, and in turn to lower construction rates and/or an increased change of use, e.g. a shopping centre is rededicated to an office building. This assumption is modelled with an annual reduction of the initial sales growth by 1.5%.

Table 1 Parameters used in four different scenarios

	Energy efficiency measures	**Renovation rate**	**New building development**
1 scenario (status quo scenario including moderate energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating)	Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented which reduce specific energy demand by 57%, 49%, 50%, 25%, 26%, respectively	Moderate yearly renovation rate (thermal yearly renovation rate reducing space heating and ventilation is 1.8% and for other energy services is as follows: 5.5% for lighting, 5.3% for refrigeration and appliances)	Linked to GDP scenario from 2012-2030 (OECD (2016)) and historical sales growth resulting in high growth in the mature markets and limited growth in saturated markets
2 scenario (policies addressing higher measures for lighting, appliances, refrigeration, ventilation and space heating and control systems)	Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating are implemented which reduce specific energy demand by 59%, 53%, 53%, 45%, 36%, respectively	As in the first scenario	As in the first scenario
3 scenario (policies addressing higher energy efficiency like in 2nd scenario and additionally there is a renovation rate obligation for space heating)	As in the second scenario	Yearly thermal renovation rate is increased by 3.5% reducing energy demand for space heating	As in the first scenario
4 scenario (external framework condition scenario – internet sale scenario combined with status quo scenario)	As in the first scenario	As in the first scenario	Annual initial sales growth is reduced by 1.5% which correspondingly reduces the new building construction rate

4.1.2. Disaggregation of the shopping centre building stock

The shopping centre building stock is categorised into small, medium, large and very large buildings. This categorization is based on the International Council of Shopping Centres (ICSC) statistics, which divides European traditional shopping centres into four scheme sizes: very large (80,000 m² and above), large (40,000–79,999 m²), medium (20,000–39,999 m²) and small (5,000–19,999 m²) (ICSC 2008). These categories are then disaggregated into three building periods, buildings built before 1990, 1991-2002 and buildings built 2003-2012. In total, 12 shopping centre categories are built for each country (see figure below). ICSC statistics provide information on the opening year of 4299 shopping centres in 27 European countries (ICSC 2014). These data are used to derive number of shopping centres in different building categories and countries.

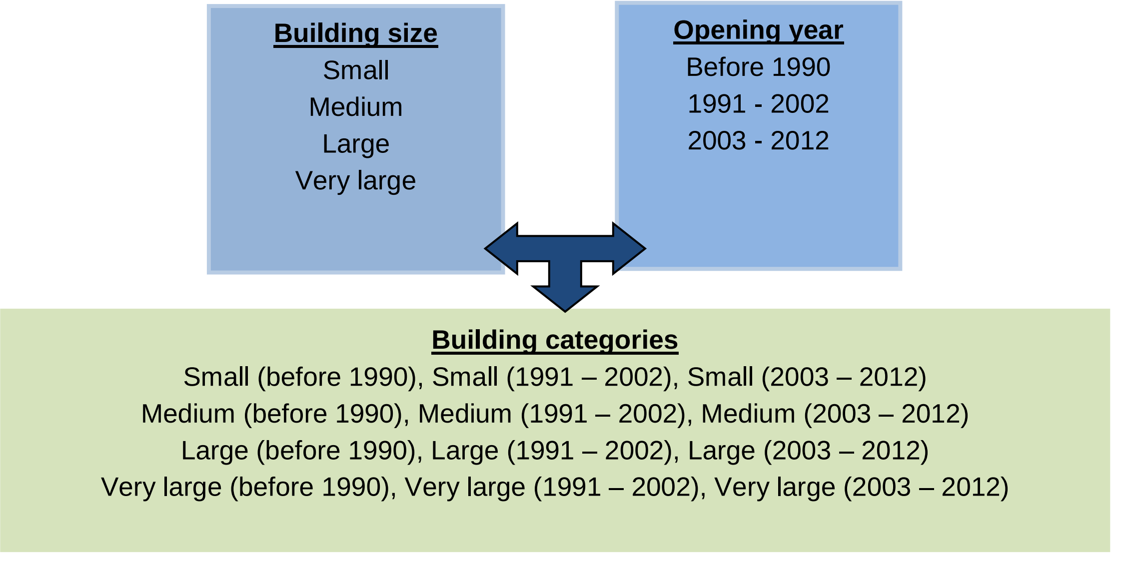

Figure 4 Building categories as combination of the building size and opening year used for each European country

The composition of small, medium, large and very large buildings is being analysed. Table 2 shows the typical composition of the shopping centre categories which is based on literature and analysis of the European shopping centres. The share of the shop categories and their size has a significant impact on the building gains and losses as well as energy demand for refrigeration, appliances and lighting. The following shop types are defined: SHP (retail stores including clothing, hobby and home), CMA (common areas), MDS (medium and big size supermarkets), RST (restaurants and cafes) and WRH (warehouses and other services). Table 2 shows that in small shopping centres, the share of the supermarkets is higher compared to large and very large shopping centres while in large and very large shopping centres, the share of restaurants, cafes and food courts is higher compared to small and medium shopping centres. Thus, the large and very large shopping centres typically offer more entertainment, for example restaurants and cafes. This information is used to define the typical specific energy demand for lighting, refrigeration and appliances typically used in different shop categories.

Table 2 Shopping centre store composition, (calculation based on raw data from Steen & Strøm (2012), Unibail-Rodamco (2013), ECE 2013, Intu Gr. (2013), Britishland (2014), IGD (2014))

Building categories	**Shop types**				
	SHP (Retail stores: clothing, hobby, home)	***CMA (Common area)***	***MDS (Medium stores, big size stores, super-markets)***	***RST (Restaurant, cafes, food courts)***	***WRH (Other services: ware-house, service rooms etc.)***
Small	36%	25%	20%	8%	11%
Medium	42%	25%	15%	9%	9%
Large	50%	25%	9%	10%	6%
Very large	54%	25%	6%	12%	3%

Figure 5 and Figure 6 show the total gross leasable area by shop size in the EU-28 and Norway. According to ICSC 2016, the Shopping centre building Gross Leasable Area (GLA) is 151.1 Million m^2 in EU-28 + Norway in 2015 (ICSC 2014). The largest shopping centre gross leasable area is located in the United Kingdom (22.2 Million m^2) followed by Germany (19.6 Million m^2), Spain (16.7 Million m^2) and France (12.8 Million m^2). The smallest shopping centre gross leasable area is located in Malta (0.02 Million m^2) followed by Cyprus (0.13 Million m^2), Luxembourg (0.23 Million m^2), Croatia (0.4 Million m^2), Slovenia (0.6 Million m^2) and Estonia (0.72 Million m^2). The diffusion of the shopping centres is influenced by the size and the inhabitant number in the country, but also by the shopping centre market saturation. The former EU-15 + Norway remain saturated markets and there is only limited activity in relation to the development of new centres while in most Central and Eastern Europe (CEE) countries, the shopping centre market is still an under-supply (for more information, see Bointner and Toleikyte, 2014). When it comes to the typical size of the buildings, the trend shows that in countries such as Austria, Belgium, Denmark, Finland, Malta, the Netherlands, Norway and Sweden, the small shopping centres make up the largest share on the total gross leasable area. In the mature markets such as Croatia, Latvia, Lithuania, Romania and Slovenia, large shopping centres dominate (see Figure 5). This trend is related to the construction period of the shopping centre.

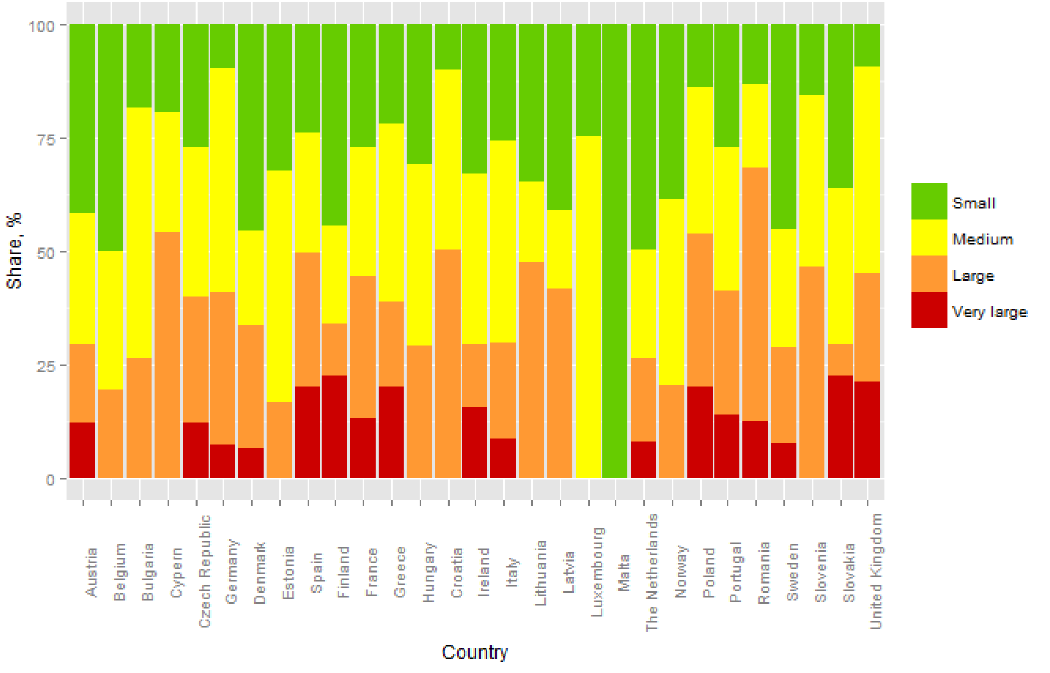

Figure 5 Share of the total gross leasable area by size in the EU-28 and Norway in 2012 (ICSC 2014).

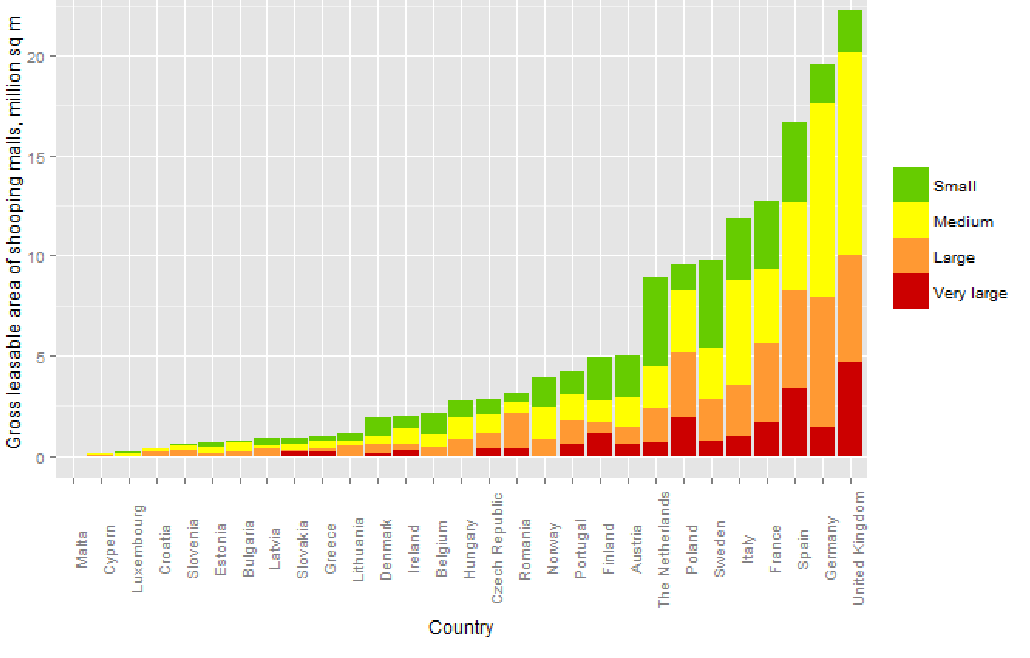

Figure 6 Gross Leasable Area of Shopping centres [Million m²] by size in the EU-28 and Norway in 2015 (ICSC 2014).

In the next step, we disaggregate the shopping centre building stock into three building periods, buildings built before 1990, 1991-2002 and buildings built 2002-2015.

Figure 7 shows the share of the total gross leasable area by opening year in EU-28 and Norway in 2012. The oldest shopping centre building stock is in Sweden followed by Denmark and France. In Sweden, more than half of the investigated shopping centre buildings were built before 1990. The share of the buildings gross floor area built before 1990 is 59%, 47% and 39% in Sweden, Denmark and France, respectively. In the following countries, more than 50% of the shopping centres gross floor area were opened between 2002 and 2015: Bulgaria, Cyprus, Hungarian, Ireland, Lithuania, Latvia, Malta, Romania. The analysis shows that in the EU-15 + Norway, the shopping centre building stock is older compared to CEE countries. The shopping centre era began after the economic transition in the formerly socialist CEE countries. Thus, the shopping centre stock is still young. There are many shopping centre buildings in the EU-15 which have to be refurbished and reconstructed in order to have a modern design while in CEE countries reconstruction of the buildings is currently not so important (Bointner and Toleikyte, 2015).

Based on the building period, the U-values (thermal transmittance) of the building elements for each European country were collected. The U-values are used to calculate energy need for space heating using monthly based energy balance approach (see the following section). U-values were collected using different databases provided by European projects INSPIRE and ENTRANZE as well as national technical regulations. The average U-values in the EU28 plus Norway are given in Table 3 and in Annex (Table 8) for each country.

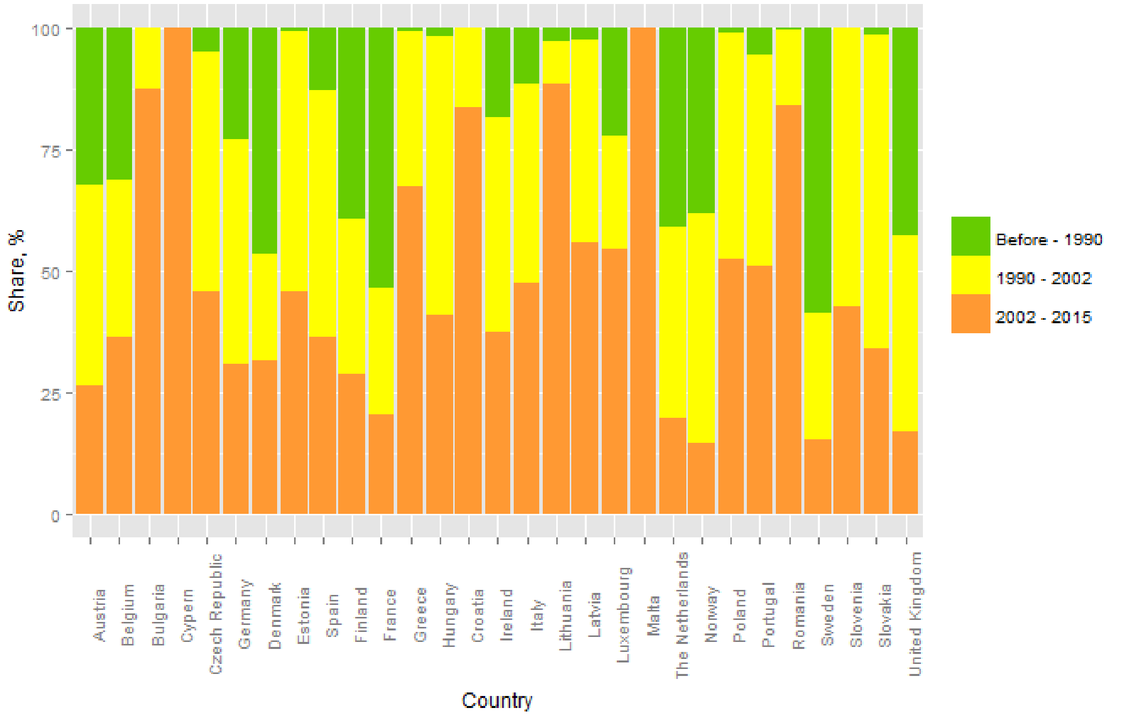

Figure 7 Share of the total gross leasable area by opening year in EU-28 and Norway in 2012 ((ICSC, 2014)

Table 3 The average U-values of building elements, [W/m^{2}K] for the different vintages (INSPIRE, ENTRANZE and national technical regulations)

	Before 1990	Between 1991 and 2002	After 2002
Window	3.26	2.58	2.1
Wall	0.97	0.79	0.54
Floor	0.89	0.76	0.58
Roof	0.88	0.68	0.52

4.1.3. Energy demand calculation

Energy demand for space heating, space cooling, appliances, ventilation, refrigeration and lighting was calculated for each shopping centre category (see section 4.1.2. Disaggregation of the shopping centre building) for each country.

Energy needs for space heating and cooling of the shopping centre categories in a country is modelled on a monthly basis by using a module of the building stock simulation tool Invert-EE/Lab (Müller, 2015). The model calculates based on the Austrian, German and EU standards (Pöhn 2011, ÖNORM B 8110-5, DIN 4108-72009 01, EN ISO 13790: 2008). The energy needs for space cooling and heating are calculated by using the monthly energy balance approach. The data required to calculate specific energy demand for space heating and cooling were collected in the CommONEnergy project Task 5.2 “Energy-Economic evaluation of shopping malls retrofitting” and are available in deliverable 5.2 “Shopping mall assessment – SMA” which is an economic assessment tool available on the project website. Following data are used to calculate the energy demand for space heating, cooling and hot water for a typical shopping building:

- Description of buildings and components (building geometry, thermal transmittance of building envelope elements)
- Transmission and ventilation properties (temperature adjustment factor of building elements, ventilation type, heat recovery type)
- Heat gains from internal heat sources and solar radiation (shading reduction factor, glazing type, area of glass, solar irradiance)
- Climate data (monthly outdoor temperature, solar radiation)
- Occupation behaviour and comfort requirements (user profiles, indoor temperature (set-point temperature), hot water demand)

Energy demand for lighting, appliances, refrigeration and ventilation is calculated using usage duration and specific power which varies based on the shop type (such as retail store, common areas, supermarkets, restaurants, cafes, and warehouses). The specific power (see Table 4) was defined based on the ASHRAE Energy standards for buildings and shopping centre case studies from the Commonenergy project (ASHRAE Standard 90.1-2013, Schönberger 2013, Westphalen and Koszalinski 1999, Goetzler et al, 2009). The usage duration was specified using typical opening hours of the shopping centres in EU-28 and Norway and national holidays.

Table 4 Specific power for different shop types for lighting, appliances, refrigeration and ventilation used in status quo scenario (ASHRE Standard 90.1-2013, Schönberger 2013, Westphalen and Koszalinski 1999, Goetzler et al, 2009)

Specific power, W/m²	Shop types				
	SHP (Retail stores: clothing, hobby, home)	*CMA (Common area)*	*MDS (Medium stores, big size stores, super-markets)*	*RST (Restaurant, cafes, food courts)*	*WRH (Other services: ware-house, service rooms etc.)*
Lighting	36.2	23.7	27	28.2	15
Appliances	10	5	10	10	5
Refrigeration	0	0	25.9	16.4	0
Ventilation	0.7	8.3	3.7	20.8	10.6

In the first scenario (status quo scenario), the market uptake and diffusion of the moderate energy efficient technologies are in place. To calculate the reduction of the energy demand for lighting, appliances, refrigeration and ventilation, we use reduced power for different shop types as is given in Table 5. By using these powers, the calculated specific energy demand for lighting, appliances, refrigeration, ventilation and space heating are reduced by 57%, 49%, 50%, 25%, 26%, respectively. In the second scenario, there are more ambitious technologies on the market and there are policies triggering investments in the ambitious energy efficiency measures. Moreover there is the mandatory use of active control systems for lighting, appliances, refrigeration, ventilation, heating and cooling systems. Under this premise, we calculate energy demand for lighting, appliances, refrigeration, ventilation by using reduced power (Table 5). Due to active control, building automation according to EN 15232 offer large energy saving potential in wholesale and retail (Siemens, 2016). According to Siemens (2016) 5% additional savings are assumed for lighting, appliances and refrigeration, 13.5% for heating and 27% for ventilation and cooling. These savings are equal to a shift from C (standard case) to B (advanced energy efficiency) class building automation control systems in the wholesale and retail sector. These values are taken into account to calculate the energy savings for lighting, appliances, refrigeration and ventilation. Energy efficiency measures for lighting, appliances, refrigeration, ventilation and space heating reduce specific energy demand by 59%, 53%, 53%, 45%, 36%, respectively. The specific power for different shop categories and energy services were set based on the shopping centre case studies from the Commonenergy project and Commonenergy report analysing main drivers for deep retrofitting of shopping malls (Haase et al, 2017).

Table 5 Specific power for different shop types for lighting, appliances, refrigeration and ventilation used in the first and fourth scenario (first number) and in the second and third scenario (second number)

Specific power, W/m²	Shop types				
	SHP (Retail stores: clothing, hobby, home)	*CMA (Common area)*	*MDS (Medium stores, big size stores, super-markets)*	*RST (Restaurant, cafes, food courts)*	*WRH (Other services: ware-house, service rooms etc.)*
Lighting	18.1/17.1	4.5/4.3	13.5/12.8	14.1/13.4	4.5/4.3

Specific power, W/m²	Shop types				
	SHP (Retail stores: clothing, hobby, home)	*CMA (Common area)*	*MDS (Medium stores, big size stores, super-markets)*	*RST (Restaurant, cafes, food courts)*	*WRH (Other services: ware-house, service rooms etc.)*
Appliances	5/4.8	2.5/2.4	5.0/4.8	5.0/4.8	2.5/2.4
Refrigeration	0	0	13.0/12.3	8.2/7.8	0
Ventilation	0.4/0.3	4.2/3.0	1.8/1.3	10.4/7.6	5.3/3.9

In a next step, the total energy demand space heating, space cooling, appliances, ventilation, refrigeration and lighting in the total shopping centre building stock in each EU-28 plus Norway is calculated. Based on the specific energy demand per square meter in shop categories (see section 4.1.2. Disaggregation of the shopping centre building stock) and the total floor area within these shop categories, total energy demand for all abovementioned energy services is calculated.
The *TFA* (total floor area) of shopping centre category *i* in country *j* is multiplied by the abovementioned specific energy consumption per m² *q* equals the total energy demand *Q* [TWh] of the total shopping building stock over time *t*.

$$Q_{j,(t)} = \sum_{i=1}^{n} q_{i,j\,(t)} * TFA_{i,j\,(t)} \qquad (1)$$

4.1.4. CO_2 emissions

CO_2-emission factors are used to calculate emissions caused by the shopping centre building stock´s final energy demand for space heating, space cooling, lighting, appliances, refrigeration, and ventilation. The average amount of CO_2 emitted per kWh (in gCO2/kWh) is linked to the fuels used for the space heating and production mix of electricity.
Before calculating the CO_2-emissions caused by the shopping centre building stock´s final energy demand, the energy fuel mix from 2012 to 2030 is assessed.
Energy fuel mix used for the energy demand for space heating is assessed using the share of the fuel mix in each investigated country in the service sector and applied as exogenous parameter. The share of the fuel mix is linked to the current policy scenario developed by the European project Zebra2020 (Toleikyte et al, 2016). This project analysed how current building standards and other policy settings affect the building stock transition and corresponding energy demand targets of the building sector until 2050. The energy fuel mix in the service buildings which was assessed in the abovementioned project was applied for the shopping centre demand scenarios in order to calculate greenhouse gas emissions caused by this building sector.
CO_2-emission conversion factors for electricity from 2012 until 2030 were calculated in the project based on the Report from the European Commission (Gantner 2016, EC 2011).
In the scenarios, the main key drivers for the CO_2-emissions in the European shopping centres are the overall energy demand, the replacement rate of the energy efficiency measures, and reduction in CO_2-intensity of the electricity generation.

4.1.5. Development of building renovation and new construction until 2030

The annual renovation of the shopping centre building stock for each building age band is being calculated following a Weibull-distribution with the renovation rate λ(t) in year t

$$\lambda(t) = \frac{\beta}{T} * \left(\frac{t}{T}\right)^{\beta - 1} \quad (2)$$

in which β denotes the shape factor and T the characteristic life time (see Table 6). T has been calculated for each country based on extensive data derived from the Global Shopping Centre Directory of the International Council of Shopping Centres (ICSC (2014)). Table 6 shows characteristic life times for different retrofitting solutions: lighting, refrigeration and appliances, as well as, thermal renovation. Table 7 indicates parameters used for the third scenario (in this scenario, there is an obligation to increase the yearly thermal renovation rate by 3.5 %). To implement this instrument into the modelling, the characteristic life time of the buildings were decreased (see Table 7). The characteristic life time of the buildings undertaking thermal renovation is decreased from 22.4 in the status quo scenario to 18 years in the energy efficiency obligation scenario. This decrease leads to the average yearly renovation rate of 3.5% in this scenario.

Table 6 Characteristics of the Weibull-Distribution for building renovation (ICSC 2014, Müller 2015)

Renovation option	Renovation measure	Shape factor β [-]	Characteristic life time T [years]
Lighting	Installation of LEDs	2.7	10
Refrigeration and appliances	More efficient system installation	2.7	12
Thermal Renovation	Whole building envelope, built before 1990	2.7	22.4
	Whole building envelope, built between 1990 & 2002	4.0	
	Whole building envelope, built after 2002	5.0	

Table 7 Characteristics of the Weibull-Distribution for building renovation used in energy efficiency obligation scenario

Renovation option	Renovation measure	Shape factor β [-]	Characteristic life time T [years]
Lighting	Installation of LEDs	2.7	10
Refrigeration and appliances	More efficient system installation	2.7	12
Thermal Renovation	Whole building envelope, built before 1990	2.7	18
	Whole building envelope, built between 1990 & 2002	4.0	
	Whole building envelope, built after 2002	5.0	

Figure 8 and Figure 9 show the penetration of the building stock which undertakes these renovation options: lighting, refrigeration and appliances and thermal renovation from 2012 to 2030. It can be seen, that almost 99% of the buildings during the time period from 2012 to 2030 install new lighting systems. The penetration of the thermal renovation is clearly much lower. While in the status quo scenario, approximately 40% of all buildings undertake thermal renovation until 2030, in the obligation scenario (3^{rd}), approximately 60% of all buildings are taking actions. This is due to the fact that there is a political instrument which obligates the countries to achieve the yearly renovation rate in the shopping centre building stock by 3.5%.

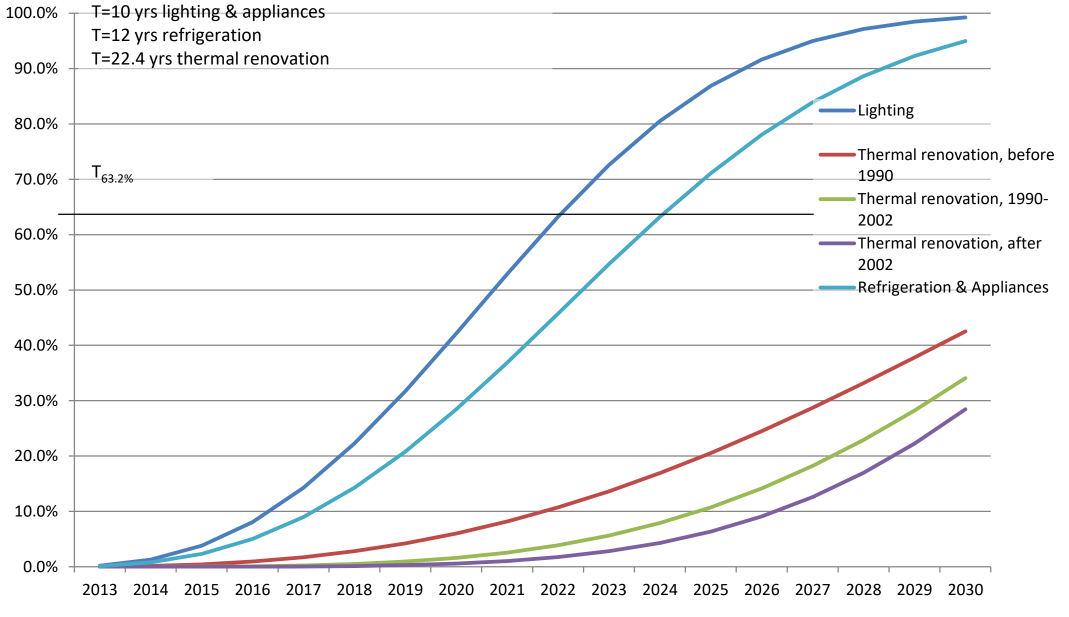

Figure 8 Penetration of the building stock which undertakes different renovation options from 2012 to 2030 used in scenario 1(status quo), scenario 2 (energy efficiency scenario) and scenario 4 (internet sales scenario)

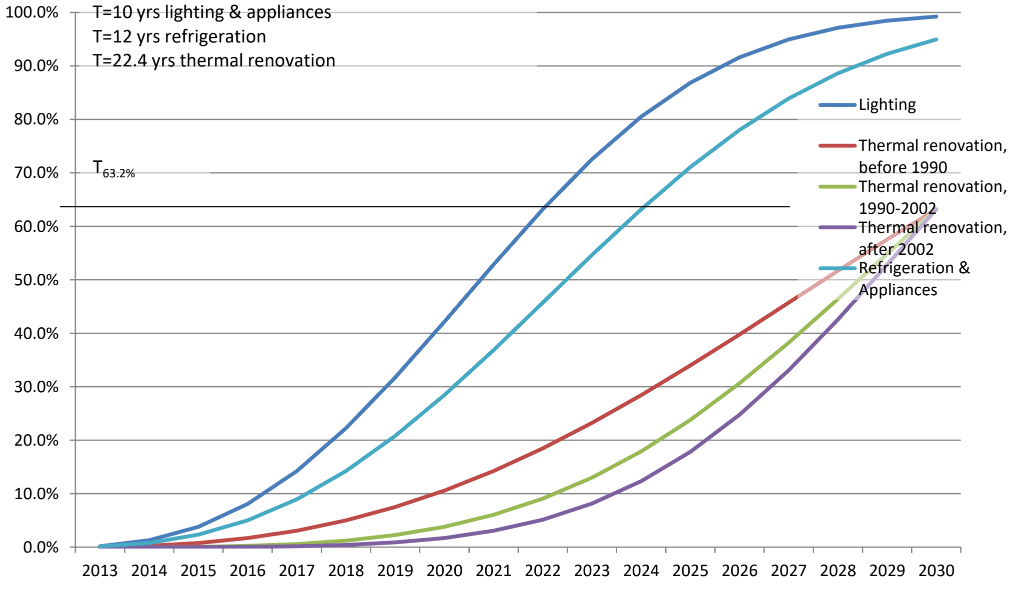

Figure 9 Penetration of the building stock which undertake different renovation options from 2012 to 2030 used in scenario 3 (energy efficiency obligation)

The calculation of the newly built shopping centres is linked to the economic development of the respective country, in particular the gross domestic product (GDP) and the annual sales growth in the shopping centre. This calculation is based on historic data on annual sales growth in the shopping centre branch the since 2000 to 2015 and GDP scenarios until 2030. More precisely, the annual new construction of shopping centre floor area is based on the following indicators:

- The GDP from 2000 to 2020. It has been derived from the World Economic Outlook Database of the International Monetary Fund (IMF 2013), estimated from 2015 onwards.
- The annual sales growth from 2000 to 2012 (ICSC 2014)
- The GLA of shopping centres from 2000 to 2015 have been processed based on raw data derived from ICSC (ICSC 2014).

The future development of the GDP, the sales growth and the total annual constructed floor area follow a linear trend, taking the whole period since 2000 into consideration. The floor area depends on the sales growth and the sales growth depends on the GDP.

The analysis of the market penetration of the European shopping centre was carried out in the CommONEnergy Report “Shopping malls features in EU-28 + Norway”. The analysis shows that countries with strong market position and strong market growth are Estonia and Slovenia, where the GLA per capita and sales growth is above the EU-average . The countries with low share of the market place and high growth rate markets are Slovakia, Bulgaria, Romania, Hungary, Latvia, Lithuania, Luxembourg and Poland. In these countries, the market growth in the last 12 years was very high and the GLA per 1000 Capita is still low, so there is an exploitable untapped potential for growth. Bulgaria and Romania show a large potential for new shopping centres. Contrary, a high GLA per capita with low market growth is observed in Croatia, Ireland, Norway, Sweden, Austria, Portugal, Denmark, Netherlands and the United Kingdom. These markets have reached their maturity (in terms of GLA per capita) and the average sales growth is slowing down.

4.2. Results

4.2.1. Floor area development

Figure 10 shows the share of the total gross leasable area of the new shopping centre building development from 2012 to 2030 and existing shopping centre building stock which was built until 2012 in EU-28 and Norway. The share of the new buildings in 2030 varies from country to country. The share of the new buildings in the total building floor area in 2030 is above 50% in Bulgaria, Lithuania, Latvia, Luxembourg, Malta, Poland, Romania and Slovakia. In these countries, the market growth in the last 12 years was very high and the GLA per 1000 Capita is still low and consequently there is an exploitable untapped potential for the new building development. In Norway, Sweden and the United Kingdom, the new shopping centre construction rate from 2012 to 2030 is very low and the share of the new buildings makes up less than 15% on the total shopping centre floor area. The countries which were identified as the markets with low share of the shopping centres per capita and low market growth countries will continue a moderate penetration of the new shopping centre building. The share of the new building floor area on the total floor area is approximately 30% in 2030 in the following countries: Cyprus, Denmark, Estonia, Finland, France, Greece, Croatia, Ireland, The Netherlands and Spain. This development of the total gross leasable area of the new shopping centre was used in the first scenario (status quo scenario), second and third scenarios.

For the internet sale scenario, it was assumed that more and more people search and buy goods and services in web shops. This is comfortable, independent from opening hours and location. The online market is growing by 1.5% every year and reduces the new shopping centre building construction rates. The yearly construction rates under this scenario (4) vary from country to country from 0.3% in Norway reaching 7.2% in Romania. Figure 11 shows the share of the total gross leasable area in 2030 of new buildings built between 2012 and 2030 and existing building stock built until 2012 in the internet sale scenario. The new building development is very slow in Norway, Sweden and the United Kingdom, reaching the share of 6%, 12% and 9% respectively on the total gross leasable area in 2030. Unlike in these countries, the new building construction penetration is still quite high in some of the European transition countries, such as Bulgaria, Lithuania, Latvia, Poland, Romania and Slovakia. The share of the new building gross leasable area on the total shopping centre leasable area is 45%, 42%, 60%, 35%, 45% and 40% in Bulgaria, Lithuania, Latvia, Poland, Romania and Slovakia respectively.

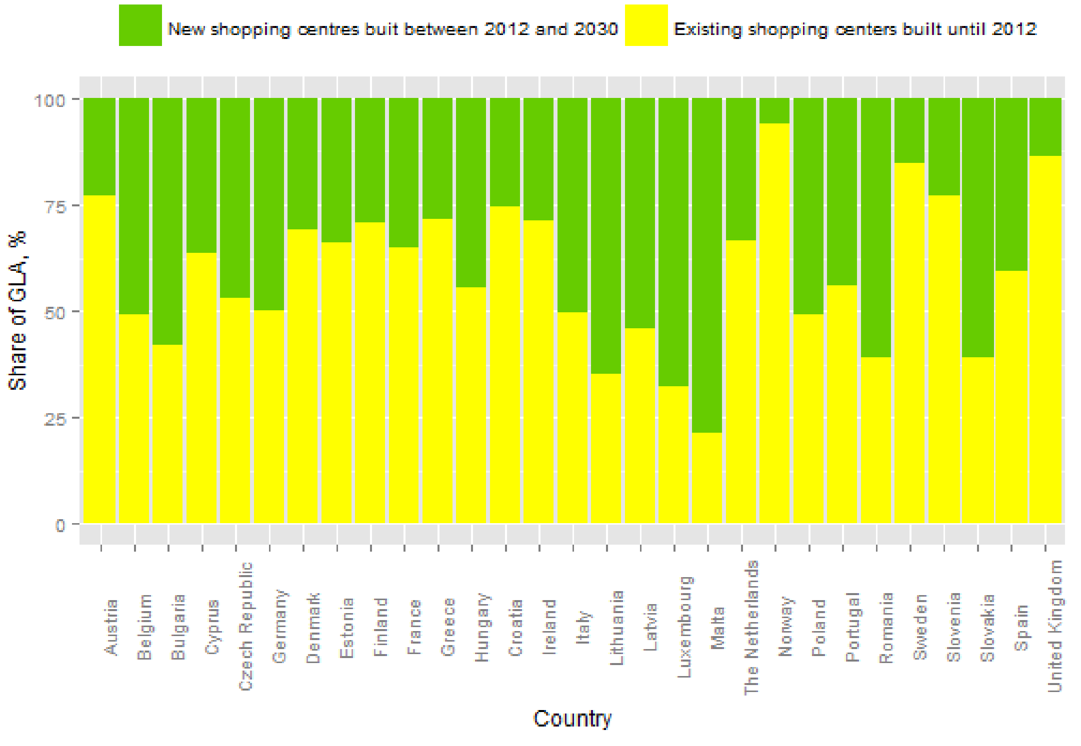

Figure 10 Share of the total gross leasable area in 2030 of new buildings built between 2012 and 2030 and existing building stock built until 2012

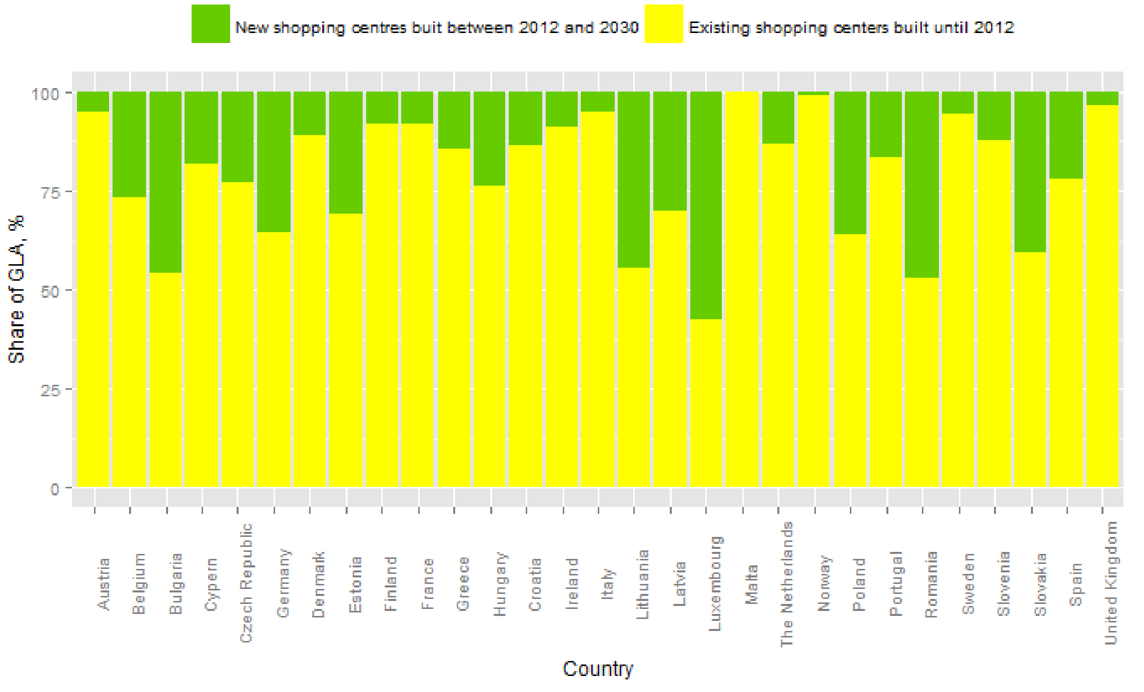

Figure 11 Share of the total gross leasable area in 2030 of new buildings built between 2012 and 2030 and existing building stock built until 2012 calculated and used for the internet sale scenario (scenario 4)

4.2.2. Energy demand breakdown

The breakdown of the energy demand by energy services (space heating, cooling, ventilation, refrigeration, appliances and lighting) is assessed for different building categories and all European countries. The analysis allows identifying the impact of the different building construction periods, climate and type on the specific final energy demand.

The share of the lighting, space cooling, refrigeration, appliances, space heating and ventilation on the total electricity energy demand in an average shopping centre is currently as follows: 30%, 22%, 17%, 17% 8% and 5% respectively. It can be seen, that unlike in a typical residential building where the energy demand for space heating dominates (all-around Europe besides southern Europe), energy demand for lighting makes up the highest share on the total energy demand in a typical shopping centre.
Figure 12 shows the annual specific electricity demand per building gross leasable area in different services in EU-28 and Norway. The total annual specific electricity demand in shopping centres varies from 300 kWh/m² to 410 kWh/m² in small shopping centres and from 250 kWh/m² to 360 kWh/m² in large shopping centres (see Figure 13). Small

shopping centres tend to have a higher specific energy demand per m² compared to a typical large shopping centre due to the higher share of the retail shops (supermarkets) and high share of the energy demand for refrigeration in these types of shopping centres. In the large shopping centres, the specific energy demand for electricity and energy demand for cooling is higher compared to the small shopping centres due to the higher share of the clothing, hobby and home shops.

Specific energy demand in the shopping centres varies from one country to another. However, the difference in the energy demand between the countries is not so large compared to the residential buildings. As mentioned above, energy demand for space heating is almost invisible on the total energy demand of European shopping centres. Even in the Northern European countries, the share of the specific heating energy demand in the specific total energy demand is 4.2% in Norway and 6.5% in Latvia for example. The difference between these countries is due to the thermal characteristics of the building envelope.

The main difference throughout the whole Europe is in the energy demand for space cooling varying from 19% to 31% in a typical small shopping centre in Estonia and Portugal respectively. The high share of the cooling energy demand in the shopping centres in all European countries is mainly caused by internal heat gains from lighting, people and equipment, and strengthened by the climate in the southern Europe.

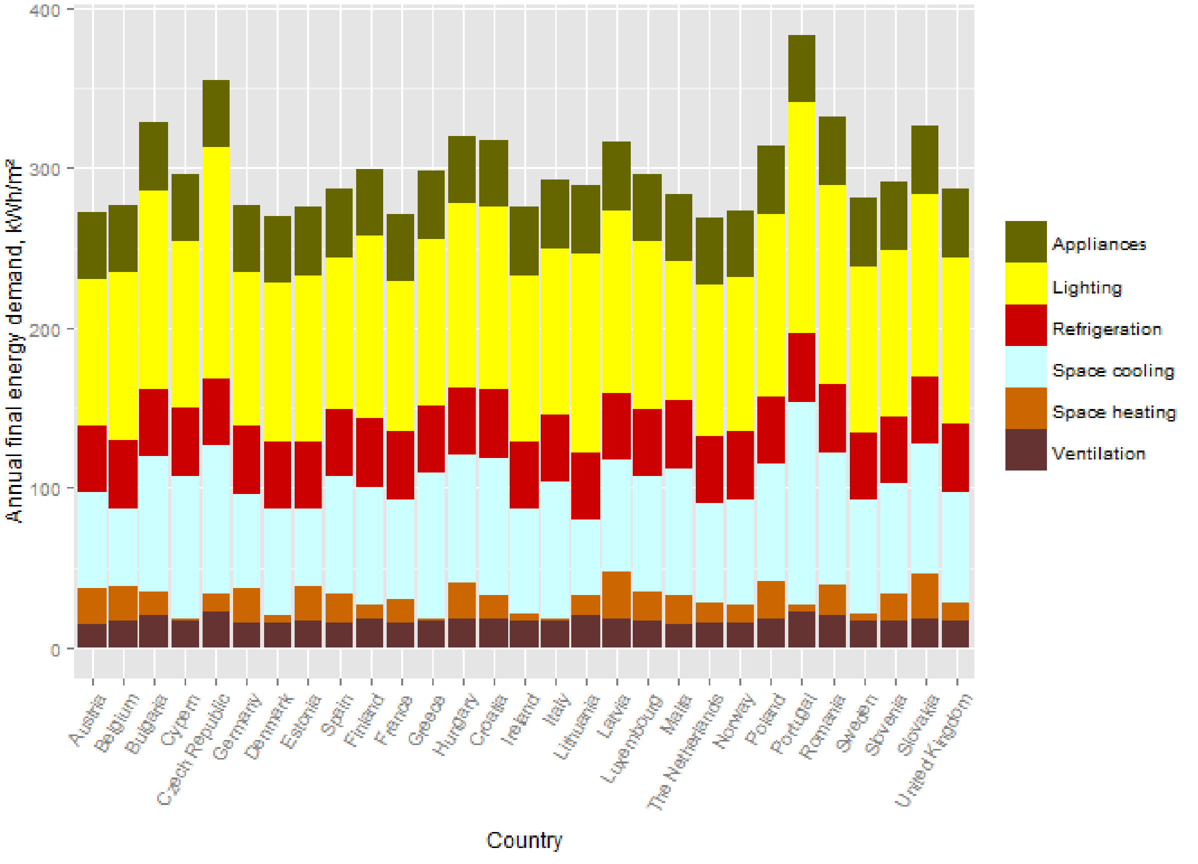

Figure 12 Annual electricity demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation in the base year in EU-28 and Norway

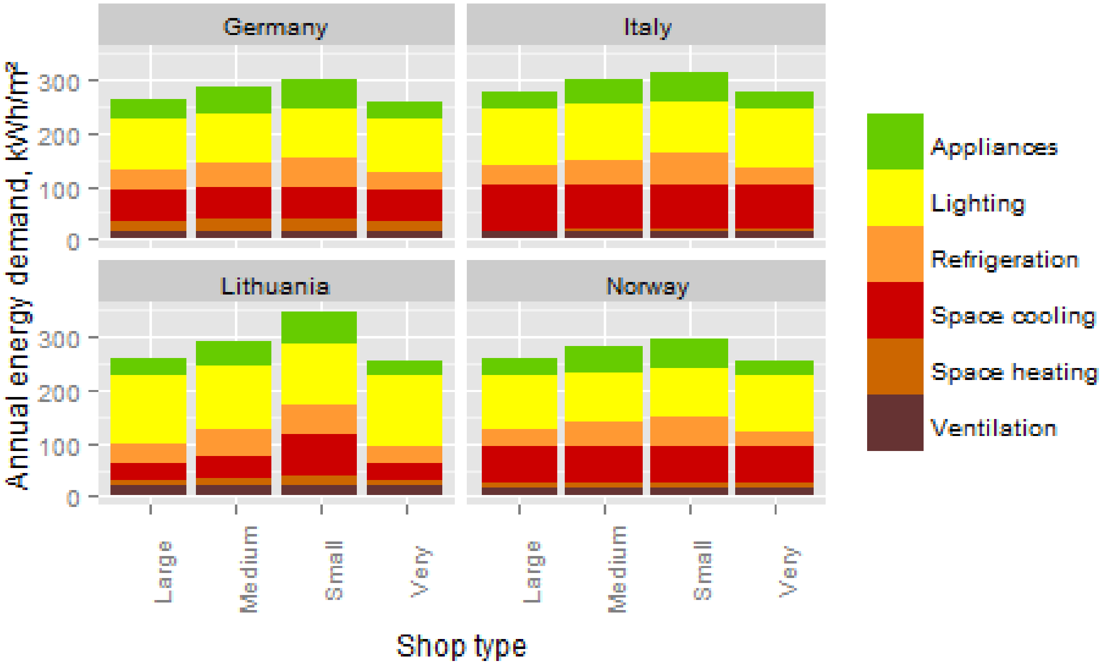

Figure 13 Annual specific electricity demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation used in different shop types in Germany, Italy, Lithuania and Norway

Figure 14 shows the annual energy demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation before renovation and after renovation (moderate and advanced energy efficiency measures in scenarios 1 and 2 respectively) for an average shopping centre. By using the moderate energy efficiency technologies, the calculated specific energy demand for lighting, appliances, refrigeration, ventilation and space heating is reduced by 57%, 49%, 50%, 25%, 26%, respectively. This moderate renovation package is implemented in the first scenario (status quo scenario). Advanced technologies are implemented in the second and third scenario assuming that there are more ambitious technologies on the market and there are policies triggering investments in the ambitious energy efficiency measure. By using advanced technologies for lighting, appliances, refrigeration, ventilation and space heating specific energy demand is reduced by 59%, 53%, 53%, 45%, 36%, respectively.

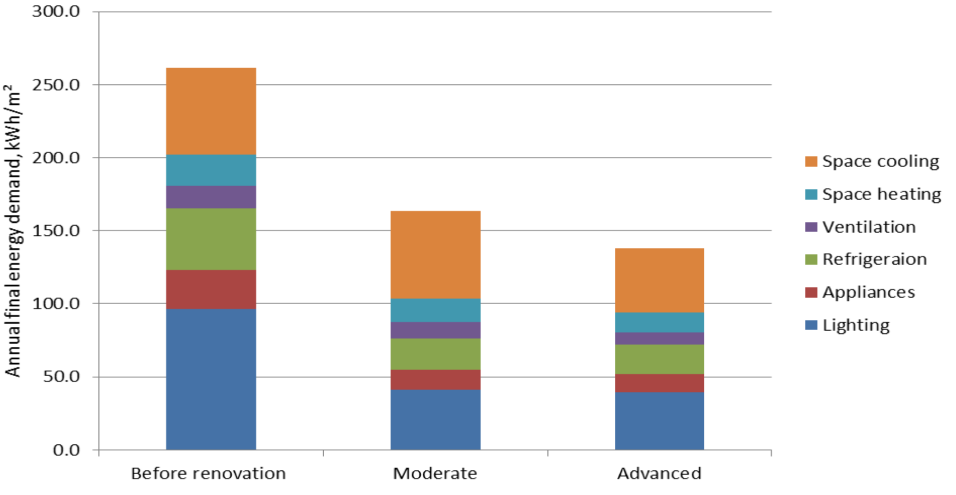

Figure 14 Annual energy demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation before renovation and after renovation (moderate and advanced energy efficiency measures). Moderate energy efficient technologies are used in the first scenario (status quo scenario). Advanced technologies covering active control systems used in the second scenario and third scenario.

4.2.3. Energy demand scenarios

Figure 15 shows final total energy demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation in the European shopping centre buildings in 2012. The total energy demand was calculated using a bottom-up approach as described in section 4.1. The highest energy demand in the shopping centre buildings is in the United Kingdom followed by Germany and Spain. The shopping centres in these countries consume almost 6 TWh, 5.3 TWh and 4.6 TWh respectively. Data on the total energy demand in 2012 for each European country is the starting point for the energy demand development until 2030 in all four scenarios. The scenario development was calculated taking into account different parameters such as thermal renovation of the building envelope, change rate of the lighting, appliances and refrigeration systems as well as new building construction rate. All of these parameters are influenced by the country specific gross domestic product and its development (GDP), market uptake of the innovative technologies and last but not least policy implications.

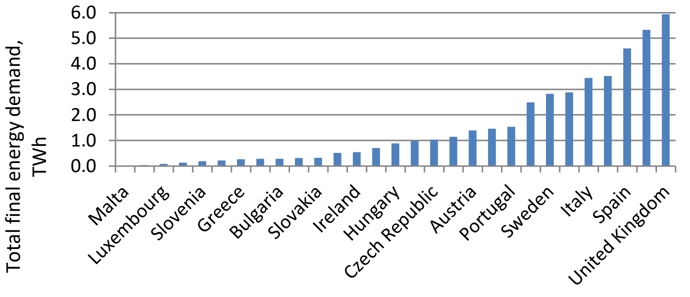

Figure 15 Total final energy demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation in the shopping centre building stock in 2012 in EU-28 and Norway

We calculated the final energy demand of the energy services in EU28 plus Norway (Figure 16). Final energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting was 43 TWh in the shopping centre building stock in 2012. With the share 33% the energy demand for lighting dominates in the total final energy demand followed by space cooling (25%), appliances (16%), refrigeration (15%), ventilation (6%) and space heating (5%) in EU28 plus Norway. By using the energy efficiency measures, 36% of the total energy savings can be achieved until 2030 in the status quo scenario using moderate energy efficiency measures. The highest energy saving potential can be achieved by replacing the lighting technologies. 59% of the energy demand for lighting can be saved from 2012 to 2030. In the second scenario, which includes policies addressing higher measures for lighting, appliances, refrigeration, ventilation and space heating and control systems, 45% of the total energy savings can be achieved by 2030. In this scenario, lighting again has the highest saving potential.

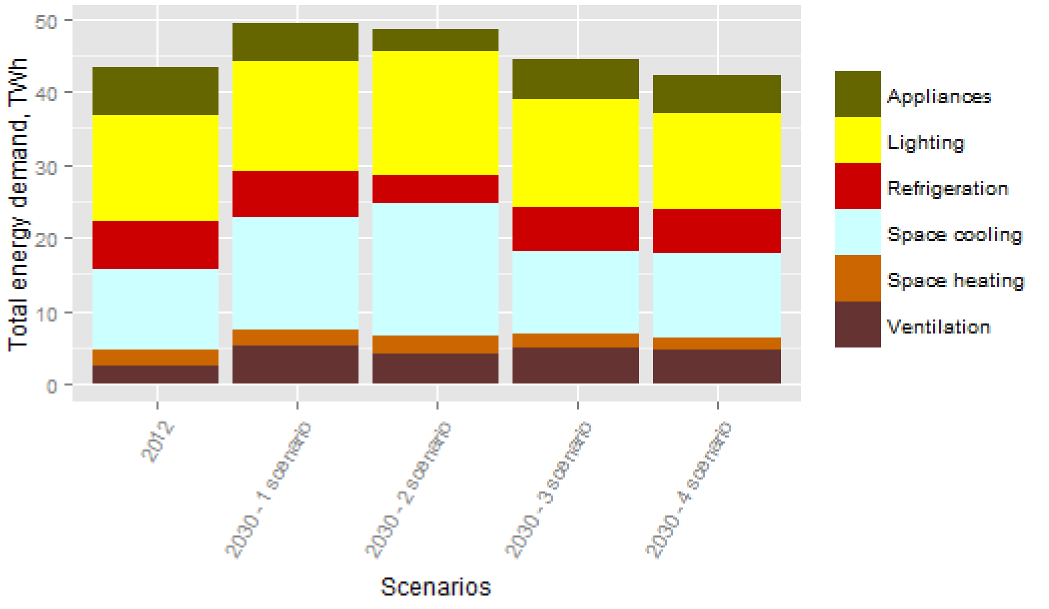

Figure 16 Final total energy demand by energy services in the shopping centres in EU28 plus Norway in 2012 and in 2030 in four scenarios

Figure 17 shows the change in the final energy demand in the shopping centre building stock from 2012 to 2030 in all four scenarios. There is an obvious trend in the results showing an energy demand reduction in all scenarios in the saturated markets and energy demand increase in non-mature markets from 2012 to 2030. One of the reasons is the development of the shopping centre building stock.

In *status quo scenario* (orange bar, Figure 17), in the non-mature markets such as Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia, the final energy demand will increase from 2012 to 2030. Total energy demand in the shopping centre building stock will increase by 120%, 49%, 30%, 60%, 125%, 70%, 125%, and 75% in Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia respectively. The main reason of the growing energy demand in these countries is the increasing number of the new buildings. Assessment of the future new building development (see previous section) has shown that in all abovementioned countries, the share of new buildings in 2030 reaches almost 50% of the total gross leasable area. Figure 18 shows the share of the total final energy demand by buildings built in different periods on the total energy demand in 2012 and 2030 in status quo scenario. The share of the total energy demand of the new buildings which are built between 2012 and 2030 varies from 55% to 75% in 2030. When it comes to the saturated markets such as Austria, Ireland, Norway, Sweden and the United Kingdom, it can be seen, that the total energy demand is going down by 20%, 5%, 40%, 25% and 25% respectively from 2012 to 2030 (Figure 17). The main drivers of the energy demand reduction are firstly the renovation of the existing shopping centre buildings and secondly, the new construction rate which is low due to the market saturation of shopping centres in 2012 (see section 4.1.5). The share of the energy demand of the new buildings (built from 2012 to 2030) on the total energy demand in 2030 varies from 8% in Norway to 35% in Ireland.

The second scenario which includes policies for more ambitious measures for lighting, appliances, refrigeration, ventilation and space heating and control systems shows a higher energy demand reduction from 2012 to 2030. The final energy demand from 2012 to 2030 will decrease by 24%, 45%, 35% and 5% in Austria, Norway, Sweden and France respectively. However, in the CEE markets the increase in energy demand is much lower compared to the status quo scenario in this scenario. In the second scenario, the final energy demand from 2012 to 2030 will increase by 94%, 111%, 51% and 99% in Bulgaria, Lithuania, Poland and Romania respectively.

In the third scenario, in addition to policies in the second scenario, the yearly thermal renovation rate is increased by 3.5% reducing the energy demand for the space heating. 25%, 46%, 36% and 6% of the energy savings are achieved in Austria, Norway, Sweden and France respectively.

In fourth scenario, Internet sale scenario (yellow bar, Figure 17)*,* the online market growth leads to reduced shopping centres sales and in turn to lower construction rates. This parameter has an obvious influence on the total energy demand development in many investigated countries from 2012 to 2030. However, in this scenario it was assumed that not saturated shopping centre markets are less affected by internet sales than saturated markets, which is also reflected in the energy demand development until 2030. In the following countries, there is still a growing trend in the future energy demand: Bulgaria, Lithuania, Poland and Romania. In the internet sale scenario, the final energy demand from 2012 to 2030 will increase by 58%, 24%, 23% and 56% in abovementioned countries respectively. However, the increase in energy demand is much lower compared to the previous scenarios.

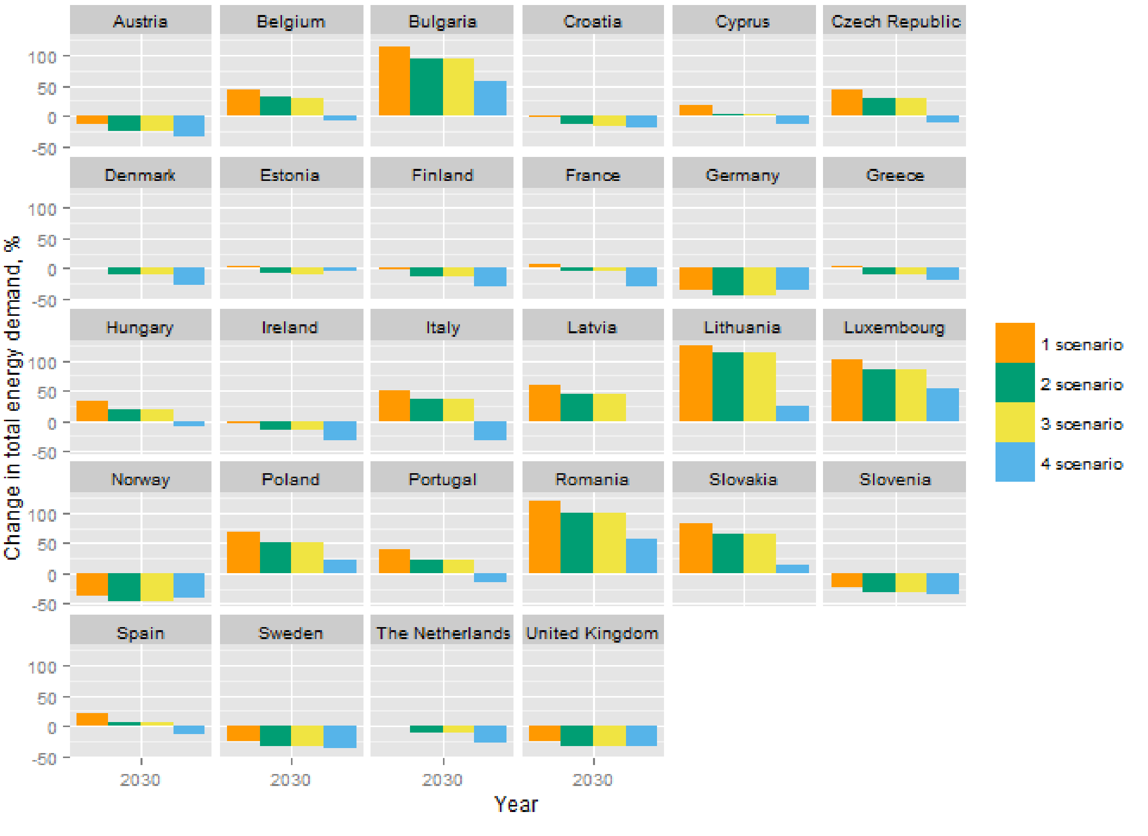

Figure 17 Change in total energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting from 2012 to 2030 in the European countries in different scenarios

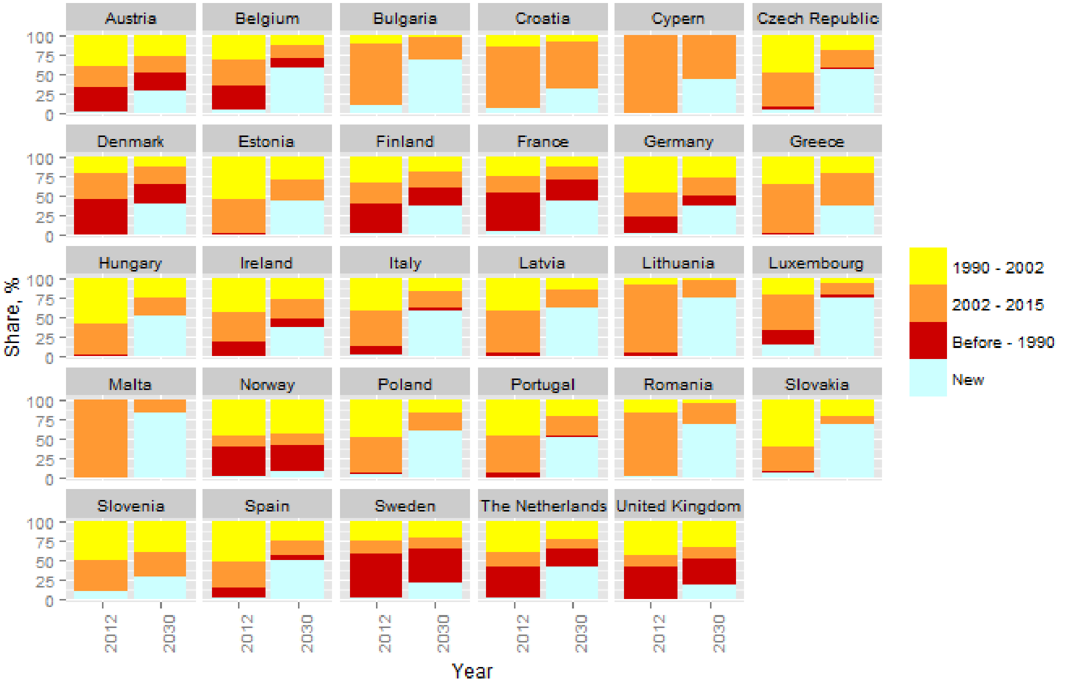

Figure 18 Share of buildings on the total final energy demand in 2012 and 2030. In 2030, new buildings are these built between 2012 and 2030 (Status quo scenario)

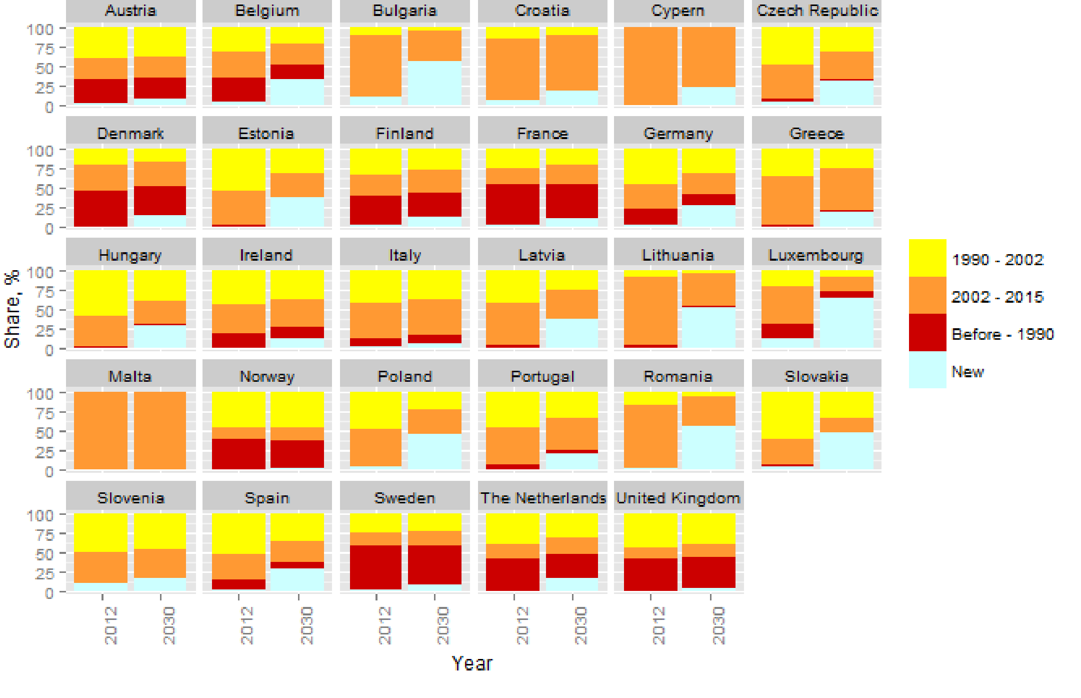

Figure 19 Share of buildings on the total final energy demand in 2012 and 2030. In 2030, new buildings are these built between 2012 and 2030 (Internet sale scenario)

4.2.4. CO2-emissions

Total CO_2-emissions caused by the energy demand in the European shopping centres were calculated. Figure 20 shows total CO_2-emissions development caused by energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting from 2012 to 2030 in the European countries in different scenarios.

There are two main drivers for the future CO_2-emissions development: (1) The overall energy demand and its development in the shopping centre buildings; (2) The reduction in CO_2-intensity of electricity generation.

To begin with the overall energy demand, the CO_2-emission scenarios follow the same trend as the energy demand scenarios (see Figure 17). While in the saturated markets CO_2-emissions are going down from 2012 to 2030, in non-mature markets, there is an increase in the total CO_2-emissions in the same period.

When it comes to the CO_2-intensity of electricity generation, we firstly must show the share of the electricity consumption on the total energy demand in the shopping centre buildings. Electricity provides the highest share of the total energy demand in all investigated countries. The energy demand for lighting, appliances, space heating, refrigeration and ventilation represents a high share on the total energy demand and this is supplied by electricity. Yet, the energy carrier mix of the heating energy demand is more diverse. The energy carrier mix for space heating varies from one country to another. Gas is the most dominate energy carrier in 2012 in EU-28 plus Norway. Share of gas energy consumption on the total energy carrier mix is 52% followed by district heating (13%) and electricity (8%).

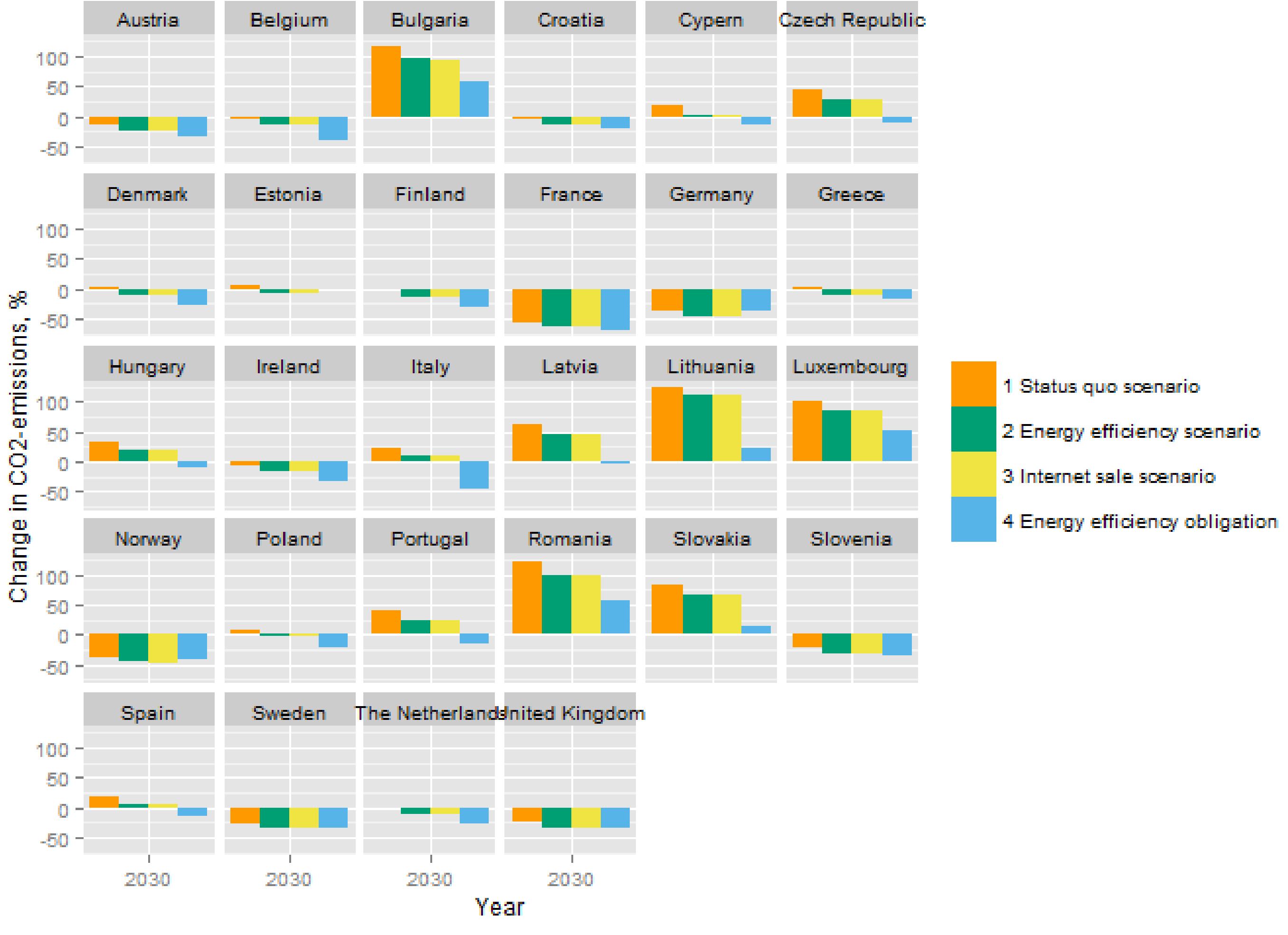

Figure 20 Change in total CO2-emissions caused by energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting from 2012 to 2030 in the European countries in different scenarios

5. Conclusions

In this report, the energy demand scenarios in the European shopping centre building stock from 2012 to 2030 were calculated taking different economic and technical conditions into account. These scenarios were calculated using a bottom-up approach by breaking down the energy demand into six energy services: energy demand for space heating, space cooling, lighting, refrigeration, appliances and ventilation.

Final calculated energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting was 43 TWh in the European shopping centre building stock in 2012. The future energy demand depends on the quality of renovation, the replacement rate of building technologies, the rate of new shopping centre construction and the market saturation in the respective country.

All emerging markets have a growing energy demand in the status quo scenario. For instance, in the formerly socialist Central Eastern European countries the shopping centre era began after 1990, therefore the shopping centre stock is young compared to many western European countries. However, if energy efficiency measures are implemented and/or the retail market changes due to expanding web shops, the energy demand in these markets will reduce as it was shown in the other three scenarios exploring the effect of higher energy efficiency and migration of sales online. The main conclusions are highlighted below:

Conclusion 1: Lighting technologies have the highest replacement rate in the shopping centres. Moreover, the energy demand for lighting makes up the highest share on the total final energy demand. The energy demand for lighting in the existing shopping centre building stock in EU28 and Norway can be reduced by 59% from 2012 to 2030 in the status quo scenario and by 62% in the second scenario which includes policies for more ambitious energy efficiency measures and control systems. Improvements and new innovative technologies (LED, control systems) have a high potential to reduce energy demand in the existing shopping centres.

Conclusion 2: Electricity is the main energy carrier covering energy demand in the European shopping centres. Thus, reduction of the greenhouse gasses is highly dependent on the electricity sector and its decarbonisation.

Conclusion 3: In the transition economies and especially in Bulgaria, Lithuania, Latvia, Poland, Romania and Slovakia there is an exploitable untapped potential for the new building development. The share of the new buildings built between 2012 and 2030 on the total building floor area in 2030 is above 50%. Consequently, the total energy demand in the shopping centre building stock is growing until 2030 in these markets. There is a need for new and innovative energy efficiency technologies or new green business models. Building codes and certification schemes to enhancing green branding could play an important role in encouraging investment in energy efficiency measures for the shopping centres.

Conclusion 4: Policy makers can support and guide shopping centres to reduce their energy demand through clear and stable policies which provide long term drivers to increase energy efficiency. Policies addressing shopping centres must pay attention to their complex physical structure and multiple stakeholders (owners, tenants, customers and administration) involved in decision making processes. Policies addressing shopping centres should build on existing and efficient voluntary certification schemes such as BREEAM certification and green leases. Moreover, an in-depth, ex-ante evaluation of the impact of any shopping centre policy on the numerous stakeholders should be conducted to improve understanding and aid development of successful approaches. A position paper on standardisation providing recommendations to improve European policy can be found in deliverable 5.10 of the present project.

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7. Annex

7.1. Input data

Table 8 U-values of building elements of buildings built in different building periods and countries (INSPIRE, ENTRANZE, OIB Guideline 6, Ordinance № 7 of 2004 (value T_internal < 15 C), Hunarian technical Regulation 2014, KDP 446/2009, CSN 73-0540:2011 (CA-EPBD 2012), BR 2010, National Building Code (CA-EPBD 2012), Technical Guidance L, Lithuanian Building Technical Regulation STR 2.01.09.2012, RGD 31/08/2010, Bouwbesluit 2012 (GBPN), STN 73 0540-2: 2012 (CA-EPBD 2012))

		U-values of building elements, [W/m²K]			
		Wall	Window	Roof	Floor
Austria	before 1990	0.6	2.1	0.6	0.6
	1991 - 2002	0.4	1.4	0.5	0.5
	2002 - 2010	0.3	1.3	0.5	0.5
Belgium	before 1990	1.8	3.95	0.94	0.94
	1991 - 2002	1.7	3.7	0.8	0.8
	2002 - 2010	1.3	2.3	0.7	0.7
Bulgaria	before 1990	1.3	3.1	0.8	0.8
	1991 - 2002	1	2.7	0.6	0.6
	2002 - 2010	0.4	1.9	0.5	0.5
Croatia	before 1990	0.7	4.6	0.5	1.1
	1991 - 2002	0.5	2.7	0.3	0.5
	2002 - 2010	0.4	1.8	0.25	0.3
Cyprus	before 1990	1.5	5.9	1.31	1.31
	1991 - 2002	1.5	2.5	1.31	1.31
	2002 - 2010	1.5	1.6	1.31	1.31
Czech Republic	before 1990	0.7	2.8	0.5	0.8
	1991 - 2002	0.5	2	0.4	0.6
	2002 - 2010	0.4	1.5	0.24	0.5
Denmark	before 1990	0.61	2.17	0.31	0.57
	1991 - 2002	0.4	1.4	0.2	0.5
	2002 - 2010	0.3	1.4	0.2	0.3
Estonia	before 1990	0.3	1.1	0.3	0.3
	1991 - 2002	0.2	1	0.2	0.2
	2002 - 2010	0.2	1	0.2	0.2
Finland	before 1990	0.42	2.12	0.36	0.36
	1991 - 2002	0.3	1.7	0.3	0.3
	2002 - 2010	0.3	1.5	0.3	0.3
France	before 1990	1.2	3.87	1.38	1.38
	1991 - 2002	1	3.3	0.8	0.8
	2002 - 2010	0.4	2.7	0.4	0.4
Germany	before 1990	1.2	2.9	0.36	0.85

	1991 - 2002	0.85	1.9	0.3	0.4
	2002 - 2010	0.35	1.3	0.3	0.4
Greece	before 1990	0.8	3.7	0.7	0.7
	1991 - 2002	0.7	3.5	0.7	0.7
	2002 - 2010	0.7	3.5	0.8	0.8
Hungary	before 1990	0.7	2.7	0.8	0.8
	1991 - 2002	0.7	2.7	0.8	0.8
	2002 - 2010	0.5	2.2	0.5	0.5
Ireland	before 1990	1.15	3.82	0.67	0.87
	1991 - 2002	0.7	2.9	0.4	0.8
	2002 - 2010	0.3	2.3	0.4	0.5
Italy	before 1990	0.8	4.57	0.5	0.5
	1991 - 2002	0.8	3.6	0.5	0.5
	2002 - 2010	0.1	3.6	0.4	0.4
Latvia	before 1990	1	2.5	1	1
	1991 - 2002	0.8	2.5	1	1
	2002 - 2010	0.5	2.5	0.3	0.3
Lithuania	before 1990	0.6	2.3	0.7	0.4
	1991 - 2002	0.4	1.9	0.3	0.3
	2002 - 2010	0.3	1.9	0.2	0.3
Luxembourg	before 1990	1.21	2.67	0.6	0.6
	1991 - 2002	0.5	1.6	0.5	0.5
	2002 - 2010	0.4	1.5	0.5	0.5
Malta	before 1990	1.6	5.8	2	2.1
	1991 - 2002	1.6	5.7	1.7	2.1
	2002 - 2010	1.6	5.3	1.7	2
The Netherlands	before 1990	0.76	3.45	1.08	1.08
	1991 - 2002	0.5	2.9	0.9	0.9
	2002 - 2010	0.4	1.8	0.5	0.5
Norway	before 1990	0.3	2.4	0.2	0.3
	1991 - 2002	0.24	1.8	0.17	0.23
	2002 - 2010	0.19	1.29	0.13	0.15
Poland	before 1990	0.8	2.6	1.1	1.1
	1991 - 2002	0.6	2.3	1	1
	2002 - 2010	n.a.	2.1	0.7	0.7
Portugal	before 1990	1.55	4.45	2.75	
	1991 - 2002	1.3	4.2	1.5	1.9
	2002 - 2010	0.8	3.8	0.8	0.8
Romania	before 1990	1.4	2.4	1.2	1.1
	1991 - 2002	1.4	2.4	1.1	1

	2002 - 2010	1	1.3	0.5	\1
Slovakia	before 1990	0.7	2.9	1.5	1.5
	1991 - 2002	1.1	n.a.	1.4	1.4
	2002 - 2010	0.5	n.a.	1.1	1.1
Slovenia	before 1990	0.9	1.6	0.8	0.8
	1991 - 2002	0.9	1.6	0.8	0.8
	2002 - 2010	0.6	1.6	0.5	0.5
Spain	before 1990	1.99	4.63	1.61	1.61
	1991 - 2002	1.7	3.3	0.8	0.8
	2002 - 2010	0.9	2.8	0.8	0.8
Sweden	before 1990	0.31	2.8	0.22	0.2
	1991 - 2002	0.2	2.5	0.1	0.2
	2002 - 2010	0.2	0.9	0.1	0.2
United Kingdom	before 1990	1.1	4.78	0.84	1.31
	1991 - 2002	0.5	2.7	0.3	0.5
	2002 - 2010	0.4	1.8	0.2	0.3

7.2. Country figures

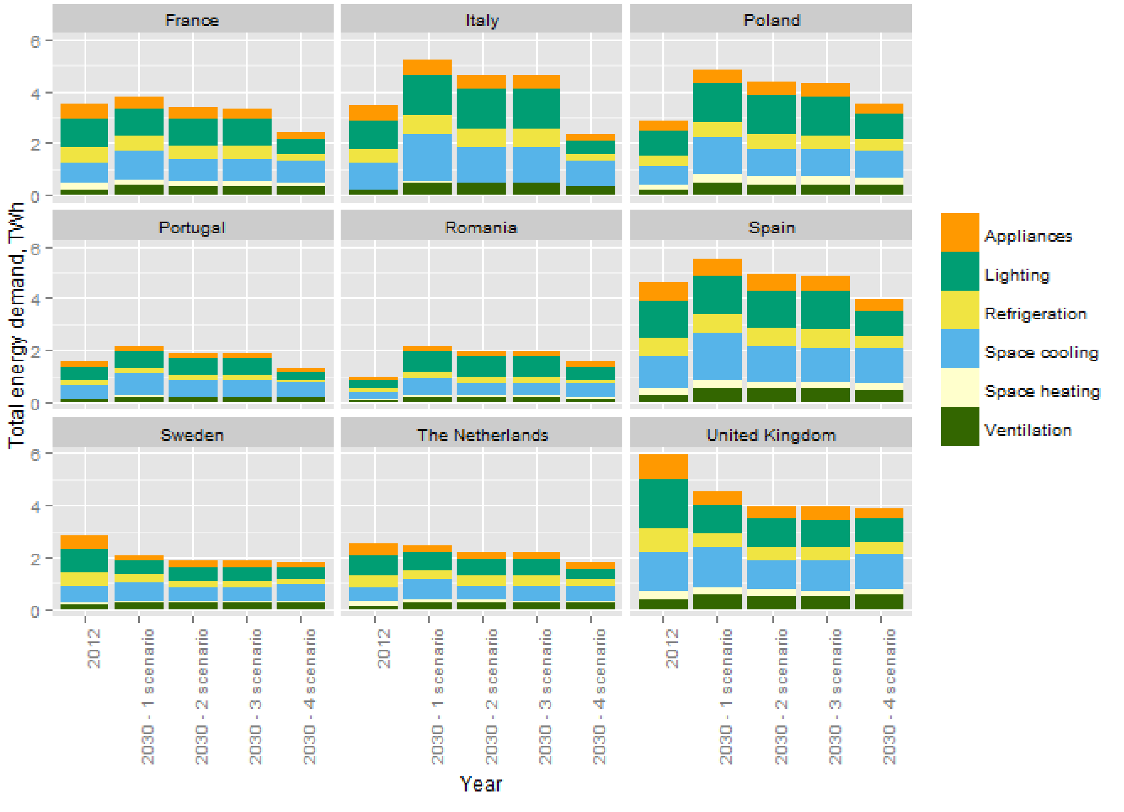

Figure 21 Final total energy demand by energy services in the shopping centres in France, Italy, Poland, Portugal, Romania, Spain, Sweden, The Netherland and the United Kingdom in 2012 and in 2030 in four scenarios

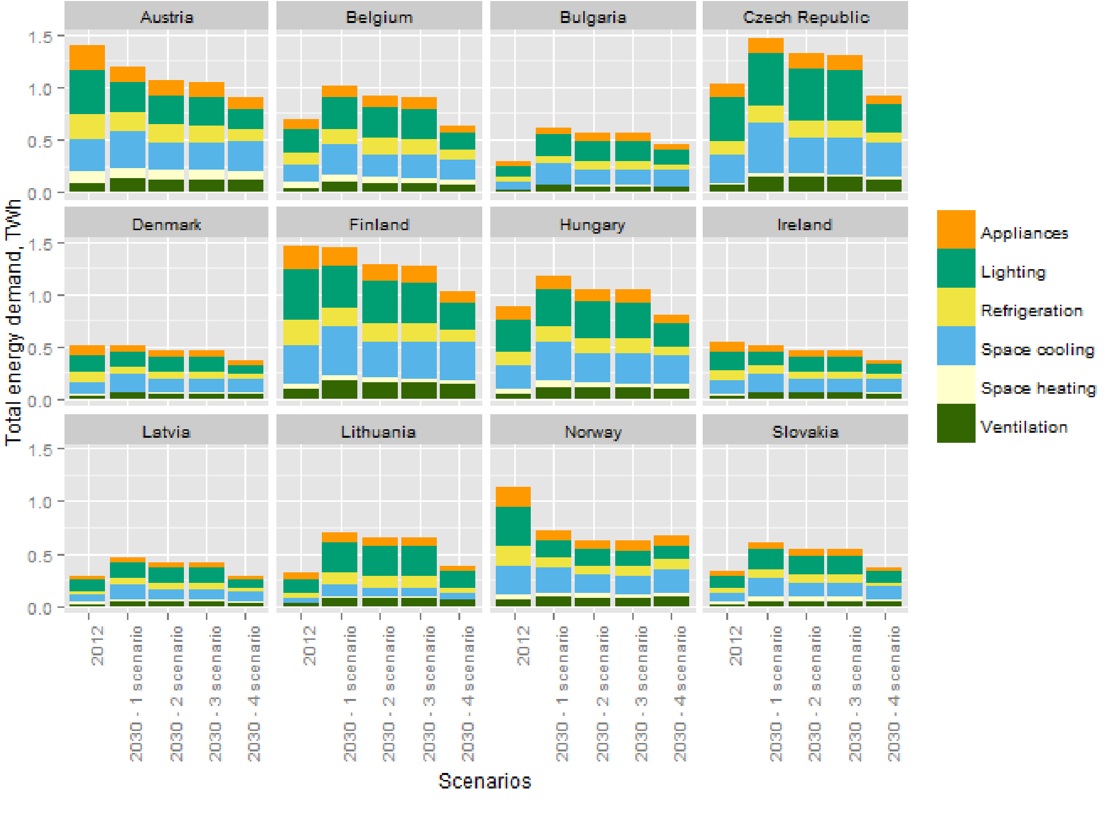

Figure 22 Final total energy demand by energy services in the shopping centres in Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, Hungary, Ireland, Latvia, Lithuania, Norway, Slovakia in 2012 and in 2030 in four scenarios

Figure 23Final total energy demand by energy services in the shopping centres in Croatia, Estonia, Greece, Luxembourg, Malta, Slovenia, Cyprus in 2012 and in 2030 in four scenarios