European shopping centre building stock – a pathway towards lower energy consumption via innovative energy policy

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Abstract

The European shopping centre building stock offers a high energy saving potential and good ground to implement energy efficiency measures. Looking at macro-economic parameters such as sales growth and shopping centre floor area per capita, the stock of shopping centres is expected to growth especially in the European transition economies while remaining stagnant in the saturated markets of western and northern Europe. The energy demand for lighting, refrigeration, ventilation, space cooling and heating, is correspondingly growing in these transition markets. On the other hand, in the saturated markets, the major challenge is to renovate the existing building stock of shopping centres. Both, new and retrofitted buildings require technology solutions and a corresponding policy framework to enhance energy efficiency and the use of renewable energy sources, while improving indoor environmental quality that is of primary importance for the attractiveness of the sales place. In this paper, the current and future energy demand in the European shopping centre building stock is assessed to 2030 using (i) specific power consumption and operating duration for lighting, appliances, refrigeration and ventilation, (ii) shopping centre categories' gross leasable area, (iii) developments in building renovation and new construction and (iv) standard and advanced energy efficiency technologies. A number of policy scenarios on the future total energy demand are derived showing the impact of the most important drivers such as renovation rates and implemented energy efficiency solutions. The paper provides recommendations on how to increase the use of energy efficiency measures in European shopping centres, thus assisting the sector to contribute to the European 2030 climate and energy targets addressing the following stakeholders, owner/tenants, real estate investors and policy makers.

Introduction

European shopping centre provides a huge potential to reduce total energy demand and contribute to the European low carbon economy. However, the European shopping centre building sector is a complex sector compared to the residential sector due to their complexity as physical structures and the social multi-stakeholders decisional processes. Investments in energy efficiency solutions leading to long-term energy savings are often hampered by several barriers. First of all, the 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. Secondly, decision making process when implementing energy renovation measures is a complex process involving two main stakeholders, tenants and owners/managers. While the energy efficiency of shopping centres is not of primary importance for tenants, the owners and managers are interested in energy efficiency (Woods et al, 2015). And last but not least the future retail market development and the growth of internet sales in web shops are essential, potentially leading to lower footfall, reduced shopping centres sales and in turn to lower renovation and construction rates or a change of use.

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 paper contains the following steps: (I) describing the methodology and the main input data of the shopping centre building stock (II) defining the scenario framework (III) showing the results on the development of the gross leasable area of the shopping centres and their energy demand (IV) providing recommendations on how to overcome barriers which hamper to invest in energy efficiency solutions and finally (V) deriving conclusions.

Methodology and input data

Total final current and future energy demand in the shopping centre's building stock is calculated using a bottom-up 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 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 and refrigeration as well as insulation of the building envelope influencing energy demand for space heating and cooling. Four different scenarios are calculated shoving the influence of above mentioned parameters.

BREAKING DOWN THE SHOPPING CENTRE BUILDING STOCK

The shopping centre building stock in Europe is classified by small, medium, large and very large buildings. This classification is based on statistics of the International Council of Shopping Centers (ICSC), dividing European traditional shopping centres into four 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) shopping centres (ICSC, 2008). This disaggregation enables to define the composition of the shop types such as common areas, retail stores, restaurants and others, which are typical for different size of the shopping centres investigated in the FP7-project CommONEnergy (see Table 1). Table 1 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. All this information let us to define the typical specific energy demand for lighting, refrigeration and appliances typically used in different shop categories.

In the next step, the buildings are disaggregated into four building age periods: shopping centres built before 1990, built between 1991 and 2002, built between 2003 and 2015 and new shopping centres built between 2016 and 2030. This categorization let us to identify the U-values (thermal transmittance values of the building elements) of the buildings built in the different vintages. U-values were collected for each European country using different databases provided by the European projects INSPIRE and ENTRANZE as well as national technical regulations. The U-values vary from one country to another. The average U-values for the different vintages are as follows: before 1990 (U_{roof}=0.88, U_{window}=3.26, U_{floor}=0.89, U_{wall}=0.97), between 1991 and 2002 (U_{roof}=0.68, U_{window}=2.58, U_{floor}=0.76, U_{wall}=0.79), after 2002 (U_{roof}=0.52, U_{window}=2.1, U_{floor}=0.52, U_{wall}=0.54). Moreover, based on the number of buildings built in different time periods we calculate the renovation rate and new construction rate until 2030 in all European countries. Figure 1 shows the share of the shopping centre gross leasable area by opening year on the total gross leasable area in 2012 in EU-28 and Norway. The oldest shopping centre building stock is in Sweden followed by Denmark and Finland. Almost 50% of the shopping centres were built before 1990 in Sweden, Denmark, Finland, France, United Kingdom, the Netherlands and Norway. There are many shopping centre buildings in the EU-15 which have to be refurbished and reconstructed in order to have a modern design. The shopping centre building stock is young in the following countries: Slovenia, Estonia, Hungarian, Greece, Latvia, Poland, Czech Republic, Lithuania, Slovakia, Romania and Croatia. The shopping centre era began after the economic transition in the formerly socialist CEE countries.

FUTURE NEW BUILDING CONSTRUCTION AND RENOVATION RATES

To assess the future construction and renovation rate in the buildings in each European country, the country's GDP (Gross Domestic Product) and sales growth data are analysed. The GDP for each country, between 2000 and 2030, was derived

Table 1. Shopping centre store composition, share of shops on the total shopping centre floor area (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 %

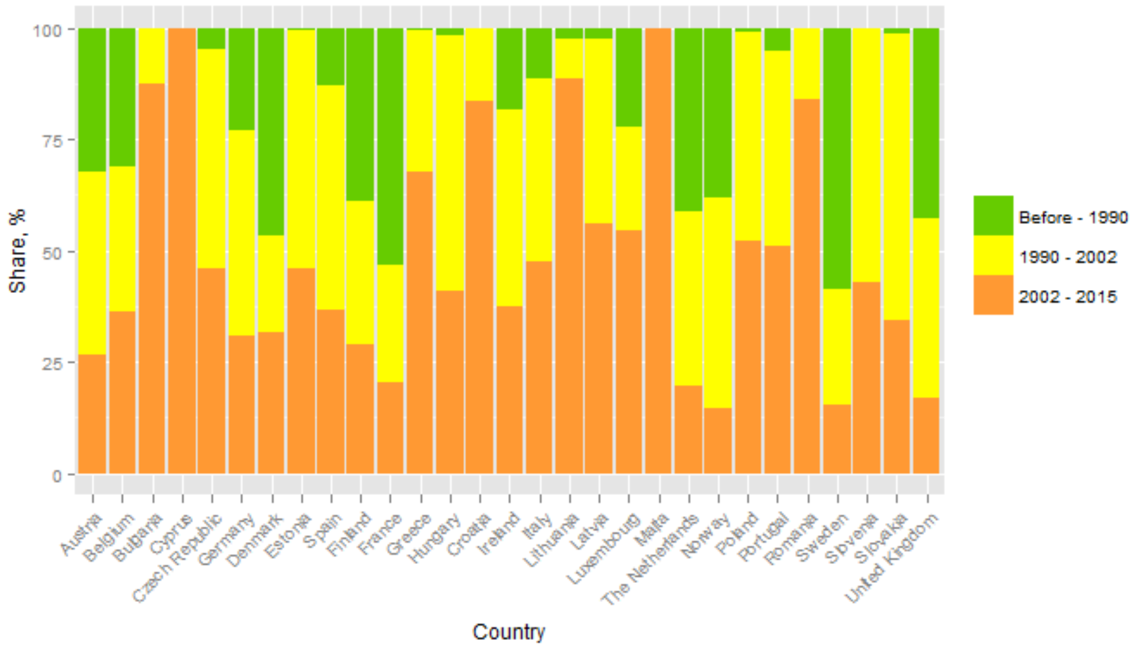

Figure 1. Share of the total gross leasable area by opening year in EU-28 and Norway in 2012(ICSC, 2014).

from the OECD (2016). Historical sales growth data of shopping centres per country from 2000 to 2012 comes from the ICSC (2014) statistics. The historical sales growth data of shopping centre are then correlated with the GDP by 2030. In this analysis, we identified that the development of new shopping centres is limited in most European countries. However, there is still an under-supply in the so called non-mature markets in Central and Eastern Europe (CEE).

The renovation rate λ(t) in year t for each building age class is calculated with a Weibull-distribution.

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

in which β denotes the shape factor and T the characteristic life time.

Different shape factors and characteristic life times assessed in CommONEnergy are being used for the replacement of lighting, appliances, refrigeration, ventilation, heating and cooling systems and thermal renovation of the building envelope. The characteristic life time has been calculated with data on opening and renovation years of shopping centres listed in the Global Shopping Center Directory (ICSC, 2016).

ENERGY DEMAND CALCULATION

Energy demand for space heating, space cooling, appliances, ventilation, refrigeration and lighting was calculated for each shopping centre category (see section "Breaking down the shopping centre building stock") for each country. Specific energy demand calculation for space heating and cooling was carried out using the monthly energy balance approach based on EN 13790 methodology (ISO 13790:2008). The calculation was made with the building simulation tool Invert-EE/Lab (Müller, 2015).

Energy demand for lighting, appliances, refrigeration and ventilation is calculated using specific power (see Table 2). For each shop type, the specific power and daily usage duration for lighting, appliances, refrigeration and ventilation is set. Data on specific power and usage duration are based on the ASHRAE Energy standards 90.1-2013 for buildings and shopping centre case studies as analysed in the project Commonenergy (Schönberger 2013, Westphalen and Koszalinski 1999, Goetzler et al, 2009). By multiplying the power of services in a particular shop with duration (hours per year) we calculate the specific energy demand for lighting, appliances, refrigeration and ventilation. Duration of use of lighting, appliances and refrigeration was specified taking into account the typical opening hours of the shops and vacations in a particular country.

Figure 2 shows calculated specific annual demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation used in European shopping centres. Energy demand for lighting makes up the highest share on the total annual energy demand followed by space cooling. The share of the lighting, space cooling, refrigeration, appliances, space heating and ventilation on the total final energy demand in an average shopping center is as follows: 30 %, 22 %, 17 %, 17% 8 % and 5 % respectively. Even in the Northern European countries, the share of the specific heating energy demand on the specific total energy demand is 4.2 % in Norway and 6.5 % in Latvia as example. 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, strengthened by the climate in the southern Europe. The specific energy demand for the abovementioned services was calculated for different shopping centre categories, small, medium, large and very large. The total annual specific 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. Small shopping centres have the highest energy demand due to the high share of the supermarket floor area on the total shopping centre floor area which

Table 2. Specific power for different shop types and services (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 areas)	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	6.8	8.3	3.7	20.8	10.6

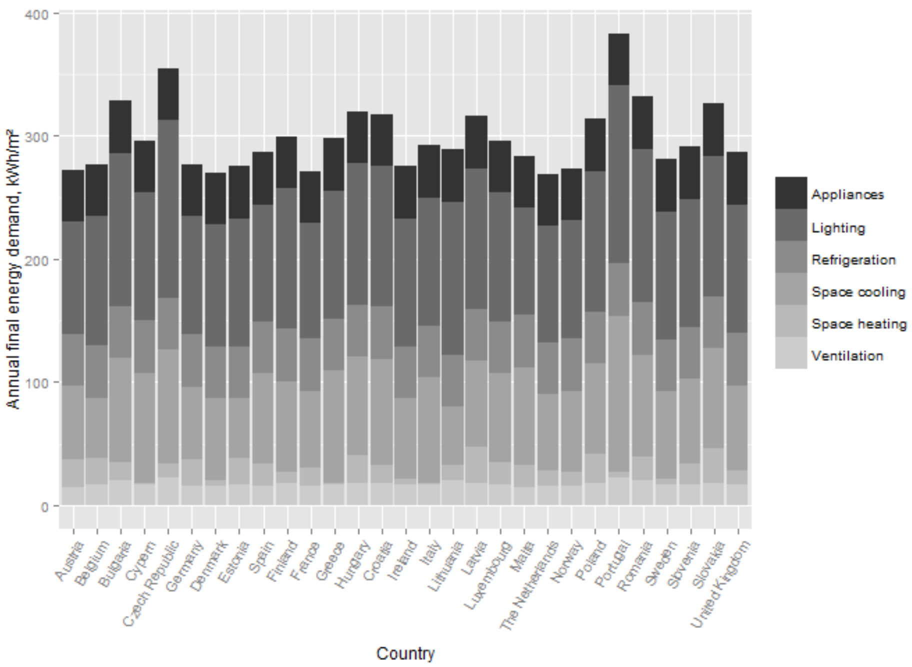

Figure 2. Calculated specific final annual demand for appliances, lighting, refrigeration, space heating, space cooling and ventilation per m² gross floor area in an average shopping center in EU28 and Norway.

leads to higher energy demand for refrigeration and appliances compared to other shop types.

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 try to identify their impact on the final energy demand 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 and, (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 3.

1. *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.

2. *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.
3. *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 %.
4. *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 partial 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 not saturated 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 %.

Results

Figure 3 shows the change in the final energy demand in the existing 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 main reasons is the development of the shopping centre building stock. In the non-mature markets such as Bulgaria, Lithuania, Poland and Romania, the share of new buildings built between 2012 and 2030 gross floor area is 60 %, 70 %, 50 % and 63 % respectively. 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. Unlike in the non-mature markets, in the saturated markets the new shopping centre construction rate from 2012 to 2030 is very low. In countries such as Austria, Norway, Sweden, France, the share of the new building gross leasable area built between 2012 and 2030 is 24 %, 8 %, 25 % and 30 % respectively. In the first scenario, which is the status quo scenarios, the change of the final energy demand from 2012 to 2030 is -15 %, -38 %, -27 % and 6.5 % in Austria, Norway, Sweden and France respectively. The second scenario which includes policies addressing 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. 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 the abovementioned countries. Due to the strong increase of the new buildings in the non-mature markets until 2030, the total energy demand will increase, too. In the first scenario, which is the status quo scenarios, the final energy demand from 2012 to 2030 will increase by 114 %, 125 %, 67 % and 120 % in Bulgaria, Lithuania, Poland and Romania respectively. The second scenario which includes policies addressing more ambitious measures for lighting, appliances, refrigeration, ventilation and space heating and control systems, shows that the increase in energy demand is much lower compared to the status quo scenario in the abovementioned markets. 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. The Internet sale scenario which reduces the future shopping centre growth shows a significant difference of the change in energy demand compared to the status quo scenario in abovementioned markets. In the internet sale scenario, the final energy demand from 2012 to 2030 will increase by 58 %, 24 %, 23 % and 56 % in Bulgaria, Lithuania, Poland and Romania respectively.

We calculated the final energy demand by the energy services in EU28 plus Norway (see Figure 4). Final energy demand

Table 3. 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

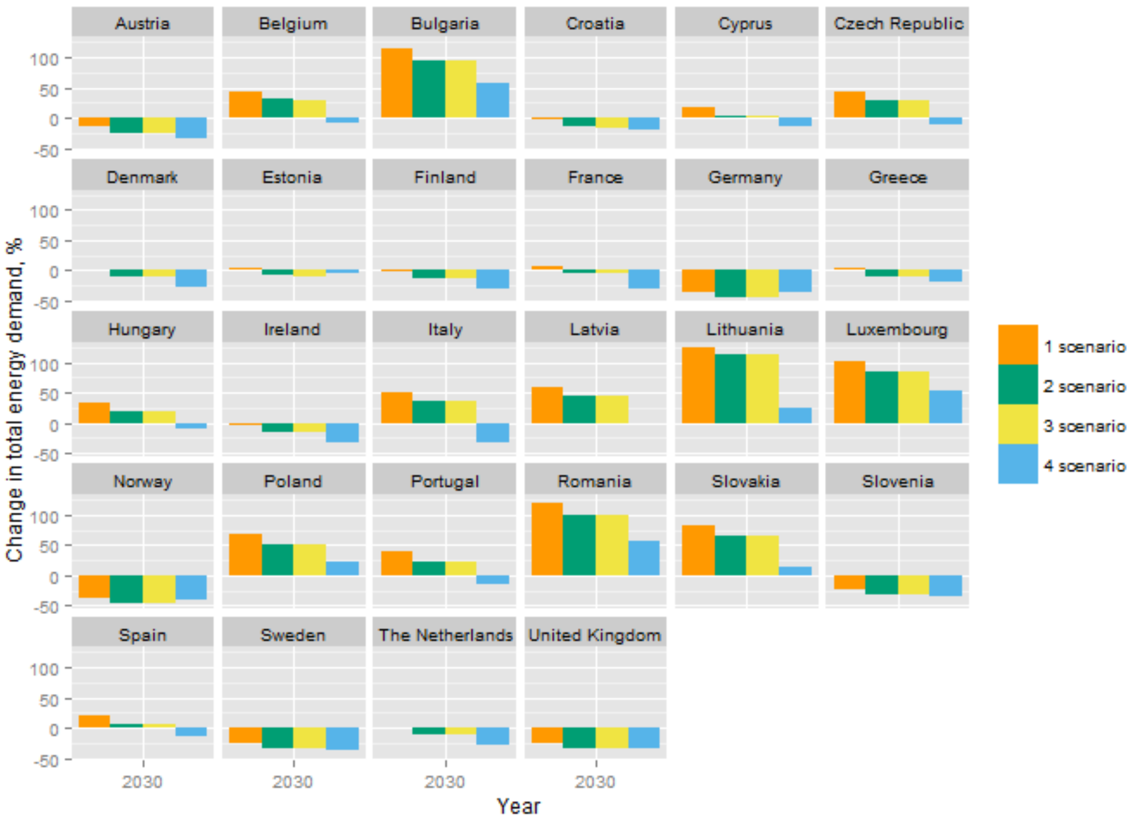

Figure 3. Change in total energy demand for space heating, cooling, appliances, ventilation, refrigeration and lighting from 2012 to 2030 in the European countries in different scenarios.

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 (see table 3 describing these 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.

Recommendations

The present research reaffirms that the shopping center sector is equally complex as the residential sector due to the variety of physical structures and the social multi-stakeholders decisional processes. Shopping centers cannot adapt to predefined typical structures with corresponding characteristics due to the correlation of variable design with customer attraction that calls for innovative architectural design. Based on our analysis and the presented literature and experiences gained through the CommONEnergy project, we suggest the following recommendations to achieve a long-term energy savings in the European stock of shopping centres. The recommendations are presented in four categories, each correspondingly addressing the energy related systems, multi-stakeholder processes, government policy-making, and industry-led initiatives:

1. Upgrade the energy-related systems of shopping centres with the aim of reducing energy consumption and reaping the multiple benefits of energy efficiency.
   a. Increase system efficiencies (i.e. by separating heating and cooling systems from ventilation), and by optimizing the use of equipment via automation controls, such as motion and air quality sensors. The modules of a shopping centered should be considered holistically as a system interdependent with aspects such as weather, customer preferences and retailers. Synergies should be pursued and energy conflicts avoided.
   b. Introduce minimum performance requirements for individual technical systems e.g. refrigeration cabinets, active control systems. Define max. illumination rates for shop types and opening hours to reduce the energy consumption of tenants.
   c. Institutionalize the position of an energy manager or external reviewer, when the shopping centers' floor area is above a certain threshold, and ensure the availability of training programmes for facility managers.
   d. Upgrade the Building Management System to improve controls and align them with external illumination and weather conditions. Install systems for automatic energy monitoring and metering in order to allow informed decisions and accurate appraisal of energy performance.
   e. Design teams should guide shopping centres in their first year after construction or refurbishment, monitor energy consumption and help the centre to adjust their systems (HVAC, control, lighting, …)
2. Pay attention to multi-stakeholders processes, especially to landlord-tenant relationships.

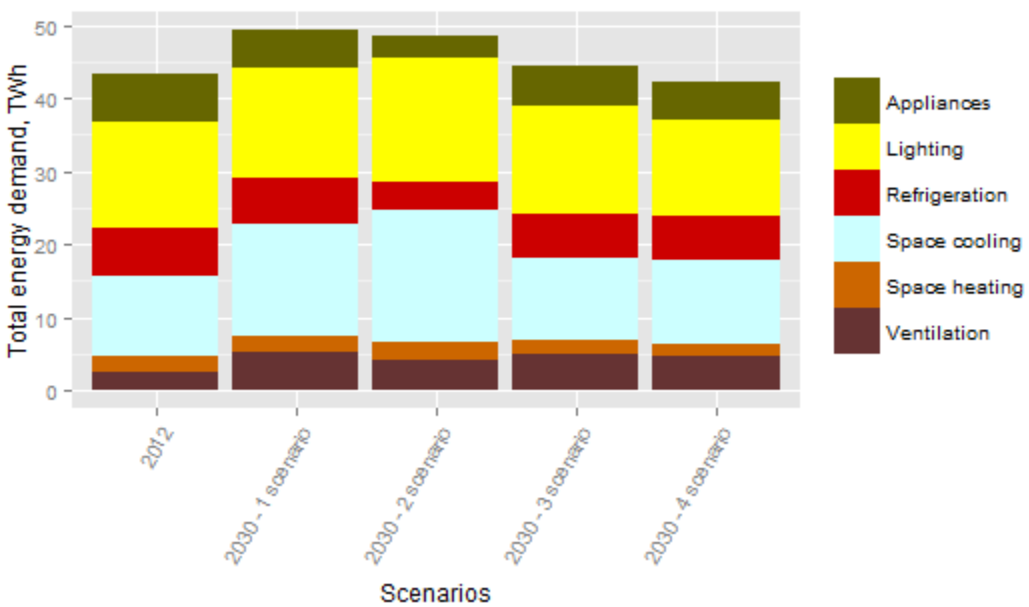

Figure 4. Final total energy demand by energy services in the shopping centers in EU28 plus Norway in 2012 and in 2030 in four scenarios.

a. Design budget processes to overcome split incentives between tenants and landlords. Account in a transparent matter for the energy intensity and maintenance costs of the owners and the tenants in order to increase system cohesion (holistic approach) and overcome split incentives.

b. Ensure the adequate provision of information to tenants so that they understand their role in energy consumption and identify clear opportunities for cost reductions, i.e. through tax benefits.

c. Promote green leases in order to address the issue of unfair distribution of cost/benefits between owners and tenants, thus aligning the financial and energy incentives of building owners and tenants and enabling them to work together for the efficient operation of buildings.

d. Use areas of high footfall to raise the customers' awareness for energy efficiency, e.g. display energy consumption, and highlight applied measures energy to reduce energy consumption.

3. Support stable policy and long-term planning drivers.

   a. Define nZEB, energy positive and smart building standards for shopping centers.

   b. Shopping centres will benefit from energy reductions if included in the definition of EED's Article 5. Policy makers should consider to extent the provisions of the Energy Performance of Buildings Directive to include shopping centers to all references to "buildings frequently visited by the public".

   c. Policymakers should set forth obligations for major asset owners to submit renovation roadmaps for shopping centers and take the lead in developing industry best practices and guidelines that bring the shopping centre sector in line with the 2050 vision of a decarbonized building stock.

4. Adopt suggested industry-led practices.

   a. Adopt energy efficiency as a risk asset component and monitor the relationship between energy use and asset value. Operationalize the benchmarking of energy use in relation to charged services, rental income and other core profitability indicators.

   b. Create key performance indicators for the evaluation of shopping malls energy needs and require their participation in benchmarking programmes that include solid monitoring, reporting and verification methodologies.

   c. Ensure that energy efficient measures (heating systems, envelope, monitoring &controls) will be included in every intervention of planned preventative maintenance as part of strategic assets management planning.

   d. Mainstream awareness campaigns for property owners and related professionals in order to inform and implement corporate policies.

Shopping center owners and investors could be considering their energy footprint in a wider approach by taking into account access to the shopping center, transportation means, zero-carbon transport and the environmental impact of logistics and the supply chain. These aspects have not been the focus of the resent paper, but the authors believe that additional research is required in order to make these considerations more visible to the industry.

Conclusions

In this paper, 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 shopping centre building stock in 2012. The future energy demand is depending on the quality of renovation and the replacement rate of building technologies, the new shopping centre construction and the market saturation in the respective country. Literally this means all emerging markets have a growing energy demand in the status quo scenario. For instance, in the formerly socialist CEE countries the shopping centre era began after 1990 and the shopping centre stock is young compared to many western European countries. However, if energy efficiency measures are being implemented and the retail market will change by expanding web shops, the energy demand in these markets will go down as it was shown in the last scenario. The following main conclusions can be highlighted:

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 total shopping centre building stock in EU28 and Norway can be reduced from 2012 to 2030 by 59 % in the status quo scenario and by 62 % in the second scenario which includes policies addressing 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 shopping centres.

Conclusion 2: In the transition economies and especially in these countries 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. According to Haase et al (2015), certifications enhancing green branding play an important role in the decision of investing in energy efficiency measures for the shopping centres. Building codes might have a similar motivational function as certification schemes.

Conclusion 3: Policies addressing any issue shopping centres must pay attention to the socio-economic and technical complexity of this sector. For instance, the physical structure of shopping centres and the social multi-stakeholders decisional processes involving owners, tenants, customers and administration are a case sui generis. Thus, policies addressing shopping centres should build on already existing and efficient, voluntary certification schemes such as BREEAM certification or green leases. Moreover, an in-depth, ex ante evaluation of the impact of any shopping centre policy on the numerous stakeholders should be conducted.

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