CommONEnergy

DELIVERABLE 2.1

Shopping malls features in EU-28 + Norway

European Commission
DG Research and Innovation
SP1 - Cooperation
Collaborative project
Large-scale integrating project
FP7-2013-NMP-ENV-EeB

GRANT AGREEMENT No. 608678

CommON*Energy*

Re-conceptualize shopping malls from consumerism to energy conservation

FP7 European Union Funding for Research & Innovation

Technical References

Project Acronym	CommON*Energy*
Project Title	Re-conceptualize shopping malls from consumerism to energy conservation
Project Coordinator	Roberto Lollini Accademia Europea Bolzano, Viale Druso 1, 39100 Bolzano/Italy roberto.lollini@eurac.edu
Project Duration	1 October 2013 – 30 September 2017 (48 Months)

Deliverable No.	D2.1
Dissemination Level	PU
Work Package	WP2
Lead beneficiary	TU-WIEN
Contributing beneficiary(ies)	BPIE, EURAC, Fraunhofer IBP, SINTEF, D'Appolonia
Author(s)	Raphael Bointner and AgneToleikyte
Co-author(s)	Ruth Woods, Bogdan Atanasiu, Antonio De Ferrari, Chiara Farinea, Federico Noris
Reviewed by	Bogdan Atanasiu, Matthias Haase, Roberto Lollini and Kristian Stenerud Skeie
Date	30/11/2014
File Name	Shopping malls features in EU-28 + Norway

This document has been produced in the context of the CommONEnergy Project

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 608678. All information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability. For the avoidance of all doubts, the European Commission has no liability in respect of this document, which is merely representing the authors view.

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Executive summary

The European wholesale and retail sector is the big marketplace of Europe, contributing with around 11% of the EU's GDP. 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 malls are of particular interest due to their structural complexity and multi-stakeholders decisional process, due to the high potential of energy savings and carbon emissions reduction, as well as due to their importance and influence in shopping tendencies and lifestyle.

CommONEnergy focuses on reducing the energy consumption in EU shopping malls by developing smart renovation strategies and solutions. The big challenge is to provide sustainable options that are also cost-effective with an acceptable payback period for this business sector. In order to gain an understanding of the current shopping mall building stock, this report investigates shopping malls features in the EU-28 and Norway based on an extensive literature survey and on a broad and detailed data collection process.

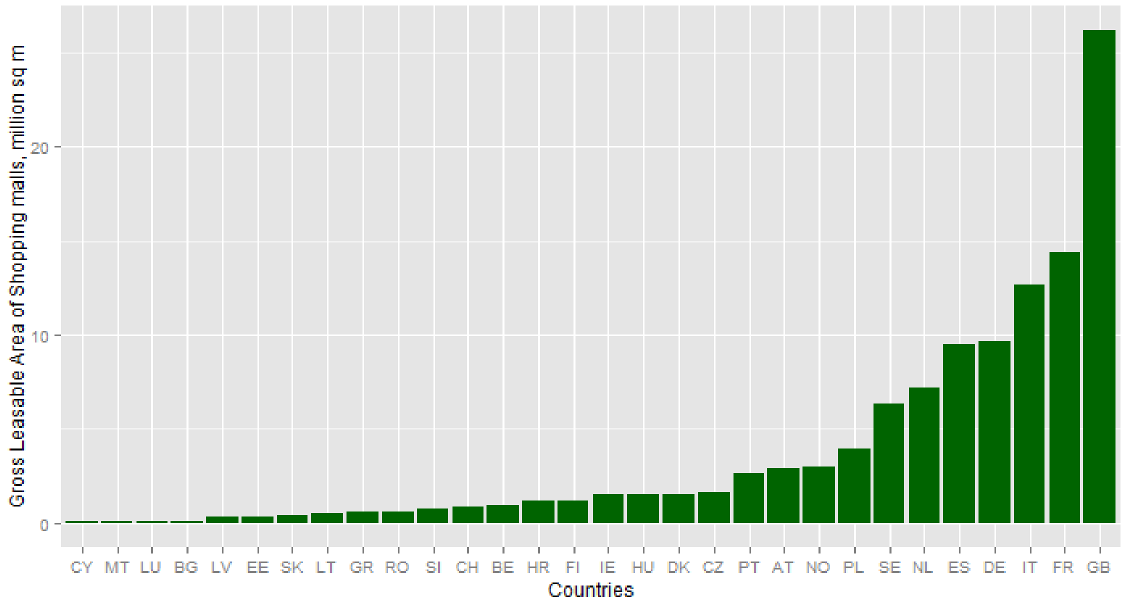
It has been a long way from medieval markets, middle eastern bazars and 18th century arcades to modern shopping centres as we know today. Thus, based on a comprehensive literature review, a definition and categorisation criteria of shopping centres in their functional and social context provides a solid ground for CommONEnergy. Shopping centres vary, among other criteria, 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 with its future and boundaries, a CommONEnergy Shopping centre definition was set.

A shopping centre is 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:

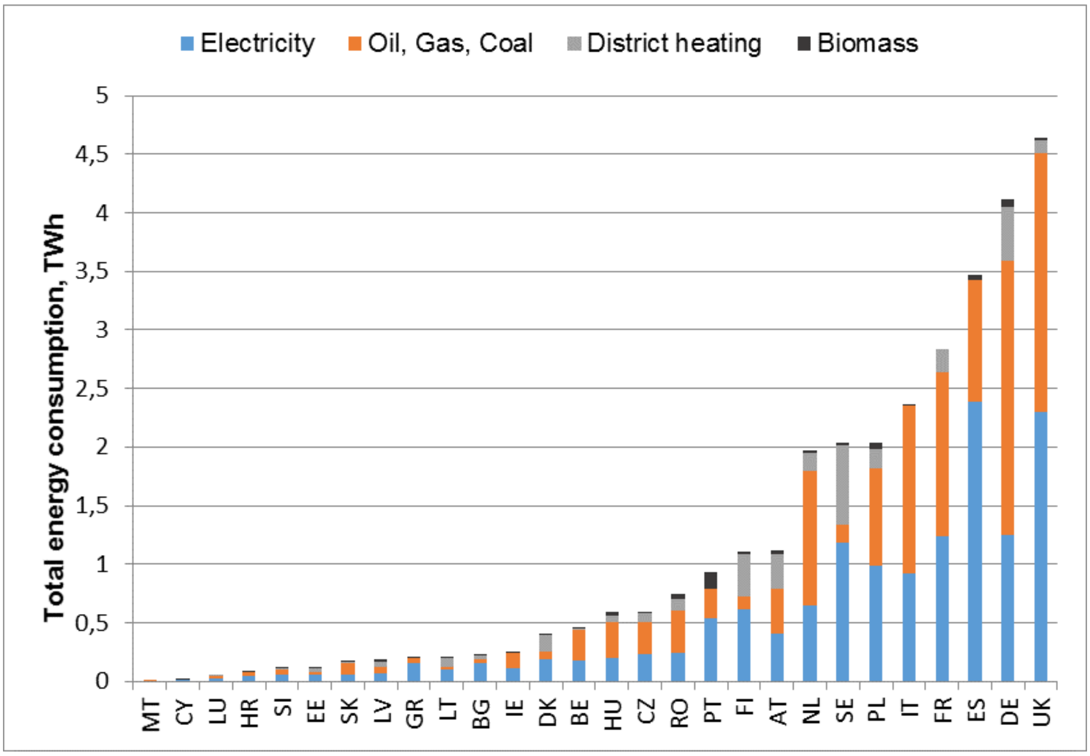
- a retail complex containing several stores or units and
- a minimum gross leasable area (GLA) of 5,000 m^2 except some specific types of shopping centres, e.g. market halls

Quantitative evaluations of shopping centres, as defined, are complemented by qualitative assessments. Today, there is more than 112 million m^2 shopping centre gross leasable area in the EU28, including Norway of shopping centres larger than 5.000 m^2. The average gross leasable area per 1000 capita in EU-28 + Norway and Switzerland is 224 m^2, whereas Central and Eastern European countries are below average, because these markets are not mature, yet. This is also supported by a relatively young shopping centre building stock in these countries. On the other hand, the shopping centre building stock is much older in

Western Europe and offers opportunities for energy efficient refurbishment and redevelopment. The shopping centre renovation rate is 4.4 % - very high compared with the renovation rate of 1 to 1.5 % in the residential sector.

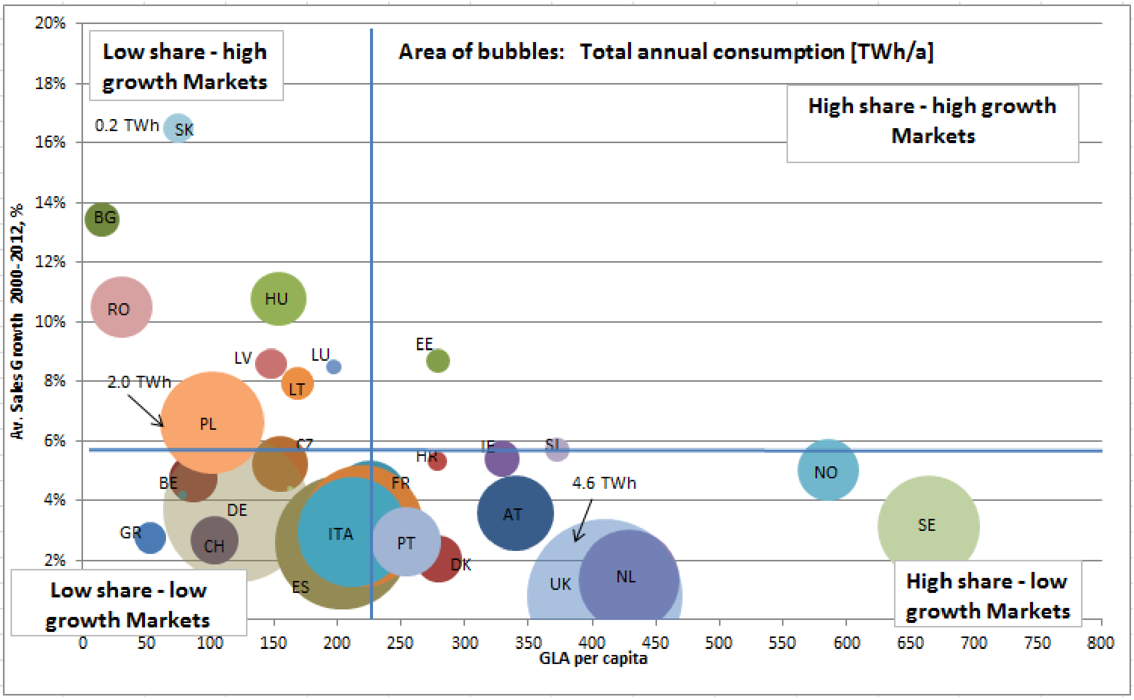


Gross Leasable Area of Shopping centres larger than 5000 m² in the EU-28 and Norway



Total energy consumption of the EU-28 shopping centre building stock subdivided by energy carrier

The final energy consumption of the shopping centre stock is associated with the gross leasable area (estimation: 32.2 TWh in 2013). Countries with a large floor area also have elevated energy consumption, whereat the specific energy consumption per square meter on European average is estimated by 272 kWh/m²a. The final energy estimate and the specific energy consumption are based on 119.2 million m² shopping centre gross leasable area in the EU28 + Norway and Switzerland. Moreover, this sample includes shopping centres smaller than 5.000 m². The predominant energy carriers in the service sector and also in shopping centres are electricity and natural gas.

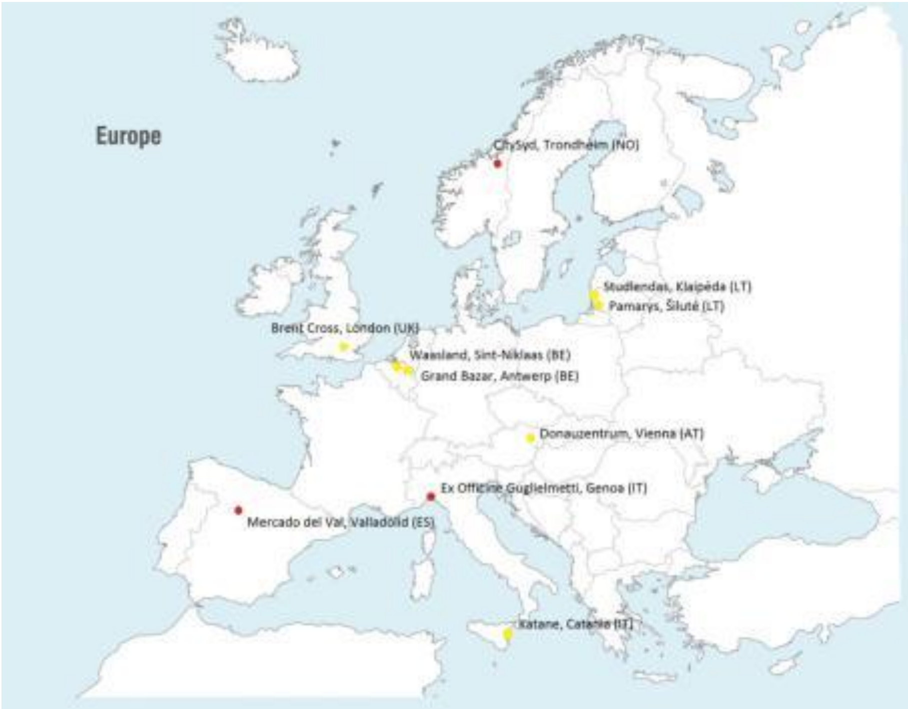


Average Sales Growth 2000-2012 and GLA per Capita in the EU-28, Norway and Switzerland. The area of bubbles indicate the total annual energy consumption, blue lines indicate the mean values

These data collections and calculations serve as basis for selecting ten reference shopping malls that will be modelled and evaluated within the activities of the project. The selection is done according to six predefined criteria in order to be representative of the European stock for different technology concepts and functions as well as covering main climatic zones. In particular, the six criteria are climate condition, market saturation, location, shopping centre typology, building typology and the opening year. Following these criteria, shopping centres from seven European countries were selected. The project team will then identify inefficiencies and develop systemic solutions which will be virtually tested (simulated); The first 3 buildings are the democases that will be retrofitted during the project. The following CommON*Energy* reference buildings cover a broad range of typical European shopping centres:

- City Syd (CS), Medium Shopping centre
- Mercado del Val (ME), Specialised and Others

- Genova Ex-Officine Guglielmetti (GE), Specialised and Others
- Centro Commerciale Katané (KA), Medium Shopping centre/ Hypermarket
- Donau Zentrum (DO), Very Large Shopping centre
- Brent Cross (BC), Very Large Shopping centre
- Pamarys (PA), Small Shopping centre/ Hypermarket
- Studlendas (ST), Small Shopping centre
- Waasland Shopping Center (WA), Large Shopping centre
- Grand Bazar (GB), Small Shopping centre



Reference building distribution (red dots indicate demo-cases, yellow dots other reference buildings

The matrix on the next page shows the reference buildings and their relation to the six selection criteria. Most of the criteria-combinations are covered with one or even more shopping centres.

Finally, an overview of national building codes, regulation constraints and relevant existing policy frameworks for shopping centres complete the report. Most countries periodically update their building energy codes, some more frequently than others. This process ensures that codes reflect changes in technology and design that offer increased energy efficiency and cost-effectiveness. This holds true for shopping centres, the wholesale and retail sector as well as the whole building stock. Finally, our results may serve as a comprehensive basis for decision making among European stakeholders on their way towards sustainability as mentioned in the beginning.

Reference buildings and the selection criteria

Selection Criteria		Climate condition			Market saturation		Location		Shopping centre typology			Building typology		Opening year		
		Heating Dominated	Cooling Dominated	Heating and cooling Dominated	Well-developed markets	Emerging markets	Urban	Suburban	Small shopping mall	Medium and large Shopping mall	Specialised and Others	Reconceptualized building	Shopping center purpose	Before 1990	Between 1990 and 2002	After 2002
Climate condition	Heating Dominated	CS/PA/ST			CS	PA/ST	ST	CS/PA	ST/PA	CS			CS/PA/ST	CS		PA/ST
	Cooling Dominated		GE/KA		GE/KA		GE/KA			KA	GE	GE	KA	GE		KA
	Heating and cooling Dominated			ME/BR/DO/WA/GB	ME/BR/DO/WA/GB		ME/DO/GB	BR/WA	GB	BR/DO/WA	ME	ME	BR/DO/WA/GB	ME/BR/DO/WA	GB	
Market saturation	Well-developed markets				CS/ME/GE/BR/KA/DO/WA/GB		ME/GE/KA/DO/GB	CS/BR/WA	GB	CS/BR/KA/DO/WA	ME/GE	ME/GE	CS/BR/KA/DO/WA/GB	CS/ME/GE/BR/DO/WA	GB	KA
	Emerging markets					PA/ST	ST	PA	PA/ST				PA/ST			PA/ST
Location	Urban						ME/GE/KA/DO/ST/GB		ST/GB	KA/DO	ME/GE	ME/GE	KA/DO/ST/GB	ME/GE/DO	GB	KA/ST
	Suburban							CS/BR/PA/WA	PA	CS/BR/WA			CS/BR/PA/WA	CS/BR/WA		ST
Shopping centre typology	Small shopping mall								PA/ST/GB				PA/ST/GB		GB	PA/ST
	Medium and large Shopping mall									CS/BR/KA/DO/WA			CS/BR/KA/DO/WA	CS/BR/DO/WA		KA
	Spezialised and Others										ME/GE	ME/GE		ME/GE		
Building typology	Reconceptualized building											ME/GE		ME/GE		
	Shopping Center purpose												CS/BR/KA/DO/PA/ST/WA/GB	CS/BR/DO/WA	GB	KA/PA/ST
Opening year	Before 1990													CS/ME/GE/BR/DO/WA		
	Between 1990 and 2002														GB	
	After 2002															KA/PA/ST

1. Introduction

The European wholesale and retail sector is the biggest marketplace of Europe, contributing with around 11% of the EU's GDP[1] while triggering additional significant contributions through the supply chain economy related to it. More than 6 million companies are acting in the retail sector while around 30 million Europeans works in commerce[2]. 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 malls are of particular interest due to their complexity as physical structures and the social multi-stakeholders decisional processes. Shopping malls offer high energy savings and carbon emissions reduction potential and have an important influence in shopping tendencies and customers' lifestyle. Thus, in order to achieve the environmental and energy goals, it is needed to understand the complexity, size, functional and social context of shopping malls.

The project CommONEnergy focuses on reducing the energy consumption in the EU shopping malls by developing smart renovation strategies and solutions. The big challenge is to provide sustainable options but at the same time on cost effective with an acceptable payback period. For reaching this, a holistic approach will be used by considering all technical, economic, environmental and social aspects. Therefore a Systemic Retrofitting Approach will be applied aiming to lead to a reduction of energy demand (i), power peaks and greenhouse gas emissions (ii) increasing share of renewable energy source (iii) short pay-back time and (iv) high indoor environmental quality. Finally, ten to twenty systemic solution-sets for retrofitting shopping malls will be developed as well as support tools and methods for energy-economic evaluation, lean construction and management procedures. Further continuous commissioning, environmental and sociocultural impact assessment, healthy, safety and security are also considered. The inclusion of all these aspects is considered in order to reach a wide replication potential of the systemic retrofitting solution-sets.

In order to gain an understanding of the current shopping mall building stock, which is the basis for the abovementioned aim of CommONEnergy, this report investigates shopping malls features in the EU-28 and Norway based on an extensive literature survey and on a broad and detailed data collection process. The first part of the report presents a detailed definition and categorisation criteria of shopping centres in their functional and social context. This is closely linked to the preferences, interests and decision patterns of shopping centre stakeholders, also including their acceptance of energy efficient and renewable technologies. These main stakeholder groups commonly associated with shopping centres are customers,

[1] http://ec.europa.eu/commission_2010-2014/president/news/archives/2014/03/pdf/services_en.pdf
[2] http://ec.europa.eu/environment/industry/retail/pdf/issue_paper_1/Energy_Efficiency_en.pdf

tenants, the management and the community. A detailed description and discussion of these four groups including functional pattern and socio-cultural aspects is provided in the CommONEnergy Report “Functional Patterns and Socio-Cultural Aspects” (Woods et al., 2014b).

The second part of the report provides a comprehensive evaluation of the existing typologies of shopping malls in Europe as the gross leasable area, the age of the buildings, and the energy consumption for heating, ventilation and air conditioning. A comparative cross-country analysis is also carried out. Quantitative evaluation of shopping centres is complemented by qualitative assessments. Furthermore, it comprises an in-depth analysis of the European shopping malls. Energy conservation challenges in the commercial building sector are presented in the CommONEnergy Report “An analysis of systemic energy inefficiencies” (Woods et al., 2014a).

The third part of the report proposes a selection of ten reference shopping malls that will be modelled and evaluated within the future activities of the project. The selection was done according to criteria presented in this section in order to be representative for the European stock for different technology concepts and functions as well as covering main climatic zones.

Based on a literature review and on the survey undertaken within the project, an overview of national building codes, regulation constraints and relevant existing policy frameworks is presented in the fourth part of the report. Finally, the results are presented in an interactive online data mapper available at www.commonenergyproject.eu/data_mapper.html. This online tool represents a user-friendly and tailor-made platform of national and comparative international indicators relevant for the commercial building stock. Conclusions and final remarks complete the report providing the foundation for further project activities and a comprehensive basis for decision making among European shopping mall stakeholders.

2. Shopping Centre Definitions

There are two main terms commonly used to describe what are basically the same retail form, shopping centre and shopping mall. The difference is primarily associated with geographic use. Shopping mall is the term most commonly used in North America; shopping centre is the term most commonly used within the European context (ICSC, 2005, 2006, 2008).

2.1 Historical background

There is a history to the physical form of shopping centres that is associated with large number of retail forms, markets (indoors and outdoors), middle eastern bazars, arcades and department stores all have obvious physical similarities to shopping centres, but also small corner shops and emporia are related (Morrison, 2003). The most basic retail form is the open air market and there have always been markets; even before we had money we had markets (Mauss, 2005). Traditional markets still exist, sometimes alongside hypermodern shopping centres (Birmingham and Wakefield city centres in the UK provide examples of this). The basic pattern of retail trade developed during the middle ages around the market square. During the 15th and 16th century the church, town hall and shops were established in close proximity to a town square and its market. It was an urban strategy connected to trade which often influenced the entire form of the city (Calabi, 2004). During the 19th century the growing urban population was increasingly housed in high density accommodation far away from the self-sufficient rural economy which had previously been the norm. Wages improved for middle and working classes, bringing a demand for goods and changing expectations about the shopping experience (MacKeith, 1986). In addition there were a growing number of manufactured goods available. The traditional open air market had to compete with new retail forms, indoor markets, emporia, arcades and department stores. 19th century shopping took place in structures which were specifically planned for the activity of shopping, previous formats developed more haphazardly and shopping in town halls and exchanges was an activity which was more secondary to the building's other uses (Coleman, 2006).

Figure 1: The Textile Market in Norwich in the 18th century by Robert Dighton (source: www. norwichtextiles.org.uk, © Norwich Textiles)

Markets and shopping centres provide customers with goods and services; they also offer entertainment, for example cinemas and food courts and a place for social interaction[3]. However while marketplaces are often outdoors, with numerous stalls without clear physical boundaries competing for sensory attention, shopping centres offer customers an ordered shopping experience often within a single air-conditioned building.

Strip malls or shopping precincts are immediate precursors to todays enclosed shopping centres. These, in a similar way to the 18th and 19th century Arcades, provided a unified row of stores, offering some kind of protection from the weather. Arcades were found in town centres intersecting ordinary shopping streets. Arcades responded to the social and urban planning issues in increasingly urbanised cities, first in London and Paris. Land for expansion was scarce and arcades were developed around the existing street plan. They allowed an intensified land use and the utilisation of under-used rear areas (Coleman, 2006). Strip malls and shopping precincts were a suburban phenomenon, a result of increasing urban expansion. In North America the urban expansion began during the late 19th century, in Europe this was a post Second World War expansion (Dawson, 1983).

[3] Social interaction may take place in all areas of shopping centres. Shopping is typically an activity which takes place between family and friends (Woods, 2012, Miller, 1998). However social interaction may take place between staff and customers, friends and strangers. The social activity may take place during the act of shopping, or it may take place communal resting areas, food courts, restaurants and during other leisure activities found in larger Super-Regional centres such as ice rinks and bowling alleys.

The number of shopping centres increased in accordance with a post-war rise in incomes, greater consumer mobility and the emergence of new retail chain stores (ICSC, 2008). In 1945 there were 45 shopping "malls" across the whole of USA; by 1958 there were 2900 suburban malls. The first generation of malls was the strip mall. The growth in the expansion was primarily based on 6 factors (Coleman, 2006):

- Population growth
- Restricted space in urban centres
- Increasing car ownership
- Traffic congestion in urban centres
- Abundance of available and accessible land
- Technological developments in ventilation, air-conditioning systems and lighting

North American suburban shopping centres were part of residential satellites, combining large amounts of new housing together with the shopping centre which serviced the community's needs. The form of shopping centres gradually changed. The first fully enclosed shopping centre opened in 1956, the Southdale centre in Edina, Minnesota in the USA, designed by architect Victor Gruen (Morrison, 2003). The Southdale centre was inspired by the new technology which made possible large climate controlled environments and the belief that customers will shop longer and spend more money if they feel comfortable (Coleman, 2006).

In Europe shopping centres began to be established during the late 1950's and the first one opened in Vallingby, Sweden in 1954 (ICSC, 2004). Shopping centres in other forms, open and enclosed spaces, have existed much longer. Department stores, a closely related retail form, which are today often found within shopping centres (anchor stores), also provide a broad range of goods and services within a single air-conditioned building. The difference being that shopping centres have numerous units or stores under their roof, but a department store is basically one large store where the customer can move freely between different kinds of merchandise, different areas and levels within the store, and can pay for everything at the end of the visit. Nevertheless, some variations of department stores have a pay points serving each section or level within the store, and customers pay for goods purchased in the section.

Figure 2: The Southdale Shopping Centre (Edina, Minnesota) in 1956 (source: www.mnopedia.org/structure/southdale-center, © Minnesota Historical Society)

Figure 3: Donau Zentrum shopping centre (Vienna) in 1985; on the left the construction work of the expansion, in the first part from the opening year 1975 (source: http://commons.wikimedia.org/wiki/File:133R01020785_von_U_Bahn_Haltestelle_Zentrum_Kagran,_Blick_Richtung_Wagramerstrasse,_Donauzentrum,_links_Erweiterungsbau_zum_Donauzentrum.jpg, © TARS631)

European shopping centres did not initially develop on the urban outskirts or in suburbs. Shopping centres met retail and planning needs provided by a growing post-war European population with increasing spending power. In Central and Eastern European countries, however, the concept and development of shopping centres did not start until the 1990s

(EMEA, 2013). Shopping centres, as mentioned earlier, have similarities to other retail forms where a group of retailers are gathered together in a more or less organized limited physical area. What made 1960's shopping centres different from previous retail developments, in addition to enclosed space and air-conditioning, is that they were designed for a motor age. They do not just have space for shops they also provide space for car parks and loading bays for goods (Morrison, 2003). The problem with city centre traffic congestion was recognized before the Second World War, and the bombed out and rundown city centres of 1950's and 60's post-war Europe supported the perception that something needed to be done about European town and city centres. Some cities rebuilt and reused existing street patterns to create their shopping centres, for example Exeter and Bristol in the UK. Pedestrian precincts were a form applied to separate traffic routes from shoppers. Other cities centres, for example Plymouth and Coventry, radically redeveloped to incorporate modern shopping centres (Morrison, 2003). The first Bullring shopping centre in Birmingham, which opened in 1964, was at the centre of a city which based its wealth at that time on the car industry, and the shopping centre which was located at the hub of a city centre ring road, championed motorized transport with car parks and a bus station inside the shopping centre complex (Woods, 2012). Many contemporary shopping centres still have a motorised focus, but an increasing number of town centre redevelopments are offering less space to cars and focusing more on public transportation networks. This is due to city centre congestion caused by car based transport. The redevelopment of the Bullring shopping centre in 2003 is an example of this.

Figure 4: The Bullring shopping centre is located in the heart of Birmingham's city centre "Birmingham Bullring panorama -England" (Source: by Original uploader was ChrisJB at en.wikipedia Later version(s) were uploaded by Ian Dunster at en.wikipedia. http://commons.wikimedia.org/wiki/File:Birmingham_Bullring_panorama_-England.jpg)

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 shopping centres covered a retail space of 25 million m^2 (ICSC, 2008). In 2007 it was estimated that there were 5,700 shopping centres, with a retail space of 111 million m^2 of gross leasable area (112.1 mil m^2 in 2013). After 2000 tendencies show that shopping centre space will increase in Central and Eastern Europe while in more mature markets the focus will be on extensions, upgrades and regenerations (DTZ 2012). Older shopping centres are being refurbished in order to remain competitive and this has coincided with a need to regenerate town and city centres (ICSC, 2008). Planning legislation, for example in the UK, where the development of out of town shopping centres is strictly regulated, is encouraging the redevelopment of existing retail centres. In addition customers are increasingly expressing a preference for smaller arcades and market halls rather than the larger enclosed shopping centres (Coleman, 2006).

2.2 What is a Shopping centre?

There currently exist a wide number of different shopping centre sizes, forms and functions. New types of shopping centres emerge which meet public and retail needs, but the new types do not replace existing shopping formats, they instead add to the range of shopping facilities which already exist (Coleman, 2006). It is therefore difficult to include all the variations into a single definition of shopping centres. A useful shopping centre definition should be broad enough to allow for some regional variations. It should also provide clarity about the physical framework, for example are shopping centres open, enclosed or both. It should also say something about types of shopping centres, the size of the centre and the number of retail units. Management form is also relevant in a shopping centre definition. In addition a definition should also say something about the location of the shopping centre.

According the International Council for Shopping centres (ICSC), a shopping centre is "*a scheme that is planned, built and managed as a single entity, comprising units and communal areas, with a minimum gross leasable area*[4] *(GLA) of 5,000 square meters*" (ICSC, 2005). There exist in addition a number of other European shopping centre definitions. A survey from 2005 presents definitions from 32 European countries, stating at the same time that only 12 countries have a definition which is generally accepted and operated according to (ICSC, 2005). Shopping centres are defined most rigorously in Western European countries such as Portugal, Germany, France and Spain, but the UK (which has one of the largest shopping centre markets) as late as 2005 did not have an industry standard definition.

The ICSC is a retail organization and there also exist standards and definitions outside the retail industry. For example in Norway, the national political standard used for regional decision-making about the establishment and extension of shopping centres operates with this definition, "*the shopping centre is understood as retail units and building complexes that are established, operated or appear as a unit, as well as outlets that require customer membership cards to gain entry. Supermarkets are perceived as shopping centres in this*

[4] Gross leasable area (GLA) is the amount of floor space available to be rented in a commercial property. Specifically, gross leasable area is defined as the total floor area designed for tenant occupancy and exclusive use, including any basements, mezzanines, or upper floors (Wikipedia, 2014)

context. The same applies to department stores that sell one or more types of retail products. A shopping centre is also understood as retail trading located in several units within an area such as a retail park" (Forskrift, 2008). Within the retail industry in Norway shopping centres are defined as, "*a building or collection of buildings which are planned, built and managed as a single entity. The individual functions/ businesses are collected in a single building or grouped around a square, pedestrian street or open space. The retail space should be more than 2499* m^2 *and the centre should include at least 5 different retail units. The centre often has its own sales and marketing services*" (Senterhåndboken, 2008). There are similarities between the two Norwegian definitions, but the national political standard which is to be used during the planning process has a broader understanding of the physical framework of the shopping centre, although it does not specify size. The Norwegian example offers insight into the local and regional variations within the Shopping centre definition. A CommON*Energy* definition should take the variety within the European context and the reasons for it, into account.

In addition to the definitions by the retail industry and government bodies, it is also relevant to point out that shopping centres are also defined as a building type by the Energy performance building directive (EPBD Recast 2010/31/EU), which stipulates that a shopping mall belongs to the class of wholesale and retail trade buildings, which is one of the nine building categories. In the document "Classification of types of constructions" (CC 1998), buildings are subdivided into residential and non-residential buildings. Non-residential buildings are constructions which are mainly used or intended for non-residential purposes. Wholesale and retail trade buildings include shopping centres, shopping malls, department stores, detached shops and boutiques, halls used for fairs, auctions and exhibitions, indoor markets and service stations.

The Central Product classification regulated by the United Nations gives under section 5, Constructions and construction services, the following classification of subclass 53122[5]: the subclass "commercial buildings" include buildings used primarily in the wholesale and retail trades: shopping centres, shopping malls, department stores, detached shops and boutiques, indoor markets. This classification places shopping centres in relation to other retail forms but information about different shopping centre types is required. Types help us to understand something about the physical form of shopping centres, what retail services they provide, and their role and placement within the community.

[5] The United Nations Statistics Division provides a detailed structure and explanatory note of the commercial building subclass 53122 (Section: 5 - Constructions and construction services, Division: 53 – Constructions, Group: 531 – Buildings, Class: 5312 - Non-residential buildings, Subclass: 53122 - Commercial buildings): http://unstats.un.org/unsd/cr/registry/regcs.asp?Cl=25&Lg=1&Co=53122

2.3 Typologies, Background, New and Established Retail Forms

A shopping centre definition should provide an overview of relevant contemporary shopping centre building types. In addition, a useful shopping centre definition should offer a broad foundation, but also suggest common elements from existing shopping centre types which allow the recognition and inclusion of different members of the shopping centre family.

Three main types of shopping centres were established during the mid-1950s, neighbourhood centre, community centre and regional centre. The types are based on the size of the centre, function and tenant mix (Dawson, 1983). This classification provides a useful background despite the development of new types which do not fit the classification.

- **Neighbourhood centre**: the function is to provide convenience goods and personal services. There is often a key tenant such as a supermarket. A local retail function is reinforced by planned services nearby, such a library or primary school. The physical form may vary from enclosed air-conditioned space to strip-malls or precincts. Sizes suggested in 1983 range from 3,000 to 10,000 m^2. A customer will do daily shopping in a neighbourhood centre; it is often close to home.
- **Community Centre**: provides convenience-oriented goods with a greater variety of shops than in a neighbourhood centre. The anchor shop is a supermarket or hypermarket, sometimes with a mini-anchor of electronic products or sportswear. It provides a wider range of apparel and other soft goods than neighbourhood centres. The suggested GLA size is 10,000 to 30,000 m^2. In North America community centres were a feature of suburban development and they are not so common in Europe. Community centres were a product of planned decentralisation of metropolitan regions. They were often built at a major transport intersection and, thus shopping is car or public transport-based.
- **Regional Centre**: the suggested size is 30,000 – 100,000 m^2. Although it is suggested that centres over 75,000 m^2 could be placed in a new category, which is Super-Regional. A regional centre provides a broad range of general merchandise. It is built around a department store, but the larger centres may have more than one department store. Regional centres need a catchment population of over 150,000 and they are generally located at motorway intersections.
- A further category suggested by Dawson to supplement the initial 1950's categorisation is the **Super-Regional centre**. These centres became more common during the 1980's. Size-wise they are commonly over 100,000 m^2 (or 75,000 m^2 as mentioned before), with more than one department store. Some regional centres have developed to become super-regional, but they are often new developments.

Super-regional centres often have individual design features such multi-screen cinemas and ice rinks. It is primarily car-based shopping.

The Investment Property Databank (IDP) defines a shopping centre as "*a purpose-built centre of at least 5,000 square meters with 5 units or more. "The property should have a public area for pedestrians and be managed as a single entity by a property team*" (IDP, 2004). This definition appears to exclude the redefinition of historical or other kinds of buildings as shopping centres, and excludes the possibility that a shopping centre could be a single retail entity. The ICSC definition from 2005, mentioned above, offers a broad flexible definition, where a shopping centre is understood as a single planned, built and managed entity with retail units and communal areas, and a minimum leasable area of 5,000 m^2. However it says little about the activity in the shopping centre and although it allows for physical variations it offers little information about what these could be composed of. In addition the ICSC provides a framework which classifies shopping centres into 11 broad-based international types.

Table 1: International Standard for European Shopping Centre Types, (ICSC 2005)

Format	Type of scheme		Gross Leasable Areas (GLA)
Traditional	**Very Large**		80,000 m^2 and above
	Large		40,000 – 79,999 m^2
	Medium		20,000 – 39,999 m^2
	Small	**Comparison-Based**	5,000 – 19,999 m^2
		Convenience-Based	5,000 – 19,999 m^2
Specialised	**Retail Park**	**Large**	20,000 m^2 and above
		Medium	10,000 – 19,999 m^2
		Small	5,000 – 9,999 m^2
	Factory Outlet Centre		5,000 m^2 and above
	Theme-Oriented Centre	**Leisure-Based**	5,000 m^2 and above
		Non-Leisure-Based	5,000 m^2 and above

The traditional centre is understood as an all-purpose scheme that could be enclosed or open–air and is classified by size. Specialised centres are specific purpose built schemes that are most commonly open-air and are again classified by size. This table provides clarity about size; it also specifies what its main retail base is, for example comparison-based, convenience-based or leisure-based[6]. A limitation associated with this table is that it

[6] Comparison-based centres include retailers typically selling fashion goods, home furnishing, electronics and general merchandise such as toys and luxury goods. Convenience-based centres include retailers that sell essential goods and are typically anchored by a grocery store or supermarket (ICSC, 2005).

assumes that it is possible to clearly delineate between the different types of shopping and type of shopping centres. This is not always possible, for example the situation in Norway does not fit with a clear categorization because the majority of shopping centres combine comparison and convenience based shopping. In the UK the categorization, separating convenience and comparison based shopping works better. In addition the table offers little information about location. In an overview of the retail development process Guy (2003) provides a table which gives more information about the retail base, as well as some information about location.

Table 2: A typology of planned shopping developments (Guy in Freathy, 2003)

Type of development	Anchor store	Size range (m^2)	Trip purpose
Focused centre	Supermarket or hypermarket	5,000 – 20,000	Convenience shopping
Retail Park	None	5,000 – 30,000	Household shopping
Shopping mall	Hypermarket or department store	10,000 – 100,000	Comparison shopping
Regional centre	Department stores	50,000 – 150,000	Comparison shopping, leisure
Factory Outlet	None	5,000 – 30,000	Comparison shopping, leisure
Specialty centre	None	5,000 – 20,000	Leisure

Table 2 offers a similar categorization in relation to shopping activity according to type of development, comparison, convenience and leisure, but the description of type is closely related to location. Location is important during the planning process, as is the associated catchment area, influencing stakeholders on all levels; owners and managers, tenants and customers. In the table's supporting text, the types are described (Guy, 2003):

- Focused centres typically serve the surrounding residential area with convenience shopping needs, they are known as local or neighbourhood centres in North America or as district centres in the UK.
- Retail Park is often found in off-centre locations and sells bulky household goods.
- Shopping mall may have a freestanding position, but it may also be located in a town centre. It often includes one or more anchor stores and several smaller units. This kind of centre often attempts to replicate the amount and variety of shopping space in long-established and central shopping areas.
- Regional shopping centres exist in freestanding positions rather than as part of an existing centre.
- Factory outlet is similar physically to smaller malls but has no anchor stores and commonly found on the edge of the centre or outside the centre.

- Specialty centres resemble shopping malls or may be converted from one or more older buildings. They have no anchor store, specialise in certain kinds of goods and often cater to a tourist market and are found within a town centre.

Location is therefore relevant to the broader understanding of how a shopping centre functions and its role within the urban context. Terminology such as urban, suburban and rural may be used provide information about shopping centre types but only appear to a small extent in the definitions and frameworks which provide background for the definition provided here.

A further categorisation of shopping centres is provided by Coleman (2006). This categorisation was developed to fulfil the requirements of a book describing the shopping environments and was not intended to define the present situation within the industry. However the categorisation gives an overview of the existing types and subcategories which supplements the previous definitions and typologies. It also offers an overview with regards to location and provides a clear separation between "Out-of-town suburban shopping" and "Town centre shopping". These first two categories are defined by location and the type of accommodation found in the vicinity of the shopping centre. These categories were established by the mid-1960s. The third type of new emerging types of shopping allows the inclusion of novel shopping environment which are not easily included in the two other categories. Although the new emerging types suggested by Coleman are interesting in terms of the associated challenges such as size, energy use and combined usage, they are not directly relevant for a CommON*Energy* definition.

Table 3: Contemporary Types of Shopping Centres according to Coleman (2006)

<table>
<tr><td rowspan="14">Contemporary Types of Shopping Centre</td><td rowspan="5">Out-of-Town Suburban Shopping</td><td>Non-Town Centre Shopping Malls</td><td rowspan="5">Regional Shopping centres</td><td>Regional Shopping and Leisure Centres</td></tr>
<tr><td>Retail parks</td><td>New Town Regional Malls</td></tr>
<tr><td>Factory Outlet Centres</td><td>Lifestyle Centres</td></tr>
<tr><td rowspan="2">Entertainment Centres</td><td>Retail Resorts</td></tr>
<tr><td>Hybrid Centres</td></tr>
<tr><td rowspan="5">Town Centre Shopping</td><td colspan="3">Town Centre Malls</td></tr>
<tr><td colspan="3">Galleria and Vertical Malls</td></tr>
<tr><td colspan="3">1st Generation Urban shopping centres</td></tr>
<tr><td colspan="3">Speciality Shopping</td></tr>
<tr><td colspan="3">New Urban Quarters</td></tr>
<tr><td rowspan="4">New Emerging Types of Shopping Centres</td><td colspan="3">Retail entertainment Destinations</td></tr>
<tr><td colspan="3">Focused Retail Centres</td></tr>
<tr><td colspan="3">Railway Orientated Retail</td></tr>
<tr><td colspan="3">Airport Concourse</td></tr>
</table>

There are many definitions and typologies of shopping centres used in shopping centre industry. The following list presents the typologies and their definitions used in different context, describing functionality or location of the centres.

- **Enclosed shopping centres** provide retail opportunities within one environmentally controlled/ air conditioned building. Enclosed shopping centres protect customers, workers and merchandise from the out-door climate. Victor Gruen the architect, who pioneered the enclosed shopping centre during the 1950's, suggested that customers who feel comfortable will shop longer and spend more (Coleman, 2006).

- **Open shopping centres** such as strip malls and shopping precincts include more than one retail unit which are attached to each other, but customers cannot go from store to store without going outside. Retail units are often in a row or a U-form with a central open courtyard. The first 1950's shopping centres had an open design. Contemporary shopping centre developments often offer more open designs. Examples are Oracle in Reading, UK and Beursplein in Rotterdam, The Netherlands.

- **Convenience shopping** provides articles which are purchased regularly and often frequently (Dawson, 1983). Convenience goods are perishable goods provided by supermarkets or smaller grocery stores. It may be understood as daily shopping done at smaller neighbourhood centres, but convenience shopping may also be bulk shopping done at convenient intervals (Coleman, 2006).

- **Comparison shopping** provides articles which are long term purchases usually bought at irregular intervals. Quality, price and style are important factors in the selection (Dawson, 1983).

- **Anchor stores:** A key tenant or larger store, usually a department store in a shopping centre. In larger regional or super-regional centres containing more than one anchor store, they are commonly located as far as possible from each other to maximise the amount of exposure of smaller units.

- **Leisure activity:** Shopping may be understood to be a leisure activity, if it is not directly connected to a specific aim, such as purchasing long term or perishable merchandise. This kind of shopping has its fair share of negative associations. It is often seen as extreme shopping, an over the top activity devoted to indulgence. Shopping in these terms is associated with materialism, hedonism and self-indulgence (Miller, 1998). Leisure in shopping centres may also be related to other activities not directly related to shopping, often found in larger regional and super-regional centres, such as going to the cinema, ice skating and bowling, but also visiting cafes and restaurants are leisure activities.

- **Hypermarket** is a store usually larger than 5,000 m^2, combining a supermarket and a department store including grocery and general merchandise, which allow customers to satisfy all their daily shopping needs in one place. A hypermarket often has a parking area and a restaurant.

- A **market hall** (sometimes also called market house) is a covered space in which a market to buy and/or sell groceries, provisions or livestock is held. Historic market halls from the 19th or early 20th century, often a one- or two-story building, are usually covered by a cast iron or steel structure, varying from several hundred up to more than 10.000 square meters. A famous example is the Great Market Hall in Budapest.

2.4 CommON*Energy* Shopping Centre Definition

Based on the above mentioned literature, the CommON*Energy* Shopping centre definition was set. The definition is as follows:

A shopping centre is an arrangement of one or more retail buildings comprising business 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:

- a retail complex containing several stores or units and
- a minimum gross leasable area (GLA) of 5,000 m^2 except some specific types of shopping centres, e.g. market halls

Beside these criteria defining the building typology of shopping centres, further criteria are needed to put them into their social and environmental context. These criteria (location, type of development, the size and the GLA, the type of anchor stores and the trip purpose) are shown in Table 4 below.

Table 4: CommONEnergy definition of shopping centres

<table>
<tr><th>Location</th><th>Type of development</th><th>Size</th><th>GLA [m²]</th><th>Anchor store</th><th>Trip purpose</th></tr>
<tr><td rowspan="2">Town Centre Shopping/ urban</td><td>Neighbourhood centre/ community centre</td><td rowspan="3">Small shopping centres</td><td>5,000 – 19,999 m²</td><td>Supermarket or hypermarket</td><td>Convenience shopping</td></tr>
<tr><td>Speciality centre (market halls, historical buildings, other)</td><td>Usually 5,000 m² and above</td><td>Traditional markets, tourist shops</td><td>Leisure, convenience shopping</td></tr>
<tr><td>Out-of-Town Shopping/ suburban</td><td>Retail Park and Factory Outlets</td><td>5,000 – 30,000 m²</td><td>None</td><td>Household shopping, Comparison</td></tr>
</table>

					shopping, leisure
	Regional centre	Medium/ large shopping centres	20,000 – 79,999 m^2	One or more department stores	Comparison shopping
	Super-regional centre	Very large shopping centres	80,000 m^2 and above	Several department stores, entertainment centres	Comparison shopping, leisure

This definition is the basis for selecting the reference buildings presented in chapter 4. The main aim of this selection is to present different buildings, which identify the typical shopping centres throughout the Europe. The relevant reference building selection criteria are the shopping centre typology, the GLA, the opening year, the climate condition of the site, namely heating dominated, cooling dominated or both, the location – urban or suburban - as well as the shopping centre market saturation of the whole country. These criteria are further elaborated in chapter 3 and described in chapter 4.

3. General Data of the European shopping centre stock

3.1 Breakdown and categorization

Non-residential buildings comprise a more heterogeneous and complex sector compared to the residential sector due to variations in usage pattern, energy intensity and construction techniques. They include different types of buildings such as offices, shops, hospitals, hotels, restaurants, supermarkets, sport centres and schools. In the Directive on the energy performance of buildings (EPBD 2002 and EPBD 2010), the non-residential building sector is divided into the following seven sub-categories: wholesale and retail, offices, educational facilities, hotels and restaurants, hospitals, sports facilities and others. BPIE (2011) provides the same composition of the non-residential building stock and gives information on the share of the total floor area of each non-residential building typology (see Figure 5).

It is estimated that the whole EU-28 and Norway building floor area is almost 24 billion m^2 (BPIE 2013a). Almost half of the whole floor area is concentrated in the four following countries: Germany, France, Italy and the United Kingdom. The share of residential building floor area is 75% while the non-residential buildings make up 25% of the total building floor area in EU-28 and Norway (Entranze 2013), (BPIE 2013a). According to the BPIE survey, the sub-category Wholesale and Retail buildings include detached shops, shopping centres, department stores, large and small retail, food and non-food shops, bakeries, car sales and maintenance, hair dresser, laundry, service stations, fair and congress buildings and other wholesale and retail (BPIE 2011). That shows the complexity of the building stock.

The retail and wholesale buildings with a share of 28% comprise the largest portion of non-residential floor area while office buildings with a share of 23% are the second biggest category (see Figure 5). Educational buildings comprise 17% of the total non-residential building floor area followed by Hotels and Restaurants (11%), Hospitals (7%), Sport facilities (4%) and Others (11%).

According to BPIE, the total Wholesale and Retail floor area is 1,668 Million m^2 in EU-28 + Norway in 2013 (BPIE 2013a). Figure 6 shows the Wholesale and Retail floor area by country. It can be seen that the largest Wholesale and Retail floor area is in Germany (458 Million m^2), followed by UK (279 Million m^2) and France (207 Million m^2) (BPIE 2013a and Entranze 2013). These countries account for approximately 57% of the total wholesale and retail floor area in the EU-28 plus Norway and Switzerland.

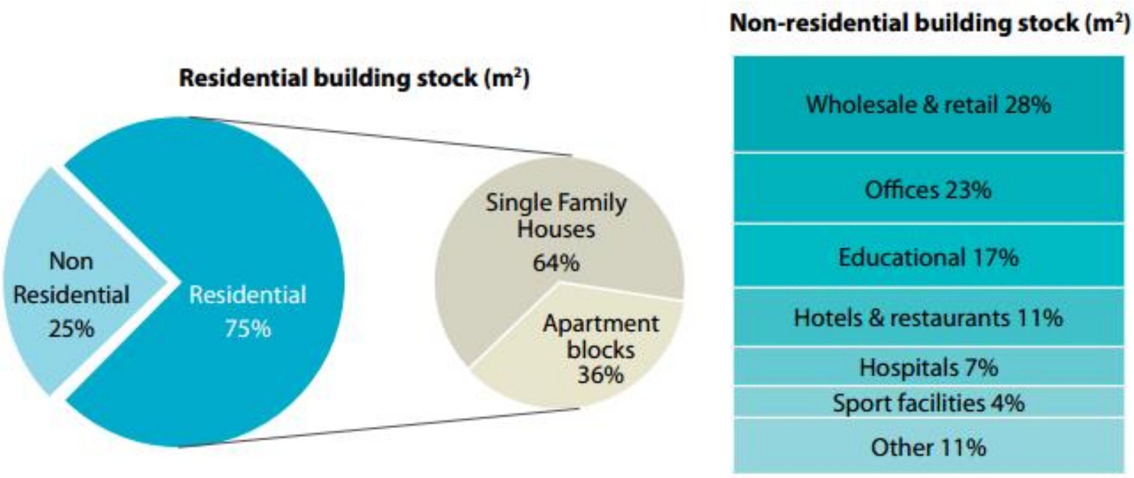


Figure 5: Breakdown of residential and non-residential building stock in Europe (BPIE Report, 2011)

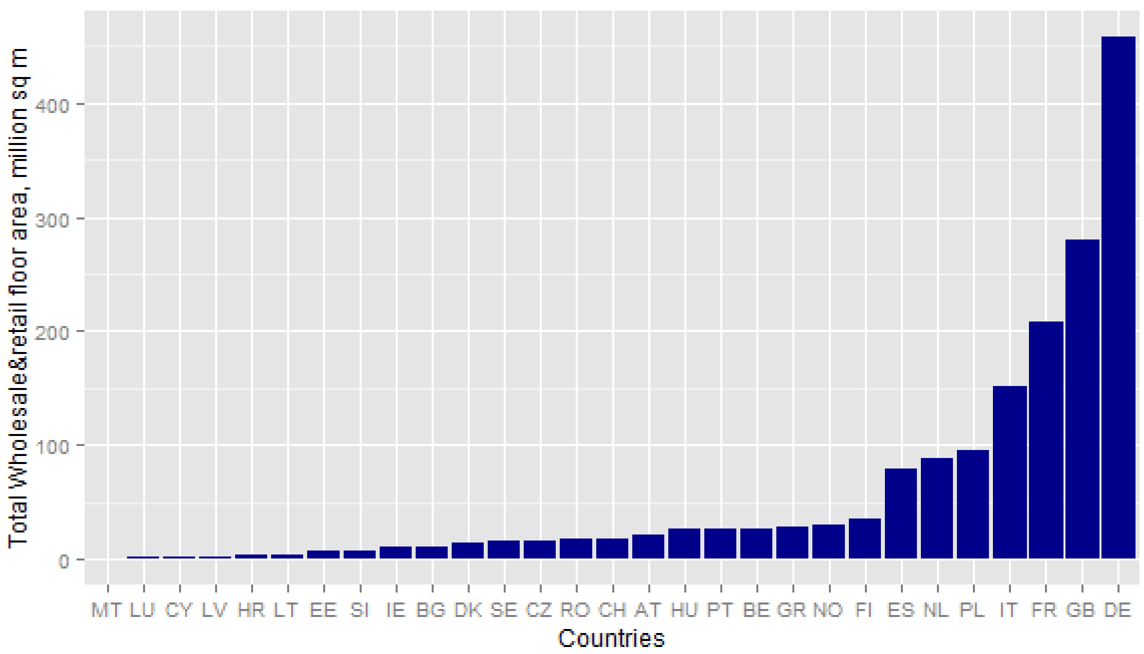


Figure 6: Total Wholesale & retail buildings floor area, Million m² in several European countries (Illustration based on Entranze 2013 and BPIE 2013a)

The wholesale and retail category is very heterogeneous; the floor area per sub-category cannot be found in the literature. However, there is a comprehensive database on Shopping centres provided by International Council for Shopping centres (ICSC) available (ICSC 2014a). The relevant ICSC definition of a shopping centre is given in chapter 2.3. Based on these ICSC statistics, supplementary data from BPIE (2011) and a comprehensive data collection of the EU project ENTRANZE (www.entranze.eu), the GLA of shopping centres is analysed. Moreover, the GLA is broken down per country and compared in relation to the total wholesale and retail building stock.

According to ICSC, the Shopping centre building Gross Leasable Area (GLA) is 112.1 Million m^2 in EU-28 + Norway in 2013 (ICSC 2014a). That makes up app. 6.7% of the total wholesale and retail building floor area in EU-28 plus Norway in 2013 (ICSC 2014a and BPIE 2013a). The largest shopping centre gross leasable area is located in UK (26.2 Million m^2) followed by France (14.4 Million m^2) and Italy (12.7 Million m^2) (see Table 5 and Figure 7). These countries account for approximately 46% of the total shopping malls gross leasable area (GLA) in EU-28 and Norway.

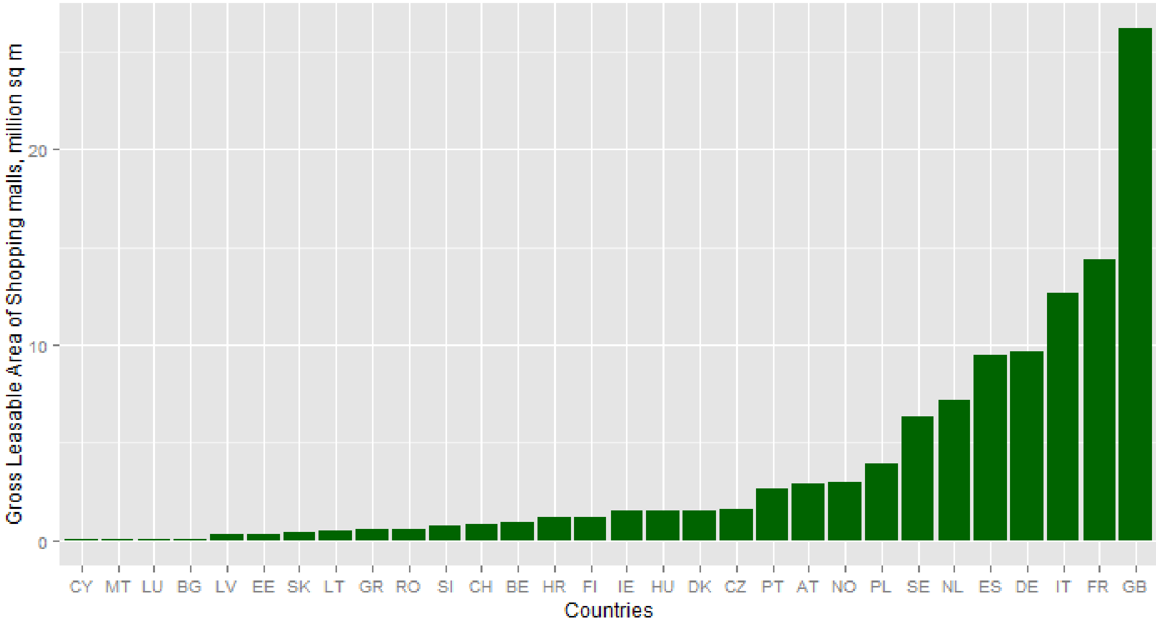


Figure 7: Gross Leasable Area of Shopping centres [Million m^2] larger than 5.000 m^2 in the EU-28 and Norway (Illustration based on ICSC, 2014a)

Table 5: Building floor area by building categories in EU-28 + Norway in 2008 (Entranze 2013), (BPIE 2013a), (ICSC 2014a)

Country	Building floor area[7], Million m^2	Residential floor area, Million m^2	Non-residential floor area[8], Million m^2	Wholesale and retail building floor area, Million m^2	Shopping malls, Gross Leasable Area[9], Million m^2
EU-28 + NO	23,696.1	18,030.7	5,665.4	1,668.2	112.1
Austria	455.8	341.4	114.3	21.0	2.9
Belgium	484.1	379.3	104.8	27.2	1.0
Bulgaria	261.1	197.2	63.8	11.7	0.1
Cyprus	46.7	38.9	7.8	2.0	0.2
Czech Rep.	398.3	309.6	88.7	15.8	1.6
Denmark	420.1	297.6	122.5	13.9	1.6
Estonia	49.4	37.4	12.0	6.5	0.4
Finland	307.0	199.9	107.1	35.5	1.2
France	3,386.9	2,479.5	907.4	207.0	14.4
Germany	4,334.0	3,229.7	1,104.3	458.0	9.7
Greece	462.6	322.6	140.0	28.4	0.6
Hungary	402.1	303.3	98.8	25.9	1.5
Ireland	227.8	184.6	43.2	11.2	1.5
Italy	2,992.8	2,576.9	415.9	152.0	12.7
Latvia	77.6	61.1	16.6	2.6	0.3
Lithuania	135.2	104.0	31.2	3.5	0.5
Luxembourg	21.2	16.3	4.9	1.3	0.1
Malta	17.5	13.5	4.0	1.0	0.1
Netherlands	925.6	630.8	294.8	88.9	7.2
Poland	1,327.5	942.1	385.4	95.9	3.9
Portugal	512.9	410.1	102.8	26.7	2.7
Romania	515.8	456.4	59.3	18.3	0.6
Slovakia	170.8	132.7	38.2	*n.a.*	0.4
Slovenia	88.3	60.8	27.5	6.9	0.8
Spain	1,918.0	1,568.0	350.0	78.8	9.5
Sweden	539.0	386.5	152.5	15.3	6.4
UK	2,660.6	1,924.5	736.1	279.5	26.2
Croatia	145.0	112.8	32.2	3.2	1.2
Norway	412.5	313.0	99.5	30.2	3.0

[7] Residential and service buildings for all listened countries except Norway; for Norway non-residential buildings also include industrial, agricultural, forestry and garage buildings.
[8] Only service buildings including Wholesale & trade, Offices, Hotel & Restaurants, Health, Education, Other buildings
[9] Shopping malls with a minimum gross leasable area (GLA) of 5,000 m²

Figure 8 shows the share of the total Shopping centre Gross Leasable Area on the total Wholesale and retail building floor area in selected European countries. Shopping centre floor area has only a small share on the total Wholesale and retail building floor area. The Shopping centre leasable Gross area in Sweden amounts 42% of the total Wholesale and Retail building area. This is by far the highest share throughout the Europe. The average EU-28 plus Norway share of the investigated buildings is almost 7%. However, the share varies from county to country. In Austria, Czech Republic, Denmark, Ireland, Latvia, Lithuania, Slovenia and Spain, the share of the Shopping centres is more than 10%. In the following countries, shopping centres make up less than 5% of the total Wholesale and Retail floor area: Belgium, Bulgaria, Finland, Germany, Greece, Poland and Romania.

Figure 8: Share of shopping centre gross leasable area on the total wholesale and retail building floor area[10], breakdown by country (Illustration based on Entranze 2013, BPIE 2013a and ICSC, 2014a)

[10] To be fully consistent, the total shopping centre floor area should be compared with other wholesale and retail floor area. However, please note that the total shopping centres floor area, which is larger than the GLA, is not available.

3.2 Market development and saturation

As is shown in the previous section, the total GLA of the shopping centres varies from country to country. It is a very dynamic sector, 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).

According to DTZ´s research, there is only limited activity in relation to the development of new centres in most countries, but there is still an under-supply in Central and Eastern Europe (CEE). There is, however, a huge opportunity for refurbishment and redevelopment of existing centres throughout Europe (DTZ 2011). In recent years, shopping centre development was strongest in the EU-accession countries[11] (ICSC 2008), which is also supported by later reports (SCT 2014). The European retail market has recovered from the economic crisis, also in the most affected countries Spain, Italy and Ireland. The retail investments in Europe reached 41.3 billion EUR in 2013, which is 20% more as in 2012 and the highest value since 2007 (SCT, 2014).

In this section, the market saturation and development are analysed by using the following quantitative criteria: Shopping centre GLA per capita and development of shopping centres sales growth. This information leads to the prediction about further development of the shopping centre stock market in the European countries.

Shopping centre floor area per capita varies greatly in the European countries as shown in Figure 9. The estimation is based on the ICSC database on GLA of shopping malls in 2013 and Eurostat population statistics from 2013 (Eurostat 2014). Figure 9 shows the average GLA per 1000 capita in EU-28 + Norway is 224 m². Shopping centre GLA per 1000 capita is 664.8 square meters in Sweden, followed by Norway (586 m²), Netherlands (429 m²) and UK (410 m²). The following eleven European countries are above the European mean value: Sweden, Norway, Netherland, UK, Slovenia, Austria, Ireland, Denmark, Estonia, Hungarian and Portugal.

Shopping centre floor area per 1000 capita is lower than the EU average of 225 m² in more than the half of the European countries; this refers primarily to the EU-accession countries (Bulgaria, Romania, Slovakia, Poland, Latvia, Hungary, Czech Republic and Lithuania). The lowest shopping centre area per capita is in Bulgaria and Romania with a floor space of 15 m² per 1000 capita and 30 m² per 1000 capita respectively.

[11] The "accession" countries referred comprise most of the recently joined members of the European Union: Bulgaria (2007), the Czech Republic (2004), Estonia (2004), Hungary (2004), Latvia (2004), Lithuania (2004), Poland (2004), Romania (2007), Slovakia (2004) and Slovenia (2004) (ICSC 2008).

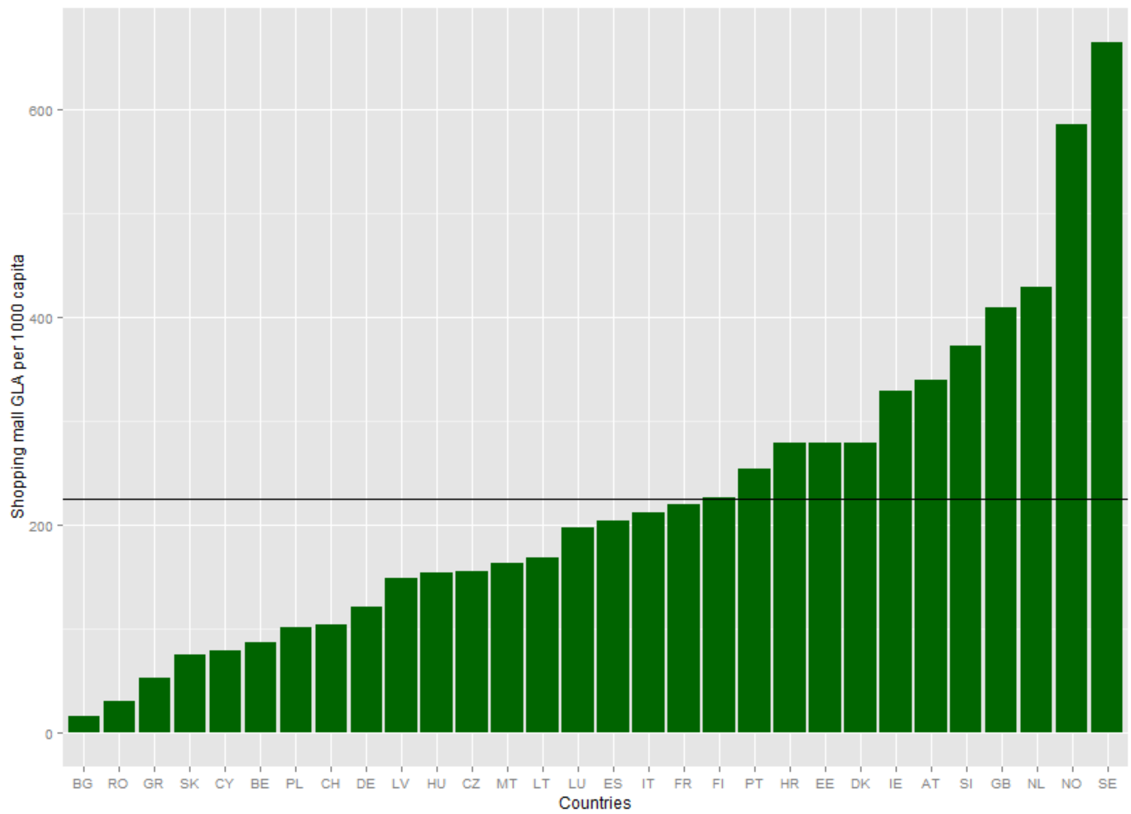


Figure 9: Shopping centre GLA per 1000 capita in EU-28 + Norway and Switzerland; the black line indicates the mean (Illustration based on ICSC, 2014a and Eurostat, 2014)

In order to analyse shopping centre market development and saturation, we use the growth-share matrix (BCG-matrix). The idea of the concept is to categorize markets (or business units) by their comparative growth rates and share of the marketplace (Wesemann 2007). According to the market share and growth rates, markets are grouped into four categories: low share and high growth markets, low share and low growth markets, high share and high growth markets and high share and low growth markets.

- Markets with low GLA per capita but high growth rates markets show an exploitable untapped potential.
- Markets with low GLA per capita and low growth rates are the least interesting ones from an investor's perspective.
- Markets with high GLA per capita and high growth rates are considered to be the stars from an investor's perspective.
- Markets with high GLA per capita but low growth rates are mature and deliver rather stable incomes. They are also called cash cows.

The market growth rate is based on the shopping centre sales growth between 2000 and 2012 in the considered countries and displayed against the GLA of the shopping centres per

1000 capita. By analysing countries market growth rates, the average of all countries´ sales growth between 2000 and 2012 (horizontal line) was calculated at 5.6% p. a. Further, the average GLA in square meters per 1000 Capita of the all countries was calculated (225 $m^{2)}$. These two parameters divide the European countries into the four abovementioned categories.

Figure 10 shows average sales growth 2000-2012 and GLA per Capita in the EU-28 + Norway. The blue lines indicates the average GLA in square meters per 1000 Capita of the all countries (vertical line) and the average of all countries´ sales growth between 2000 and 2012 (horizontal line). The analysis shows that countries with strong market position and strong market growth are Estonia and Slovenia. In other words, the GLA per capita is above the EU-average and sales growth is also above 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. Especially Bulgaria and Romania show a large potential for new shopping centres. Luxemburg might be the exception within this category. The country's GLA per capita is almost EU average, but Luxemburg was not affected by the economic crisis, and therefore the sales grow is higher than the EU average. Irrespective of other influencing parameters, the analysis shows that the countries with low share of the market place and low growth rate markets are Belgium, Czech Republic, Malta, Cyprus, France, Germany, Greece, Switzerland, Spain and Italy. However, as mentioned above, it is important to note that the low floor area per capita in Belgium, Germany and Switzerland is influenced by spatial planning restrictions (DTZ 2012). For instance, Germany is the European top-selling market measured by the total turnover (SCT, 2014). Moreover, the low sales growth is a consequence of the economic crisis in some of these low GLA and low growth markets. The GLA per capita in France, Italy and Spain is almost EU average. Assuming a band width around the mean value of ± $25m^2$ per 1000 capita, Finland, France, Italy and Spain would be grouped in a medium category. The same is true for the average sales growth; Croatia, the Czech Republic, Ireland, Norway and Slovenia are within a band width of ±0.6% around average. 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.

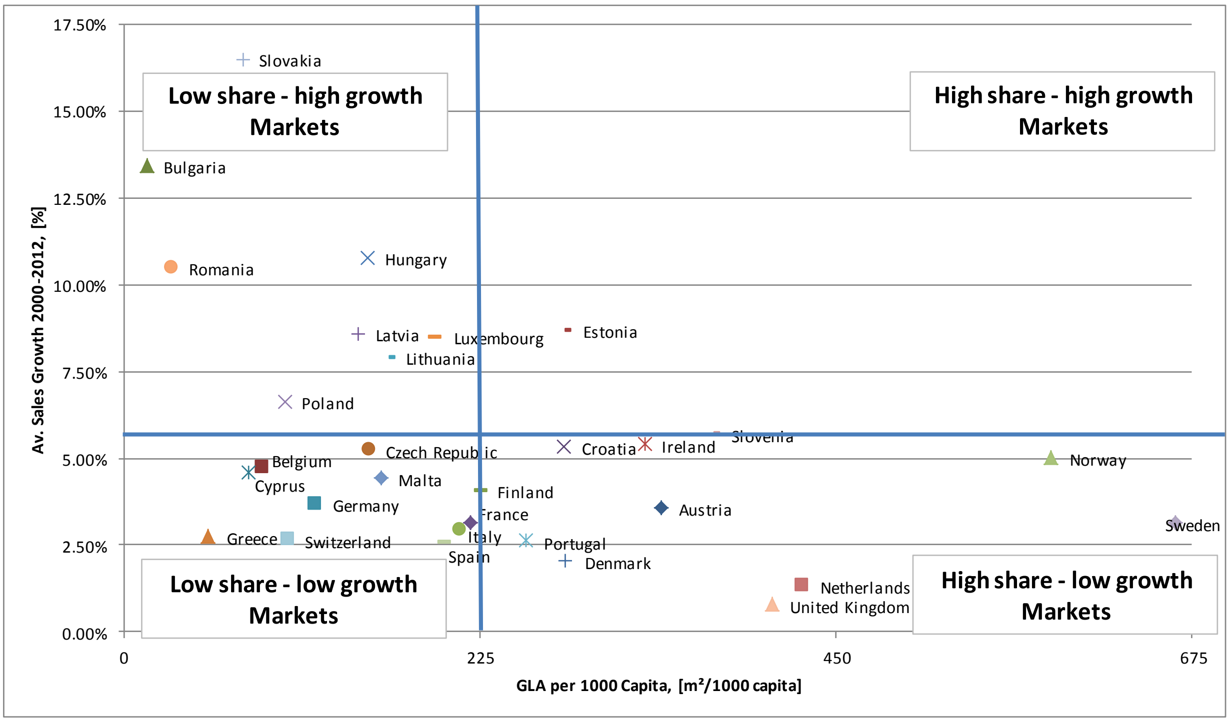


Figure 10: Average Sales Growth 2000-2012 and GLA per Capita in EU-28 + Norway (blue lines indicate the mean value; illustration based on ICSC, 2014a and Eurostat, 2014)

3.3 Opening year

ICSC statistic provides information on opening year of 4299 shopping centres in 27 European countries (ICSC, 2014a). This data was used in order to understand the average age of the stock shopping centres and to compare the European countries.

Figure 11 and Figure 12 show the distribution of the construction year of shopping malls in 27 European countries (EU except Cyprus and Malta for which are no data available, but Norway). Figure 11 shows the shopping centre opening year in the former EU-15 + Norway, while Figure 12 – in central and eastern European member states (CEE countries). The opening year in the investigated countries is shown in a box-plot diagram. The highest “whisker” shows the greatest value, excluding outliers (dots) while the lowest shows the least value, excluding outliers. The median (middle quartile) marks the mid-point of the data and is shown by the line that divides the box into two parts. The middle “box” represents the middle 50% of scores for the group. Seventy-five percent of the scores fall below the upper quartile. Twenty-five percent of scores fall below the lower quartile.

The oldest shopping centre building stock is in Sweden followed by Denmark and Finland (see Figure 11). In Sweden, half of the investigated shopping centre buildings were built between 1965 and 1990 (green area). The median opening year of all covered shopping malls in Sweden is 1989. In Denmark and Finland, half of the investigated shopping centre buildings were built between 1973 and 2005 as well as between 1980 and 2004 (green area), respectively. The median opening year in Sweden, Denmark, Finland, France, the United Kingdom, Netherlands, Norway, Germany, Estonia, Belgium, Austria, Ireland and Italy is before 2000. In the following countries, the median shopping centre opening year is after 2000: Slovenia, Estonia, Hungarian, Greece, Latvia, Poland, Czech Republic, Lithuania, Slovakia, Romania and Croatia. This shows that the shopping centre building stock is young in these countries (see Figure 12).

The analysis shows that in the EU-15 + Norway, the shopping centre building stock is older compared to CEE countries. Apart of some earlier outliers, 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.

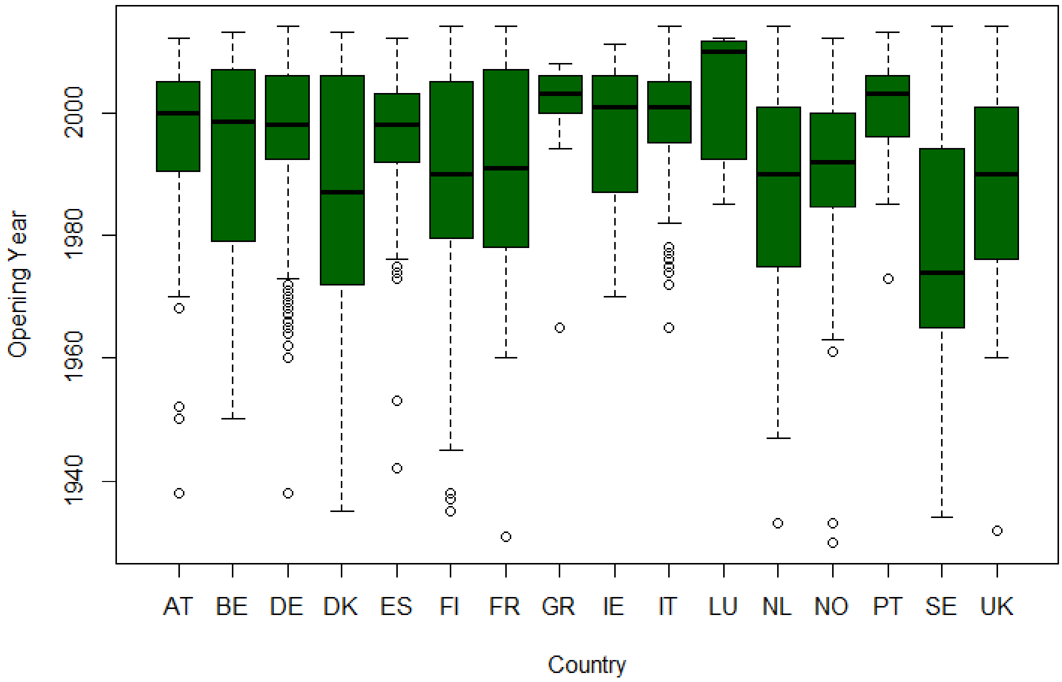


Figure 11: Distribution of shopping centre construction years in EU-15 + Norway (Illustration based on ICSC, 2014a)

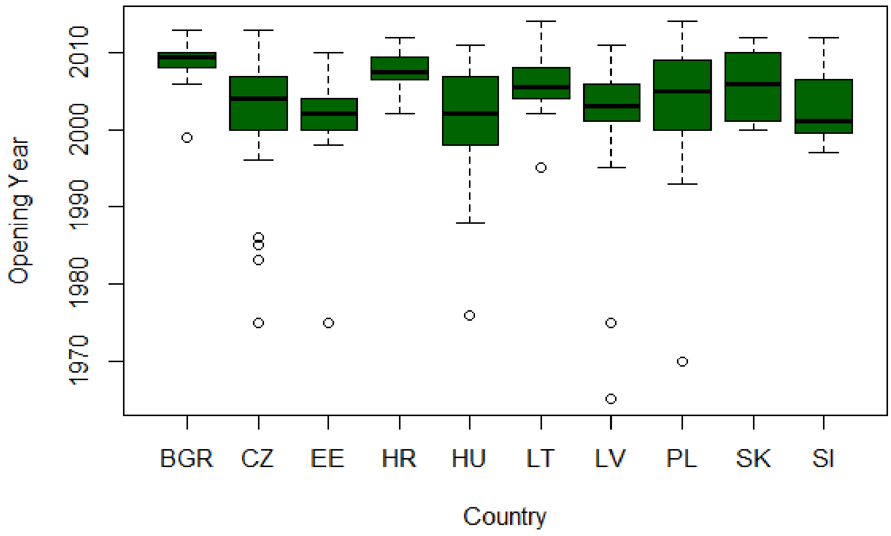


Figure 12: Distribution of shopping centre construction years in new CEE countries (Illustration based on ICSC, 2014a)

With regards to the history of shopping centres presented in chapter 2.1 it can be assumed that shopping centres with a construction year before 1955 are reconceptualised buildings, unless they are market halls or expanded shopping arcades. This means that most of these buildings before 1955 have been built for a different purpose. However, it can be assumed that most of today's shopping centres were initially designed and constructed as such. However, it is not possible to draw any conclusions on a current reconceptualising rate from other buildings towards shopping centres.

Further, data on the time span between the construction of 3400 shopping malls and their renovation year (ICSC, 2014a) lead to a robust estimate of the renovation rate of 4.4% p.a. This means the whole shopping centre building stock is refurbished within 22-23 years. Compared to the current renovation rate of around 1% of the whole building stock in Europe (BPIE, 2011) this is very high. This high shopping centre renovation rate also supported by direct talks with representatives of the shopping centre sector and Schneider et al. (2012), who report that shopping centres are refurbished regularly to look stylish, representing a modern lifestyle. This is also related to the lifetime of building components, such as windows, walls, heating, ventilation and air conditioning systems. Obviously these components have different lifetimes, which are addressed in the forthcoming CommONEnergy "Shopping Mall Assessment Tool". This economic tool is based on buildings' component lifetime and will be closely linked to the Online Data Mapper (see Chapter 3.6).

Findings in the following subchapter show the size and types of shopping centres in Europe. Most CEE countries are dominated by medium and large sized shopping centres while in the EU-15 and Norway are dominated by small ones. This is influenced by the time of the construction and shows the dynamics of the building size over time.

3.4 Size and type

ICSC statistics divide European Shopping centres in two categories: traditional shopping centres and specialised shopping centres. A traditional shopping centre is an all-purpose scheme that could be either enclosed or open-air and classified by size (ICSC 2008). Traditional shopping centres are subdivided 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) (cf. chapter 2, ICSC 2008). A specialised centre is usually a purpose-built retail scheme that is typically open-air and could be further classified by size (ICSC 2008). Specialised shopping centres are Retail Parks, Factory Outlet Centres or Theme Oriented: Leisure- or Non-Leisure-Based (ICSC 2008).

Thus, Figure 13 shows the distribution of shopping centres by segment: Small Shopping malls (5,000–19,999 m²), Medium, large and very large shopping malls (20,000 and above m²) as well as Specialised and Other shopping centres (Retail parks, Factory Outlet Centres and Theme Oriented) in the EU-28, Norway and Switzerland.
The small shopping centres dominate in most countries. In Austria, Belgium, Switzerland, Denmark, Finland, Malta, the Netherlands and Sweden, more than 70% of all shopping centres are Small shopping malls (GLA of 5,000–19,999 m²). In the Czech Republic, Estonia, Spain, France, Hungarian, Lithuania, Norway, Portugal and Slovakia, the share of the small Shopping malls of the total shopping centre buildings is more than 50%. The Medium and Large shopping malls (20,000 and above m²) dominate in the following countries: Bulgaria, Cyprus, Germany, Croatia, Ireland, Luxemburg, Poland and UK. The share of this type of shopping centres is more than 50%.

The specialised centre's share of the total shopping centre building stock is small in all countries. It is smaller than 5% in the following countries: Austria, Belgium, Cyprus, Germany, Denmark, Estonia, Spain, Finland, Hungarian, Ireland, Lithuania, Luxemburg, Latvia, Malta, the Netherlands, Norway, Poland and Sweden. However, in Bulgaria, Greece, Romania, Slovenia and Slovakia, the share of this type of shopping centre is more than 10%.

Two parameters can be considered which have an influence on the size of the shopping centres in the investigated countries. The first is the time of construction of the shopping centres which was analysed in the previous chapter. The second important parameter are spatial planning restrictions.

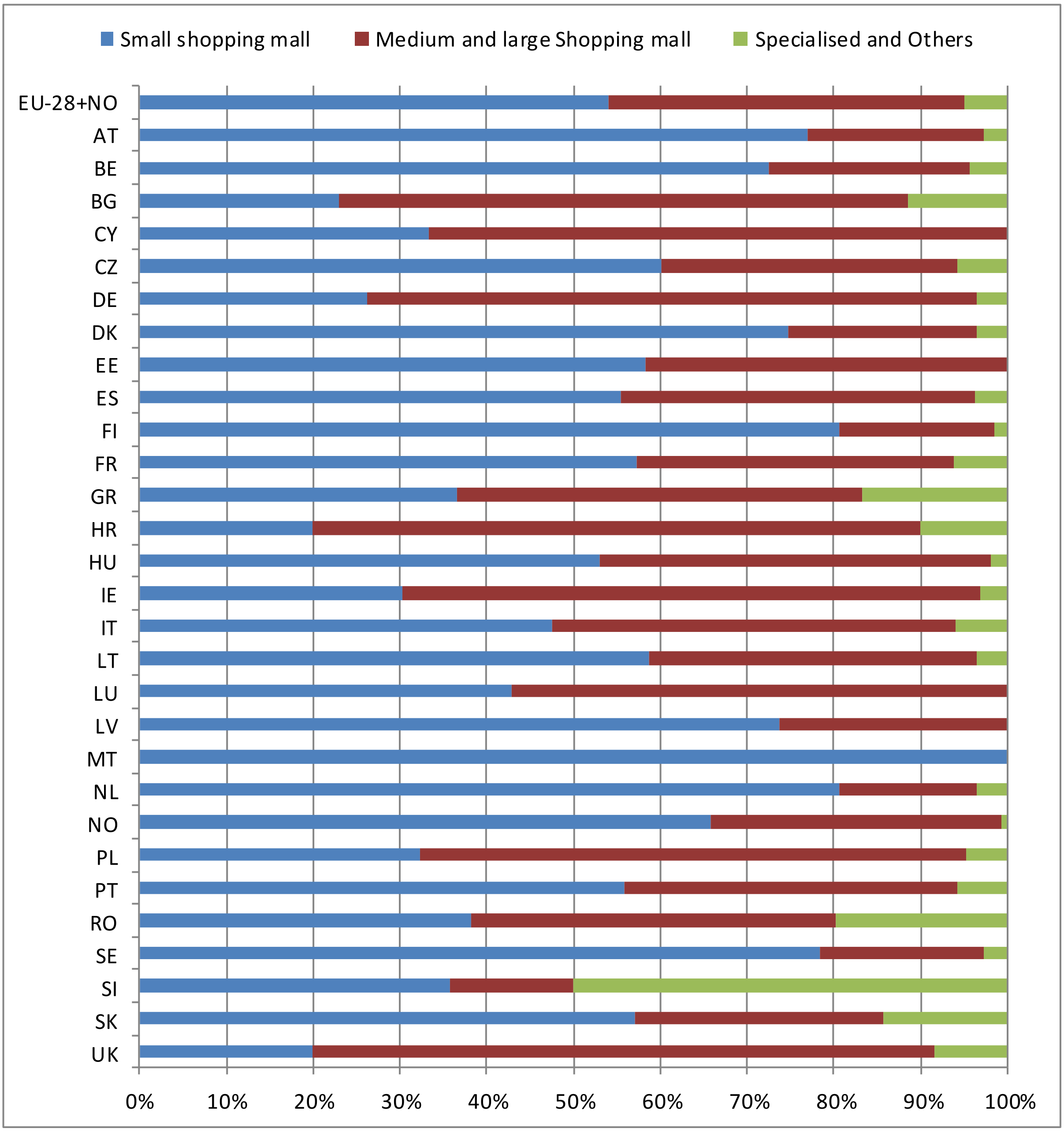


Figure 13: Share of Small, medium and large shopping malls as well as Specialised and others shopping centres in EU-28 + Norway (Illustration based on ICSC, 2014a)

3.5 Energy Consumption and Supply

3.5.1 Energy consumption in the service building sector in Europe

Final energy demand in the whole EU-28+Norway residential and service sector[12] in 2012 was 5165 TWh (Eurostat 2014). The residential sectors share of the final energy demand is 66% while service sector´s share is 34%. The division varies from country to country. Figure 14 illustrates division between final energy use in service sector and residential sector in EU-28. Energy use in the service sector is higher than 40% in Cyprus, Italy, Luxembourg, Malta and Netherlands. The share of the energy use in the service sector on the total energy use in the building sector is less than 20% in the following countries: Bulgaria, Denmark, France, Germany, Greece, Latvia, Lithuania, Poland, Romania, UK and Croatia (Entranze 2013).

Figure 15 shows the energy consumption by energy carrier in the non-residential building stock in the EU-28. Electricity and natural gas are the major energy carriers in all countries. Electricity, with more than 50% on the total final energy demand in the service sector dominates in the following countries: Bulgaria, Cyprus, Estonia, Finland, Greece, Malta, Portugal, Slovenia, Spain, Sweden and Croatia. The mainly used energy carrier in the service sector is oil, gas and coal in Belgium, Germany, Hungary, Ireland, Italy, Luxembourg, Netherlands and Slovakia. In Denmark, Finland, Lithuania and Sweden, the share of the district heating is more than 30%. Biomass is the least used energy carrier in the service sector. However, in Latvia and Portugal, the share of this energy carrier is 13% and 14%, respectively.

[12] Service sector includes office buildings, wholesale and retail buildings, education buildings, hotels and restaurants, hospitals and sports facilities. Thus, wholesale and retail is a subcategory of service buildings. Commercial buildings are used for commercial use and include building categories such as office and retail buildings.

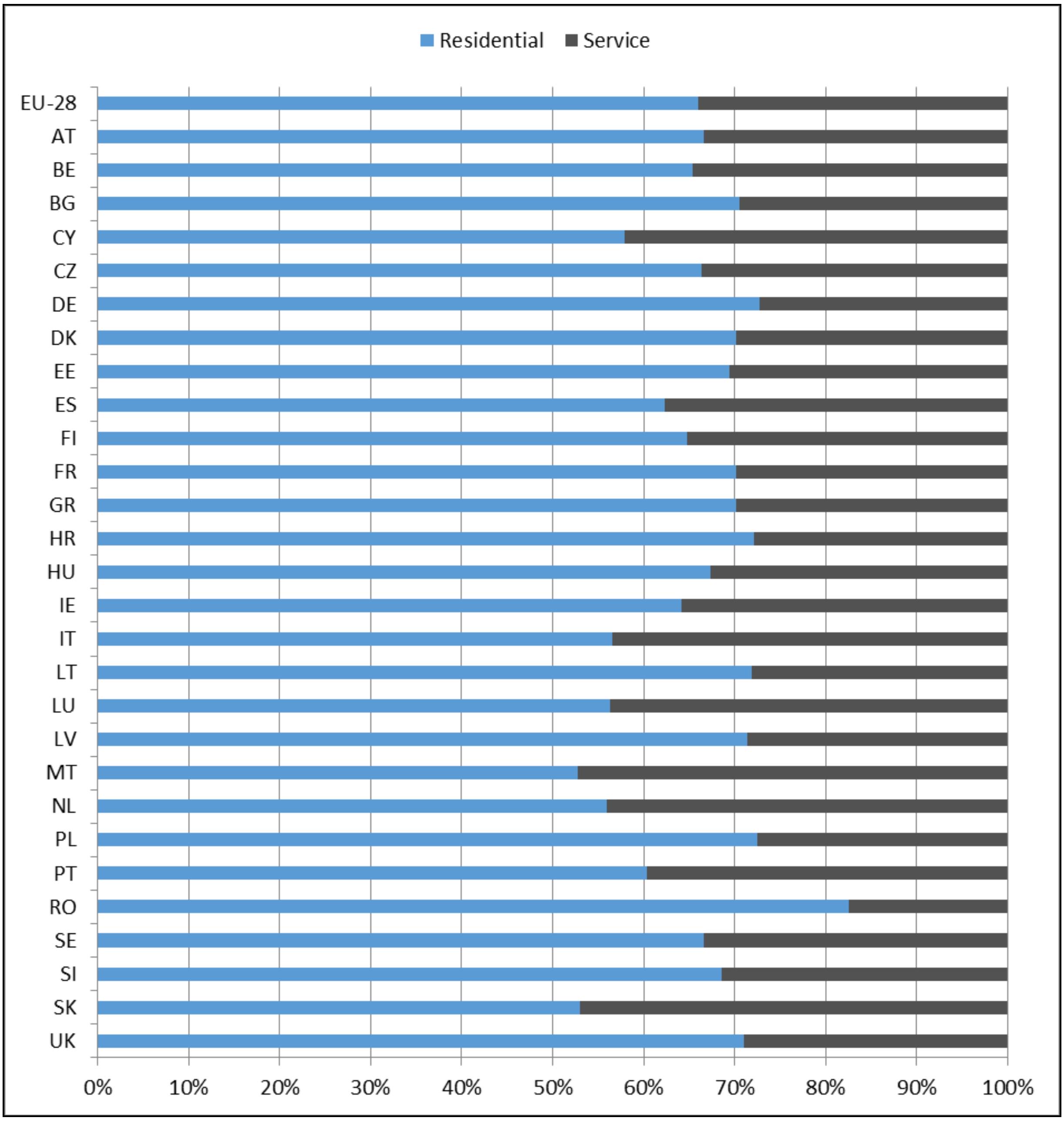


Figure 14: Breakdown of building energy use by sector (in residential building sector and service buildings) in EU-28 (ENTRANZE, 2013)

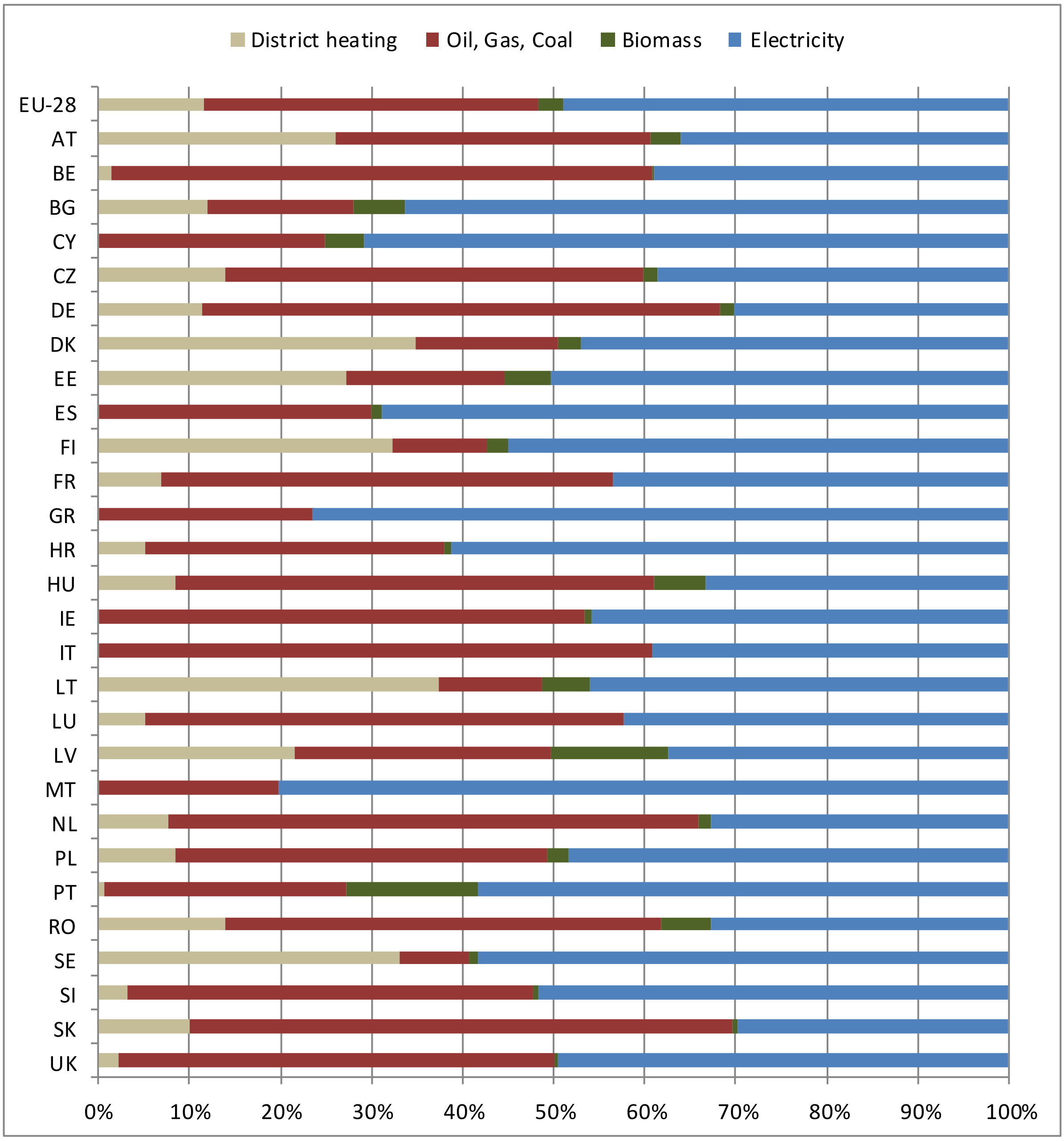


Figure 15: Energy consumption divided by energy carrier in non-residential building stock in EU-28, 2008 (ENTRANZE, 2013)

In comparison, 2012 in the USA commercial buildings consumed more than 5300 TWh of primary energy, representing 46.0% of building energy consumption and 18.9% of U.S. energy consumption. Office and retail space and educational facilities were representing about half of commercial sector energy consumption. The residential sector consumed 6100 TWh of primary energy, equal to 22.3% of U.S. energy consumption (Berkeley National Laboratory 2012).

3.5.2 Energy consumption of Shopping centres

Shopping centres have many differentiated functions such as food conservation, marketing of products and improved comfort which cause high energy consumption. This is also the reason for the diverse energy consumption composition in the shopping centres. While in the residential buildings, energy is mainly consumed by heating, cooling, hot water, cooking and appliances (BPIE 2011), in the shopping centres, energy is used for store lighting, ventilation, heating and air-conditioning, food refrigeration and others (Schönberger et al. 2013). According to a review of various sustainability reports by Schönberger et al. (2013) the total final energy consumption of European food stores ranges between 500 and 1000 kWh/m^2a. Food stores specific energy use is up to five times higher compared to residential and office buildings. Further, Schönberger et al. (2013) report an average energy consumption of 270 kWh/m^2a for non-food stores smaller than 300 m^2 and 200 kWh/m^2a for stores larger than 300 m^2. As a basis for an estimate of the average energy demand, this magnitude is also supported by Tassou et al. (2011) in a UK-case study and the database of the EU-project Entranze (2013).

Data collected from several European retailers' sustainability reports show the share of the average energy consumption of the food retailers (Schönberger et al. 2013):

- 50 % for food conservation by refrigeration
- 25 % for lighting
- 20 % for heating, ventilation and air conditioning, HVAC
- 5 % for electric appliances and others internal processes.

However, the composition of the energy consumption varies from one retailer to another. Non-food retailers, have a different share of energy use compared to food retailers (see Figure 16). For example, the electricity consumption of appliances in electronics stores is higher than in other kinds of shops, which are more dependent on lighting, such as furniture- or Do-It-Yourself-stores (Schönberger et al. 2013).

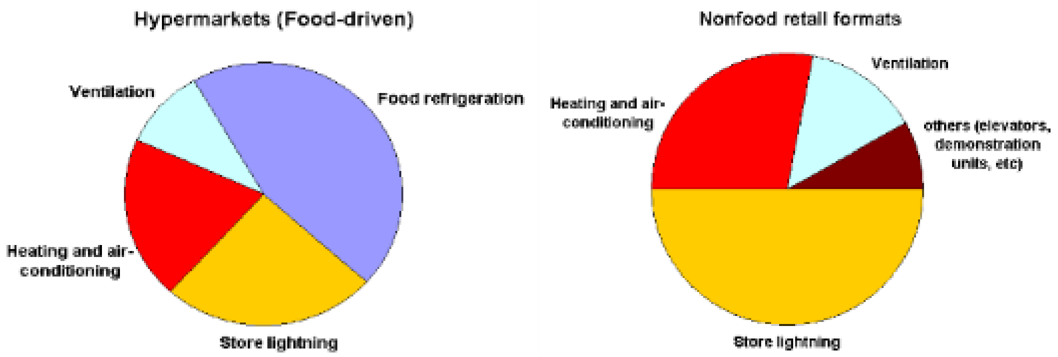


Figure 16: Share of total energy demand in retail building (Retail forum for sustainability, 2009)

Stensson et al. (2009) estimate the specific energy use of 116 shops situated within three Norwegian shopping malls. The analysed shopping categories are as follows: clothing (clothing, shoes, jewellery), hobby (sports equipment, bookshops, toys, music, games), home (Furniture, decoration, telephony, hardware), supermarkets, service (hairdresser, travel agency, drugstore, optician, photography) and not categorized. Table 6 shows minimum, maximum and mean specific energy use in the investigated shopping centres in Norway. The highest specific energy use is in the supermarkets. The mean value of the estimated Norwegian supermarkets is 585 kWh/m^{2}a. Mean energy use in in clothing, hobby and home shops is 164, 156 and 161 kWh/m^{2}a, respectively.

Table 6: Minimum, maximum and mean specific energy use in different shop categories based on a study of 116 retail units in three Norwegian shopping centres (Stensson et al., 2009)

	Clothing	Hobby	Home	Supermarket	Other Services	Not categorized
Number of shops	56	8	15	3	11	12
Min, [kWh/m²a]	65	53	95	260	105	68
Max, [kWh/m²a]	380	283	401	1027	336	697
Mean, [kWh/m²a]	164	156	161	585	311	276

Moreover, an analysis of the specific energy consumption was carried out with data derived from an anonymous shopping centre in Central Europe. By investigating the specific energy use in 238 shops in this shopping centre, specific energy uses per shop category comparable to Stensson et al. (2009) were found as shown in Table 7. Our results on the specific energy use are a bit higher in all categories except for supermarkets, which are lower. In addition the table shows the results for anchor stores combining stores of almost all categories. They are significantly larger than other stores and have – on average – lower specific energy consumption.

Table 7: Mean floor area and specific energy use in different shop categories (calculation based in an anonymous shopping centre) Note that "anchor stores" are not a separate category and subsumed in the other categories. Own calculation

	Anchor Stores	Clothing	Hobby	Home	Supermarket	Other Services	Not categorized
Number of shops	*(14)*	89	6	15	8	90	31
Mean floor area [m²]	*(3205)*	421	241	645	824	174	318
Mean spec. energy use, [kWh/m²a]	*(158)*	180	206	244	456	385	288

Moreover, the sustainability reports of several real estate companies and their shopping centres (Steen & Strøm (2012), Unibail-Rodamco (2013), ECE (2013), Intu Group (2013), Britishland (2014) and IGD (2014)) have been analysed. The energy consumption per square meter of 132 shopping centres and their GLA throughout seven European countries was taken from these reports. In addition, the store composition of 159 shopping centres was identified. The aggregate is presented in Table 8. As shown, the larger a shopping centre is, the larger is the clothing and hobby GLA, while the GLA of supermarkets and not categorised shops is decreasing. The GLA of home stores as well as other services shows no clear trend. In general, home and clothing stores account for more the two thirds of the GLA, followed by supermarkets. The other store categories have small portions of the GLA.

Table 8: Store composition [%] per GLA of 159 shopping centres in Europe (calculation based on raw data from (Steen & Strøm (2012), Unibail-Rodamco (2013), ECE (2013), Intu Group (2013), Britishland (2014), IGD (2014) and an anonymous shopping centre)

	Clothing	Hobby	Home	Supermarket	Other Services	Not categorized
small shopping centre	26%	1%	35%	20%	11%	6%
medium shopping centre	33%	1%	34%	17%	9%	6%
large shopping centre	36%	2%	39%	12%	8%	5%
very large shopping centre	36%	2%	33%	9%	10%	5%
Total average	**32%**	**1%**	**35%**	**16%**	**9%**	**6%**

The constructive configuration and the installed technology, which also influences the energy consumption of shopping centres, are mainly given by the building typology (see above). There is no typical configuration of shopping centres and no quantitative data on this issue available, making a robust estimation on installed technologies possible. Shopping centres are individually designed and equipped, depending on main surrounding geographic, economic, social and technological conditions. From a general point of view, the constructive configuration and the installed technology may include aspects such as:

- Architectural features and aesthetical restrictions in relation to functional pattern (see “Table 16, Typical areas in shopping centres” in the CommONEnergy Report “Functional Patterns and Socio-Cultural Aspects” (Woods et al., 2014b).
- building envelope: geometry (e. g. surface to volume (S/V) ratio, complex shapes), construction material and insulation
- building equipment and lighting
- technologies for heating, ventilation and air conditioning
- technologies for hot water supply

These mentioned constructive and technological aspects (except shape ratios), directly influencing the potential of energy conservation in shopping centres are presented in the CommONEnergy Report “An analysis of systemic energy inefficiencies” (Woods et al., 2014a). Valid data on S/V ratios are not available. A commercial buildings' database of the U.S. Energy Information Administration[13] generally includes such data but it says about shopping centres that "*the establishments has characteristics that can - and do - vary significantly from the other establishments*" (U.S. EIA, 2014). Therefore, only a limited number of variables are available for shopping centres in this database containing region, floor area, construction year, climate zone, number of shops and the energy source used for heating and cooling, including energy consumption (U.S. EIA, 2008). However, most of these variables are not characteristic for European shopping centres and given the prosperous development of shopping centres with base year 2003 somehow outdated. Moreover, the database does not include shape ratios of shopping centres. For these reasons the database has not been used within CommONEnergy and calculations were based on other sources, such as the following.

According to DEFRA (2006) the energy consumption of stores in a shopping centre depends on:

- current business practices, e. g. the significance of green building certificates such as LEED or the application of LED for energy efficient lighting,
- the store's product mix (clothing, food, lifestyle products, multiple products, etc.),
- the customers' frequency, depending on opening hours and location, the customers' activities in the shop and their shopping time,
- the *"store format"*
- in food stores, also on the "*equipment used for in-store food preparation, preservation and display"*
- the presence and type of store-rooms, cooling chambers and warehouses

By using the data of the specific energy demand per GLA and shop category, the total energy consumption per country is calculated. Therefore, based on the results presented in Table 7 and Table 8, the specific energy consumption of shopping centres is calculated as first step. Table 9 shows these results, the energy consumption per square meter of shopping centres. The energy consumption of shops varies – on average – from 228 to 280 kWh/m²a. As expected, the specific energy consumption is decreasing while the size of the shopping centre is increasing. The common area comprises hallways, resting places, sanitary facilities, technical and cleaning rooms, the centre management, security facilities as well as other auxiliary areas. This energy consumption of the common area was calculated - 117 kWh/m²a. A detailed breakdown per shopping centre size is not available. The total final energy consumption (shops plus common area) per GLA varies from 257 to 309 kWh/m²a GLA with an average consumption of 290 kWh/m^2_{GLA} a.

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[13] Commercial Buildings Energy Consumption Survey of the U.S. Energy Information Administration www.eia.gov/consumption/commercial/data/2003/index.cfm?view=characteristics

Table 9: Specific Energy consumption [kWh/m²a] of shopping centres (calculation based on raw data from (Steen & Strøm (2012), Unibail-Rodamco (2013), ECE (2013), Intu Group (2013), Britishland (2014), IGD (2014) and an anonymous shopping centre; note that the common area data is not available per shopping centre size; data does not include energy used for mobility)

	Specific energy consumption of shops [kWh/m²a]	Specific energy consumption of the common area[14] [kWh/m²a]	Total specific energy consumption per GLA [kWh/m²a]
small shopping centre	280	117	309
medium shopping centre	263	117	292
large shopping centre	248	117	278
very large shopping centre	228	117	257
Total average	**261**	**117**	**290**

This is in the same magnitude like Stensson et al. (2009), who report a total energy consumption in Norwegian and Swedish shopping malls of 291 and 279 kWh/m^{2}a respectively. Nevertheless, to our understanding our as well as the sample of Stensson et al. (2009) include more energy efficient shopping centres than the European average, which makes it reasonable to assume our results as bottom-line.

In a next step, we calculated the total energy consumption of shopping centres per country. The *GLA* of shopping malls *j* in country *i* multiplied by the specific energy consumption per m² *ec* of the GLA depending on the shopping centre size *s* and the common area equals the total energy consumption *EC* [TWh] of shopping centres

$$EC = \sum_{i=1}^{n} \sum_{j=1}^{m} GLA_{i,j} * (ec_{GLA,s} + 0{,}25 * ec_{Common}) \quad (1)$$

Unfortunately the exact space of the common floor area and therefore the total floor area of shopping centres in Europe is unknown. Thus, the GLA as the only available (and creditable) source has been taken for the calculation. Moreover, to estimate the energy consumption of the common area, it has been assumed that it amounts 25% of the GLA, which is also presented in formula (1).
Therefore, - centre by centre - the GLA of 5209 shopping centres (ICSC, 2014a) in Europe is multiplied with the respective total specific energy consumption per GLA from Table 9 and summed per country. The results are shown in Table 10. To the authors' understanding, it is the first time that total energy consumption of shopping centres in Europe is calculated. The reader should keep in mind that no reference value is available; neither for single countries nor for Europe. This is also true for the superior building category wholesale and retail.

[14] The specific energy consumption of the common area is constant over all shopping centres sizes. No breakdown available.

Therefore, the total energy consumption of 32.2 TWh should be interpreted as bottom-line estimate. Moreover, energy used for mobility (e. g. to get to the shopping centre) is not included. Obviously, the total energy consumption is closely linked to the country's GLA. The UK, Germany, Spain, France and Italy have in descending order the largest energy consumption. These five countries account for 54% of the total energy consumption of the 30 countries (EU28 plus Norway and Switzerland) (see Figure 17).

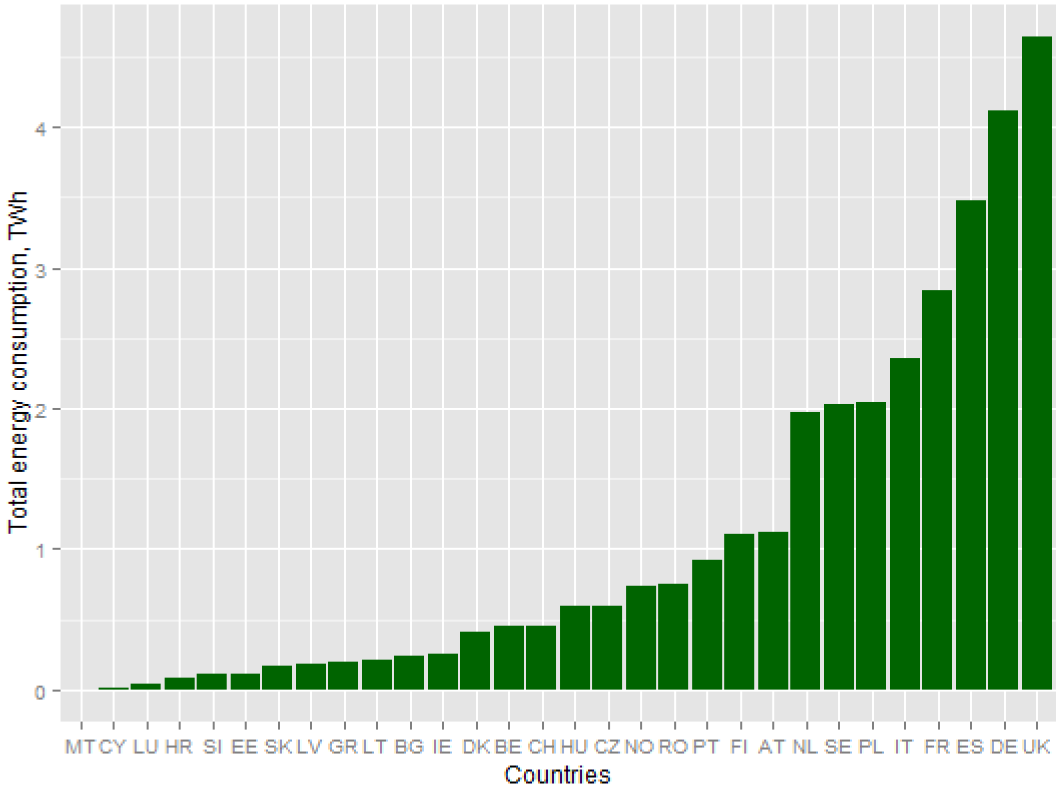

Figure 17: Total final energy consumption in EU shopping centre buildings (own calculation, without energy used for mobility)

Table 10: Energy consumption and specific energy consumption of shopping centres in Europe (calculation based on Steen & Strøm (2012), Unibail-Rodamco (2013), ECE (2013), Intu Group (2013), Britishland (2014), IGD (2014), ICSC (2014a); data does not include energy used for mobility)

Country	No. of shopping centres with GLA data	GLA[15] [mil m²]	Total Energy Consumption [TWh]	Mean specific Energy Cons. [kWh/m²$_{GLA}$ a]
Austria	261	4.00	1.12	279
Belgium	113	1.59	0.45	281
Bulgaria	26	0.89	0.23	262
Switzerland	107	1.62	0.45	281
Cyprus	3	0.06	0.02	262
Czech Rep.	105	2.20	0.59	270
Germany	500	15.53	4.11	265
Denmark	91	1.45	0.41	280
Estonia	24	0.44	0.12	271
Spain	485	12.89	3.47	270
Finland	260	3.96	1.11	280
France	478	10.45	2.84	271
Greece	30	0.73	0.20	268
Croatia	10	0.30	0.08	264
Hungary	103	2.17	0.59	273
Ireland	33	0.94	0.25	265
Italy	359	8.73	2.36	270
Lithuania	29	0.78	0.21	272
Luxembourg	8	0.17	0.05	267
Latvia	42	0.67	0.18	276
Malta	1	0.02	0.01	309
Netherlands	500	6.96	1.97	283
Norway	151	2.63	0.73	278
Poland	231	7.72	2.04	264
Portugal	138	3.44	0.93	269
Romania	81	2.83	0.74	263
Sweden	498	7.25	2.03	280
Slovenia	14	0.41	0.11	264
Slovakia	28	0.62	0.17	274
UK	500	17.65	4.64	263
EU-28 + CH & NO	**5209**	**119.2**	**32.2**	**272**

[15] The presented shopping centre GLA differs from the GLA presented in Table 5. The shopping centre count is different (e. g. Table 10 include shopping centres smaller than 5.000m²), different editors of the samples and the latest update differs. The GLA presented in Table 5 gives a better overview, while the GLA in Table 10 is available per shopping centre, which is needed for calculation.

Based on the calculated total final energy consumption in the EU shopping centre buildings (see Table 10) and energy consumption divided by energy carrier in non-residential building stock (Figure 15), a rough estimation of the final energy consumption subdivided by energy carriers in shopping centres was carried out (see Figure 18). Electricity with 46% makes up the largest share of the total energy consumption in the shopping centres building stock in the EU-28. The share of the fossil fuels is 42% of the total energy consumption in EU-28 shopping centre building stock. District heating and biomass are used by approximately 10% and 2%, respectively. Data on other renewable energy sources are not available. Photovoltaics, wind energy, hydropower and auxiliary energy for heat pumps are included in electricity, whereat the renewable share is depended on the respective country's electricity mix over time. The final energy consumption of solar thermal heating and cooling is completely unknown for shopping centres.

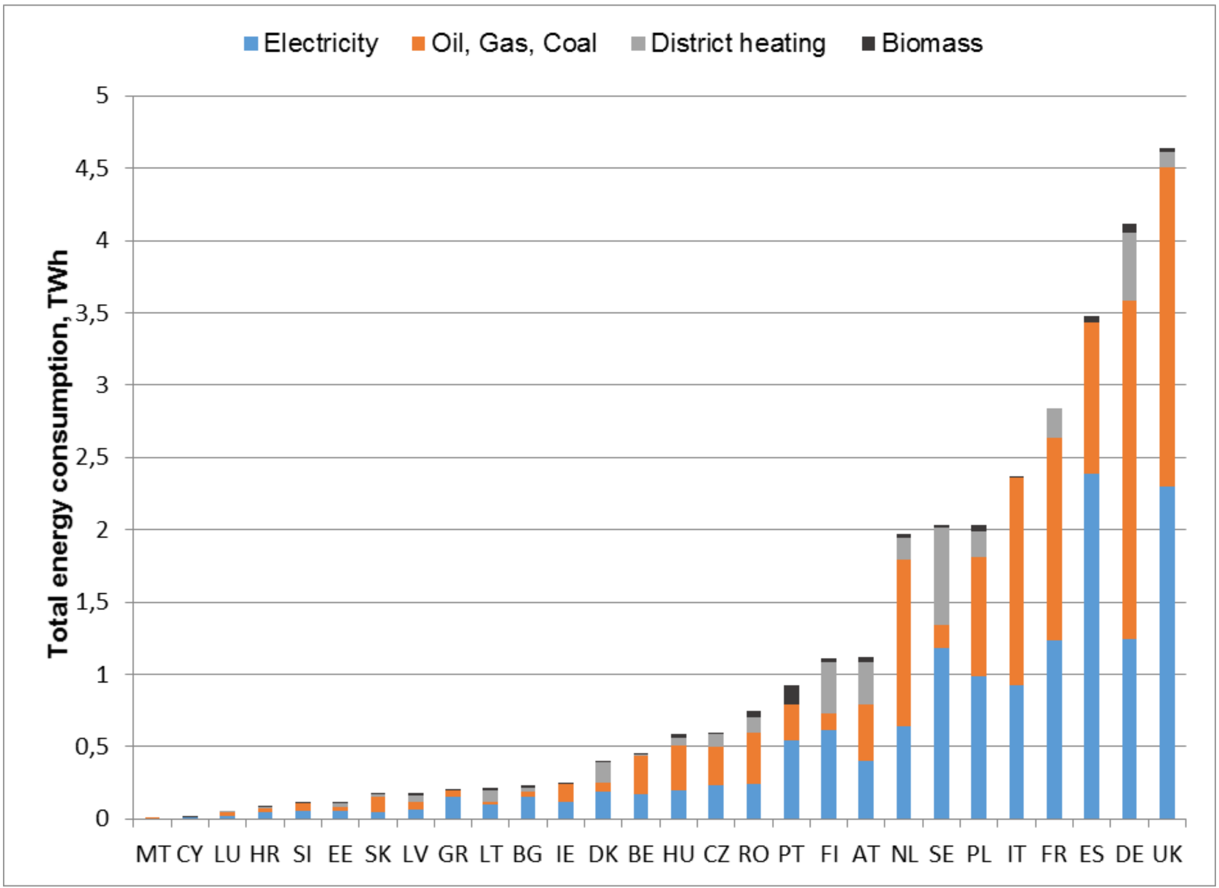

Figure 18: Total energy consumption of the shopping centre building stock in the EU-28[16] subdivided by energy carrier (calculation based on Steen & Strøm (2012), Unibail-Rodamco (2013), ECE (2013), Intu Group (2013), Britishland (2014), IGD (2014), ICSC (2014a) and ENTRANZE, 2013; data does not include energy used for mobility)

[16] Norway is not included because energy consumption by energy carrier is not available for the service sector.

3.5.3 Market growth vs. energy consumption

Chapter 3.2 has shown the relations between market growth and gross leasable area. Mature markets are usually related to low sales growth rates at large GLA per capita. In general, for non-mature markets it is the opposite way round. This concept is now being extended to energy consumption of shopping centres. Thus, Figure 19 similar to Figure 10 above 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.

The total final energy consumption in shopping centres in the EU-28, Norway and Switzerland is 32.2 TWh (see chapter 3.5.2). Countries with high sales growth rates currently represent 13.8% of the energy consumption whereat countries with low GLA per capita account for 13.1% and countries with high GLA per capita for 0.7%. These markets are mainly marked by new construction, while refurbishment plays a minor role, which is also supported by the building age presented in chapter 3.3. Reconceptualization of existing buildings towards shopping centres may be the prior goal of CommONEnergy in these countries. Nevertheless, novel technologies have to be applied in existing buildings to start early diffusion. Therefore, two CommONEnergy reference buildings are located in Lithuania as shown in chapter 4.4.

Countries with low sales growth and high GLA per capita, considered as mature markets, will see only limited activity in relation to the development of new centres in the next years. 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 associated with shopping centres in these countries, they provide a huge energy saving potential due to building renovation activities and CommONEnergy has three reference buildings in these countries.

The situation in countries with low sales growth and low GLA per capita is quite ambivalent and varies from country to country. Moreover, many countries are very close to the average, whether in sales grow 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 face difficult economic conditions such as Greece. Nevertheless, this part accounts with 45.0% for the largest portion of the total energy consumption and offers both, incentives for new constructed shopping centre as well as renovations. For this reason, five reference buildings are located these countries.

Form 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.

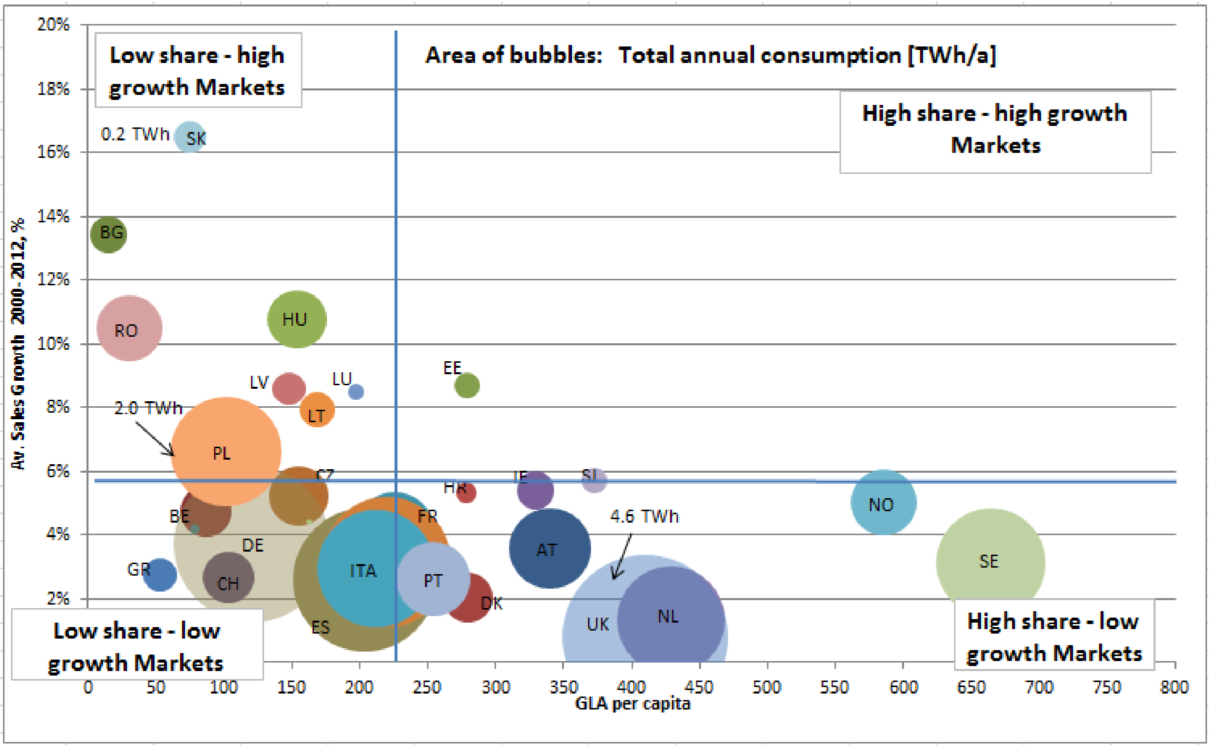

Figure 19: Average Sales Growth 2000-2012 and GLA per Capita in the EU-28, Norway and Switzerland. The area of bubbles indicate the total annual energy consumption, blue lines indicate the mean values

3.6 Online Data Mapper

The results are presented in an interactive online data mapper available at www.commonenergyproject.eu/data_mapper.html. This online tool represents a quick, easy and tailor-made access of national and comparative international indicators on the commercial building stock.

Buildings in the online data mapper refer to two main categories of buildings: residential and non-residential buildings. Residential buildings are further divided into single family and multifamily dwellings, non-residential buildings refer to buildings in the service sector and include the sub-categories (office buildings, hospitals, schools and universities, hotels and restaurants, buildings for wholesale and retail trade). Shopping centres are a sub-category of wholesale and retail trade. Over the project’s duration, the online data mapper will integrate forthcoming CommONEnergy tools such as interactive scenarios of the future energy demand and renovation activities in European shopping centres. Within this process, an advanced version of the online data mapper will be made available. The current version (September 2014) is based on the project ENTRANZE and includes residential as well as non-residential building categories. It will be replaced by the abovementioned, advanced version.

How to use the online data mapper:

1. Navigate through data series on the top left column
2. Select/click data series of your choice: maps and graphs are automatically displayed
3. On the map, click on a country to display more detailed data
4. To download/export map and graph data series, click on the Excel logo
5. A country ranking is displayed for each selected data series in a column on the right side of the map
6. A number of definitions are available in the building definition section

A detailed handbook on how to use the online data mapper is available at www.entranze.enerdata.eu/documents/guideline-datatool.pdf.

Figure 20: Current version of the online data mapper in December 2014

3.7 Summary and Discussion

The whole building floor area in the EU-28 plus Norway is almost 24 billion m^2, whereas the total wholesale and retail floor area is 1.668 billion m^2. The shopping centre building Gross Leasable Area (GLA) is 112.1 million m^2, with the largest area located in the UK (26.2 million m^2) followed by France (14.4 million m^2) and Italy (12.7 million m^2).

The average GLA per 1000 capita in EU-28 + Norway and Switzerland is 224 m^2. The largest shopping centre GLA per 1000 capita is 665 square meters in Sweden, followed by Norway (586 m^2), Netherlands (429 m^2) and UK (410 m^2). These countries are among those with the highest market saturation. Thus, there is only limited activity in relation to the development of new centres in these countries, but there is still a shopping centre under-supply in Central and Eastern Europe. This is also reflected by high average sales grow rates in these countries as well as a relatively young shopping centre building stock. On the other hand, the oldest shopping centre building stock is in Sweden followed by Denmark and Finland. In Sweden, half of the investigated shopping centre buildings were built between 1965 and 1990. Therefore, these mature markets offer a huge opportunity for (energy efficient) refurbishment and redevelopment of existing shopping centres.

The predominant energy carriers in the service sector are electricity and natural gas in all the countries. It can be assumed that this holds also true for shopping centres. Electricity, with more than 50% of the total final energy demand, dominates in Bulgaria, Cyprus, Estonia, Finland, Greece, Malta, Portugal, Slovenia, Spain, Sweden and Croatia. Fossil fuels are the mainly used energy carrier (oil, gas and coal) in Belgium, Germany, Hungary, Ireland, Italy, Luxembourg, Netherlands and Slovakia. Notably, in Denmark, Finland, Lithuania and Sweden the share of district heating is more than 30%.

The final energy demand of non-residential buildings in the EU-28 plus Norway was 1756 TWh in 2012. Unfortunately, a detailed breakdown for the wholesale and retail sector is not available in the literature. However, by applying a bottom-up approach multiplying the GLA of single shopping centres with the mean specific energy consumption per square meter, we obtained an estimation of the total energy consumption (without mobility) of 32.2 TWh. As expected, countries with a large GLA also have high energy consumption. The specific energy consumption per square meter GLA ranges from 309 kWh/m^2a in Malta to 262 kWh/m^2a in Bulgaria and Cyprus. Smaller shopping centres tend to have a larger consumption per square meter and food stores greater consumption than non-food stores.

As shown by the market development and market saturation analysis in chapter 3.2, there is a large untapped potential for much more new built and reconceptualised shopping centres in Central and Eastern Europe in the future, which is also supported by Cushman & Wakefield (2014). In well-developed markets, mostly in Western and Northern Europe, energy efficient refurbishment of existing shopping centres will be the predominant development in the next years.

Overall, the energy use in buildings is a rising trend and this is likely to continue if insufficient action is taken to improve the performance of buildings. Thus, we recommend introducing energy efficiency standards for new construction, retrofit and operation of shopping malls to reduce both, the energy demand and the greenhouse gas emissions. This is in line with Sheth et al. (2014), who report a raising demand for green buildings from tenants, investors and governments. Governmental action may include e. g. green building certificates. More information on currents laws is provided in chapter 5. In the light of the EU targets for 2020, 2030 – and even beyond, our results may serve as a comprehensive basis for decision making among European shopping centre stakeholders

4. Reference Buildings

4.1 Introduction

Because of the variety among shopping centres across Europe as shown in the previous chapter (e. g. size and site, building type and age, energy use, market conditions), and the influence that this diversity has on the applicable technologies, European shopping centres will be classified based on selection criteria, which are described in chapter 4.2.

Ten reference buildings serve as examples of shopping centres in Europe and they will be used as a reference for the identification of inefficiencies and the development of the systemic solution sets. The drivers for the development of these solutions include the potential for energy savings on individual and aggregate level, comfort and health benefits, as well as financial and environmental/ social considerations. These buildings will be used in CommON*Energy* to virtually test the application of the technologies and concepts developed via simulations and for laboratory test conditions. Three demo-cases representative of different retrofitting starting points were chosen after a preliminary analysis of the shopping centre stock: a re-conceptualised shopping centre in Genova (IT), an old public market in Valladolid (ES) and a modern shopping centre close to Trondheim (NO). Seven other reference buildings comprising many different building configurations were chosen from all over Europe.

Aspects important in the selection of reference buildings, are among others a) typical functional patterns for building management and control strategies, b) architectural archetype, c) moisture, indoor climate and thermal analysis, d) day light vs. artificial light, e) energy generation, recovery and distribution, energy saving potential, RES use and, f) the influence of retrofitting on the neighbourhood. Furthermore, best practice for transportation via energy storage and recharging of customer's electrical vehicles while shopping will be investigated, together with social considerations and the interaction between electric loads and the grid. All these aspects of the reference buildings will also take into account the analysis of economic pay-back periods, possibilities of industrialization and standardization as well as maintenance needs. These aspects will be tackled in forthcoming CommONEnergy reports.

Finally it is important to note that the selection of reference buildings is also dependent on the willingness of shopping centre owners to provide us with data. This means the final selection of the reference buildings is not only based on the selection criteria, but also practical limitations set by the availability of relevant examples within the European shopping centre industry. Virtual reference buildings could in theory overcome these limitations. However, they have been rejected because the importance of the social context of shopping centres, which cannot be pictured virtually; cf. "Functional Patterns and Socio-Cultural Aspects" (Woods et al., 2014b).

The sample covers a lot of different shopping centre features and different levels of renewable energy coverage. Nevertheless, it is an impossible challenge to provide all the possible configurations, and this has limited the selection of reference buildings. The following subchapters (4.2, 4.3) give an overview of the selection criteria. Subchapter 4.4 provides information on the reference buildings. Although, all data is available for the calculations within CommONEnergy, the publicly presented level of detail is dependent on the shopping centre owners. Some of the data is confidential.

4.2 Selection criteria

Following the above mentioned requirements for defining reference buildings, the selection of these buildings is based on several aspects, such as the age of the building, its size and shape, the total number of shopping malls in the respective country and applied technologies. The criteria build upon the basic outline provided by the shopping centre definition (see subchapter 0). The reference buildings cover a broad range of typically installed systems in European shopping centres. These criteria are described in the following subchapters at length.

Table 11: Selection criteria of the reference buildings

Climate condition	Heating Dominated
	Cooling Dominated
	Heating and cooling Dominated
Market saturation	Well-developed markets
	Emerging markets
Location	Town centre/ Urban
	Out of town/ Suburban
Shopping centre typology	Small shopping centre
	Medium and large Shopping centre
	Specialised and Others
Building typology	Re-conceptualised building
	Purpose built shopping centre
Opening year	Before 1990
	Between 1990 and 2002
	After 2002

The following table indicates the possible combination of the selection criteria, including different types of shopping centres, which builds on the shopping centre definition presented in subchapter 2.5.

Table 12: Definition of CommONEnergy selection criteria

Shopping centre typology	Shopping centre sub-typology	GLA [m²]	Anchor store	Building typology	Opening year	Location	Climate condition	Market saturation
Small shopping centre	Comparison shopping	5,000 – 19,999 m²	Supermarket or hypermarket	Reconceptualized building / Shopping Centre purpose	Before 1990 / Between 1990 and 2002 / After 2002	Urban (town centre) / Suburban (out of town)	Heating Dominated / Cooling Dominated / Heating and cooling Dominated	Well-developed markets / Emerging markets
	Convenience shopping	5,000 – 19,999 m²	Department store					
Medium and large Shopping centre	Medium	20,000 – 39,999 m²	Hypermarket or department store					
	Large	40,000 – 79,999 m²	One or more department stores					
	Very Large	80,000 m² and above	Several department stores					
Specialised and Others	Retail Park	5,000 – 30,000 m²	None					
	Factory Outlet	5,000 m² and above	None					
	Market Hall	not fixed	None					
	Others	5,000 m² and above						

4.2.1 Climate condition

One important criterion is the climate zone, because heating and cooling have an important influence on the energy demand of a building. Figure 21 shows the share of the European shopping centre area by heating degree days (HDD). One quarter of the European shopping malls are located in countries with less than 2000 heating degree days and another quarter between 2000 and 3000 heating degree days[17]. The largest share, 43%, is located between 3000 and 4000 HDD and 10% is located in cold climatic zones.

[17]Countries with less than 2000 HDD on average in ascending order are Malta, Cyprus, Portugal, Greece, Spain and Italy; less than 3000 HDD are in France, Croatia, Bulgaria, Belgium, Netherlands, Ireland and Hungary; less than 4000 HDD are in Slovenia, United Kingdom, Romania, Luxembourg, Germany, Slovakia, Denmark, Czech Republic, Austria and Poland; more than 4000 HDD are Lithuania, Latvia, Estonia, Sweden, Norway and Finland; Eurostat (2013).

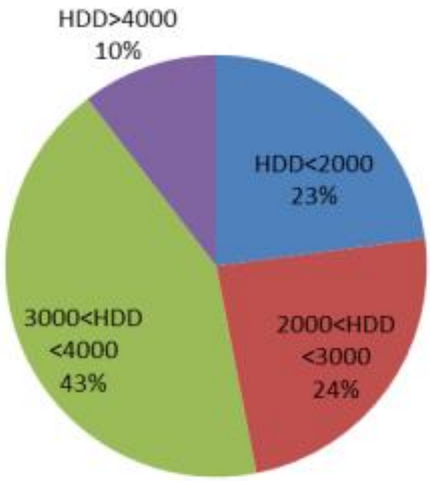

Figure 21: Share of European shopping centre area by heating degree days (illustration based on ICSC database and Eurostat 2013)

The same relation holds true for the cooling demand of buildings, which is considered via cooling degree days (CDD), but the shopping centres' distribution by CDD is different than by HDD (not illustrated). However, as shown by Cory et al. (2011), solely cooling degree days are not sufficient in measuring the cooling demand of non-residential buildings, even in cool climate zones. While single family residential buildings space conditioning is expected to be driven mainly by the external climate, the non-residential buildings are heavily influenced by the internal gains in the building. Thus we consider the internal loads via lighting, electric appliances, employees and customers in the shopping centres as relevant for cooling. This is in conjunction with the setting of heating, ventilation and air conditioning (HVAC). In order to classify reference buildings regarding the climate condition, the method described by Cory et al. (2011) is applied. Three space conditioning processes used in the assessment are heating, cooling and ventilation. In this work (Cory et al. (2011)), the dominating climate condition is defined as making up 70 percent or greater of the buildings space conditioning needs (i.e. heating dominated, or cooling dominated) If both, the heating and cooling needs are less than 70 percent, the climate is classified as mixed dominated (i.e. heating and cooling dominated). According to these criteria, three different climate conditions were defined: heating dominated, cooling dominated and heating and cooling dominated.

Simulations to define the climate condition of the reference building sites were executed in EnergyPlus, a freely available energy simulation software provided by the US Department of Energy. Therefore, a simplified shopping centre model was generated using the EnergyPlus Example File Generator[18]. Weather data was created using "Meteonorm" software[19], which

[18] EnergyPlus is available under http://apps1.eere.energy.gov/buildings/energyplus and the example file generator under http://apps1.eere.energy.gov/buildings/energyplus/cfm/inputs/

interpolates weather data from nearby available weather stations according to the GPS position of the reference buildings.

Table 13: Climate conditions (based on Cory et.al (2011))

Heating dominated	Heating energy need makes up 70 percent or greater of the building space conditioning needs (heating, ventilation and cooling)
Cooling dominated	Cooling energy need makes up 70 percent or greater of the building space conditioning needs (heating, ventilation and cooling)
Heating and cooling dominated	Heating and cooling energy needs are less than 70 percent of the building space conditioning needs (heating, ventilation and cooling)

4.2.2 Market saturation

There are obviously large differences between well-developed markets and emerging markets. The quantitative differentiation (GLA per 1000 capita) between well-developed and emerging markets is provided in subchapter 3.2

Mature markets need qualitative instead of quantitative growth. This means, proper refurbishment and enlargement of existing shopping centres for future development is the focus in those markets in Western and Central Europe. Due to raising competition with internet sales platforms and omni-channel retailing, shopping centres need new ways of presenting themselves (ICSC, 2013). However, e-retail sales only account for 6% of the total retail sales in the USA. *“For shopping center owners the Internet creates the opportunity to have a direct relationship with our consumers,” said William Taubman, COO of centre owner Taubman Centers*, in the USA. Therefore many centres are currently adopting their profile by competing in both the traditional retail and the e-commerce environment. Rick Chichester CEO of a commercial real estate services firm argues that shopping centres have the upper hand *as long as “they are able to use their “online presence to enhance the in-store experience” (*ICSC, 2014b). A French shopping centre owner calls for impressive architecture and high quality retail while an Italian centre manager expects an increasing polarisation between luxury and low-price shopping, which requires also new strategies of convincing the customer. In some of the well-developed markets is also a tendency towards “re-urbanisation” of shopping malls observable. This means the highest market potential is seen in small and medium sized shopping centres, which are close to the city centre (ICSC, 2013). For instance, Germany offers the opportunity to target 20 large cities with more than 300.000

[19] The “Meteonorm” software provides the climate at any location in the world by spatial interpolation methods and simulates a typical year with a weather generator. http://meteonorm.com/en/

inhabitants in a single market and *"is by far the most attractive global retail market, ahead of Austria, France, the UK and China"* as stated by a market analyst (SCT, 2014). In these well-developed markets is only a very limited potential for large regional and super-regional, suburban centres left (ICSC, 2013).

On the other hand, the market is stagnant in most of the Southern European countries or even declining as a consequence of the economic crisis. However, the branch has many expectations on the future development in Eastern Europe. Currently many new projects are under way in the Baltic countries, Bulgaria and Romania (ICSC, 2013). This Central and Eastern European region differs from the shopping centres in Western Europe. For instance, e-commerce is not so important in these emerging markets and the age of the shopping centre building stock is significantly younger (cf. subchapter 3.3).

4.2.3 Location

The location is relevant to the broader understanding of how a shopping centre functions and its role within the urban context. Location is important during the planning process, as is the associated catchment area, influencing stakeholders on all levels; owners and managers, tenants and customers (Guy, 2003). The spatial delineation also describes whether they comprise a node or centre of activity, or whether they are part of a larger trade area, which exhibits some agglomeration effects (DeLisle 2009). Moreover, location is an important aspect for transportation and the possibility of an enlargement of the shopping centre and the energy carrier used for HVAC and electricity final uses supply. This covers in general fossil fuels, nuclear and renewable energy as well as district heating systems. The power generation mix is of special importance for energy storage and power supply to the grid because of primary energy- and CO_2-conversation factors as well because of the possible time- and weather- dependency of energy surplus or deficit in the grid. According to Guy (1998), three locations were identified:

- Urban/town centre: Includes town centre and edge of town centre. The town centre is the historic central retail core of a town, possibly including modern shopping malls. Edge of town centre is defined as an area characterised mainly by non-retail land uses but within easy walking distance of the retail core.
- Suburban/out of town: this refers to traditional suburban retail areas, ribbon developments or locations close to road junctions/ intersections or on brownfield sites that are/were industrial areas.
- Rural: a site originally rural in nature or bounded by rural land. Due to the fact that shopping centres are located in urban and suburban areas, rural was not included in the definition of CommONEnergy.

Table 14: Location types and their features

	Types of shopping centres related to location	**Transportation infrastructure**
Urban/ Town centre	Shopping centres in urban areas are usually (old) re-conceptualised buildings or initially designed as shopping centre buildings (cf. chapter 2)	Usually both, public and private transportation is available (cf. chapter 2)
Suburban/ Out of town	In suburban areas shopping centres are usually built for this purpose (cf. chapter 2)	Although public transport may be available, suburban shopping centres are mainly dominated by individual mobility (cf. chapter 2).

4.2.4 Shopping centre typology

The main aim of this criterion is to classify the European shopping centres by physical characteristics such as appearance and size. The classification criteria are based on the overview of the classification of shopping centres by Guy (1998). Three typologies were selected upon the findings of the share of shopping centre types in subchapter 3.4. They are defined as follows (cf. chapter 1.5):

- Small shopping centre
  A small shopping centre has a GLA between 5.000 and 19.999 m² and the number of stores is limited to a few dozens. It consists of two sub-categories
  - Comparison shopping
    Purchase of non-daily products (cf. chapter 2); a department store is usually the anchor of the centre.
  - Convenience shopping
    Purchase of daily products (cf. chapter 2); Supermarkets or hypermarkets are usually the anchor store. Also called focused centres, they typically serve the surrounding residential area with convenience shopping needs and consist of a supermarket or hypermarket. They are known as district centres in the UK or centres intercommunaux in France (Reynolds, 1993 cited in Guy 1998).
- Medium and large Shopping centre
  Shopping centre may have a freestanding position, but it may also be located in a town centre. It often includes one or more anchor stores and several smaller retail units, and (in larger and more recent centres) a food court, and leisure uses such as cinema or ice rink. Small comparison goods shops selling clothing, footwear, leisure, and luxury items are particularly important, and help distinguish the centre from retail

parks and other types of centre. Further large anchor stores guarantee a high footfall. This shopping centre type includes three sub-categories:
  - Medium shopping centre, with an GLA between 20,000 and 39,999 m²
  - Large shopping centre, with an GLA between 40,000 and 79,999 m²
  - Very large shopping centre, with an GLA of 80,000 m² and above
- Specialised and Others
  Specialised and other centres resemble shopping malls or may be converted from one or more older buildings.
  This category comprises all other types of shopping centres and specialised centres.
  - Retail Park, with an GLA between 5,000 and 30,000 m²
    Retail Park is often found in off-centre locations and sells bulky household goods such as furniture, washing machines, DIY material, etc. and in some cases, clothing, shoes and other personal/fashion goods. It should be sited outside the town centre and contain at least three retail warehouses, defined as single storey retail units.
  - Factory Outlet, with an GLA of 5,000 m² and above
    Factory outlet is similar physically to smaller malls but has no anchor stores and commonly found on the edge of the centre or outside the centre. The outlets sell price discounted goods and are usually managed by manufacturing or wholesale organisations. They are usually part of comparison shopping selling surplus goods such as outdated fashions, slightly imperfect specimens etc.
  - Market Hall, which GLA is not fixed
    Usually they have no anchor store and are subject to convenience shopping.
  - Others, with an GLA of 5,000 m² and above
    Specialised in certain kinds of goods and often cater to a tourist market and are found within a town centre. Their purpose is leisure-based.

More details on different types of shopping centres is also provided in the CommONEnergy Report “Functional Patterns and Socio-Cultural Aspects” (Woods et al., 2014b).

4.2.5 Building Typology

With regards to the building type we distinguish between re-conceptualised buildings and buildings originally constructed for the shopping centre purpose. Re-conceptualised buildings were initially built for a) a different purpose than shopping or b) shopping apart from typical shopping centres. These buildings are undergoing a complete re-conception of the design towards a conversion into a shopping centre. Retrofitting is the process of modifying something after it has been manufactured. For shopping centre buildings this means making changes to the systems inside the building or even structures itself at some points after its initial construction and occupation. This process is done with the expectation of improving amenities for the building's occupants and/or improving the performance of the building. In particular, green retrofits are any kind of upgrade at an existing building that is wholly or partially occupied to improve energy and environmental performance, as well as the comfort and quality of the space in terms of natural light, air quality and noise. Examples of this category are e.g. historic market halls, buildings with aesthetical aspects such as the protection of historic monuments or former industrial complexes.

Within the non-reconceptualised category are all buildings which were initially constructed as shopping centres. A new construction refers to site preparation for, and construction of, entirely new structures and/or significant extensions to existing structures whether or not the site was previously occupied.

4.2.6 Opening year

As shown in subsection 3.3 the age of the shopping centre stock in central and eastern European countries differ significantly from western and southern Europe. This comes from the fact that shopping centre market diffusion already started in the 1960s in Western Europe but after the fall of the iron curtain in Eastern Europe. The sample includes reference buildings from both regions, including older and modern reference buildings.
We divided our sample of around 4300 shopping centres in Europe, which indicates the opening year (ICSC, 2014a), into three classes, each with an equal number of centres. One-third of the building stock in Europe was opened before 1990, one-third was opened between 1990 and 2002 and the last third was opened after 2002.
The opening year also reflects the spirit of time and the available technology, typical shapes and design as well as the construction. These characteristics are described in the historical development of shopping centres in chapter 2. Moreover, the age also indicates the need for a retrofit or that the centre may have undergone numerous changes or redevelopments.

4.3 Data collection

In order to provide input data for all aforementioned aspects with regard to the reference buildings, 74 specific datasets were specified, subdivided into five main groups: general building data, internal gains, building geometry, building envelope (complete building envelope, external and internal walls, roofs and upper floor ceiling, windows and skylights, basement, thermal bridges), and building service technology were collected. In addition, if available, building plans were obtained from the shopping centre owners. A detailed list showing the collected data is provided in the Annex (see chapter 8.1).

4.4 Reference building list

Based on the above mentioned criteria on European shopping centres, we choose ten shopping malls from seven countries that represent typical features and configurations. These reference buildings are located in Austria, Belgium, Italy, Lithuania, Norway, Spain and United Kingdom. These seven countries count exactly for 50% of the European shopping centre stock. Although there is no optimal solution to cover all criteria with ten cases, the reference buildings are a best-fit for the needs of CommON*Energy*. An overview of these shopping centres is given in the table below and in Figure 22.

Table 15: List of selected reference buildings

Name of the shopping centre	Owner	Location	Country	Abbreviation	Shopping centre typology
City Syd	Trondos & Storebrand	Trondheim	NO	CS	Medium Shopping centre
Mercado del Val	Ayunta-miento de Valladolid	Valladolid	ES	ME	Specialised and Others
Genova Ex-Officine Guglielmetti	INRES	Genova	IT	GE	Specialised and Others
Centro Commerciale Katané	INRES	Catania	IT	KA	Medium Shopping centre/ Hypermarket
Donau Zentrum	Unibail-rodamco	Vienna	AT	DO	Very Large Shopping centre
Brent Cross	Hammerson	London	UK	BC	Very Large Shopping centre
Pamarys	Dervina ir partneriai	Silute	LT	PA	Small Shopping centre/ Hypermarket
Studlendas	Baltisches Haus	Klaipeda	LT	ST	Small Shopping centre
Waasland Shopping Center	Devimo Consult	Sint-Niklaas	BE	WA	Large Shopping centre
Grand Bazar	Devimo Consult	Antwerp	BE	GB	Small Shopping centre

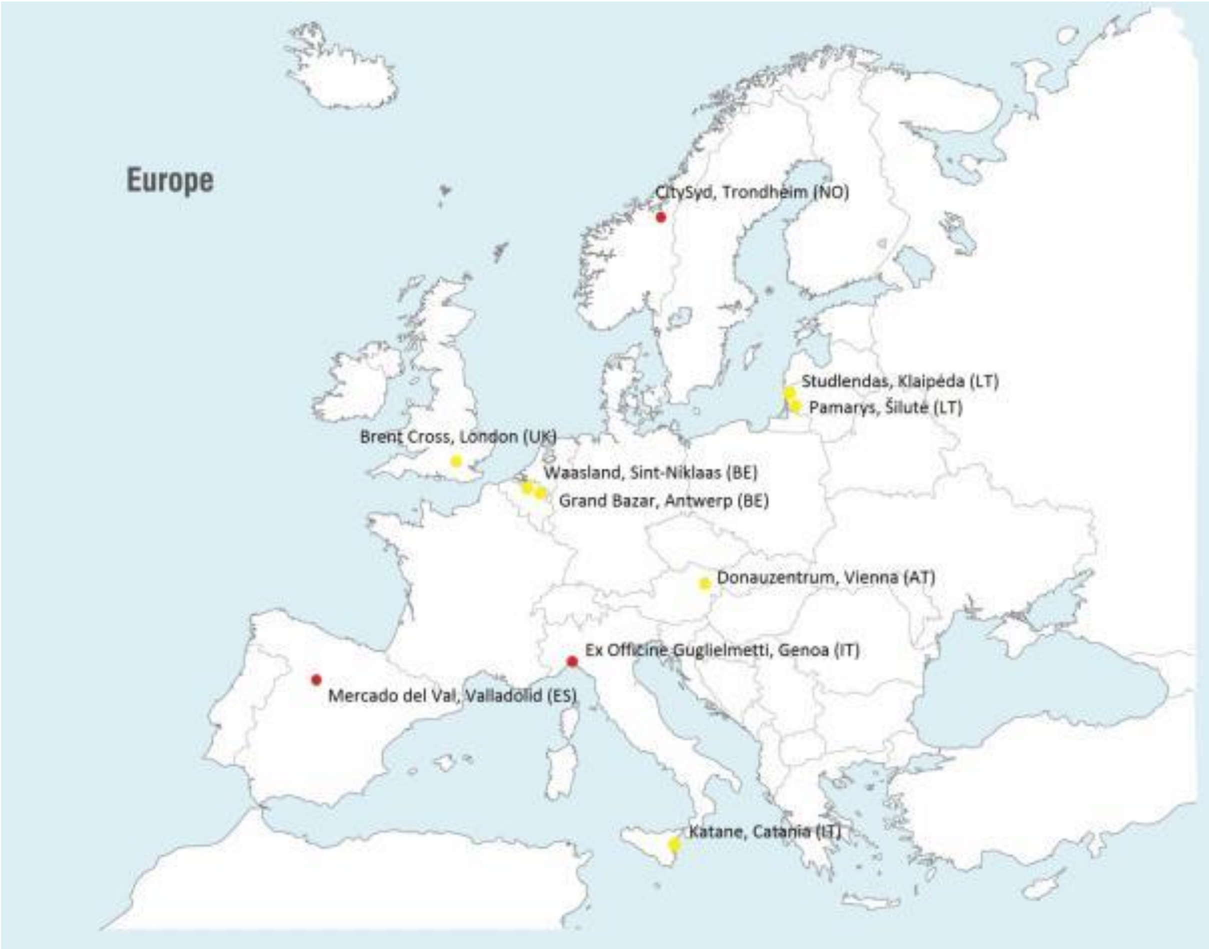

Figure 22: Reference building distribution (red dots indicate demo-cases and yellow dots - other reference buildings)

Table 16: Detailed overview; match of the reference buildings and the selection criteria (Abbreviations: see page 64)

Selection criteria		Climate condition			Market saturation		Location		Shopping centre typology			Building typology		Opening year		
		Heating Dominated	Cooling Dominated	Heating & cooling Dominated	Well-developed markets	Emerging markets	Urban	Suburban	Small shopping mall	Medium and large Shopping mall	Specialised and Others	Reconceptualized building	Shopping center purpose	Before 1990	Between 1990 and 2002	After 2002
Climate condition	Heating Dominated	CS/PA/ST			CS	PA/ST	ST	CS/PA	ST/PA	CS			CS/PA/ST	CS		PA/ST
	Cooling Dominated		GE/KA		GE/KA		GE/KA			KA	GE	GE	KA	GE		KA
	Heating & cooling Dominated			ME/BC/DO/WA/GB	ME/BC/DO/WA/GB		ME/DO/GB	BC/WA	GB	BC/DO/WA	ME	ME	BC/DO/WA/GB	ME/BC/DO/WA	GB	
Market saturation	Well-developed markets				CS/ME/GE/BC/KA/DO/WA/GB		ME/GE/KA/DO/GB	CS/BC/WA	GB	CS/BC/KA/DO/WA	ME/GE	ME/GE	CS/BC/KA/DO/WA/GB	CS/ME/GE/BC/DO/WA	GB	KA
	Emerging markets					PA/ST	ST	PA	PA/ST				PA/ST			PA/ST
Location	Urban						ME/GE/KA/DO/ST/GB		ST/GB	KA/DO	ME/GE	ME/GE	KA/DO/ST/GB	ME/GE/DO	GB	KA/ST
	Suburban							CS/BC/PA/WA	PA	CS/BC/WA			CS/BC/PA/WA	CS/BC/WA		ST
Shopping centre typology	Small shopping mall								PA/ST/GB				PA/ST/GB		GB	PA/ST
	Medium & large Shopping mall									CS/BC/KA/DO/WA			CS/BC/KA/DO/WA	CS/BC/DO/WA		KA
	Spezialised and Others										ME/GE	ME/GE		ME/GE		
Building typology	Reconceptualized building											ME/GE		ME/GE		
	Shopping Center purpose												CS/BC/KA/DO/PA/ST/WA/GB	CS/BC/DO/WA	GB	KA/PA/ST
Opening year	Before 1990													CS/ME/GE/BC/DO/WA		
	Between 1990 and 2002														GB	
	After 2002															KA/PA/ST

4.4.1 City Syd, Trondheim, NO

City Syd shopping centre is a suburban mainly car-dependent shopping centre, built on the outskirts of Trondheim when land prices in the area were cheap. The E6 motorway which is the main north to south route in Norway runs along the western side of the shopping centre. Opened in 1987 and covering an area of 28,500 m2, it was redeveloped in 2000 and it is now 38,000 m^2 on three floors, with 1,000 outdoor parking spaces. It houses 70 retail units. 4.2 million visitors per year generate an annual turnover of 250 million EUR. The shopping centres primary group of customers comes from the city of Trondheim, but it has a large catchment area and attracts customers from all over central Norway. City Syd was the largest shopping centre in the region until 2009, and it remains one of the largest in central Norway. The heating needs are covered by 2 heat pumps, supplemented by district heating when needed and connected to the ventilation system (air to water dual heat pump). Cooling is provided via the ventilation system and in addition there are fan coils in most of the stores.

In October 2012 a 25,000 m^2 expansion of the shopping centre was proposed, the redevelopment plan includes green roofs on both existing and new buildings, and a public park.

Figure 23: Front view of City Syd, main entrance

Figure 24: Illustration of the planned entrance area

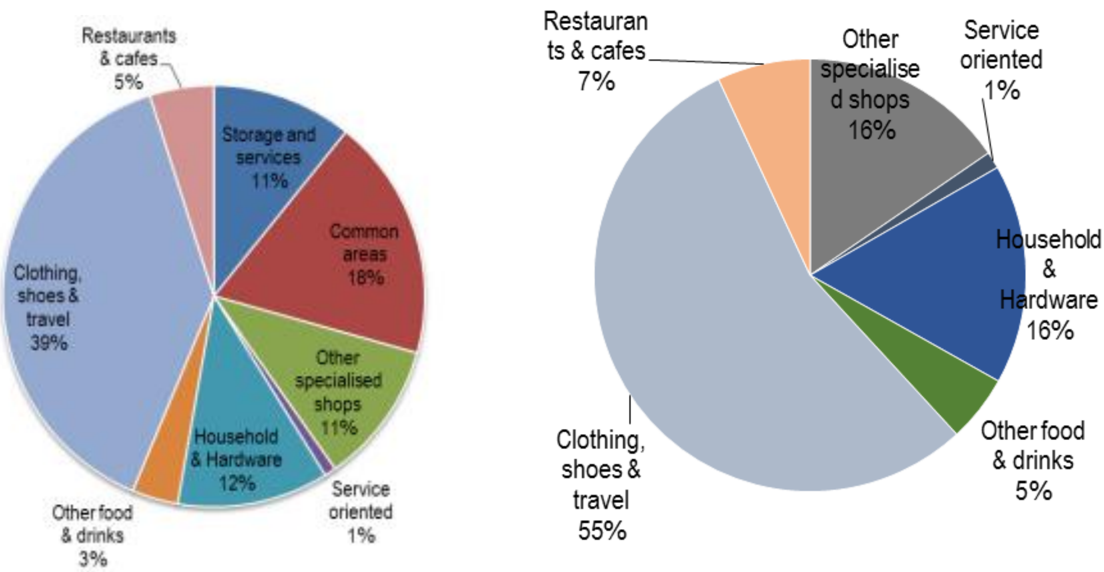

Figure 25: Composition of the floor area per type of shop (Excluding TRONDOS part); left: with common areas, storage & services, right: tenant area

Selection criteria:

Climate condition	Heating Dominated (88%)
Market saturation	Well-developed markets
Location	Suburban
Shopping centre typology	Medium Shopping centre (38.000 m²)
Building typology	Purpose built shopping-centre
Opening year	Before 1990 (1987)

4.4.2 Mercado del Val, Valladolid, ES

Valladolid City, capital of Castilla y León region in Spain, is a medium sized urban area with around 500.000 inhabitants and is the leading economic and commercial centre in the Northwest of Spain.

"Mercado del Val" is an iron structure market whose construction was completed in 1882. It is a historical market within the city centre, and represents an interesting case from a building and social point of view. Originally, it had stones for foundations and plinth, and iron for the other elements; ventilation was achieved using inclined blinds made of iron sheets. A stained glass lantern was installed but later eliminated. It was first renovated in 1981 focusing mainly on the maintenance and sanitation of the structure. The limestone blocks, wall bricks, slats and the cover were also restored. In addition the water, electricity and heating facilities were modernised. The market reopened at the end of 1983, with 114 stalls and 2,230 m^2.

The current intervention will improve the building's performance for the benefit of traders, industrialists and the users, turning it into a 21st century market. At the moment each retail unit has its own autonomous air-conditioning system to produce their cooling needs. The planned intervention aims therefore to reinstate the late nineteenth century building as a representative of an architecture and commercial activity from that period, being respectful to its essence, but transforming it into an innovative building that meets the potential and commercial needs of the 21st century.

Figure 26: Mercado del Val before renovation

Figure 27: Sketch of the refurbished market hall

Selection criteria:

Climate condition	Heating (50%) and Cooling (50%) Dominated
Market saturation	Well-developed markets
Location	Urban
Shopping centre typology	Specialised and Others / market hall (4.792 m² total floor area incl. 417 m² parking area after reconceptualization)
Building typology	Reconceptualised building
Opening year	Before 1990 (1882, opening after reconceptualization not fixed)

4.4.3 Ex-Officine Guglielmetti, Genova, IT

The ‘Genova Ex OfficineGuglielmetti’, situated in the populous neighbourhood of Valbisagno, is a shopping centre including a Coop grocery store of about 4000 m^2 retail space that will be renovated. Next to the centre, industrial buildings will be demolished and partially rebuilt with a connection to the existing shopping centre. At the end of the refurbishment, there will be a modern shopping centre, a grocery store and other medium and small retail units. The intervention will also include a hotel with 150 rooms (not included in the CommONEnergy project), parking lots (below and above ground) and a plaza for the neighbourhood citizens. The area will go through a major urban redevelopment: the built volume will be smaller than now and the floor area will be recovered and included in the urban use. In agreement with Genoa municipality, neighbourhood council and local citizen associations, it is expected to build also a theatre and a garden, on the roof of the existing building.

Figure 28: Building before renovation

Figure 29: Sketch of the refurbished shopping centre

Selection criteria:

Climate condition	Cooling Dominated (73%)
Market saturation	Well-developed markets
Location	Urban
Shopping centre typology	Specialised and Others (12.350 m² after reconceptualization)
Building typology	Reconceptualized building
Opening year	Before 1990 (grocery store from 1984, opening after reconceptualization in 2017)

4.4.4 Centro Commerciale Katané, Catania, IT

The Centro Commerciale Katané in Catania (Sicily) owned by IGD and Ipercoop Sicilia opened in 2009. A two floor gallery with more than 60 retail units, located between the sea and the road to Mount Etna, offers a GLA of 27.521 m² of which are 8.000 m² is dedicated to a hypermarket. The hypermarket offers all kind of convenience goods such as fresh food and delicatessen, pharmacy, textile, household goods and multimedia. The hypermarket is currently developing an "investment and management low cost" design with more attention to reduce building' and management costs, lower water consumption in lavatories and service areas and a reduction of the warehouses area. The air-conditioned gallery is equipped with a high efficiency heating plant including a heat pump. The roof of the commercial centre is a parking area.

Figure 30: Palm trees in front of the Katanè shopping centre

Figure 31: The large gallery of the Centro Commerciale Katané

Selection criteria:

Climate condition	Cooling Dominated (80%)
Market saturation	Well-developed markets
Location	Urban
Shopping centre typology	Medium Shopping centre with Hypermarket (27.521 m² GLA)
Building typology	Purpose built shopping-centre
Opening year	After 2002 (2009)

4.4.5 Donau Zentrum, Wien, AT

First opened in 1975, the Donau Zentrum was continuously enlarged over the next decades. Since the last renovation in 2012, the shopping centre has a gross leasable area of 133.000 m² on two floors, hosts 260 shops and a Cineplexx cinema centre. 1.7 million live within a 30 minute catchment area and the centre has a footfall of 18 million per year. Located in 22nd district of Vienna, the shopping centre has direct access to the metro, several local bus lines and a tram as well as a taxi station. Moreover, the centre offers parking decks with six free electric car charging points and six bike parks equipped with charging stations for e-bikes.

Since 2003, the shopping centre is owned by Unibail-Rodamco. A solar thermal system and heat recovery of the ventilation supplemented by Vienna's district heating cover the heating energy demand. 170.000 kWh/a electricity is produced on-site with a photovoltaic system installed on the cinema centre's roof, which covers 5% of the total annual energy demand for common areas in the entertainment centre (Donau Plex). Off-site electricity is supplied by 100% hydropower (green certificate provided by the utility). Ground- and rainwater serve as source for toilets and waste water is recycled for the car wash one of the parking decks. Main tenants are Thalia, Saturn, H&M, Zara, Interspar, C&A, Hollister, Superdry, Nespresso and Bose.

As shown in Figure 34, the largest share of the GLA is occupied by anchor stores and supermarkets. These stores are supplemented by clothing shops (14%) and a small portion of household and hardware stores as well as service providers. Gastronomy accounts for 6% of the GLA while one quarter is not categorised / not specified. Value of this Shopping centre as reference building is that Donau Zentrum is a super-regional, very large shopping centre including a leisure centre located in an urban area in one of Europe's largest cities. The building had a specific final energy consumption of 268 kWh/m²a (average 2011-2013).

Figure 32: Front view of the Donau Zentrum (source: Unibail-Rodamco)

Figure 33: Interior of the building part 6/7 (source: Unibail-Rodamco)

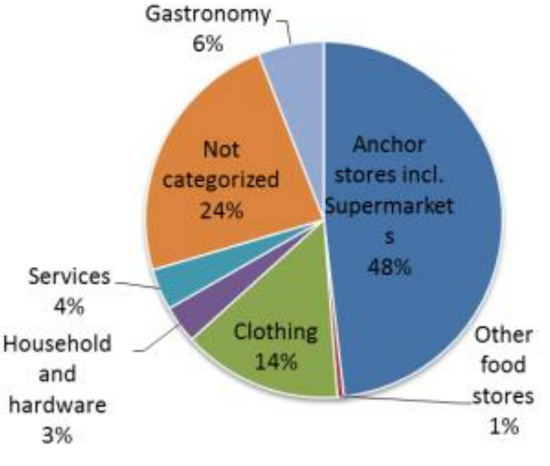

Figure 34: Composition of the floor area per type of shop

Selection criteria:

Climate condition	Heating (55%) and Cooling (45%) Dominated
Market saturation	Well-developed markets
Location	Urban
Shopping centre typology	Very Large Shopping centre (133.000 m² GLA)
Building typology	Purpose built shopping-centre
Opening year	Before 1990 (1975)

4.4.6 Brent Cross, London-Barnet, UK

Located at the junction of the M1 motorway and the London North Circular, the shopping centre is well positioned to serve the 2 million people within its core catchment area who spend just under £9.9 bn on non-grocery items. Brent Cross has one of the largest retail catchments in the UK with an annual footfall of 15 million visitors. Owned by Hammerson and Standard Life, the shopping centre offers 84.200 m^2 GLA with 118 tenants on two floors. Although it is smaller than more recent shopping centres such as the MetroCentre, Bluewater, Lakeside and Westfield London, it has one of the largest incomes per unit area of retail space in the UK.

When Brent Cross Shopping Centre opened in 1976 it was the first stand-alone shopping centre in the UK. It was initially constructed in a dumbbell shape running east-west parallel to the North Circular Road, with the two largest stores (John Lewis and Fenwicks) at the ends. It was expanded and renovated beginning in 1995, with additional shops and restaurants on an arm running north from the middle. A multi-storey car park replaced the remainder of the open parking area to the north. Brent Cross currently offers 8,000 free car-parking spaces, but according to the planning application submitted in March 2008 will eventually introduce parking charges. Brent Cross is one of the top properties of Hammerson's 1.7 million m^2 retail space in the UK and France, and, therefore, an expansion of the centre adding 55.000 m^2 is planned (SCT, 2014).

Figure 35: Inner Courtyard of Brent Cross

Figure 36: Entrance of Brent Cross

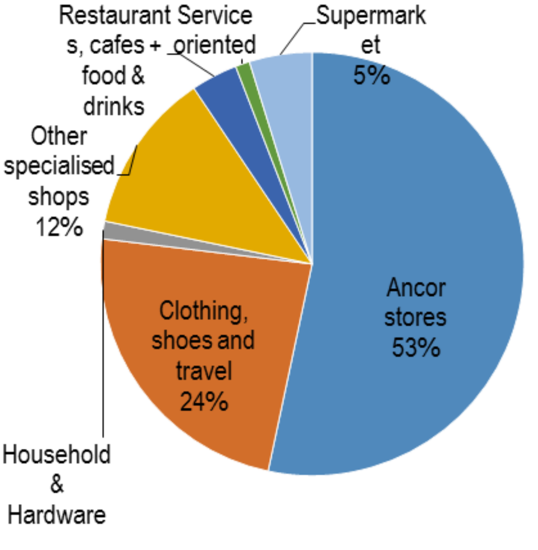

Figure 37: Composition of the floor area per type of shop

Selection criteria:

Climate condition	Heating (56%) and Cooling (44%) Dominated
Market saturation	Well-developed markets
Location	Suburban
Shopping centre typology	Very Large Shopping centre (84.200 m^2 GLA + 55.000 m^2 planned expansion)
Building typology	Purpose built shopping-centre
Opening year	Before 1990 (1976)

4.4.7 Pamarys, Šilutė, LT

Pamarys Shopping centre is located in Šilutė, a city in the south of the Klaipeda city in Lithuania. Šilutė is the capital of Šilutė district municipality. The population in Šilutė is 20.813 (Šilutės rajono savivaldybe 2014).

The centre is located approximately 2 km from the city centre. The total floor area of the building is 6020 m². Pamarys was opened in 2004. Pamarys offers a food store (IKI), a centre for decoration, construction materials and household items (Pasidaryk Pats), a bowling/billiard club. pharmacy, optics, and gardening store.

The Shopping centre is located on the outskirts of the city, close to the two residential areas: an apartment building area and a single-family house area. Since the Shopping centre offers a Bowling club and a big food store (IKI), the Shopping centre is also attractive for customers from other parts of the city. The Shopping centre has free parking place for approximately 210 cars (5000 m²). Pamarys Shopping centre is owned by Dervira ir partneriai, UAB and managed by Baltisches Haus.

Energy demand for space heating and hot water is supplied by the furniture factory heating power plant which is next to the Shopping centre. In order to achieve energy efficiency through providing heat energy, air from indoors is used by the installed HVCA. Approximately 10% of the thermal energy used for HVCA is taken from outdoor in order to ensure indoor air quality which is measured by CO_2 sensors. This solution together with high thermal building quality lead to the low specific energy costs for space heating and according to the shopping centre owner, is has lowest energy use when compared with all shopping centre buildings in Lithuania. The shopping centre is planning to install a solar thermal collector with the aim to cover the total water heating energy demand.

Figure 38: Pamarys centre seen from the parking area (source: www.balthaus.eu)

Figure 39: Inside the shopping centre (source: www.balthaus.eu)

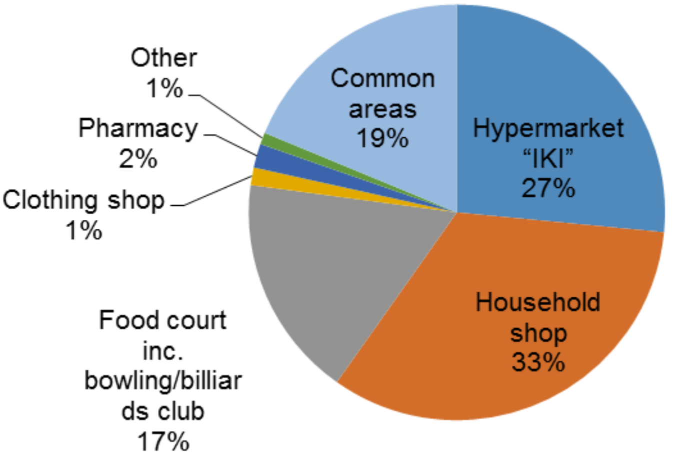

Figure 40: Composition of the floor area per type of shop

Selection criteria:

Climate condition	Heating Dominated (79%)
Market saturation	Emerging markets
Location	Suburban
Shopping centre typology	Small Shopping centre with Hypermarket (6020 m² total floor area)
Building typology	Purpose built shopping-centre
Opening year	After 2002 (2004)

4.4.8 Studlendas, Klaipėda, LT

Klaipėda City with around 157.000 inhabitants is the third largest city in Lithuania and the capital of Klaipeda country. Historically Klaipėda has been one of the fastest growing municipalities in Lithuania where the Klaipėda Seaport makes a significant contribution to the growth of the city (Klaipėda City Municipality 2014).

The STUDLENDAS shopping centre is a shopping and service complex located in Klaipeda. The shopping centre is near to the campus of Klaipėda University and approximately 4 km from the Baltic Sea. The shopping centre was opened in 2006. The bright and modern shopping centre offers more than 50 retail units on two floors. Besides clothing, bank services, household items and cafés, a large food store (IKI) offers convenience goods. The STUDLENDAS shopping centre is the first project in Lithuania which combines the private and public segments. The total building floor area is 12.637 m². 15% of the building floor area is used by the Klaipeda University.

The Shopping centre STUDLENDAS is owned by Baltisches Haus, a company that currently manages over 200,000 square meters of real estate throughout Lithuania. (Baltisches Haus 2012). The owner is continuously working on energy improvements of the building and its technical equipment. There are light sensors installed in all SC areas. Electricity consumption can continuously be monitored. For the lighting, LEDs are installed in the parking areas. The waste heat coming from the food refrigeration is used for the heating purpose.

Figure 41: The main entrance and the parking area (source: www.balthaus.eu)

Figure 42: Inside Studlendas shopping centre (source: www.balthaus.eu)

Selection criteria:

Climate condition	Heating Dominated (74%)
Market saturation	Emerging markets
Location	Urban
Shopping centre typology	Small Shopping centre (12.637 m² total floor area)
Building typology	Purpose built shopping-centre
Opening year	After 2002 (2006)

4.4.9 Waasland Shopping Center, Sint-Niklaas, BE

With its 45.578 m² GLA, the Waasland Shopping Center is the largest one-floor shopping centre in Benelux. It is located in Sint-Niklaas town, Belgium (i.e. between Antwerp and Ghent) and close to main roads. The centre opened in 1972, and underwent a major renovation and extension in 2003/2004.
The shopping centre offers 2.750 parking places located both in front of the building and on part of its rooftop. 140 shops offer a broad range of clothing, home decoration, comparison goods and food. Inno Gallery, C & A, H & M, United brands, Vanden Borre and super market Delhaize are the main anchors of the Waasland Shopping Center.

Waasland Shopping Center is managed by Devimo Consult, a multidisciplinary company specialized in professional management, operation and development guidance of shopping centers and retail areas. Devimo Consult currently manages about 34 shopping centres, galleries and sites with a total GLA of 686.416 million m² (GLA).

Already implemented in the centre are light, air-conditioning and heating control systems, LED lighting, refrigeration waste heat recovery, energy audits, etc. Waasland SC is also the first shopping centre of Belgium using windows (solar reflective) films which contribute to keep the heat inside the building in winter, to prevent overheating in summer and to reduce the "magnifying glass" effect due to the many glass surfaces in WaSC. In 2012, 600 light bulbs of 150W had been replaced by 25 W LEDs providing consistent energy savings while light quality/intensity had been preserved. The investment of around 30.000 euro had a payback time of 1 year.

As a result of all these measures, WaSC energy consumption had been reduced by 26%. Therefore, the service costs for energy in WaSC remained almost stable over the last decade, while the electricity price increase of around 29% had been largely compensated by the energy savings delivered by renovation.

Figure 43: Main entrance of the Waasland Shopping Center (source: BPIE with courtesy of DEVIMO)

Figure 44: Main square in the centre (source: BPIE with courtesy of DEVIMO)

Selection criteria:

Climate condition	Heating (59%) and Cooling (41%) Dominated
Market saturation	Well-developed markets
Location	Suburban
Shopping centre typology	Large Shopping centre (45.578 m² GLA)
Building typology	Purpose built shopping-centre
Opening year	Before 1990 (1972)

4.4.10 Grand Bazar, Antwerpen, BE

Grand Bazar shopping centre has a GLA of 17.904 m^2 and is located in the city centre of Antwerp, Belgium, close to the Groenplaats (big Central Square of the city).

Grand Bazar opened in 1993 through a significant rebuild and extension of an old warehouse from 1885.

The shopping centre hosts around 50 shops, including a food supermarket (i.e. Carrefour), ICTs and leisure equipment stores (e.g. FNAC being the biggest), clothes and housing etc.

In 2011 extensive renovation within the existing walls was undertaken, leading to a very modern interior with panoramic central escalators with a large skylight that increase the use of natural light. Replacement of conventional light systems with LED lighting and the new escalators with frequency controlled motors are the most important energy efficient measures implemented during this renovation. Grand Bazar shopping centre is managed by DEVIMO Consult.

Figure 45: Grand Bazar, inside view from upper level (source: www.grandbazarantwerp.be)

Figure 46: Grand Bazar shopping centre (source: www.architectura.be)

Selection criteria:

Climate condition	Heating (65%) and Cooling (35%) Dominated
Market saturation	Well-developed markets
Location	Urban
Shopping centre typology	Small Shopping centre (17.904 m² GLA)
Building typology	Purpose built shopping-centre (rebuild of a 1885 warehouse)
Opening year	Between 1990 and 2002 (1993; rebuild of a 1885 warehouse)

4.5 Summary

The main aim of this section is to classify European shopping centres based on selection criteria describing several aspects, such as the opening year of the building, its location, the climate condition and market saturation, the building as well as the shopping centre typology. Ten shopping centres from seven European countries are selected as reference buildings for the identification of inefficiencies and the development of the systemic solutions which will be developed and virtually tested in CommON*Energy*. These ten shopping centres are:

- City Syd, a medium Shopping centre, located in Trondheim, Norway
- Mercado del Val, a specialised shopping centre (market hall), located in Valladolid, Spain
- Genova Ex-Officine Guglielmetti, a reconceptualised shopping centre, located in Genova, Italy
- Centro Commerciale Katané, a medium Shopping centre with a hypermarket, located in Catania, Italy
- Donau Zentrum, a very Large Shopping centre, located in Vienna, Austria
- Brent Cross, a very Large Shopping centre, located in London, UK
- Pamarys, a small Shopping centre with a hypermarket, located in Silute, Lithuania
- Studlendas, a small Shopping centre, located in Klaipeda, Lithuania
- Waasland Shopping Center, a large Shopping centre, located in Sint-Niklaas, Belgium
- Grand Bazar, a small Shopping centre, located in Antwerp, Belgium

5. Survey of International Building Codes

This chapter is aimed at providing a general overview of the most relevant national building codes, regulation constraints and policies on buildings' energy performance that have been enacted by worldwide governments in recent years. In the following, a literature review and survey of other relevant existing legislative and policy frameworks will be conducted, along with considerations and comparisons on the expected effectiveness of the different implementations. The focus is set on both new and existing commercial buildings, provided that significant information is available.

Summarizing some of the figures shown in Section 2.1, it is estimated that there are 24 billion m^2 of useful floor space in the EU27. In comparison to the US and China, Europe has the highest building density (building floor space over land area). The European stock varies remarkably in terms of building types; differences also exist from country to country. Nevertheless, they can be broadly divided into residential and non-residential sectors where each sector alone consists of multiple types.

Table 17: Population, land area, building floor space and building density in Europe, USA and China (Own illustration; building floor space taken from BPIE Report, 2011)

	Population (2013)	Land area [km^2]	Building Floor Space [m^2] (2011)	Building density [m^2/km^2]
EU 27[20]	506 million	4.381.324	24 billon	5478
USA	317 million	9.629.091	25 billon	2596
China	1.350 million	9.571.302	35 billon	3657

Building codes contain minimum requirements for energy efficient design and construction for new and renovated residential and non-residential buildings. Specifically, they set energy efficiency requirements for buildings. The improvement of these minimum energy requirements softens the environmental impact of buildings as well as generates additional energy and cost savings over the decades-long, or even centuries-long, life cycle of a building (US Department of Energy, "Building Energy Codes 101. An Introduction", 2010).

For example, following the European Directive on the Energy Performance in Buildings, most EU countries have already adopted specific building codes fixing the parameters for the minimum energy requirements in case of new construction and, in some cases, also for refurbishment. Similarly, many other non-EU countries have also defined their own specific building codes; the topic is of great interest especially in North America, where relevant examples exist.

The target of the following sections is thus to provide an overview of the main figures deriving from the analysis, based on a literature review, of the existing building codes and other energy performance policies at international level with a particular focus on the shopping centre building stock. Nevertheless, existing building codes and other policies refer to the wider category commercial buildings or wholesale

[20] Note: the mentioned study was issued before Croatia became EU-member.

and retail trade, which encompasses shopping malls too. For this reason, the following sections often refer to commercial buildings or wholesale and retail trade due to the absence of a specific regulation concerning shopping malls. Moreover, given the heterogeneousness of the building codes adopted by different States, a critical comparative analysis of these differences will also be provided.

From a methodological standpoint, the literature review will refer to building codes and applicable regulations. In particular, this analysis aims at identifying and highlighting the most relevant and mature building codes at European level with a focus also on worldwide scale for the most interesting energy efficiency policies and good practice examples. Table 18 shows the list of the selected countries and their relevant features concerning building codes.

Table 18: List of selected countries and their peculiarities concerning building codes

	Country	Relevant features
Worldwide	**USA (and California)**	Advanced building codes (IECC and ASHRAE 90.1) and municipalities' beyond-code programs with prescriptive minimum construction requirements for energy efficiency in commercial buildings; California, assessed separately: Building code (California Building Standards Code) with the most comprehensive minimum energy efficiency standards in the world
	China	National design standards for energy-efficient commercial buildings (JGJ 189-2005) and the Green Building Action Plan
	Hong Kong	Buildings Energy Efficiency Ordinance with strict minimum energy performance standards and penalty mechanism
Europe	**Denmark**	Advanced performance-based code with strict energy requirements (Building Regulation 2010)
	France	Relevant standards for total energy consumption of both new and refurbished commercial buildings (Thermal Regulation 2012 and 2005)
	Germany	One of the most stringent building codes (The Energy Saving Regulation) in the world
	Italy	Advanced energy efficiency regulations (Decree 59/2009 and National Guidelines for the energy certification) as general framework for energy performance requirements of non-residential buildings
	Norway	Advanced building code (Planning and Building Act) sharpened every fifth year with tighter constraints
	Spain	Application of minimum requirements on energy performance and minimum photovoltaic contribution to electric power for non-residential buildings (Basic Document on Energy Saving)
	Sweden	Ones of the highest energy efficiency requirements in the world (Boverket's Building Regulations 2012)
	UK	Enhancement of energy-efficient requirements (Building Regulations Part L 2013) and introduction of zero carbon standards for non-domestic buildings

5.1 Building codes for commercial buildings worldwide

Electricity use in commercial buildings is driving peak demand in the United States, Japan, and in some of the wealthier developing countries in the global South. As countries in the global South raise their standards of living and services, building electricity use is expected to continue to increase, especially in the non-residential sector.
During the past decades, governments of most of the world countries have initiated policies to reduce energy consumption in buildings. Building energy codes, also known in some countries as "energy efficiency building codes" or "energy conservation building codes" are the key policy instruments developed by governments to reduce overall energy consumption of buildings and in the meantime to ensure good living conditions to the end-users.
Typically, the existing codes fix benchmarks of energy performances to be met by the new buildings (or by existing building undertaking refurbishment). These energy performances are enclosed in documents that range from voluntary guidelines to mandatory standards and may apply to one or many building types. Probably, the most complete (in terms of sectors addressed) and most challenging codes in force can be found in the USA and in China, as described in the following sections. These cases are presented for a twofold reason: the quality of the codes produced and the relevance of these huge countries at worldwide level.

5.1.1 USA

Between 1980 and 2009, in the US the commercial floor space and primary energy consumption grew by 58% and 69%, respectively. The Energy Information Administration (EIA) projects that growth continues at slower rates between 2009 and 2035, 28% and 22%, respectively.

Building codes

The magnitude of buildings-related primary energy consumptions led to a continuous development of building codes. The International Building Code (IBC) is a model building code developed by the International Code Council (ICC) and has been adopted throughout most of the United States. Most commercial building energy codes are based on ASHRAE/IESNA Standard 90.1, jointly developed by ASHRAE (American Society of Heating and Air-Conditioning Engineers) and the Illuminating Engineering Society (IES).
This standard provides the minimum requirements for energy-efficient design of most buildings, except low-rise residential buildings. It offers, in detail, the minimum energy-efficient requirements for design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings, as well as criteria for determining compliance with these requirements. Dated back to the 70s, the standard has undergone several reviews until the latest issue in 2013.

The Energy Conservation and Production Act (ECPA) requires States to adopt the most recent version of ASHRAE Standard 90.1.

Moreover, the International Energy Conservation Code (IECC) is worth mentioning: it is an ASHRAE 90.1-based code which contains prescriptive minimum design and construction requirements for energy efficiency in residential and commercial buildings. This code applies to *commercial buildings* and the buildings sites and associated systems and equipment. Instead, ASHRAE 90.1 covers commercial buildings only, defined as buildings other than single-family dwellings and multi-family buildings three stories or less above grade. Being IECC based on ASHRAE 90.1, for commercial buildings the compliance with ASHRAE 90.1 qualifies as compliance with IECC. It is important to point out that both recent revisions of the IECC and recent revisions of ASHRAE 90.1 have been ambitious and have resulted in significantly higher energy-savings than earlier versions of the code.

Thus, the IECC and ASHRAE90.1 are baseline building energy codes which currently address the energy-efficiency requirements for the design, materials, and equipment used in nearly all new construction, additions, renovations, and construction techniques. Specifically, when reading the sections of the codes, numeric benchmarks for the following macro sectors can be found:

- Building envelope (material selection and techniques used to construct the building envelope): code requirements specify the insulation levels in the floor, ceiling, and walls and are intended to seal the building against air leakage and moisture migration. The defined energy-efficiency levels of doors and windows take into consideration heat loss and gain, depending on whether heating or cooling of the building is the predominant concern, and daylighting;
- HVAC: minimum criteria for the size of HVAC systems and equipment, taking into consideration the energy demands of the building space;
- lighting and electrical equipment: the energy codes provide minimum criteria to provide effective lighting control. Motor and transformer efficiency is also covered in this area;
- water heating: water-heating energy efficiency depends upon water-heating equipment, delivery, and operational controls. Energy codes provide minimum criteria to effectively heat and deliver hot water.

All the bullets of the previous list can have useful reflections into the CommonEnergy approach. Indeed, the energy used for the shopping malls encompasses the demand that can be limited acting on the envelope features, the HVAC systems, lighting and electrical equipment.

Beyond-code programs

Progressive states and local jurisdictions with a focus on energy efficiency and/or sustainability are increasingly building upon the baseline building energy codes and adopting beyond-code programs, either as their mandatory minimum codes or as voluntary programs that provide incentives to those that comply. What they have in common as a key component is building energy efficiency; they may have more rigorous requirements than minimum energy codes and/or address additional issues not covered in the energy codes.

Most beyond-code programs use the IECC and/or ASHRAE90.1 as a baseline, with additional requirements beyond that. They vary widely in scope – from a simple requirement to comply 10 percent above the current IECC, to comprehensive programs such as Green Globes, a product of the Green Building Initiative, and the U.S. Green Building Council's (USGBC's) Leadership in Energy & Environmental Design (LEED). As of August 2009, there were over 300 such programs adopted by states and jurisdictions nationwide. As concerns commercial buildings, the most relevant beyond-code programs are the following:

- ENERGY STAR: The U.S. Environmental Protection Agency outlines criteria for ENERGY STAR certification of homes and commercial buildings. ENERGY STAR homes are typically 15 percent more energy efficient than average minimum energy codes. New York State allows local jurisdictions to adopt ENERGY STAR as their minimum residential energy code and many, such as Brookhaven, have done so;
- Core Performance Guide: use of this guide results in commercial buildings that are 20 to 30 percent more efficient than ASHRAE 90.1-2004 buildings. Developed by the New Buildings Institute, this fee-based program is available nationwide. Its simplified design approach to energy efficiency applies to new commercial construction projects. It is designed for commercial buildings from 10,000 to 70,000 square feet[21];
- ASHRAE 189: Standard for the Design of High-Performance, Green Buildings except Low-Rise Residential Buildings, was published in January 2010. The standard was developed in conjunction with IES and USGBC and is applicable to new commercial buildings and major renovation projects. This code addresses energy efficiency, a building's impact on the atmosphere, sustainable sites, water-use efficiency, materials and resources, and indoor environmental quality. ASHRAE/IES/USGBC Standard 189 was developed for inclusion into building codes.

As described above, the United States have a complex institutional and regulatory structure that allows a continuous development and improvement of the existing building codes. This structure mainly refers to the US Department of Energy but the entire process of building codes' development is participatory, allowing different subjects to propose ideas and strategies to enhance the existing building codes. This continuous development allows creating the optimal conditions for a continuous improvement of buildings energy performance, thus reducing their impact on the national primary energy consumption and ultimately carbon emissions.

In addition, the existence of many beyond-code programs that either mandate stricter energy performance in buildings or provide incentives to those subjects that decide to participate to them on a voluntary basis is a clear indication of the national commitment to the improvement of buildings' environmental footprint, making the Unites States one of the most advanced countries in terms of building codes' comprehensiveness and performance requirements.

[21] 1 square foot is 0.09 square meters. Thus, the range is from 929 to 6,503 m².

5.1.1.1 Case study of California

It is worth mentioning this specific case, due to its particular customization. Within USA, the state of California has adopted its building code (California Code of Regulations (CCR), Title 24, also known as the California Building Standards Code), based on amendments and customization of the International Building Code. It is structured into triennial reviews; the most updated version has been released at the end of 2013 and has been made operational since January 2014.

California has probably the most comprehensive minimum energy efficiency standards for buildings in the world. The standards are very detailed, and they regulate nearly every part of energy consumption in buildings including valuable explanations and examples. The Californian codes are shared in a relative simple but comprehensive code for small residential buildings similar to the IECC code and for non-commercial and high-rise buildings based on the ASHRAE standard.

The building code provisions of Title 24 are notable for:

- Stringency: the Title 24 standards typically exceed IECC and ASHRAE efficiency levels;
- Performance-Based Provisions: California's building efficiency standards are organized into three basic components, namely mandatory features, prescriptive package requirements and performance guidelines;
- High Compliance Rates: field verification studies for Title 24-compliant buildings show that 70% of homes meet all code requirements;
- Flexibility: California is one of a few states that includes a performance-based approach that permits a wide variety of combinations of energy efficiency measures to meet code requirements;
- Receiving Active Support: the California Energy Commission (CEC) maintains an expert staff that manages the code development process and provides technical assistance in code interpretation and enforcement;
- A Forward-Looking Orientation: California periodically expands the scope and stringency of its energy codes to ensure that they capture available "potential savings" and works with its utilities on research and development to incorporate proven technologies.

5.1.2 China

Today, buildings play a very important role as they account for more than 25% of China's total primary energy consumption. This share is however likely to increase to 35% by 2030 because urbanization in China is increasing every year as shown in Figure 47: about 2 billion square meters of new buildings are completed annually.

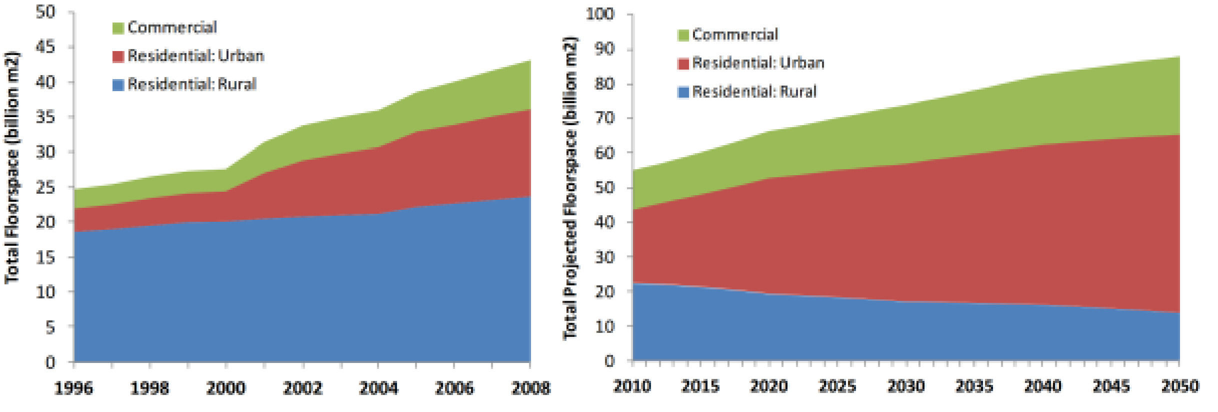

Figure 47: Left: China's reported historical total floor space by building type, 1996 – 2008 (GBPN report, 2012)
Right: China's projected total building floor space by building type, 2010 – 2050 (GBPN report, 2012)

As reported in the document "Building Energy Efficiency Policies in China" by GPBN (dated July 2012) China has pursued the development of its building energy efficiency policies since the early 1980s: starting with a preparation phase in the 80s, then with implementation of demonstration projects at a small scale (1987-1993), putting in place the regulatory, administrative, and technological support systems to promote building energy efficiency (1994-2005), and finally (since 2006) issuing the policies and codes relevant to residential retrofit, green buildings, and the application of renewable energy in building energy efficiency.

An important remark to make when dealing with the topic in China is that the definition of public building may appear misleading. In the Chinese context, public buildings include government office buildings, commercial buildings, buildings used in the service industries, buildings used for educational purposes, and hospitals.

Thus, with specific focus on commercial buildings, China's national design standard for energy-efficient commercial buildings (JGJ 189-2005) took effect on July 1, 2005 and covers new construction, expansion, and retrofits. The standard sets a goal of reducing lighting and HVAC energy use by 50% compared with the energy use in buildings constructed in the early 1980s. The standard includes two main sections, one on the building envelope and one on HVAC systems. These sections specify the minimum insulation requirements for building envelopes in different climate zones, recommend HVAC system types, and provide design guidelines rather than simply listing efficiency requirements. Only a prescriptive approach is offered for meeting lighting and HVAC requirements. For building envelope requirements, a performance-based trade-off approach can be used if prescriptive requirements are not met.

In general terms, China's energy efficiency policy is largely defined and supervised at the federal level, though implementation is often conducted by provinces and municipalities. The policy system consists of laws and regulations; major national plans (most notably the Five Year Plans); and policies (e.g.: standards, administrative measures, economic incentives) based on these laws and plans. The 11th Five-Year Plan, covering 2006-2010, set a national goal of reducing energy intensity by 20% and motivated considerable strengthening of energy efficiency policy.

The Green Building Action Plan goes beyond these targets and sets the following objectives:

- 1 billion m^2 of new green building in 12th Five Year Plan (2011-2015);

- by the end of 2015, 20% of urban building must be green buildings;
- heat metering and energy efficiency retrofit in 400 million m^2 buildings in northern cold and severe cold area;
- retrofit of 120 million m^2public buildings.

In addition, mandatory minimum standards for many appliances (including a growing number of electronic devices and lighting technologies) also exist. As mentioned in the following, China promotes a voluntary appliance energy efficiency labeling program similar to Energy Star in the United States, “Three Star” system, and mandates labeling adapted from the EU for a few appliances.
Corporate income tax incentives promote the uptake of energy efficient technologies and measures. Administrative measures promote efficiency of equipment and energy management in large commercial and public buildings, and various levels of government provide financial support for actions required by these measures.

Voluntary green building labelling schemes

In 2006 the Ministry of Housing and Urban-Rural Development released an alternative evaluation standard for green buildings. The standards included China’s Green Building Design Label, or “Three Star” system, for rating building sustainability and the Leadership in Energy and Environmental Design (LEED) rating. In addition, subsidies are also foreseen for highly rated buildings.

LEED and Three Star share common elements and a common goal – to reduce a building’s environmental impact— but the two systems diverge in their ratings and review processes.
China’s Three Star system rates residential and commercial buildings (Table 19), including apartments, hotels, and office and commercial space, from one to three stars with three stars indicating the highest performance level. Like LEED, the rating uses a point system to evaluate a building’s water and energy efficiency, materials and resources use, indoor environment, operation and maintenance, and site efficiency and outdoor environment. A building must obtain a certain number of points in every category to qualify for a star rating. A building is evaluated by a local, provincial, or national committee, depending on the location of the building and what star-level a developer hopes to obtain. One of the most important differences is the larger number of pre-requisites (control items) in the Three-star system than LEED.
All credits are totaled together for your final score in LEED regardless of the category. In contrast, the 3-star system requires every building to achieve all the control items as well as a minimum of one star in each category. To receive higher certifications you must achieve that higher score for every category. This means a three star rated building must have a three star score for every category. This method is in some ways an improvement over LEED. Since LEED credits are all counted equally, it is possible to pick and choose the easiest credits, while ignoring the more important and more difficult credits like energy efficiency.

Table 19: Criteria for green building design label rating evaluation for commercial buildings (Building Energy-Efficiency Best Practice Policies and Policy Packages, 2012)

Rating Level	Mandatory Items Included	General Items						Preferred Items
		Land Use & Outdoor Environment	Energy Efficiency	Water Efficiency	Resource Efficiency	Indoor Environment	Operational Management	
		Total: 6	Total:10	Total: 6	Total: 8	Total: 6	Total: 7	Total: 14
★	Yes	3	4	3	5	3	4	0
★★	Yes	4	6	4	6	4	5	6
★★★	Yes	5	8	5	7	5	6	10

China is moving fast towards the target of reducing the environmental footprint and energy demand of buildings: the ambitious targets of the Green Building Action Plan and the strict standards of the Three-star certification are proves of the national commitment to this issue. As a general approach, China's central and local governments have recognized the need to adopt both regulatory policies (i.e. building codes) and market-based and financial policies (i.e. building energy labels and incentives) to improve building energy efficiency.

However, at the same time, the unprecedented rate of growth in new construction in China and the government's relatively recent policy focus on building energy efficiency leaves China's building energy-efficiency codes and labeling and incentive programs facing some major challenges. Insufficient institutional and technical capacity makes the development of more stringent and up-to-date building codes difficult. A particular issue is the use of 1980s-era baseline values against which efficiency improvements are measured even though those baselines may not represent average existing conditions in the building stock today. Another challenge for China's building codes and efficiency policies is uneven enforcement and monitoring. Disparities between urban and rural building energy-efficiency levels and in the levels of policy support between central and local governments have also limited the effectiveness of all types of building energy-efficiency policies in China. The connections among the three types of building policies (codes, labeling, and incentives) in China have been limited so far; their effectiveness could be improved significantly with greater cross-cutting policy linkages.

5.1.3 Hong Kong

Hong Kong is a further example in which national indications exist for the retrofit of buildings with commercial destination use. In this case, a national code exists, the BEC (which stands for Building Energy Code), that is a document produced following the national scheme launched by the Government.

Since a very high share of the total electricity consumption in Hong Kong is contributed by buildings, in October 1998 the Electrical and Mechanical Services Department launched the voluntary Hong Kong Energy Efficiency Registration Scheme for Buildings to promote the application of Building Energy Code. To further promote building energy efficiency, the Government enacted the Buildings Energy Efficiency Ordinance in 2012 and sets strict minimum performance standards for the prescribed buildings. The Ordinance has 3 key requirements, and the second and (mainly) the third one have an important relevance to shopping centres:

1. the developers or building owners of newly constructed buildings should ensure that the 4 key types of building services installation therein, namely, air-conditioning installation, lighting installation, electrical installation as well as lift and escalator installation, comply with the design standards of the BEC;
2. the responsible persons (i.e.: owners, tenants or occupiers etc.) in buildings should ensure that the 4 key types of building services installation therein comply with the design standards of the BEC when " major retrofitting works " are carried out;
3. the owners of commercial buildings (including the commercial portions of composite buildings, e.g.: shopping malls under residential stores) should carry out energy audit for the 4 key types of central building services installation therein in accordance with the Energy Audit Code (EAC) every 10 years. The energy audits conducted at the shopping malls can be a driving force for the implementation of measures for energy efficiency.

It is highlighted that the Ordinance does not impose any retrospective effect on existing buildings. The relevant responsible persons are not required to do anything until they carry out "major retrofitting works" prescribed in the Ordinance. The following figure, an extract from the quoted BEC, provides an example of the indications fixed for Air Conditioning systems in the performance-based approach.

Table 6.12a : Minimum Coefficient of Performance for Unitary Air-conditioner at Full Load

Type of Cooling	Air-cooled				Water-cooled
Capacity range (kW)	7.5 kW & below, of types outside the scope of Room Air Conditioners in the labelling scheme specified in clause 6.12.2	Above 7.5 kW & below 40 kW	40 to 200 kW	Above 200 kW	All Ratings
Minimum COP at cooling mode (free air flow@1)	2.4 for split type 2.1 for non-split type	2.4 3 for VRF	2.4 2.9 for VRF	2.6 2.9 for VRF	3
Minimum COP at heating mode (heat pump) (free air flow@1)	2.4	2.7	2.8	2.9	not applicable

Standard rating conditions

Type of Cooling	Air-cooled		Water-cooled	
Operation condition	Condenser ambient	Room air entering equipment	Entering water temperature	Room air entering equipment
Cooling	35°C dry bulb	26.7°C dry bulb/ 19.4°C wet bulb	29.5°C	26.7°C dry bulb/ 19.4°C wet bulb
Heating	7°C dry bulb / 6°C wet bulb	21°C dry bulb	not applicable	
Water side fouling factor	0.000018m^2-°C/W for evaporator; 0.000044m^2-°C/W for condenser			

Remark:
@1: without connection of ductwork at condenser (likewise at evaporator for heat pump); the COP for equipment with high static fans (for connecting ductwork) can be determined based on the fan power of normal fans for free air flow (and not the fan power of the high static fans)

Figure 48: extract from the BEC of Hong Kong – requirements for AC

Hong Kong has thus made strides towards the enhancement of energy efficiency in buildings defining several strict minimum performance standards to be complied with from 2012 on. These policies are expected to generate highly positive impacts in reducing energy consumption, specifically in Hongkong's shopping centres.

5.2 European legislative instruments for energy efficiency

Improving the energy performance of buildings is a key factor in securing the transition to a 'green' resource efficient economy and achieving the EU Climate & Energy objectives, namely a 20% reduction in the GHG emissions by 2020 and 20% energy savings by 2020. In this context, a direct reduction of GHG emissions will be obtained by reducing the energy consumption of the buildings.

In the "Action Plan for Energy Efficiency: Realizing the Potential" (2006) the energy saving potential in both commercial and residential buildings was estimated at around 27% (91 Mtoe) and 30% (63 Mtoe) of energy use respectively and identified as providing the largest cost-effective savings potential of all sectors. In addition, the Action Plan indicates that, in residential buildings, retrofitting walls and roofs insulation offer the greatest saving opportunities, while in commercial buildings, improving energy management systems is more relevant.
With 40% of energy consumed in buildings, the EU has introduced legislation for energy efficiency in buildings to ensure energy consumption reduction. The most important legislative instrument is the Energy Performance of Buildings Directive (EPBD) (2010/31/EU). The directive required all EU countries to enhance their building regulations and following the EPBD, requirements in the EU MS have gradually started shifting from prescriptive to a performance-based approach which is regarded as a major change in the building code trends.

The EPBD stands as an important milestone for building policies, among others requiring all European Member States to:

a) Introduce minimum energy performance requirements for buildings, building elements and technical building systems,

b) Set these requirements based on a cost-optimal methodology taking into account the lifetime costs of the building, and

c) Construct only nearly Zero-Energy Buildings from 2020 onwards.

The cost-optimal methodology introduces - for the very first time - the prerequisite to consider the global lifetime costs of buildings to shape their future energy performance requirements. Thus, the evaluation of buildings' requirements will not anymore be related only to the investment costs, but will additionally take into account the operational, maintenance, disposal and energy saving costs of buildings.

Through the implementation of cost-optimal methodology, tightening of energy requirements are expected. In addition for new buildings, the recast EPBD asks all EU MS to set 'nearly zero energy buildings' requirements by the end of 2020 (and by the end of 2018 for public buildings). This means that by 2021 the latest, all new buildings constructed in the EU will have to have a very low energy consumption which should be covered, to a significant extend, by renewable energy generated onsite or nearby. In addition to EPBD, the Eco-design of the Energy-Related Products Framework Directive 09/125/EC (recast of Energy-Using Directive 32/2005/EC), the End-use Energy Efficiency and Energy Services Directive 32/2006/EC (ESD) as well as the Labelling Framework Directive 2010/30/EU (recast of 75/1992/EC) aim to contribute significantly to realizing the energy-saving potential of the European Union's buildings sector.
This section is divided into two parts. First there is a review of the overall state of implementation of the EPBD. This is followed by a review of the main components of the building code requirements.

5.2.1 Building codes requirements for new buildings

The implementation of the EPBD has resulted in a step-change in the performance-based requirements in building codes across Europe. Nearly all countries have now adopted a national methodology that sets energy performance based requirements for new buildings. A detailed assessment of the performance-based requirements for new buildings is provided in
Table 20.

As underlined in the *BPIE,* Europe's buildings under the microscope report, 2011 there is *"a large variation in the energy performance regulations of the different countries. Not only performance levels are different but even the unit, in which the performance is measured is different. Primary energy, delivered energy, various energy frames and even CO_2 emissions are used. The setting of building code requirements normally refers to either a percentage improvement requirement based on a reference building of similar features (same type, size, shape and orientation) or to an absolute value generally expressed in kWh/m^{2}y"*.

It is interesting to point out that in many countries the requirements extend only to certain building types, usually just covering the residential sector. As regards to shopping malls, it has to be said that the MS set standards for wholesale and retail trade very different between them. Moreover the performance requirements set by different Member States cannot be compared due to the different energy performance methodology. However, there is a surge of interest in the harmonization of methodology procedures as the Commission will need to demonstrate that all Member States are delivering equivalent outcomes.

Table 20: Building codes requirements for new buildings in Europe (BPIE Report, 2011)

	Single family houses	Apartment Blocks	Offices	Educational Buildings	Hospitals	Hotels & Restaurants	Sports facilities	Wholesale & retail trade
AT	H: 66 kWh/m^2a	H: 66 kh/m^2a	H:22.75 kWh/m^3a	H:22.75 kWh/m^3a C: 1kWh/m^3a	H:22.75 kWh/m^3a C: 1kWh/m^3a	H:22.75 kWh/m^3a C: 1kWh/m^3a	H:22.75 kWh/m^3a C: 1kWh/m^3a	H:22.75 kWh/m^3a C: 1kWh/m^3a
BE - Br	E70		E75	E75				E75 (services)
BE - Wl	E<100, E_{spec} <170kWh/m^2a , Overheating <17500 kh/an	E<100 Espec <170kWh/m^2a Overheating <17500 kh/an	E<100	E<100				
BE - Fl	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60					
BG	F:122-146 H&C: 82.5-102.5 kWh/m_2a	F: 90-146 H&C: 50.0-102.5 kWh/m_2a	F: 80-132 H&C:40.0-82 kWh/m_2a	F: 56-98 H&C: 40-82.0 kWh/m_2a	F: 180-242 H&C: 50-102.5 kWh/m_2a	F: 176-230 H&C: 50-102.5 kWh/m_2a	F: 90-134 H&C: 40-82 kWh/m_2a	F: 90-134 H&C: 40-82 kWh/m_2a
CH	Space heating demand (effective energy): 5 litre heating oil equivalent per m2 (based on MuKEn 2008)							
	H: 54 kWh/m_2a	H: 42 kWh/m_2a	H: 46 kWh/m_2a	H: 43 kWh/m_2a	H: 44 kWh/m_2a	H: 58 kWh/m_2a	H: 40 kWh/m_2a	H: 36 kWh/m_2a
CY	A or B category on the EPC scale							
CZ	F: 142 kWh/m^2a	F: 120 kWh/m^2a	F: 179 kWh/m^2a	F: 130 kWh/m^2a	F 310 kWh/m^2a	F: 294 kWh/m^2a	F: 145 kWh/m^2a	F: 183 kWh/m^2a
DE	New buildings must not exceed a defined primary energy demand for heating, hot water, ventilation, cooling and lighting installations (lighting installations only for							
DK	P: 52.5+1650/A kWh/m2a	P: 52.5+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a	P: 71.3+1650/A kWh/m2a
EE	P: 180 kWh/m2a	P: 150 kWh/ m2a	P: 220 kWh/ m2a	P: 300 kWh/ m2a	P: 400 kWh/ m2a	P: 300 kWh/ m2a	P: 300 kWh/ m2a	P: 300 kWh/ m2a
EL	The Primary energy requirement for new and renovated building in Greece is = 0.33 – 2.73 x Reference Building energy performance							
ES	The energy performance requirements is not expressed in units of kWh/m2a							
FI	This is based on thermal transmittance (heat loss) measured in units of W/K. For a single family house, a typical value is 134 W/K							
FR-H1	PFF: 130kWh/m^2a PESH: 250kWh/m^2a	PFF: 130kWh/m^2a PESH: 250kWh/ m^2a	n/a	n/a	n/a	n/a	n/a	n/a
FR -H2	PFF: 110kWh/m^2a PESH: 190kWh/m^2a	PFF: 110kWh/m^2a PESH: 190kWh/ m2a	n/a	n/a	n/a	n/a	n/a	n/a
FR -H3	PFF: 80kWh/m^2a PESH: 130kWh/m^2a	PFF: 80kWh/m a PESH: 2 130kWh/ m^2a	n/a	n/a	n/a	n/a	n/a	n/a
HU	P: 110-230 kWh/ m2a	P: 110-230 kWh/m2a	P: 132-260 kWh/m2a	P: 90-254 kWh/m2a				
IE	MPEPC = 0.6 & MPCPC = 0.69	MPEPC = 0.6 & MPCPC = 0.69	MPEPC & MPCPC should not exceed 1	MPEPC & MPCPC should not exceed 1				
IT	Regulations for new buildings are based on a set limit for heating, DHW, cooling and lighting. Only Class A+ to C buildings comply with requirements for new buildings							
LT	Min Class C buildings: 80 kWh/m2a for buildings over 3,000 m2, 100 kWh/m2a for buildings between 501 and 3,000 m2, 115 kWh/m2a for buildings up to 500 m2.							
LV	No performance requirements are set							
MT	No performance requirements are set							
NL	P: 68388-68552 MJ/a	P: 35595-36855 MJ/a						
NO	N: 120-173 kWh/ m^2a	N: 115 kWh/ m^2a	N: 150 kWh/ m^2a	N: 120-160 kWh/ m^2a	N: 300-335 kWh/ m^2	N: 220 kWh/ m^2a	N: 170 kWh/ m^2a	N: 210 kWh/ m^2a
PL	F: 142 kWh/m^2a H&C: 108kWh/m^2a	F: 123 kWh/m^2a H&C: 99 kWh/m^2a	F: 174 kWh/m^2a H&C: 183 kWh/m^2a	Requirements for other non-residential buildings apply				
PT	P: 203 kWh/m^2a F: 80 kWh/m^2a	P: 203 kWh/m^2a F: 80 kWh/m^2a	P: 407 kWh/m^2a F: 122 kWh/m^2a	P: 174 kWh/m^2a F: 52 kWh/m^2a	P: 465 kWh/m^2a F: 140 kWh/ m^2a	P: 523/1395 kWh/m^2a F: 157/419 kWh/m^2a	P: 233 kWh/m^2a F: 70 kWh/ m^2a	P: 1279 kWh/m^2a F: 70 kWh/ m^2a
RO	No performance-based requirements are set							
SE	F_E: 55-95 F_{NE} 110-150 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a	F_E: 55-95 F_{NE} 110-140 kWh/m^2a
SI	P: 170-200 H&C: 50 kWh/m^2a	P: 170-200 H&C: 50 kWh/m^2a	P: 163-180 kWh/m^2a a for social housing, for non-residential H&C: 30-50 kWh/m^2a, for non-residential (public investment) H&C:20-40 kWh/m^2a					
SK	P: 80-160 H&C: 42-86 kWh/m^2a	P: 63-126 H&C: 27-53 kWh/m^2a	P: 120-240 H&C: 16-56 kWh/m^2a	P: 42-84 H&C: 28-56 kWh/m^2a	P: 101-201 H&C: 27-70 kWh/m^2a	P: 94-187 H&C: 27-70 kWh/m^2a	P: 48-95 H&C: 28-56 kWh/m^2a	P: 81-161 H&C: 27-70 kWh/m^2a
UK	17-20 $kgCO_2$	16-18 $kgCO_2$	Other TER (Target carbon dioxide Emission Rate) values apply for non-domestic buildings					

5.2.2 Building codes requirements for existing buildings

The EPBD asks for energy efficiency standards in case of major renovation. One of the main provisions relating to building renovation is in Article 7 of recast EPBD stipulating the implementation of energy saving measures in the case of a major upgrade of a building (defined as one affecting 25% of the building area or where the total cost is 25% or more of the value of the building).
Nevertheless, there are large variations among EU MS in setting and putting in place these renovation requirements. In some countries two approaches exist in parallel, one based on the whole building approach and the other one on the performance of single elements. In others, the whole building approach acts as a supplementary demand or alternative to single element requirements.

5.2.3 European good practice examples for commercial buildings

The focus of this Section is on the European countries with advanced building policy frameworks that have already introduced or planned mandatory energy requirements and/or other ambitious energy efficiency policies with particular reference to non-residential buildings (wholesale & retail sector). Therefore, some good practices are briefly introduced along with the countries where the CommONEnergy demo-cases are located (Norway, Spain and Italy).

Denmark
Denmark has a long history and experience in using regulatory policy instruments such as building regulation to reduce energy demand from buildings. The first instrument to impose requirements on the energy efficiency of buildings was introduced in Denmark 1961 and by 1982 the first performance compliance option was included in the code. In 2005 the code was updated to be an overall performance regulation.

The present Danish building regulation is Building Regulation 2010 (BR10) that came into force on January 2011. In particular, the BR10 is a performance-based code that requires a mandatory energy frame calculation to establish maximum energy demand for new residential and non-residential buildings, 52.5 + 1650/A kWh/m^2/ year and 71.3 + 1650/A kWh/m^2/ year respectively, where A is the heated gross floor area. The code addresses all thermal envelope requirements and energy-using efficiency standards in the calculation including heating, cooling, ventilation, hot water, lighting (only non-residential), heat recovery and conversion and distribution losses. In addition, minimum thermal insulation standards (U values) of individual building elements are provided. For existing buildings undergoing renovation, the energy requirements are adopted for the individual building elements (construction elements, windows and installation elements) but there is no specific energy requirement on building level. The BR10 also lists solutions that are often cost-effective to implement when carried out as part of a renovation or replacement.

France

France has had prescriptive building energy efficiency requirements since 1955. The first performance based standard was implemented in 2005 in compliance with the release of the EPBD requirements in 2002. The Réglementation Thermique 2012 (RT 2012) is the current version of building code that came into force on January 1, 2013. It sets a maximum energy consumption limit of 50 kWh/m^2/year in primary energy for new residential and non- residential buildings against 150 kWh/m^2/year under the previous regulation RT2005. This value can vary according to climatic conditions, altitude and type of building use within the range 40 kWh/m^2/year to 65 kWh/m^2/year.

This requirement includes demand from space heating and cooling, ventilation, hot water and lighting and is applied to new residential, commercial (retail and wholesale) and public buildings. The penalty for non-compliance is the non-issuance of the building permit.

The thermal regulation for existing buildings was set up in 2005 (RT2005) and sets standards for the total energy consumption of refurbished buildings above certain threshold. For non-residential buildings, the total energy consumption must be at least 30% smaller than before the refurbishment.

Germany

Germany has had prescriptive building energy efficiency requirements since 1977 (the Thermal Insulation Ordinance). The first performance-based code was introduced meeting requirements for the EU EPBD in 2002. The Energy Saving Regulation, generally referred to as the EnEV2009, is Germany's energy efficiency building code and is considered one of the most stringent codes in the world. It is a performance-based code that requires a mandatory energy frame calculation to assess primary energy consumption of residential and non-residential buildings and sets out thermal insulation standards that have to be observed in new buildings and renovated buildings.

In a first step (EnEV 2009) the aim was to reduce energy, heating and hot water demand by approximately 30%, while the EnEV 2012 amendment requires a reduction of the annual primary energy consumption of new buildings in the years 2014 and 2016 by on average 12.5% and a reduction of the mean heat transfer coefficient of the building's envelope by 10% average. The requirements for existing buildings are not be tightened in view of the already high standards. In particular, the regulation addresses thermal envelope requirements and energy using or producing systems in the calculation including HVAC, hot water, lighting (non-residential only) and renewable energy.

Italy

The principles and the methods to improve energy efficiency in households and tertiary buildings are settled in Italy by the L.D. n. 192/2005, amended by the L.D. n. 311/2006, the L.D. 115/2008 and complemented by L.D. 63/2013 in compliance with the European Directive 2010/31/EU. These Decrees in combination with the Decree n. 59/2009 and the National Guidelines for the energy certification set a general framework to enforce the definition of calculation methods and minimum requirements for new and existing buildings which undergo major renovation, to define energy certification for buildings, to promote the use of high-efficiency machinery and equipment, to impose for new and existing buildings a coverage of 50% of energy consumption for domestic hot water from renewable energy sources, to provide an improvement of the minimum requirements of 10% for interventions in public buildings. According to these decrees, all Energy Performance (EP) values are expressed as a function of the climatic zone, identified by the number of heating degree days (DD) and the shape factor. Moreover, the type and level of EP requirements differ with respect to the function of the building: the primary energy requirement for heating (EPi) is expressed for residential buildings in units of kWh/m^2 while for non-residential buildings it is expressed in kWh/m^3. The EP limits for non-residential buildings expressed in kWh/m^3 are provided in Table 21.

Table 21: Energy performance limits for non-residential buildings expressed in kWh/m^3 (EPDB Building Platform, 2008; DD… Heating Degree Days)

Building form factor S/V	Climatic Zones									
	A	B		C		D		E		F
	Up to 600 DD	from 601 DD	to 900 DD	from 901 DD	to 1400 DD	from 1401 DD	to 2100 DD	from 2101 DD	to 3000 DD	beyond 3000 DD
≤0,2	2,0	2,0	3,6	3,6	6	6	9,6	9,6	12,7	12,7
≥0,9	8,2	8,2	12,8	12,8	17,3	17,3	22,5	22,5	31	31

In this context, the technical specifications UNI TS 11300 define the procedures for the calculation of the energy performance of buildings in relation to space heating and cooling and domestic hot water production. These are national guidelines for univocal application of technical specifications elaborated by CEN to support the EPBD Directive. Other limit values are also set by the decrees regarding the maximum U values for the thermal transmittance of vertical, horizontal surfaces and glazing, and the minimum thermal efficiency of heating systems in case of thermal system renovation, simple substitution of a fuel fed generator or heat pump installation.

Moreover, the Decree 28/2011 states that since June 2012 it is mandatory for new buildings and major refurbishment to cover 20% of thermal energy uses with thermal RES systems and to install 1 kW of electric renewable energy systems for every 80 m^2 of floor area. These requirements will be increased in the coming years. Regions are authorized to introduce more restricted values of energy performance requirements than those set at national level.

Norway

Energy efficiency requirements were introduced in technical building codes in 1969 in Norway. These requirements were tightened in 1987. Currently, the most important legal instrument for promoting a more environment-friendly housing and building sector is the Planning and Building Act (TEK). The Technical regulations to the Planning and Building Act have been adjusted several times to reflect changes in society. The most recent amendment came into force on July 1, 2010 (TEK 10) and has been made more stringent as a result of EU Directive 2010/31/EU. The Norwegian building code is proposed to be sharpened every fifth year with tighter constraints. The energy frame in the TEK 10 is specified for 13 different building categories (one-family houses, multi-family houses and eleven types of non-residential buildings). In the case of new buildings, renovation and extension, TEK 10 must be taken into account as there is a number of quality requirements to be fulfilled for finished buildings. The energy requirements proposed for different types of buildings and the expected energy requirements of future building codes are summarised in Table 22.

Table 22: Energy performance requirement for different Norwegian building codes and building categories (Country Report EIA, 2013)

		Energy frame [kWh/(m² & a)]					
Building Code	**TEK07**	**TEK10**	**TEK15 - Passive house**	**TEK20**	**TEK25**	**TEK30**
Residential (detached house)	135	130	80 (Heating: 15)	nearly ZEB	Intermediate	ZEB
Residential (apartment block)	120	115	80 (Heating: 15)	nearly ZEB	Intermediate	ZEB
Non-residential (office)	165	150	75 (Heating: 20, Cooling: 10)	nearly ZEB	Intermediate	ZEB

Spain

Spain first implemented prescriptive energy efficiency requirements for buildings in 1979. Recent updates have increased requirements in order to meet the expectations of the EPBD. The EPBD transposition was effected by Royal Decree 314/2006 approving the Technical Building Code (CTE) which modifies the previous energy code NBE-CT-79. The CTE includes a Basic Document on Energy Saving (HE) that contains procedures, technical rules and examples of solutions for determining whether a building complies with the stipulated performance levels. The document HE is made up of the following parts: energy demand limitation, energy efficiency of thermal installations, energy efficiency of lighting installations, minimum solar contribution to domestic hot water production and minimum photovoltaic contribution to electric power in tertiary buildings.
An update of the basic document Energy Saving DB-HE has been published in September 2013 in compliance with the European Directive 2010/31/EU. This document lays down specifications for the application of minimum requirements on the energy performance of buildings and on energy from renewable sources in buildings. Through this update the CTE takes a step towards the European target to achieve by 2020 nearly zero energy consumption new buildings.

As for the non-residential sector, the updated document DB-HE states that the energy rating for primary energy consumption in case of new buildings or extensions to existing buildings must be of equal or greater efficiency than class B, according to the basic procedure for the certification of energy performance approved by Royal Decree 235/2013. The energy efficiency classes for residential buildings are based on heating, cooling and domestic hot water consumptions while for non-residential buildings lighting and auxiliary system consumptions are also taken into account (Table 23) and are expressed in CO_2 global emission.

Table 23: Energy Efficiency Classification Indexes expressed in $kgCO_2/m^2year$ (Entranze Report, 2012)

	Energy efficiency classification indexes ($kgCO_2/m^2year$)	
Class	**Residential buildings**	**Non-residential buildings**
A	C1 < 0,15	C < 0,40
B	0,15 ≤ C1 < 0,50	0,40 ≤ C < 0,65
C	0,50 ≤ C1 < 1,00	0,65 ≤ C < 1,00
D	1,00 ≤ C1 < 1,75	1,00 ≤ C < 1,3
E	C1 > 1,75 and C2 < 1,00	1,3 ≤ C < 1,6
F	C1 > 1,75 and 1,00 ≤ C2 < 1,5	1,6 ≤ C < 2
G	C1 > 1,75 and C2 ≥ 1,50	C ≥ 2

Non-residential buildings, when are above a certain size/area, are also required to meet a minimum photovoltaic contribution to electric power. The value of nominal electric power to be installed is established depending on the climatic zone and the specific building area. In addition, the updated document includes the obligation to cover a portion of the hot water production with solar thermal systems in buildings characterized by a high hot water demand and to feature energy efficiency lighting installations. In particular, the code defines the Value of Energy Efficiency of the Installation (VEEI) and the maximum installed power of lighting systems for the different building types (retail and wholesale sector too).

Sweden

Sweden has very long tradition of energy efficiency requirements for new buildings. Already in the late 1970s stringent requirements were introduced in Sweden. Although they have only been slightly changed over time they are still today among the highest energy efficiency requirements in the world.
The current building code in Sweden is the Boverket's Building Regulations (BBR). This code encompasses many dynamic aspects including low overall U-values requirements, mandatory energy measurement, performance requirements for buildings undergoing renovation, performance targets for most building types in preparation for the nearly Zero Energy Building target of 2020. In particular, it sets mandatory overall performance demands for dwellings and non-residential buildings that depend on the location and type of heating system employed. The code outlines prescriptive requirements for the thermal envelope and encourages efficient design of the energy consuming systems including HVAC, hot water, lighting, auxiliary systems and materials. It applies to both the residential and the commercial building stock in Sweden.

UK

The UK has committed to reducing greenhouse gas emissions by 80% by 2050 (from the 1990 baseline), and energy efficiency will be central in achieving these targets. The Government has set out scenarios for 2050 which imply a per capita demand reduction of between 21% and 47% relative to a 2011 baseline, shown below[22]. Buildings play a key role in achieving these targets.

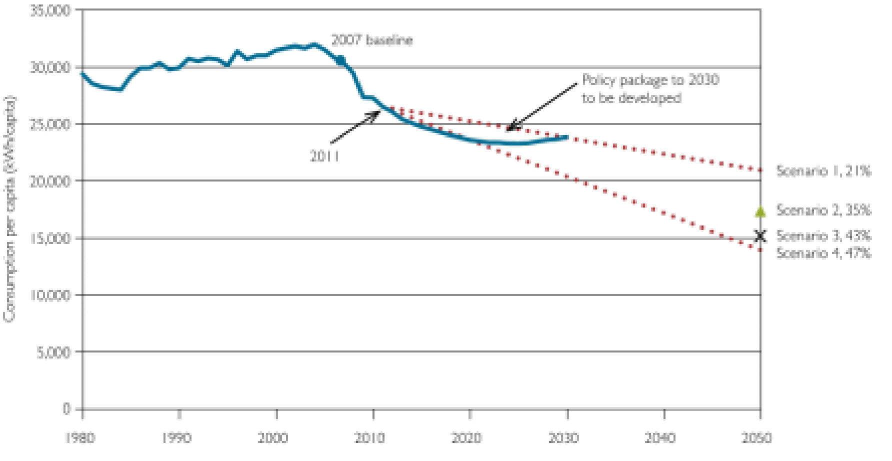

Figure 49: UK final energy consumption per capita compared against carbon plan scenarios: 1980 -2050[22]

The first set of national building standards was introduced in the Building Regulations 1965. Then, the Building Act 1984 brought fundamental changes to the building regulations regime, introducing functional performance standards and approved inspectors for the building control. In 2005, in compliance with the implementation of the 2002 EPBD, the first performance-based code was introduced. The 2010 code has been further strengthened to follow the provisions of the EPBD recast.

The current edition of the regulations is constituted by “The Building Regulations 2010” and the “Building (Approved Inspectors etc.) Regulations 2010”[23]. These main regulations, valid for most of the buildings, are the most important ones for constructions. However, some changes occurred in the following years.

- The Building (Amendment) Regulations 2011, mainly correcting errors also regarding the Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations 2007 (“the 2007 Regulations”) and the Building Regulations 2010 (“the 2010 Regulations”);
- The Building (Amendment) Regulations 2012 insert a definition of excepted energy building by reference to the meaning given in The Welsh Ministers (Transfer of Functions) (No.2) Order 2009. This is relevant to the scope of the 2010 Regulations as functions relating to such buildings in Wales were not transferred by that Order to Welsh Ministers and remain with the Secretary of State.
- The Building Regulations &c. (Amendment) Regulations 2012 provide several amendments of the Building Regulations 2010 (“the Building Regulations”), the Building (Local Authority Charges) Regulations 2010 (“the Charges Regulations”) and the Building (Approved Inspectors etc) Regulations 2010 (“the Approved Inspectors Regulations 2010”), regarding requirements and procedures.

[22] DECC Energy Efficiency Strategy statistical summary, Nov 2012
[23] Full text, in-depth information and the amendments can be found on the UK Government website: http://www.planningportal.gov.uk/buildingregulations/buildingpolicyandlegislation/currentlegislation/introduction

- The Building Regulations &c. (Amendment) Regulations 2013 have been issued in order to correct defects in two previous instruments, both of which came into force on 9th January 2013: the Building Regulations etc. (Amendment) Regulations 2012 (the "Building Amendment Regulations"); and the Energy Performance of Buildings (England and Wales) Regulations 2012 (the "EPB Regulations").
- The Building (Amendment) Regulations 2013 amend the Building Regulations 2010 ("the 2010 Regulations"), as a consequence of transposition of some articles of the European Parliament and Council Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings (recast).
- The Building Regulations &c. (Amendment) (No.2) Regulations 2013, which includes modifications on the minimum energy performance requirements for new buildings, fabric energy efficiency rates for new dwellings and the fabric energy efficiency rate calculations;

The Building Regulations contain definitions, procedures, and what is expected in terms of the technical performance of building work. They regard several aspects of buildings' performances, among which energy: they set out the 'requirements' with which the individual aspects of building design and construction must comply in the interests of the health and safety of building users, of energy conservation, and of access to and use of buildings. Moreover, the "Party Wall Act" places obligations on craftsmen and planners carrying out work. These requirements are valid at National level, with differences between England and Wales. Some non-domestic premises may also be subject to requirements in Local Acts. The Building Regulations are divided into 14 sections (Parts), Part L "Conservation of fuel and power" is the one relevant to energy efficiency. The section is divided in the following sections:

- L1A New dwellings
- L1B Existing Dwellings
- L2A New Buildings other than Dwellings
- L2B Existing Buildings other than dwellings

Conservation of fuel and power in new dwellings (L1A) and in new buildings other than dwellings (L2A) are mandatory performance-based codes that require an energy frame calculation to establish that the Design Emissions Rate does not exceed the Target Emissions Rate, which is measured in kg CO_2 for a notional building of the same shape and size. The calculation code addresses thermal envelope requirements as well as energy using and producing systems for hot water, HVAC, lighting, also including renewable energy technologies. As well as in the other European Union Countries, the key instrument for engaging buildings' users and owners into energy efficiency and sustainability is the Energy Performance Certificate (EPC) of a building, which is mandatory for any building or building part which is newly built, sold or rented out. It applies to any building or building part which uses energy for heating, cooling, and/or ventilation.

Finally, a further important instrument is the Code for Sustainable Homes. The Code is the national standard for the sustainable design and construction of new homes. It is not mandatory, it is a voluntary scheme. The Code measures the sustainability of a new home against categories of sustainable design, rating the 'whole home' as a complete package. The Code uses a 1 to 6 star rating system to communicate the overall sustainability performance of a new home. The Code sets minimum standards for energy and water use at each level and, within England, replaces the previous EcoHomes scheme, developed by the Building Research Establishment (BRE).

5.3 Summary

The evaluation of buildings' energy requirements from the EU and worldwide provided in this chapter aims to offer to building planners and designers the basic legislative references for developing energy efficient projects.
As a general conclusion, the legislative and regulatory improvements over the last decade led to a tightening of energy requirements in the EU and other world regions and contribute significantly to enhance the energy performance of new buildings and through renovation of existing ones. The weaker the energy requirements, the poorer the energy performance of buildings and the slower the market deployment of energy efficient and renewable technology. Therefore the continuous evaluation and tightening of building codes requirements is an important market driver for boosting the energy performance of buildings.
However it should be pointed out that there exist big differences in the way of treating energy efficiency through the performance requirements set by different EU Member States. Not only performance levels are different but even the unit, in which the performance is measured is different.

As regards to wholesale and retail trade sector, specific energy requirements are not always formulated, and when they are, standards and unit of measures are different.
The MS requirements for new wholesale and retail trade buildings are presented in the following list:

- Austria - Heating: 22.75 kWh/m^{3}a; Cooling: 1kWh/m^{3}a
- Belgium - Electrically heated building 75 kWh/m^{2}a (services)
- Bulgaria - Final energy: 90-134 kWh/m^{2}a; Heating and cooling: 40-82 kWh/m^{2}a
- Switzerland - Heating: 36 kWh/m^{2}a
- Czech Republic - Final energy: 183 kWh/m^{2}a
- Denmark - Primary Energy: 71.3 (+ 1650/floor area) kWh/m^{2}a
- Estonia - Primary Energy: 300 kWh/m^{2}a
- Norway - Overall Net energy demand limit: 210 kWh/m^{2}a
- Portugal - Primary Energy: 1279 kWh/m^{2}a; Final energy: 384 kWh/m^{2}a
- Sweden - Final energy for electrically heated buildings: 55-95 kWh/m^{2}a, Final energy for non-electrically heated buildings 100-140 kWh/m^{2}a
- Slovakia - Total delivered energy: 81-161 kWh/m^{2}a; Heating and cooling: 27-70 kWh/m^{2}a

As it emerges from the list, just 11 MS over 27 formulated specific requirements and it is not possible to compare them in order to establish which are the most stringent.
As regards to wholesale and retail trade buildings renovation, it can be noticed that a number of Member States has introduced minimum component performance standards when individual building elements (e.g.: windows, doors etc.) or technical systems (heating, cooling, lighting, etc.) are being replaced, while, only a few Member States have energy performance requirements for renovated buildings. For example in Denmark the energy requirements are adopted for the individual building construction elements and there is no specific energy requirement on building level. In France, on the contrary, the regulation for existing buildings sets standards for the total energy consumption of refurbished buildings that must be at least 30% smaller than before the refurbishment.

In general we can say that it is very hard to compare the different systems given the variety of calculation methods used to measure compliance and major differences in definitions. As regards to this problem, there is a surge of interest in Europe in the harmonization of methodology procedures as the Commission will need to demonstrate that all Member States are delivering equivalent outcomes.
What is certain is that the prescriptions of the building codes (i.e. the benchmarks of performance to respect, the materials and the systems to adopt) will drive the choices for retrofitting or converting the existing buildings into shopping centres because the interventions shall necessarily be tailored to those requirements.
The question to raise in therefore: who will fix the benchmarks and who has an influence on the building codes? It will be a duty of the policy makers to follow the directions drawn at EU level and to fix, case by case, the challenging targets at local level. Among these, one of the challenges can be to allocate specific indications to the sector of shopping centres, which are currently considered within the wide group of non-residential or commercial buildings, without further specifications.

6. Conclusions

It is a long way from medieval markets, Middle Eastern bazars and 18th century arcades to modern shopping centres as we know them 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 shopping centres covered a retail space of 25 million m^2. Today, there is more than 112.1 million m^2 shopping centre GLA in the EU28, including Norway. This means 6.7 percent of all retail and wholesale buildings in Europe are shopping centers. The total GLA of the shopping centres varies from country to country. It is a very dynamic sector, 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.

The largest shopping centre GLA per capita can be found in Sweden, followed by Norway, the Netherlands and the UK. These countries are among those with the highest market saturation. Thus, there is only limited activity in relation to the development of new centres in these countries. However, in CEE countries, the shopping centre market is still young and growing. This lead to the fact and tendencies that the shopping centre building stock in western European countries focuses more on extensions, upgrades and renovations while in the CEE countries on new buildings.

The abovementioned criteria influence the energy consumption of shopping centres, as the shopping centre building stock is very heterogenic in size, shopping type composition, building period etc. Thus, the total energy consumption of the whole shopping centre building stock in all EU-28 and Norway has not been calculated so far. However, based on the collected data by applying a bottom-up approach, the total energy consumption (without mobility) was estimated within CommON*Energy* for the first time. 32.2 TWh is the calculated total final energy consumption of shopping centres in the EU28, including Norway and Switzerland. The predominant energy carriers in the shopping centre sector are electricity and fossil fuels among all countries. The specific energy consumption per square meter on EU average is 272 kWh/m^{2}a.

Based on several aspects, such as the opening year of the building, the location, the climate condition and market saturation, the building as well as the shopping centre typology, we identified ten shopping centres, which serve as reference buildings. These shopping centres from seven European countries were selected for the identification of inefficiencies and the development of the systemic solutions which will be developed and virtually tested in CommON*Energy*. Obviously ten reference buildings cannot represent the whole shopping centre building stock, but they serve as examples of current trends and developments in this sector in Europe and provide an interesting cross section and relevant insight into the European shopping centre industry.

With one of these trends, the increasing GLA of shopping centres in recent years, the energy demand associated with the buildings is also increasing, which in turn highlights the need for improving the energy efficiency of our current European stock, especially the older stock. Therefore, most countries periodically update their building energy codes, some more frequently than others. This process ensures that codes reflect changes in technology and design that offer increased energy efficiency and cost-effectiveness.

The building code analysis shows that many countries in Europe have implemented performance regulations and a number of countries combine performance-based regulations with some prescriptive ones. In countries that have shifted their regulations to performance, there is also often still a significant dependence on traditional solutions. This is related to the convenience of working with current methods, and sometimes to lack of appropriate technology solutions and lack of knowledge in some regions.

From our analysis it emerges that, in the harmonization process, a performance based approach will be probably applied to every building category, in new and existing buildings. It is therefore highly recommended that stakeholders apply this kind of approach, taking example from the building codes of those countries that already developed calculations methodologies, to set the performances of their buildings. This holds true for shopping centres, the wholesale and retail sector as well as the whole building stock. Thus, we recommend introducing energy efficiency standards for new construction, retrofit and operation, specifically designed for shopping centres or speaking more general for commercial buildings in those countries, which have no such standards yet or insufficient standards. Implemented according to the European Energy Performance of Buildings Directive (2010/31/EU) these standards serve to reduce both, the energy demand and the greenhouse gas emissions of shopping centres. Moreover, voluntary or mandatory green building certificates and sustainability assessment schemes may contribute in making shopping centres more environmental friendly.

Given this context, the dominant pattern of shopping centres, the need to look modern and to offer a stylish shopping atmosphere, may contribute to this environmental target. Shopping centres are renovated more frequently than other buildings in order to meet current customer trends, which correspond to a renovation rate of shopping centres of 4.4 percent. This is very high compared with other building categories and offers the opportunity to implement measures towards increased energy efficiency faster than in other buildings. Thus, in the light of the EU targets for 2020 and the needs of the shopping centre industry, our results may serve as a comprehensive basis for decision making among European stakeholders.

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8. Annex

8.1 Data collection

- General Building Data
    - building age
    - main building utilisation
    - fraction of main building utilisation
    - second building utilisation
    - fraction of second building utilisation
    - third building utilisation
    - fraction of third building utilisation
- Internal Gains
    - average occupancy density
    - number of days of standard occupation
    - typical occupancy schedule (daily)
    - metabolic activity
    - clothing level during winter
    - clothing level during summer
    - average electric power of electric equipment
    - operation schedule (daily) for electric equipment
    - electric power of the lighting system
    - operation schedule (daily) for electric lighting
    - average illuminance of the building
    - control of the lighting system
- Building Geometry
    - Length x Width x Height
    - number of floors
    - S/V ratio
    - percentage of window area on the building envelope
    - orientation
    - fraction of the conditioned floor area supplied with a heating system
    - fraction of the conditioned floor area supplied with a mechanical ventilation system
    - fraction of the conditioned floor area supplied by a cooling / air-conditioning system
    - conditioned part of the attic storey
    - conditioned part of the cellar or underground floor
    - number of apartments in the building
    - situation of attached neighbour buildings (or apartments)
- Building Envelope Data
    - complete building envelope
        - total transmission heat transfer coefficient of the building

        - transmission heat transfer according to thermal bridges
        - airtightness of the building envelope
    - external wall
        - List of the layers from inside to outside
        - Total wall area
        - U-value of walls
        - solar absorbance of external finishing of wall (colour)
        - fraction of total wall area against outside air
    - internal walls
        - List of the layers from inside to outside of a representative internal wall
        - List of the layers from inside to outside of a representative internal wall
    - windows and skylights
        - List of the layers (glazing panes + cavities) from inside to outside
        - Total window area
        - U-value of windows
        - g-value of glazing
        - t-value of glazing
        - glazing area
        - U-value of frame
        - frame area
        - linear thermal transmittance of thermal bridge of glazing junctions
        - length of the glazing junctions
        - type of shading systems
        - Control strategy of the shading system
        - set parameter and/or schedule for the control strategy (if applicable)
        - average g-value of glazing + shading system
    - roofs and upper floor ceilings
        - List of the layers (of the most representative roof) from inside to outside
        - total roof area
        - U-value of roof elements
        - solar absorbance of external finishing of roof
        - type of representative roof element
    - basement
        - List of the layers from inside to outside
        - total basement area
        - Outside boundary conditions for basements
        - U-value of basement
    - Additional thermal bridges
        - linear thermal transmittance of additional thermal bridges
        - length of additional linear thermal bridges
        - point transmittance of additional thermal bridge
- system data

- mechanical ventilation system
- heating system
- cooling system
- DHW system
- building set points
- delivered/primary conversion factor
- Presence of water storage
- refrigeration

8.2 Building renovation requirements

The following table provides a detailed overview of the building requirements in case of major renovations according to 2010/31/EU per EU-member state (BPIE, 2011 and BPIE updates, 2013).

Country	Renovation requirements
AT	Specific maximum heating energy demand targets for major renovation of residential and non-residential buildings. Values for renovated buildings are around 25-38% higher than new build requirements. Heat recovery must be added to ventilation systems when renewed. Maximum permitted U values for different elements in case of single measure or major renovations. Prescriptive requirements to limit summer over-heating.
BE	There are specific component requirements (i.e. maximum U-values) as well as additional prescriptive requirements such as for ventilation, summer comfort etc. [Brussels]: Minimum energy performance threshold for rented homes. From 2015, major renovations should achieve a very low energy standard (NEEAP-BCR, 2011) [Flanders]: When extension or renovation, “protected volume” > 800 m³: same requirements as for new buildings (U/R-value, K-level, E-level, ventilation and for residential buildings also summer overheating). When renovation, “protected volume”≤800 m³: only U/R-values for new and renovated parts of the building + ventilation.
BG	Regulations requiring performance-based standards of existing housing and other buildings after renovation. Requirements for new and renovated buildings are the same.
CH	Renovated buildings are required to use no more than 125% of the space heating demand of an equivalent new building. A single element approach may also be applicable for renovations.
CY	Minimum energy performance requirements (class A or B) for buildings over 1 000 m² undergoing major renovation.
CZ	Performance-based requirements when a building over 1 000 m² is renovated. Requirements for new and renovated buildings are the same. Individual parts of the building envelope and systems in the buildings have to fulfill minimum requirements. If it is not possible to achieve the minimum performance criteria, this has to be proven by means of an energy audit. There are also minimum requirements in case of major renovation of individual building elements such as for U-values, internal temperature at the internal leaf of envelope structures (which has to be higher than dew point temperature), thermal bridging limits to avoid condensation, thermal stability of the room in summer and in winter, minimum efficiency of boilers, etc. Furthermore, buildings shall achieve a healthy indoor climate.
DE	Performance-based requirements when a building over 1 000 m2 is renovated. Requirements for new and renovated buildings are the same. Individual parts of the building envelope and systems in the buildings have to fulfill minimum requirements. If it is not possible to achieve the minimum performance criteria, this has to be proven by means of an energy audit. There are also minimum requirements in case of major renovation of individual building elements such as for U-values, internal temperature at the internal leaf of envelope structures (which has to be higher than dew point temperature), thermal bridging limits to avoid condensation, thermal stability of the room in summer and in winter, minimum efficiency of boilers, etc. Furthermore, buildings shall achieve a healthy indoor climate.
DK	Component level requirements when existing buildings are refurbished for change of use of the building and for complete or partial renovation of building elements or technical systems, regardless of the building size. Individual parts of the building envelope and systems in the buildings have to fulfill certain minimum requirements in the renovated building. Thus there is no overall performance requirement for the renovated building, but only for the individual components and systems. Minimum U-values and linear losses requirements. The partial renovation measures must be cost-effective (i.e. payback time shorter than 75% of the measure‘s lifetime). If the implementation of the full requirement is not profitable to the owner, a lower level of renovation or indeed none at all, has to be implemented. In case of replacement of floors, external walls, doors, windows or roof structure, requirements apply regardless of cost-effectiveness. Thermal bridging should be avoided in external construction elements including windows and doors due to the risk of condensation. There are special energy requirements (less strict) when renovating windows with small transparent fields due to preservation of architectural values. In the case of renewal of an installation in existing buildings, the same requirements of an installation in new buildings apply.
EE	Performance-based requirements for all building types when buildings undergo major renovations. Values for renovated buildings are around 25-38% higher than new build requirements.

ES	Existing buildings over 1000 m² must comply with the same minimum performance requirements as new buildings if more than 25% of the envelope is renovated. There are additional energy efficiency requirements for building elements, heating and lighting systems, minimum solar-thermal contribution and in certain cases also for minimum solar photovoltaic contribution.
FI	Shift from requirements concerning the heat loss of individual components to one indicator (the E index) describing the total calculated energy use of the building. New regulations came into effect on 1 June 2013 introducing minimum energy performance requirements for energy efficiency concerning renovations. There are three ways to achieve these requirements: a) improving the heat retaining capacity of building parts that need reparation or renewal, b) improving the energy efficiency of the building by examining the whole building's energy consumption in relation to its surface area, c) reducing the building's E-number, by reducing the total energy consumption of the buildings. Technical systems (like heating and ventilation) have their own requirements and should be checked when insulation is added to the building, when air-tightness is improved, or when systems are renewed.
FR	Performance-based requirements for buildings undergoing renovation apply for residential buildings and values depend on the climate and type of heating (fossil fuel/electricity). Requirements for components also apply during building renovation. New renovation requirements for all buildings are expected to come in 2013. For major renovations (>1000 m²): the overall energy performance target for renovated buildings built after 1948 is in the range 80-165 kWh/m²/year since 2010. For renovations <1000 m²: element-based requirements for replacement or renovation of elements (for heating, insulation, hot-water production, cooling and ventilation equipment). For large renovations, a minimum summer comfort level is required in order to avoid the use of cooling systems. Smart systems should be installed every time there is major renovation work on a building.
GR	Individual parts of the building envelope and systems in the buildings have to fulfill certain minimum requirements in the renovated building. Minimum thermal resistances defined for different types of building components and also different efficiency of systems. Thermal bridges are also considered.
HU	Performance-based requirements (in terms of primary energy) apply for residential buildings, offices and educational buildings. Requirements for new and renovated buildings are the same. The specific primary energy consumption in kWh/m² must comply with the requirement, either for the renovated zone or for the whole building-option that can be selected by the designer. The requirement cannot be met if the components are of low quality.
IT	Energy performance requirements are based on single components, with the same requirements as new buildings. There are also minimum energy efficiency requirements for boilers.
LT	Buildings over 1 000 m² undergoing major renovation must achieve the energy performance standard of a Class D building where D corresponds to 110 kWh/m²yr for buildings > 3 000 m²; 130 kWh/m²yr for buildings from 501 to 3 000 m²; 145kWh/m²yr for buildings up to 500 m². Not less than efficiency class D. Individual parts of the building envelope and systems in the buildings have to fulfill certain minimum requirements depending on renovation.
LV	Requirements on different elements are applicable.
MT	U-value requirements for building renovation.
NL	The Energy Performance Standard (EPN) sets requirements for the energy performance of major renovations of existing buildings (expressed as an energy performance coefficient). For renovations, the same EPN requirements as for new buildings apply. Stricter efficiency requirements for heating, hot water, cooling and ventilation systems in existing homes and large residential buildings (offices, schools, shops, hospitals, etc.) are expected to be applied from July 2013. All materials and products used for renovation must have an approved label.
NO	Building regulation requirements as for new buildings only apply when the purpose or use of the building is changed at renovation or in case of major renovations. The requirements are either for the renovated zone or for the whole building (an option of the designer).
PL	For major renovations or system component replacement there are the same requirements as for new buildings.

PT	Special requirements for buildings over 1000 m^2 and over a specified energy cost threshold. A mandatory energy efficiency plan must be prepared and all energy efficiency improvement measures with a payback of less than 8 years must be implemented (compulsory by law). The threshold is based upon 40% of the worst performing buildings by typology. Minimum requirements for thermal resistances defined for different types of building components and for energy efficiency of buildings systems. These values are based on moisture and mould prevention. Furthermore, buildings shall achieve a healthy indoor climate. Thermal bridging should be avoided in external construction elements including window and doors because of the risk of condensation. There are minimum energy requirements for the building as a whole as well as minimum insulation levels for the building envelope and minimum requirements for shading of windows.
RO	The actual energy performance of a building is compared with a "reference building" which is a virtual building having the same geometry as the actual building but the energy performance of a new one - concerning individual parts of the building envelope and systems (indirectly, after renovations, the building have to fulfill certain minimum requirements for the individual components and systems as well as an overall performance requirement).
SI	Minimum requirements apply to major renovations (i.e. if at least 25 % of the envelope is renovated). The requirements apply to all buildings, irrespective of floor area. There are also minimum requirements for heating systems.
SE	Depending on the size of the renovation, the renovated zone has to fulfill the energy requirements for new buildings. In case of heritage buildings or when renovation may negatively influence other features of the building, then the energy requirements may be lowered. In case of major renovation, the minimum energy efficiency requirements may be extended also to other parts of the building.
SK	When major renovation is foreseen, there are requirements to improve the thermal performance by at least 20%. There are minimum requirements in terms of energy use and energy performance (delivered energy), U-value for building structures as well as, walls, roofs, windows, insulation of heat and hot water systems, thermal comfort and indoor air quality.
UK	Specific energy efficiency requirements for residential buildings when replacing “controlled elements” such as windows, boilers and thermal elements. Moreover, there are energy performance requirements for buildings over 1 000 m^2 undergoing major renovation in so far as they are “technically, functionally and economically feasible”. For the repairing/ renewal of a building element (thermal element), like the wall, floor, roof etc., the performance of the whole element should be improved to achieve specific U-value standards. These improvements should also be technically, functionally and economically feasible (i.e. payback time ≤15 years). More specifically, for roof renovation and repair, requirements apply in case of 50% or more of the roof refurbishment. In Scotland, homes must meet the “Tolerable Standard”, which comprises of a variety of criteria, including satisfactory thermal insulation.