Smart energy services to solve the **SP**lit **IN**centive problem in the commercial rented sector

Call topic: H2020-LC-SC3-2018-2019-2020
Start date of the project: 01/09/2021
Duration: 36 months

D4.1 – INTERACTIVE WEB-APP SHOWING THE POTENTIAL FOR ENERGY MANAGEMENT IN ENERGY PERFORMANCE CONTRACTS

Deliverable D4.1 (Web-app and modelling documentation)

Due date	**28/02/2022**	**Delivery date**	**16/09/2022**
Work package	**WP4**		
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Dissemination level	Confidential		

Version and amendments history

Version	Date (MM/DD/YYYY)	Created/Amended by	Changes
V0.1	31/03/2022	A. Garrido Marijuan (TECNALIA)	First draft
V0.2	04/04/2022	L. De Tommasi (IERC)	First review
V0.3	02/08/2022	A. Garrido Marijuan (TECNALIA)	Second version
V0.4	19/08/2022	R. Agrawal (IERC)	Reviewed version
V0.5	26/08/2022	A. Garrido Marijuan (TECNALIA)	Final version for quality review
V0.6	12/09/2022	S. Kokorotsikos (Eunice)	Quality review
V0.7	15/09/2022	A. Garrido Marijuan (TECNALIA)	Final version
V1.0	16/09/2022	L. De Tommasi (IERC)	Final review and submission

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

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List of Abbreviations and Acronyms

Abbreviations	
BMS	Building Management System
BPIE	Building Performance Institute Europe
C	Central
DR	Demand Response
EPC	Energy Performance Contract
EU	European Union
JRC	Joint Research Centre
NE	North-East
NW	North-West
nZE	Nearly Zero-Energy
SE	South-East
SEDC	Smart Energy Demand Coalition
SBEI	Smart-Ready Built Environment Indicator
SRI	Smart Readiness Indicator
SW	South-West
TOU	Time-Of-Use
VAV	Variable Air Volume

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EXECUTIVE SUMMARY

The purpose of task 4.1, which development is here presented, is to develop a web-app that presents the most suitable “target” market across Europe for the SmartSPIN split-incentives business model based on Energy Performance Contracts (EPC).

The web-app focuses on different typologies of commercial buildings and facilities, summarizing their potential for EPC under different boundary conditions such as climate, demand response market maturity, and dynamic electricity tariffs. The information included in the web-app is obtained through two stages. First the qualitative identification of those buildings with the highest potential for EPC and energy management based on literature review such as public databases, statistics and surveys of the existing building stock and its performance. The exploratory qualitative analysis particularly focuses on energy cost savings potential, implicit demand response strategies such as peak-shaving or load-shifting and additional revenue streams from explicit demand response programs available. Furthermore, it evaluates the level of “smartness” associated to the EPC potential through the Smart Readiness Indicator.

The most suitable building typologies at specific regions are later modelled and simulated in different scenarios of renovation so as to assess the energy and monetary benefits from selected retrofitting scenarios.

The structure of the web-app as well is presented in this document. This structure includes the identification of the most interesting EPC opportunities (selection of type of buildings, building services, climates, demand-response strategies, etc.) along with a quantification of their potential. It also serves as a decision-making process to explore how the investment in improving the smartness of the building enables easier but more profitable energy management.

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1 INTRODUCTION

The present document presents the structure and main features of the web-app developed within task 4.1. This web-app summarizes the work carried out under task 4.1, for which focus is to identify the most suitable “target” market for the SmartSPIN split-incentives business model, focusing on different typologies of commercial buildings and facilities as well as boundary conditions such as climate, Smart Readiness Indicator (SRI), Demand Response (DR) market maturity, and dynamic electricity tariffs.

In the document, section 1 explains the main context, while section 2 shows the web-app, including detailed instructions on “how to” use this tool.

Section 3 describes the methodology used for the potential assessment of energy management within performance based contracts in commercial buildings, both for the qualitative and the quantitative phases. Section 4 presents the main outcomes of the qualitative analysis, that is, the most suitable “target” market, whereas section 5 includes the outcomes from the quantitative analysis with the potential of the target market.

1.1 BASELINE

For the purposes of Deliverable 4.1, information was extracted primarily from the following sources:

- The previous EU-funded project NOVICE, from where the methodology is based, especially WP5 deliverables.
- EU Building Stock Observatory.
- The European Union (EU) Energy Performance of Buildings Directive and Energy Efficiency Directive.
- Other previous EU-funded projects, mainly Zebra2020 and RePublic_ZEB.
- Ecofys Report on the energy status of non-residential sector in Europe.
- Smart Energy Demand Coalition (SEDC) report on the status of DR in Europe.
- Other online sources properly included in bibliography.

This information has been subject to a critical review and gathered together with a specific focus on categorization and evaluation of the buildings’ Energy Performance Contracts (EPC) potential. Although some of the references were published before 2015, the low renovation rate of the European building stock makes them suitable.

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2 WEB-APP

Within task 4.1, an interactive web-app showing the potential for energy management in EPC has been developed. The present section includes the documentation generated to explain the content and the use of the tool, which is included in the online version of the app. The web app can be accessed from this link.

2.1 STRUCTURE

At the front page of the app, what the user is going to see is:

Figure 1 **Front page of the web-app**

Several pages are available for selection:

Figure 2 **Structure of the web-app**

The page "**HOW TO**" explains how to use the tool, with direct access to the different sections with specific buttons:

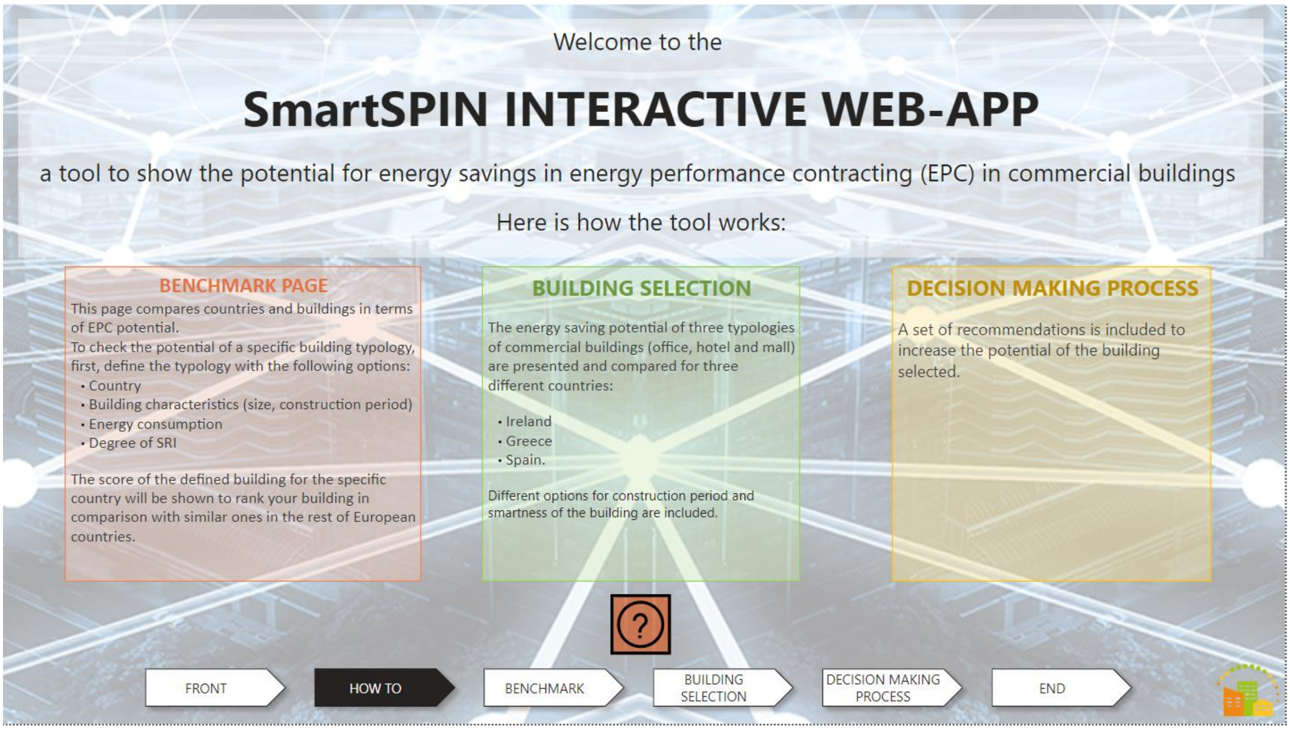

Figure 3 Web-app includes a "how to" page

There is a "help" button with access to the user guide.

Figure 4 Help button which links to further documentation on how to use the tool

The page **"BENCHMARK"** allows to check the EPC potential of the different European countries and building typology of commercial buildings. Different options are included to define the typology with the following options:

- Country;
- Building characteristics (size, construction period);
- Energy consumption, and
- Degree of SRI

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The score of the defined building for the specific country will be shown to rank the building in comparison with similar ones in the rest of European countries.

Figure 5 Defining the building typology and country the user wants information about

The average potential for energy savings thanks to EPC for the kind of building selected is shown in the orange boxes together with the comparison of the potential for the defined building to the different SmartSPIN countries.

The next page "**BUILDING SELECTION**" includes the energy saving potential of three typologies of commercial buildings (office, hotel and mall). This potential is presented and compared for three different countries:

- Ireland;
- Greece, and
- Spain.

Different options for construction period and smartness of the building are included.

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Figure 6 **The tool includes a comparison of the buildings assess during T4.1**

Within the "**DECISION MAKING PROCESS**" page, a set of recommendations is included to increase the potential of the building selected.

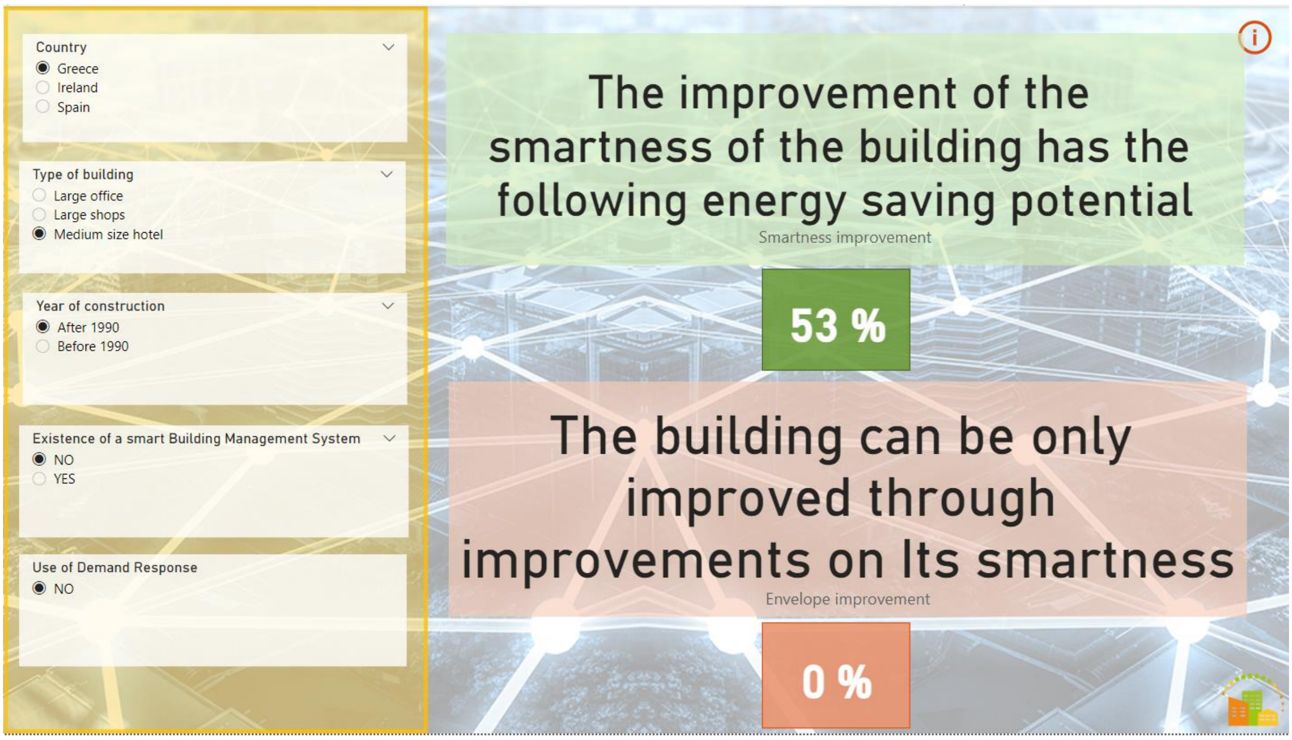

Figure 7 **Decision making process included in the tool**

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Finally, the "**END**" section includes a link to the website of the project.

Figure 8 **End page with link to the project website**

3 METHODOLOGY

The proposed methodology is built on a ranking basis. The different typologies of buildings are evaluated based on different parameters to rank them on their potential for EPC.

Table 1 shows the evaluation parameters and methodology proposed to choose the best candidates for EPC, describing the main building characteristics, legislative framework and other relevant parameters, establishing their contribution in the evaluation process:

Table 1. **Building Evaluation parameters [based on NOVICE project]**.

Parameter	Written Evaluation
Floor area	Floor area coverage is considered as a positive indicator of renovation potential. Large buildings have higher savings potential and therefore are more suitable for EPC.
Construction period	New or renovated buildings are highly efficient and have thus lower renovation potential than older buildings. Therefore, building age is a deciding factor since non-renovated, old buildings have high energy consumptions associated and more potential for EPC.
Energy Consumption per m^2 (kWh/m^2)	Energy consumption is one of the key criteria for establishing the overall retrofitting potential of buildings, since large consumption should correspond to higher energy saving potential.
SRI	Smart technologies are essential enablers for EPC since they allow for energy efficient operation, adaptation to signals from the grid and adapt the operation to variable requirements. Higher scores on the SRI are translated in higher potential for EPC.
ESCO market size	A well-established ESCO market increases the possibility to exploit EPC. Those countries where the market is mature have more potential for EPC.
DR potential	The energy saving and peak load shifting potential increases the interest in EPC.
Availability of dynamic Time-Of-Use (TOU) tariffs	In order to fully exploit the potential through implicit DR strategies, a proper framework in the form of flexible tariffs must be available. A mature market increases the possibilities for adoption of Demand Side Flexibility on the various building classes.
Explicit DR	Some countries have commercially active markets regarding explicit DR, while other are still on early stages or have total lack of market instruments.
Incentives	Financial Instruments for renovation projects are enablers for EPC.

It is important to highlight the differentiation among two types of parameters. On one hand, parameters (1)-(4) can be directly used to characterize and evaluate the EPC potential of different building classes. On the other side, the rest of parameters (ESCO market size, DR market maturity, availability of dynamic TOU tariffs, explicit DR and incentives) are country specific, and therefore independent among types of commercial buildings, but provide useful information, primarily regarding the potential at different European regions and countries. Nevertheless, information at country level is presented for all the categories as context.

In the next sections, the criteria to evaluate these parameters is explained and applied to the data found through literature review for the exploratory qualitative analysis to rank the potential for EPC

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and energy management. The qualitative analysis has as outcomes a two-layered classification, with the first layer being the building type (size, SRI, age), and the second the geographical division. Nevertheless, specific typologies of buildings will rank high independently of the country. Large, non-renovated buildings constructed before 1990 will have high potential even if the country lacks a mature DR market. The total score obtained for a specific building will be:

Total score = Points from building characteristics (floor area; age; energy consumption; SRI) + 0.5*points from country characteristics (ESCO market size; DR market maturity; availability of dynamic TOU tariffs; Explicit DR; Incentives)

The formula weights by half the country characteristics so to also foster the interest in buildings in markets behind in terms of market maturity of DR.

With the top candidates, most interesting building types and countries of interest, the quantitative analysis is presented in Section 5 based on reference models.

4 QUALITATIVE ANALYSIS

The SmartSPIN project targets different typologies of commercial buildings and facilities to implement pilot SmartSPIN split-incentives business model based on EPC. These type of buildings are commonly of significant size and are likely to already possess particular features, such as the presence of comprehensive and IT-based energy management systems that make them more suitable for retrofitting investments under the project's defined objectives.

According to the categorization of buildings included in the "Report on typology of buildings suitable for dual energy services" published within the NOVICE project, "there is limited work and no general consensus on building typologies, especially concerning the commercial and tertiary building sector". Following the work performed in the NOVICE project, the following are included in the commercial sector:

- Offices.
- Educational buildings.
- Health care facilities.
- Hotels and restaurants.
- Sport facilities.
- Wholesale and retail trade service buildings.

In the following sections, the stock characteristic of this kind of buildings in Europe is detailed. It must be highlighted that for certain characteristics, availability of data is erratic. In all figures, countries for which data are not available, were excluded from the graphs.

4.1 COMMERCIAL BUILDING STOCK CHARACTERISTICS IN EUROPE

The different characteristics of commercial buildings in Europe are described based on their typological, operational, and energy-related characteristics. The goal of this analysis is to examine the attributes of the various building types and further subcategorize them based on key factors, which can provide further insight into the evaluation of their suitability for EPC.

For the purpose of providing a more detailed view on the different energy-related characteristics within the European Union, in some parts of the document an approximate geographic subdivision of EU states was adopted into Central (C), North-East (NE), North-West (NW), South-East (SE) and South-West (SW) regions. The countries belonging to each of these regions are reported below:

- C: Austria, Belgium, Czech Republic, France, Germany, Hungary, Luxemburg, Netherlands, Poland, Slovakia.
- NE: Denmark, Estonia, Finland, Latvia, Lithuania, Sweden.
- NW: Ireland, UK.
- SE: Bulgaria, Croatia, Cyprus, Greece, Romania.
- SW: Italy, Malta, Portugal, Spain.

As the potential for EPC is very linked to the total population, only those countries with more than 5M inhabitants are considered to take into account big enough markets.

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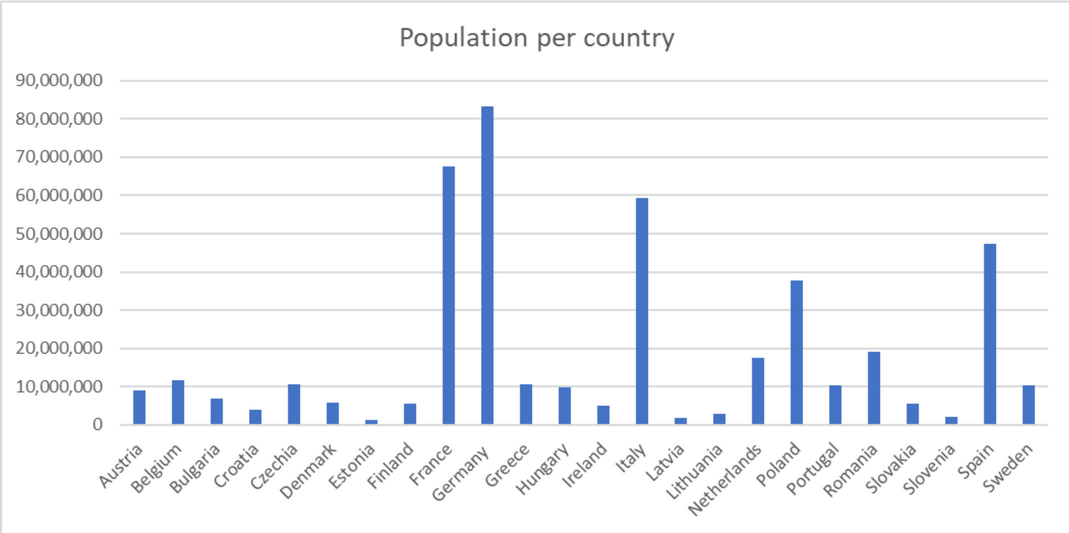

Figure 9. Population per country. Source (EUROSTAT, 2022).

4.1.1 FLOOR AREA DISTRIBUTION

Figure 10 shows the breakdown of building floor area between residential and non-residential in Europe. It can be observed that the highest ratio of non-residential is found in Slovakia, Netherlands, Lithuania and Czech Republic (EC, 2017).

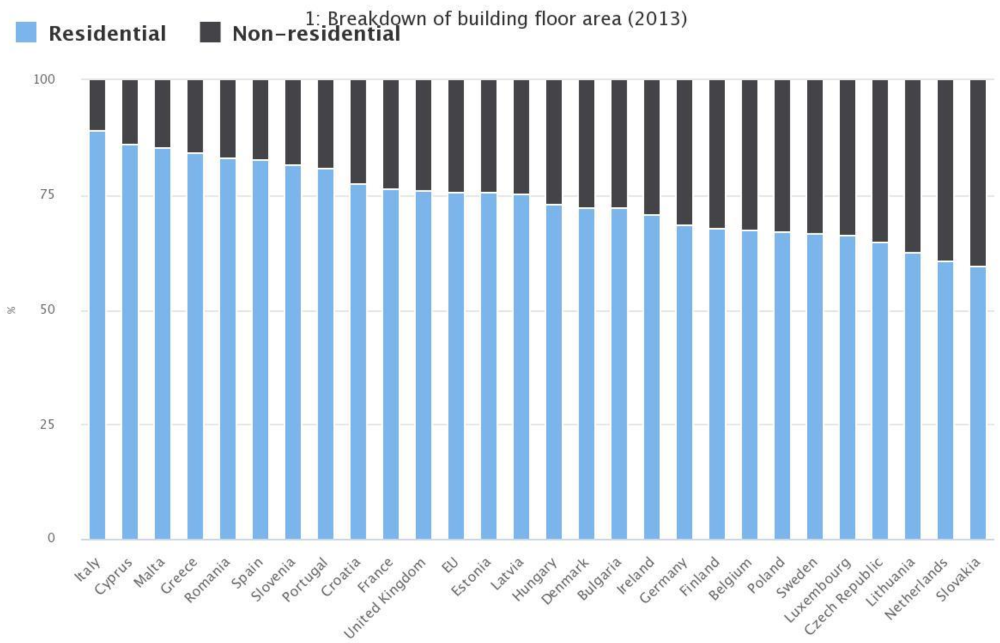

Figure 10. Breakdown of building floor area (%) between residential and non-residential sector in the EU. Source (EC, 2017).

To understand the potential on the commercial sector for EPC within the non-residential sector, the distribution of floor area by building type for the EU countries analysed by (EC, 2017) is shown in Figure 11 (Mm^2).

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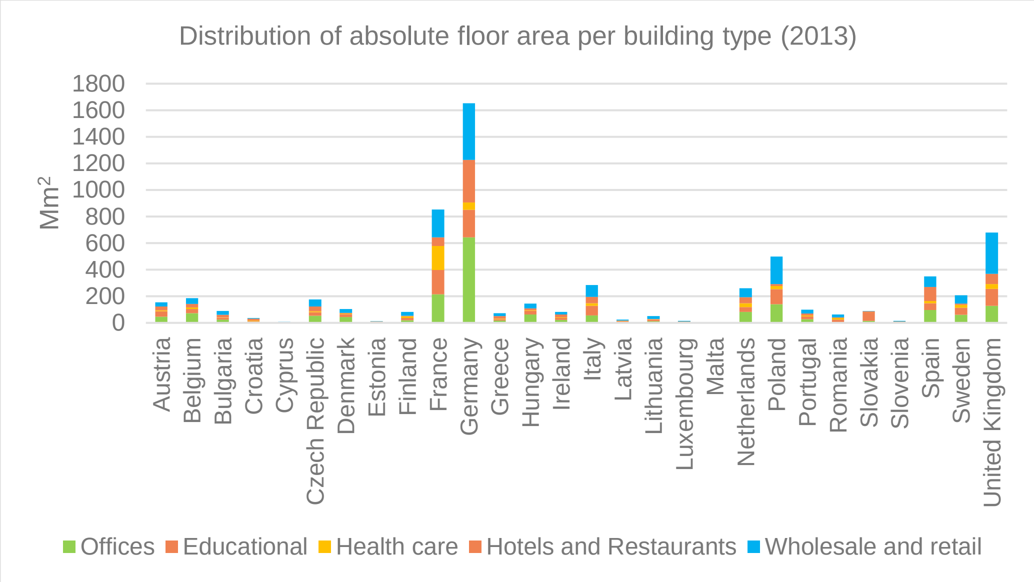

Figure 11. **Distribution of floor area (Mm²) by building type in the non-residential sector in the EU. Data was not available for Sport Facilities and Other types of buildings. Source (EC, 2017).**

Furthermore, Figure 12 shows the distribution of floor area per building type for the different countries in Europe (%), presented by (EC, 2017).

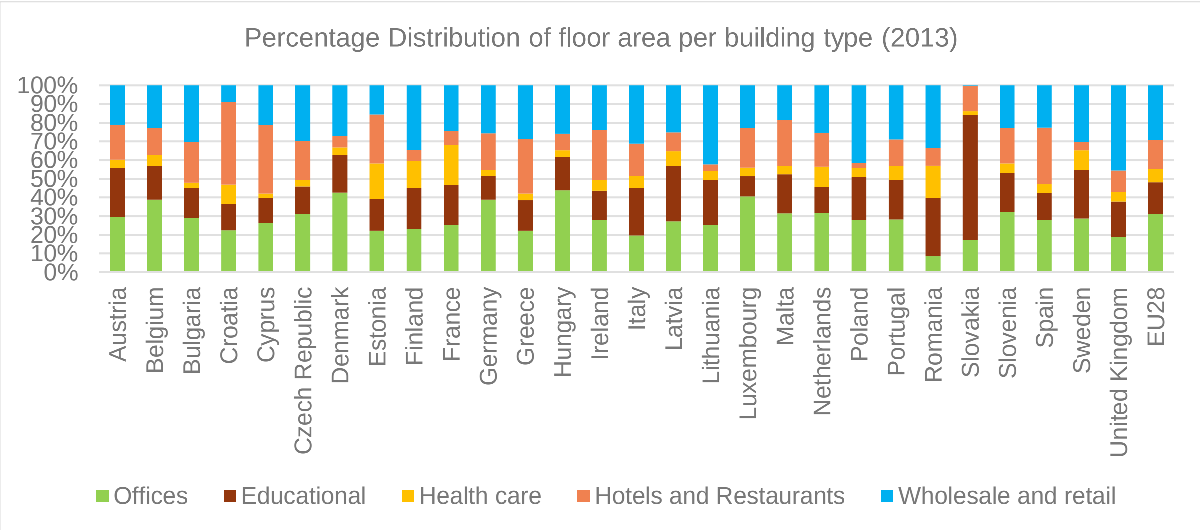

Figure 12. **Percentage Distribution of Floor area by building type in the EU. Source (EC, 2017).**

The breakdown of non-residential buildings by branches shows that distribution of floor areas is not homogeneous. While Slovakia has more of 50% of the commercial sector dedicated to educational facilities, Denmark have >40% of the floor area dedicated to offices. This first look at the non-residential sector shows that, despite the variability, two thirds of non-residential floor area (excluding sport facilities and other buildings, for which data were not available) are covered on average by offices and wholesale/retail businesses, followed, in order, by educational, hotels and restaurants and health care buildings.

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Information on the number and size of commercial buildings helps quantifying the average building size. Figure 13 shows the total number of commercial buildings for different countries.

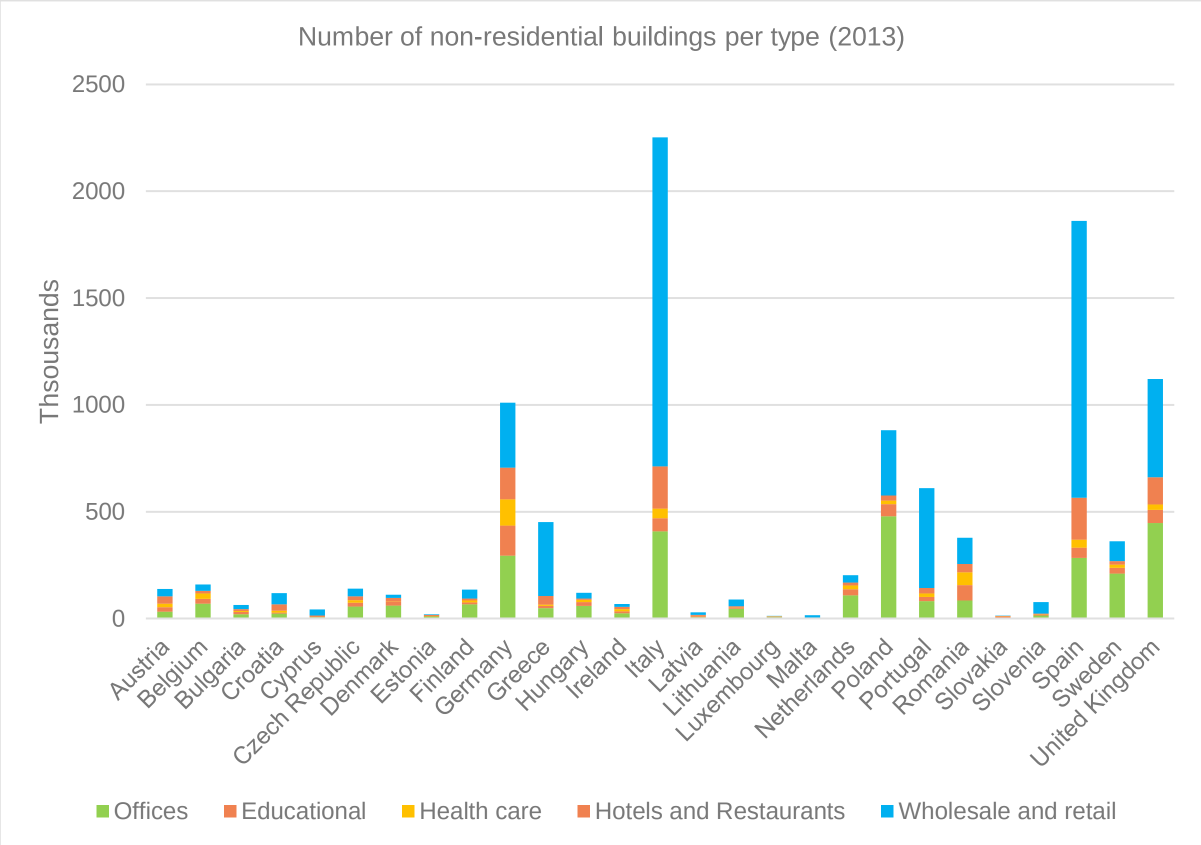

Figure 13. Number of commercial buildings per EU country (in thousands). Source (EC, 2017).

The average building sizes are shown in Figure 14.

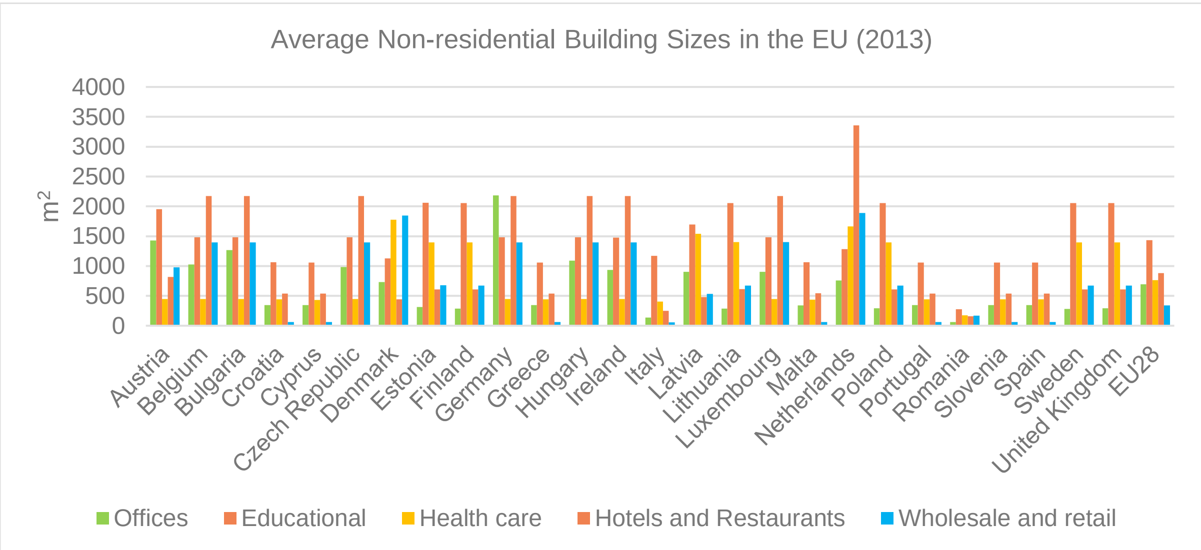

Figure 14. Average size of commercial buildings in the EU. Source (EC, 2017).

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Average sizes across the EU for commercial buildings are:

- Offices - 695 m^2 (std: 482);
- Education - 1434 m^2 (std: 446);
- Healthcare - 765 m^2 (std: 512);
- Hotels and restaurants - 881 m^2 (std: 862);
- Wholesale and retail - 338 m^2 (std: 611).

The average value is used to rank this parameter, considering buildings as:

- Large (floor area >125% of the average value).
- Medium (floor area <125% and >75% of the average value).
- Small (floor area <75% of the average value).

As additional information, an in-depth analysis regarding the size of different non-residential facilities performed from the Building Performance Institute Europe (BPIE) is presented. Figure 15 reproduces the results, where, for each building type, a 3-band size distribution is shown (Small: < 200 m^2; Moderate: > 200 m^2 & < 1000 m^2; Large> 1000 m^2), either as a percentage of the floor area or as a percentage of the number of buildings in that size band.

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Offices

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
BG	60	30	10
UK	26	27	47
NL	12	24	64
IT	5	28	67
SK	1	12	88

Number	< 200 m²	200 - 1 000 m²	> 1 000 m²
IE	95		5
CZ	30	55	15
IT	33	50	17
LT	0	79	21
SE	4.7	25.9	69.4

Hospitals

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
BG	0	30	70
SK	0	4	96
UK	0	1	99

Number	< 200 m²	200 - 1 000 m²	> 1 000 m²
LT	0	78	22
CZ	0	70	30
SE	4.4	28	67.5
IE	0	0	100

Sport facilities

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
UK	0	12	88
SK	0	10	90

Wholesale & retail

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
BG	35	55	10
UK	42	22	36
SK	1	12	86

Number	< 200 m²	200 - 1 000 m²	> 1 000 m²
CZ	25	60	15
SE	3.7	37.4	68.9

Educational buildings

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
BG	0	40	60
NL	5	4	91
SK	0	6	93
UK	1	5	94

Number	< 200 m²	200 - 1 000 m²	> 1 000 m²
IE	84.5		15.5
CZ	0	55	45
SE	5.3	37.3	57.4

Hotels & Restaurants

Area	< 200 m²	200 - 1 000 m²	> 1 000 m²
BG	10	50	40
UK	27	23	52
SK	0	4	95

Number	< 200 m²	200 - 1 000 m²	> 1 000 m²
CZ	5	65	30
SE	11.2	45	43.9

NOTES

AT: Values based on registered certificates, accounting for 1 007 data sets of non-residential buildings, most of which are office buildings.
CY: Values refer to non-residential building permits issued from 2003-2009 (and % refers to <900 m² and > 900 m² of surface area)
CZ: Estimations based on past official data, extrapolated to present time.
IE: Office values concern buildings under the responsibility of the Office of Public Works. Educational values concern only public primary and secondary schools. Hospital values include publicly owned acute and non-acute hospitals and private nursing homes
SI: The data refer to all real estate units in non-residential use
SE: Values presented are based only on certified non-residential buildings.
UK: All presented values refer only to England and Wales and the categories <200 m² correspond to <250 m² and the categories 200-1 000 m² corresponds to 250-1 000 m².
Office values concerns only commercial offices, hospital values exclude health centres and surgeries, and sports facilities include only LA sports centres
BG, EE, LT, NL: Values based on estimations by national experts

Figure 15. **Building size distribution per category in EU countries. Source (BPIE, 2011).**

Wholesale and retail are those with the most diverse size profiles, both with respect to size, as well as examined country. States from C, SW and NE Europe show high percentages of large buildings in both categories. In NW and SE Europe though, moderate-sized, or even small buildings are the most common.

4.1.2 CONSTRUCTION PERIOD

The potential of buildings for EPC is highly correlated with their construction age. According to NOVICE project, “buildings to be renovated are tertiary buildings that have been built before 2000”. The justification behind this choice is based on the fact that building energy systems are displaying a lifetime of no more than 20-25 years. Hence, all tertiary buildings that were built before 2000, are eligible for energy upgrades.

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To rank this parameter, this fact would be considered as:

- Old (non-renovated building constructed before 1990) → 3 points;
- New (built or renovated after 1990) → 0 points.

As framework information, it is of interest, thus, to examine the distribution of building types based on their construction periods per countries. Data is still somewhat limited on this respect, since relatively few countries have established records with relevant information.

Ecofys project has published a report analysis on the building stock for five European countries, namely Germany, Hungary, Poland, Spain and Sweden, and extrapolated the results, based on floor area, for the remaining EU countries (Schimschar et al., 2011). The estimated EU age statistics per building type are presented in Figure 16. The percentage of buildings constructed after 2000 ranges between 5 and 20%, with highest percentages belonging to retail, industrial and other buildings, including sport facilities.

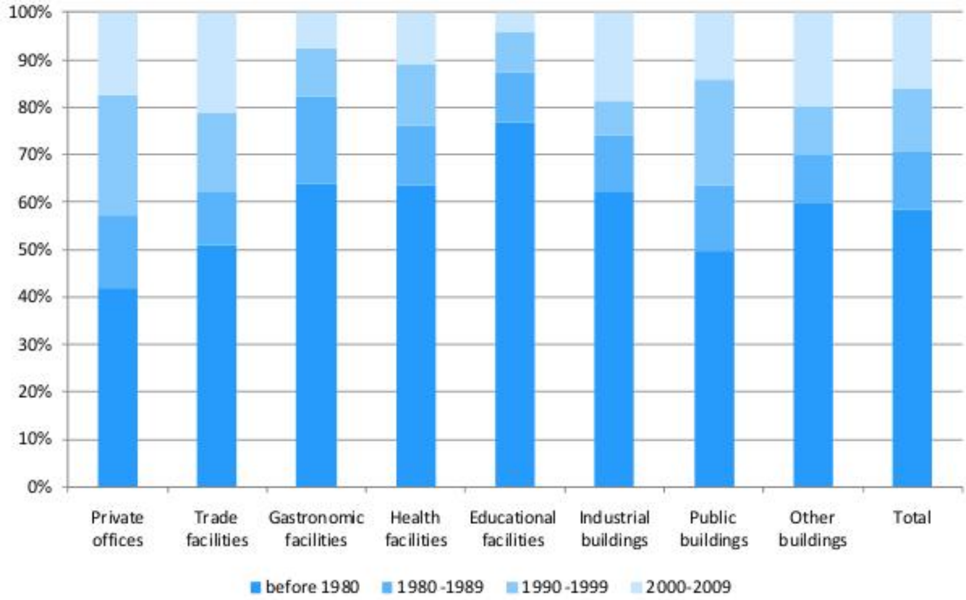

Figure 16. Distribution of EU27 non-residential floor area by building type and construction period. Source (Schimschar et al., 2011).

It can be observed that trade facilities have 50% of the stock built before 1980. While Figure 17 shows some variability across regions, it can be concluded that building age distribution follows closely the average European pattern (Radulov & Kaloyanov, 2014).

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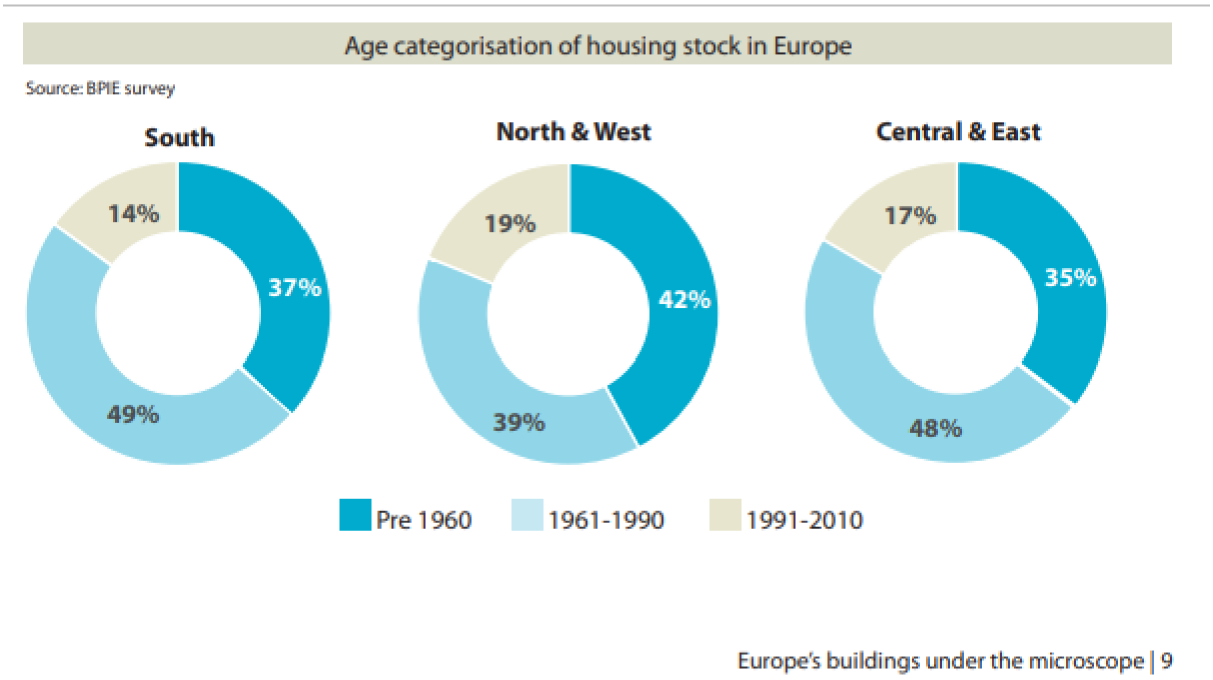

Figure 17. **Age categorisation of housing stock. Source (BPIE).**

It is also of interest to explore the renovation rate and average cost to understand the renovation potential in the commercial building stock presented by (ZEBRA2020, 2016). The rate of renovation ranges from around below 0.5% (e.g. Spain) up to 8 or even greater (Netherlands), while the cost of renovation ranges from less than 100€/m² (e.g. Poland) to over 1,000 €/m² (e.g. Germany).

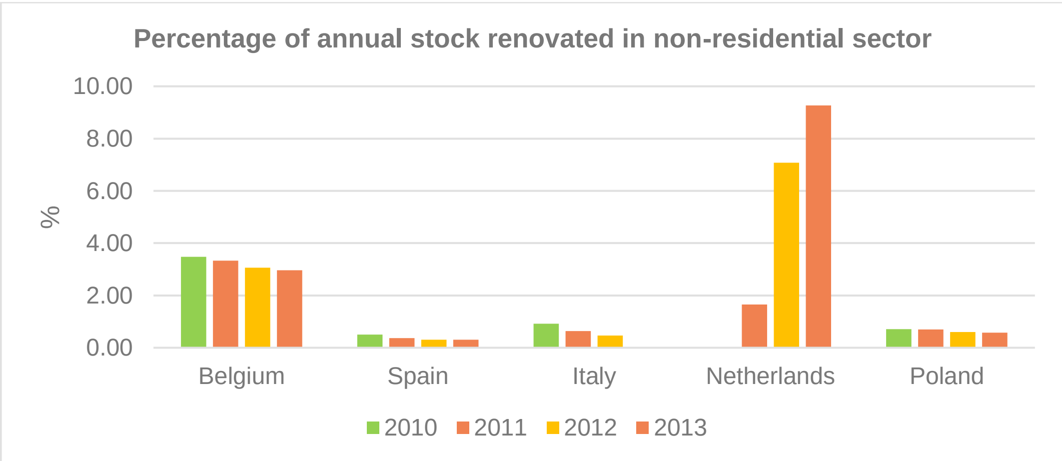

Figure 18. **Percentage of annual stock renovated in non-residential sector. Source (ZEBRA2020, 2016).**

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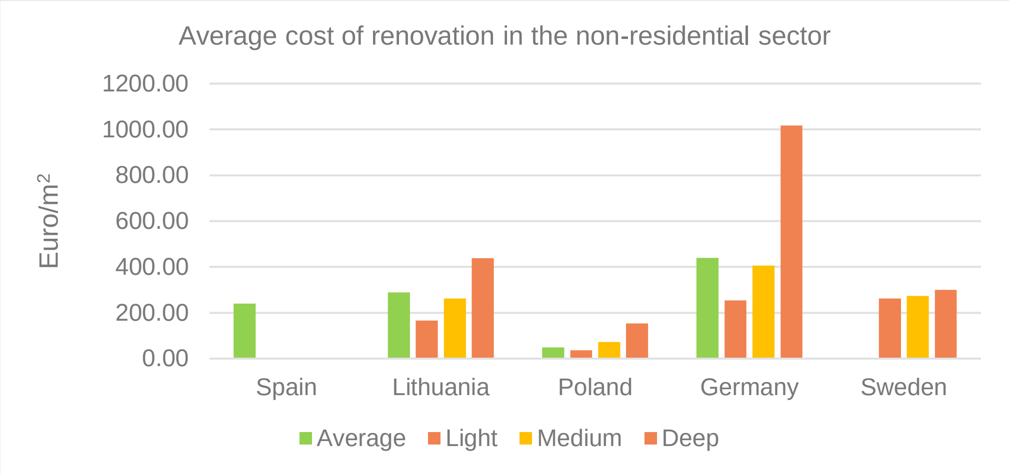

Figure 19. **Cost of renovation in the non-residential sector. Source (ZEBRA2020, 2016).**

4.1.3 ENERGY CONSUMPTION

The energy consumption is also an essential element to understand the potential for EPC in the commercial sector across Europe. Commercial buildings are significantly energy hungry, a fact that makes them well suited to the deployment of EPC schemes.

Although data is scarce, some availability is found for certain countries. Figure 20 shows the specific energy use for Slovenia, UK, Czech Republic, France, Finland and Bulgaria (EU, 2016b).

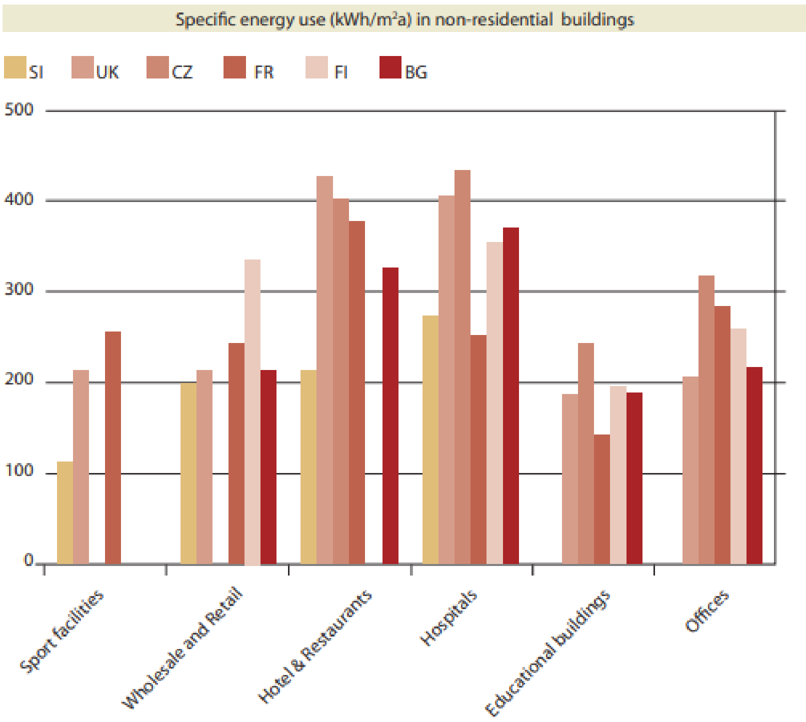

Figure 20. **Energy consumption per typology in European countries. Source: (EU, 2016b).**

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It can be observed that energy consumption per m² in the non-residential sector was calculated above 200 kWh/m² for most countries and typologies, with sport facilities and educational buildings presenting the lowest energy needs.

Further sources are shown in Figure 21, where it can be observed the great variability on energy consumption across Europe and building typologies (EU, 2016).

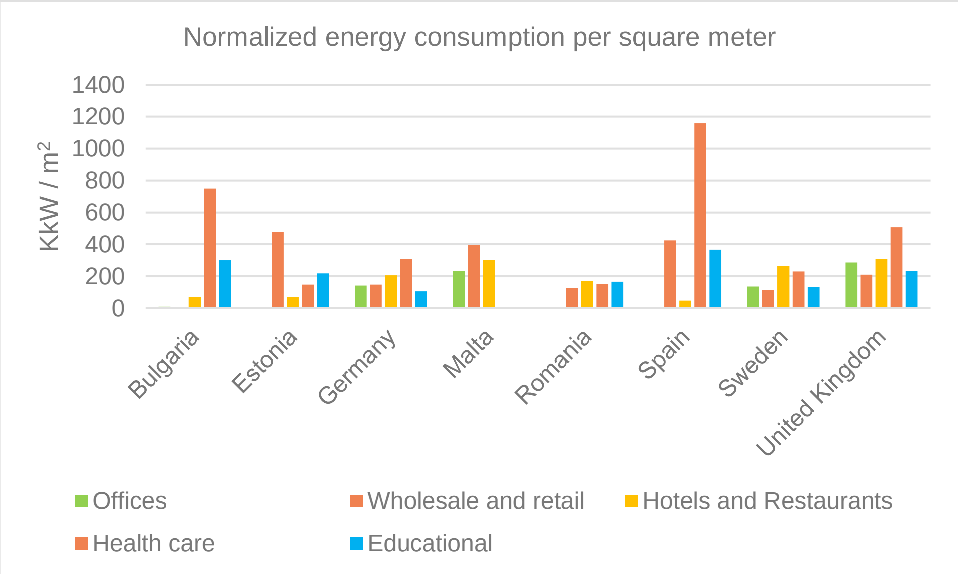

Figure 21. **Normalized energy consumption per square meter. Source: (EU, 2016).**

The presented references show that most of the data is between 100-300kWh/m^2.

Therefore, this parameter is ranked as:

- Very high (> 400 kWh/m^2) → 4 points;
- High (> 200 kWh/ m^2 and < 400 kWh/m^2) → 3 points;
- Medium (> 100 kWh/m^2 and < 200 kWh/m^2) → 2 points;
- Low (< 100 kWh/m^2) → 1 points.

Further information can be found on types of load usage in the non-residential sector. A general profile per country was extracted from the EU buildings database and is provided in Figure 22 (EU, 2016).

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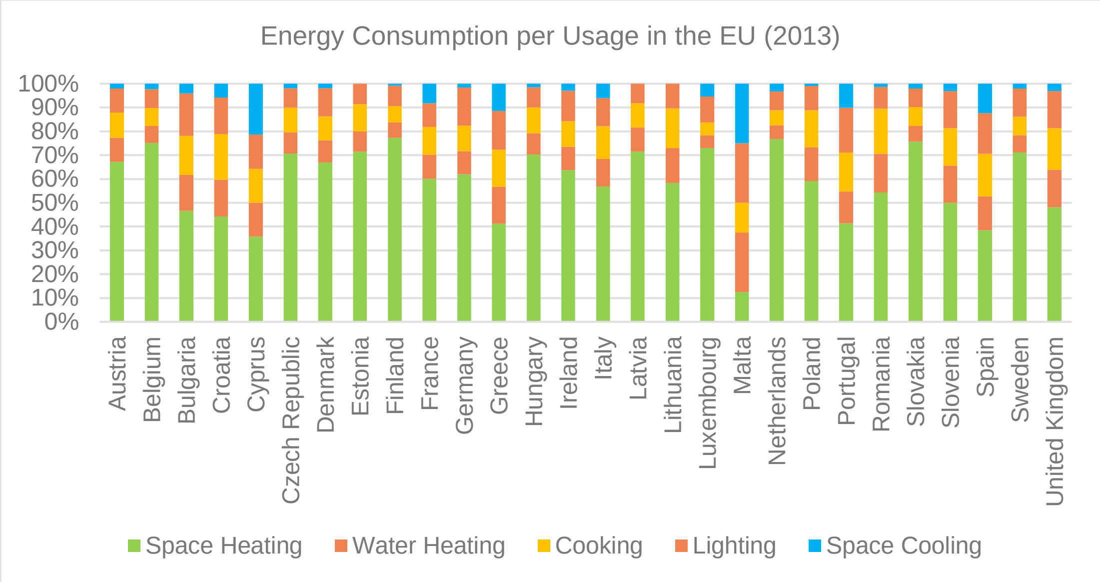

Figure 22. **Energy Consumption per Usage in the EU. Source (EU, 2016).**

It can be observed that the biggest share of energy is used up for heating purposes in the majority of countries, with heating consumption ratios around 60-75% for central and northern European countries, little energy spent for cooling, and the remaining energy used equally on water heating, cooking and lighting. As expected, southern countries (Greece, Malta, Spain, Cyprus, Croatia, Bulgaria and Portugal), have the lowest energy usage percentages for heating, balanced out with high cooling consumption.

4.2 SMART READINESS INDICATOR

The Smart-readiness across Europe has been analysed by BPIE, as showed in following figure.

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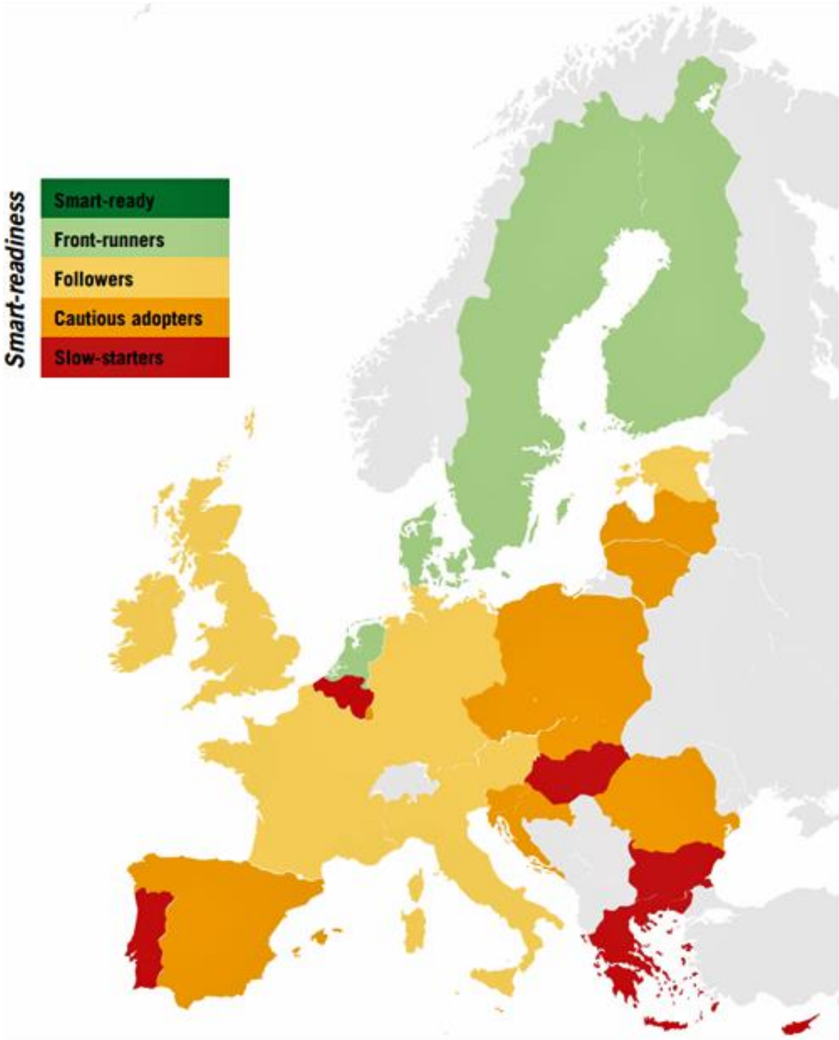

Figure 23. **Smart-readiness across Europe. Source (BPIE, 2017).**

It can be observed that Nordic countries are ahead, while southern and eastern European countries are cautious adopters. Central Europe is in a middle position. High scores on the SRI translate in higher potential of EPC, as the existence of tools such as Building Management System (BMS) allows adopting DR strategies etc.

Scarce information is available on average values for SRI across Europe. The mentioned publication from BPIE evaluates an equivalent indicator, the Smart Ready Built Environment Indicator (SBEI), an indicator that includes the performance of the building envelope, final energy consumption, existence of renewable energy consumption, as well as other factors that can be reviewed in its publication. Nevertheless, the outcome of the evaluation of SBEI across Europe shows that the built environment is far from being ready, with the average SBEI ranging “from 1.13 (Cyprus) to 2.92 (Sweden) out of 5”. The following figure shows the total ranking.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101033744.

Figure 24. SBIE across Europe. Source (BPIE, 2017).

From the information collected by BPIE and from the SRI example reported by the ALDREN project, it is clear that SRI below 50% are to be expected for the vast majority of buildings.

Therefore, the score of the individual building on the SRI is ranked as:

- High (>35%)→2 points;
- Medium (<35% and >15%)→1 points;
- Low (<15%)→0 points.

4.3 COUNTRY SPECIFIC PARAMETERS

The status of different factors that are country specific can significantly affect the evaluation and selection of suitable buildings.

4.3.1 SIZE OF ESCO MARKET

The EPC potential also depends largely on the market maturity for this kind of contracts. Figure 25 characterises the market for ESCOs in EU Member States, as recorded in a Joint Research Centre (JRC) report on ESCO market status (JRC, 2014).

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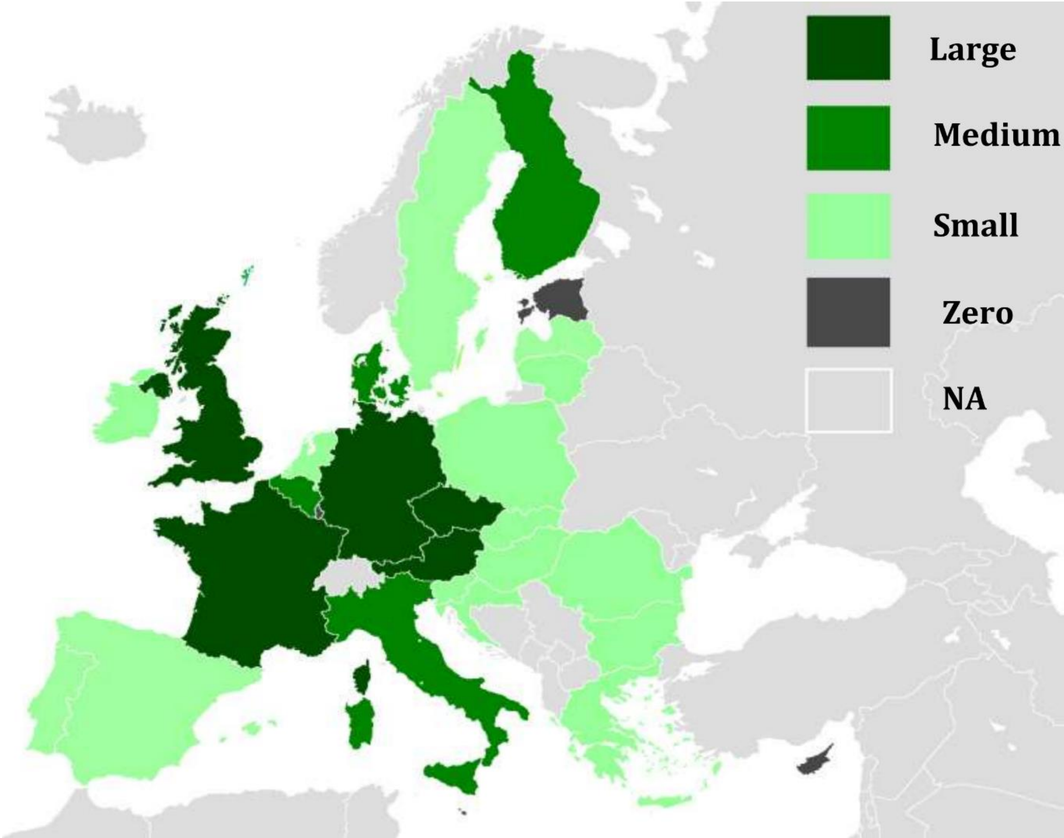

Figure 25. **The size of the ESCO market across the EU. Source (JRC, 2014).**

It can be observed the large diversity in Europe, with very well developed markets in central and north-west countries (over 500 ESCOs in Germany, over 300 in France), and very small size in the majority of countries.

4.3.2 DEMAND RESPONSE POTENTIAL

An analysis on DR in Europe included in "Cost-benefit analyses & state of play of smart metering deployment in the EU-27", shows that the potential varies significantly per country. Malta and Greece (5%), Romania (3.8%) and Luxembourg (3.5%) present the highest numbers in relative terms, expressed in % of the peak load. Figure 26 includes the numbers for almost all the countries within the EU.

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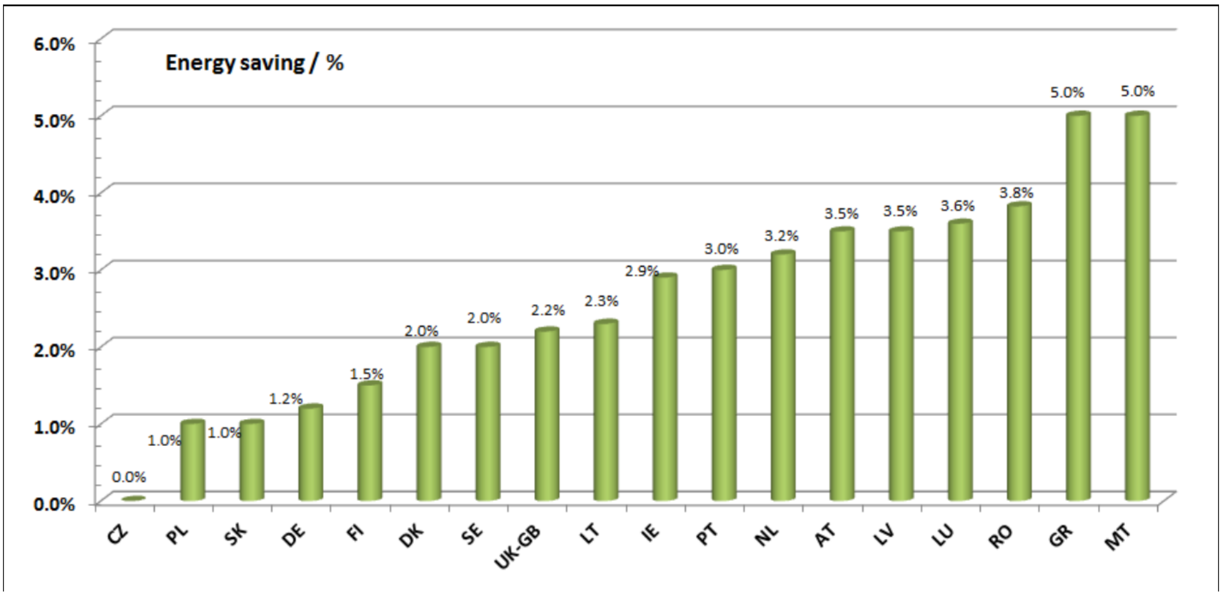

Figure 26. DR potential for energy saving and peak load shifting over total electricity consumption expected from smart metering roll-outs. Source (EC, 2014).

4.3.3 AVAILABILITY OF DYNAMIC TIME-OF-USE TARIFFS

In order to fully exploit the potential through implicit DR strategies, a proper framework in the form of flexible tariffs must be available. Figure 27 shows the state of development of smart charging tariffs across Europe, indicating the general availability of dynamic TOU tariffs.

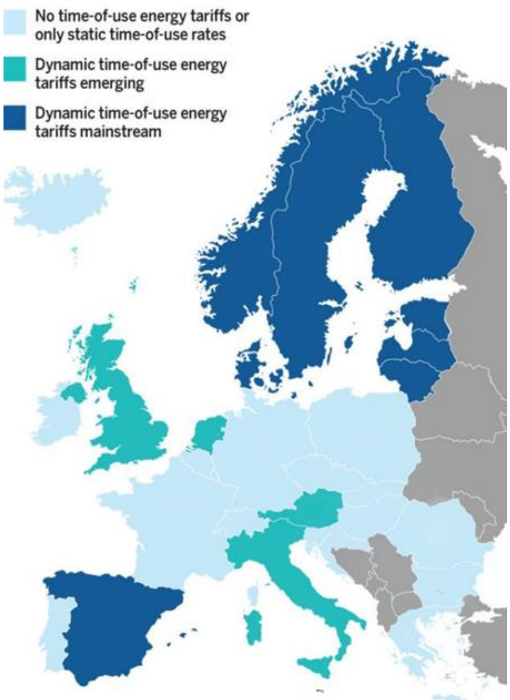

Figure 27. Availability of dynamic TOU tariffs. Source (REGULATORY ASSISTANCE PROJECT, 2022- modified).

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4.3.4 EXPLICIT DEMAND RESPONSE MARKET DEVELOPMENT

Regarding explicit DR market development, Figure 28 presents the map of explicit DR development in Europe, based on the work of the SEDC. The trend is similar to the ESCO market, with more mature markets in central and north-west countries.

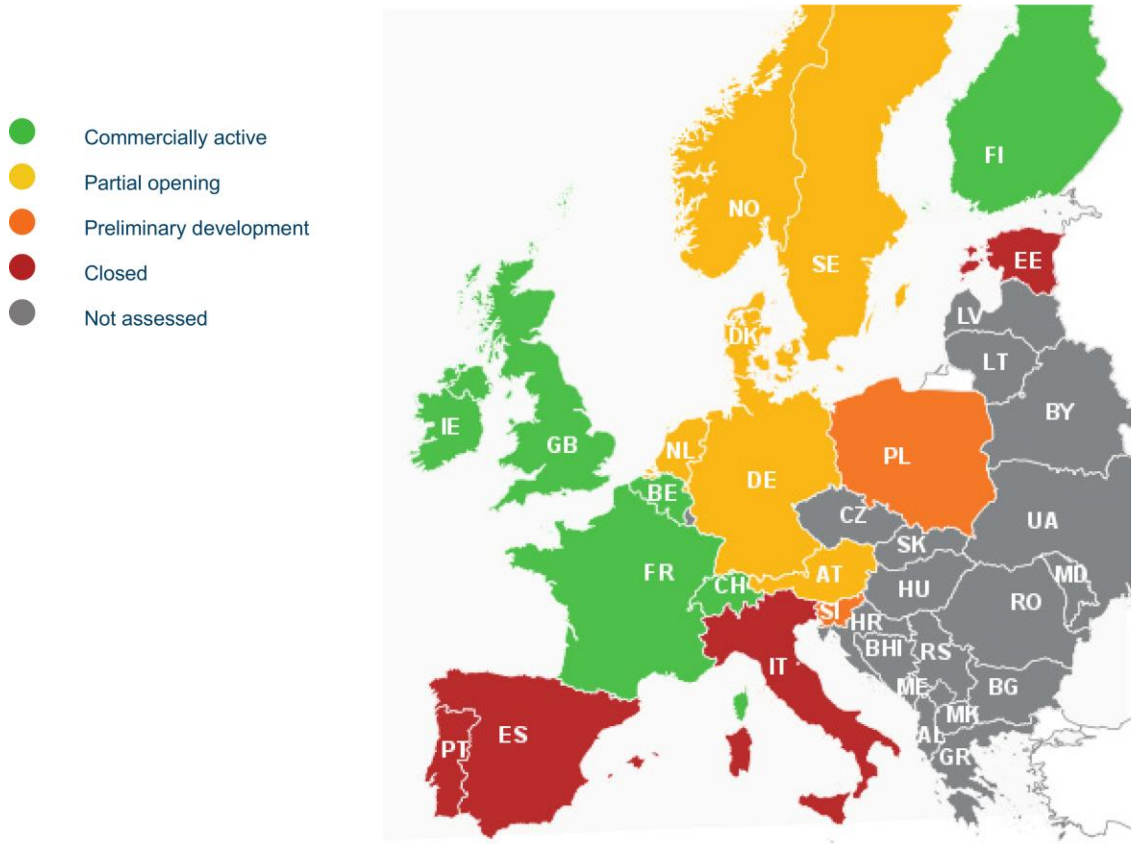

Figure 28. **Explicit Demand Response Development Map in Europe. Source (SEDC, 2017).**

In this regard, the NOVICE project stated that "southern countries are the ones lagging mostly behind in opening their energy markets to demand flexibility. NW and SW Europe, as well as parts of the central Europe are more advanced in that respect, although problems still remain. The issue most countries are facing at the moment, in order to proceed with the further integration of DR in the energy markets, is associates with measurement, baselining and verification procedures".

4.3.5 INCENTIVES

Regarding the availability of financial instruments to foster EPC, it can be observed in Figure 29 the types of financial instruments that were operational in 2013 in each member state, with grants and subsidies active in the majority of EU countries, followed, in order, by loads and tax incentives.

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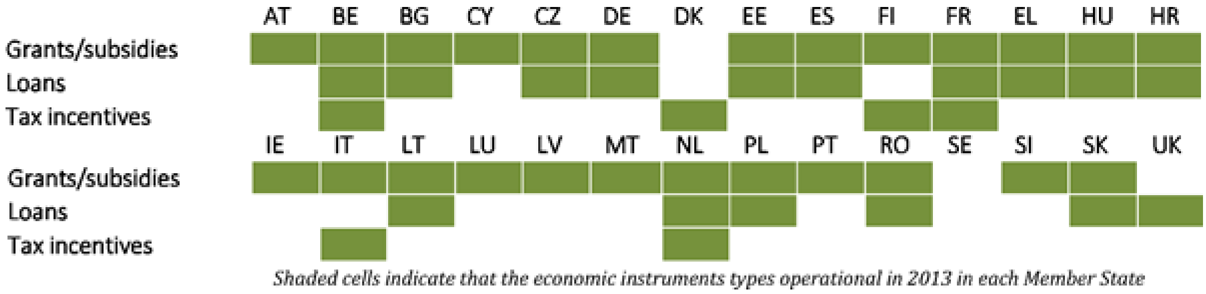

Figure 29. Economic instruments for energy renovations in the EU countries during 2013. Source (Economidou & Bertoldi, 2014).

4.4 EVALUATION OF COMMERCIAL BUILDINGS FOR PARTICIPATION IN EPC

Based on all of the above, the following conclusions are extracted.

Table 2. Written Evaluation for Wholesale and Retail.

Parameter	Written Evaluation
Average size of buildings	The average sizes across the EU, shows that educational facilities have the highest size on average (1434 m^2) followed by hotels & restaurants (881 m^2), presenting the former the highest variability. Netherlands and Denmark present the biggest buildings on average, being observed as a pattern that buildings get smaller from north to south.
Construction period	It can be observed that less than 20% of the stock was built after 1991. In spite of some variability across regions, it can be concluded that building age distribution follows closely the average European pattern. Regarding the renovation rate, it ranges from below 0.5% (e.g. Spain) up to 8% or even greater (Netherlands), with an average cost from less than 100€/m^2 (e.g. Poland) to over 1,000 €/m^2 (e.g. Germany).
Energy consumption per m^2	In terms of energy consumption, the presented references show that most of the data is between 100-300kWh/m^2 with a very irregular distribution.
SRI	It can be observed that Nordic countries are front-runners, while southern and eastern countries are cautious adopters. Central European countries are in a middle position as followers.
ESCO market	There is large diversity in Europe, with very well developed markets in central and north-west countries (over 500 ESCOs in Germany, over 300 in France), and very small size in the rest of countries.
Demand Response Potential	The potential varies significantly per country. Malta and Greece (5%) present the highest numbers in relative terms, with Czech republic (0%) and Poland showing the lowest potential.
Availability of dynamic TOU	High diversity, with Nordic countries and Southern European countries presenting these kind of tools for implicit DR.
Explicit DR	CE have commercially active markets, with the countries of SE behind on the development.
Incentives	Belgium, Netherlands and France present 3 different financial instruments to foster EPC, being NE behind on this kind of incentives.

4.5 BUILDING-SPECIFIC SCORING TABLE AND PRIORITIZATION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

A simple scoring system is proposed to assess those buildings with higher potential, with the following scale associated:

Building specific parameters

i. Floor area:
   a. Large (floor area >125% of the average value) → 2 points;
   b. Medium (floor area <125% and >75% of the average value) → 1 points;
   c. Small (floor area <75% of the average value) → 0 points.

ii. Construction period
   a. Old (built before 1990) → 3 points;
   b. New (built after 1990) → 0 points.

iii. Energy consumption per m^2
   a. Very high (> 400 kWh/m^2) → 4 points;
   b. High (> 200 kWh/m^2 and < 400 kWh/m^2) → 3 points;
   c. Medium (> 100 kWh/m^2 and < 200 kWh/m^2) → 2 points;
   d. Low (< 100 kWh/m^2) → 1 points.

iv. Smart readiness indicator
   a. High (>35%) → 2 points;
   b. Medium (<35% and >15%) → 1points;
   c. Low (<15%)→ 0 points.

Country specific parameters

v. ESCO market
   a. Large → 2 points;
   b. Medium → 1 points;
   c. Small → 0 points.

vi. Demand Response Potential
   a. High (>4%) → 2 points;
   b. Medium (>2.5% and <4%) → 1 points;
   c. Low (<2.5%)→ 0 points.

vii. Availability of dynamic TOU tariffs
   a. Dynamic TOU tariffs mainstream → 2 points;
   b. Dynamic TOU tariffs emerging → 1 points;
   c. No TOU tariffs or only static TOU rates → 0 points.

viii. Explicit DR market development
   a. Commercially active → 3 points;
   b. Partial opening → 2 points;
   c. Preliminary development→ 1 points;
   d. Closed → 0 points.

ix. Financial instruments
   a. 3 instruments → 3 points;
   b. 2 instruments → 2 points;
   c. 1 instruments → 1 points;
   d. No instruments → 0 points.

For those parameters where data is unavailable for some countries, data has been taken as the value for the region (central Europe, etc).

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In Table 3 we present scores on the parameters for each country as a reference framework to understand the potential at different European countries based on the average values presented for these countries in each category. The equation for its calculation is again included below:

Total score = Points from building characteristics (floor area; age; energy consumption; SRI) + 0.5*points from country characteristics (ESCO market size; DR market maturity; availability of dynamic TOU tariffs; Explicit DR; Incentives)

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Table 3. Evaluation scoring table for the European countries analysed.

Country	Building specific parameters				Country specific parameters					Total
	Average size of buildings	Construction period	Energy consumption per m2	SRI	ESCO market	Demand Response Potential	TOU tariffs	Explicit DR	Incentives	
Denmark	2	0	4	2	1	0	2	2	1	11
Finland	0	0	4	2	2	0	2	3	2	10.5
Italy	0	3	3	1	1	2	1	0	2	10
Netherlands	2	0	2	2	0	1	1	2	3	9.5
Spain	0	3	4	0	0	1	2	0	2	9.5
France	1	0	3	1	2	0	0	3	3	9
Belgium	1	0	3	0	1	1	0	3	3	8
Greece	0	3	3	0	0	2	0	0	2	8
Austria	1	0	2	1	2	1	1	2	1	7.5
Ireland	1	0	3	1	0	1	0	3	1	7.5
Portugal	0	3	4	0	0	0	0	0	1	7.5
Germany	1	0	2	1	2	0	0	2	2	7
Sweden	0	0	2	2	0	1	2	2	0	6.5
Czechia	1	0	2	0	2	1	0	0	2	5.5
Bulgaria	1	0	2	0	0	1	0	0	2	4.5
Hungary	1	0	2	0	0	1	0	0	2	4.5
Poland	0	0	2	0	0	1	0	1	2	4
Romania	0	0	2	0	0	1	0	0	2	3.5
Slovakia	0	0	2	0	0	0	0	0	2	3

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Nevertheless, as already stated, specific typologies of buildings rank independently of the country based on their own characteristics. To focus the study on the countries included in the consortium (Ireland, Greece, Spain), one building for each country is selected with a score as high as the highest score obtained from the prior evaluation at country level based on the average references (11 points). For this purpose, and based on the information already presented, the following archetypes are selected:

Ireland

- Scores 5*0.5=2.5 points based on their country specific parameters.
- Offices have the highest share of floor area by building type, with ≈900 m^2 of average size. This is >125% of the average value for offices in Europe, being therefore considered as large buildings, and potentially a more interesting typology for EPC.
- To reach 11 points, an office of 5,000m^2 (2 point) built before 1990 (3 point) with >400kWh/m^2 (4 points) and SRI <15% (0 points) is selected.

Greece

- Scores 4*0.5=2 points based on their country specific parameters.
- Hotels and restaurants have the highest share of floor area by building type, with ≈1000 m^2 of average size. To be above >125% of the average value for hotels & restaurants in Europe, a building of >1,100m^2 is selected as large building.
- To reach 11 points, a hotel of 4,000m^2 (2 points) built before 1990 (3 point) with >400kWh/m^2 (4 points) and SRI <15% (0 points) is selected.

Spain

- Scores 5*0.5=2.5 points based on their country specific parameters.
- Hotels and restaurants have the highest share of floor area by building type in Spain (30.37%), but to complement the study on Greece, one typology from wholesale and retail trade has been selected (the third highest share with 22.61% after offices), with <100 m^2 of average size. To be above >125% of the average value for wholesale and retail trade in Europe, a building of 430m^2 is selected as large building.
- To reach 11 points, a retail trade centre of 430m^2 (2 points) built before 1990 (3 point) with >400kWh/m^2 (4 points) and SRI <15% (0 points) is selected.

5 QUANTITATIVE ANALYSIS

The present section includes the outcomes from the model-based quantitative assessment of the top candidates identified in the exploratory analysis. This assessment is based on the methodology of the NOVICE project, using existing reference models (physics-based simulation models) of commercial buildings. This assessment explores, through the performance simulation of the selected common scenarios, the potential for EPC and energy management.

Each of the selected archetypes is modelled and simulated for 3 different locations around Europe to capture the effects of the different weather and climate patterns around Europe on the energy consumption and potential revenue streams from EPC. Selected scenarios are:

- Cfb: temperate oceanic climate in Dublin (Ireland).
- Dfb: temperate continental climate in Madrid (Spain).
- Csa: warm Mediterranean climate in Athens (Greece).

The simulated scenarios take into account:

- Energy-efficiency:
  - For every building archetype, two levels of energy consumption are contemplated, the initial and the improved one.
  - The higher efficiency level is achieved exclusively by improvements on the envelope, as improvements on control are taken into consideration within the SRI improvement:
    - Windows replacement.
    - Insulation.
    - Reduction of infiltration, improvement of air tightness.
    - Low consumption lights.
  - Regarding the cost, and based on internal know how, the price for renovation is:
    - 150€/m^2 for wall and roof insulation.
    - 250€/m^2 for window renovation.
- SRI
  - For every building archetype, two levels of SRI are contemplated:
    - <15%;
    - >15% & <35%.
  - The higher SRI level is achieved by improvements on the management of the building:
    - Variable temperature control.
    - Controlled ventilation through Variable Air Volume (VAV) fans.
    - Artificial lighting control.
  - No improvements are foreseen neither for “Maintenance & fault prediction” nor for “Information to occupants”, as the interrelation between these domains and impacts on energy consumption is not so obvious and, therefore, it is hard to capture through simulation.
  - Regarding the cost, and based on internal know how, the price for SRI improvement is 20€/m^2.
- Flexibility measures

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- for the situation of SRI>15%, two scenarios are simulated regarding flexibility measures:
  - Normal operation.
  - Switching off or reducing the use of the HVAC system and other high consumption equipment for 3 hours every day.
- This intervention is assumed to have no associated cost.
- It is worth mention that potential additional revenue streams from explicit demand response programs could be available. However, these are not considered for the estimation of the payback of this kind of intervention.

For each scenario, the following information is presented:

- Energy Per Conditioned Building Area in absolute terms [kWh/m^2·year]
- EPC potential, calculated as reduction of energy costs in €/year. To reach this number, the following equation is used:

$$Savings\ [€/year] = (Energy\ consumption_{baseline} - Energy\ consumption_{scenario}) * total\ area * energy\ price$$

  Being the energy price as follows:

Table 4. **Prices of the different energy carriers per country. Source: Eurostat.**

Country	Electricity [€/kWh]	Gas [€/kWh]
Ireland	0.18	0.055
Greece	0.22	0.02
Spain	0.15	0.035

- Payback of the intervention, calculated as the total investment divided by the total savings for each scenario.

The results must be considered as reference and not as a detailed calculation. This top-down approach, going from a general case rather than taking into consideration specific factors, is adequate for the purpose of the present work, focusing on macro variables affecting the EPC market rather than in specific building cases.

5.1 IRELAND

A three-story office building of ≈5,000m^2 built before 1990, with rectangle shape, HVAC served by a multi-zone constant volume system with electric heat is taken as baseline. The SRI is <15%.

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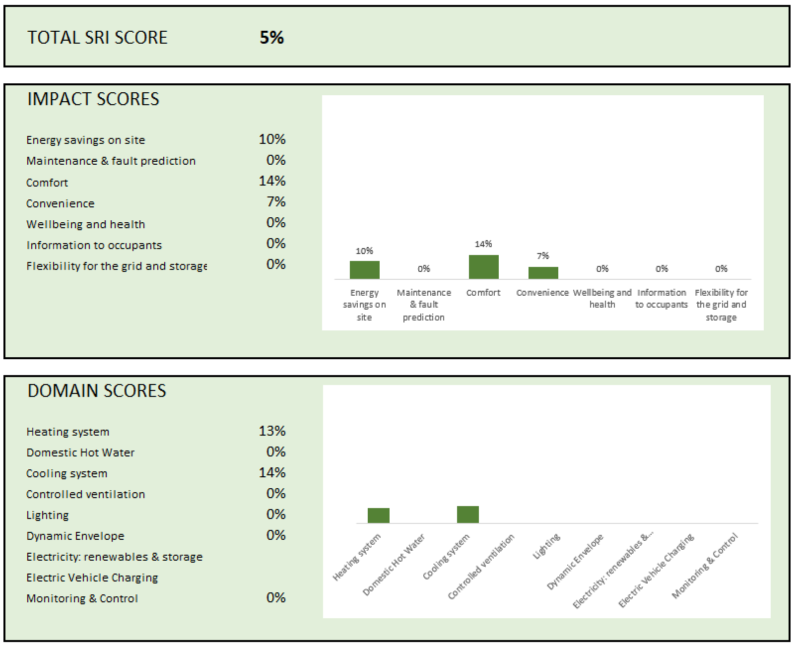

Figure 30. **SRI assessment for the Irish archetype (baseline situation).**

Further information on the simulation model and the SRI detailed evaluation for the baseline is included as an annex.

The referred scenarios and the outcomes from the simulations are shown in Table 5 below. This table includes the referred scenarios, the consumption [kWh/m²·year] of each scenario, the economic savings of the scenario with respects to the baseline situation and the payback of the investment thanks to that economic saving.

Table 5. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	432	-	-
	>15%	No	183	224,106	4 months
		Yes	174	232,478	4 months
Renovated	<15%	No	213	196,636	5.3 years
	>15%	No	79	317,593	3.6 years
		Yes	74	322,263	3.6 years

<u>Conclusions</u>

The evaluated office building has a very high potential due to its high consumption, due to the poorly insulated envelope and lack of building management strategies (absence of intelligent thermostats or occupancy control for indoor lighting).

Two different strategies have been followed to increase the efficiency of the building:

- Passive strategies, achieved exclusively by improvements on the envelope and the replacement of old equipment and lights for higher efficient ones.

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- Active strategies, by improvements on the management of the building.
- Furthermore, DR is applied to the building for two hours each day.

The outcomes of the simulation suggest that this type of buildings are very good candidates, showing large energy consumption patterns and very high potential energy savings. The use of 100% electricity to cover the heat demand positively influences on the potential for EPC as it has a higher cost than gas.

Regarding the best performing strategy, the outcomes of the simulation suggest that active strategies have higher potential at lower cost, while the combination of active and passive strategies result on high performing buildings with important revenues. On the other side, DR has very little impact when applied to high performing buildings.

5.2 GREECE

A four-story hotel building of ≈4,000m^2 built before 1990, with 74 rooms, rectangle shape is taken as baseline. The HVAC system is served by independent terminal units based on gas for heating and heat pump for cooling, while electric unit heaters are used in stairs and storage areas. The SRI is <15%.

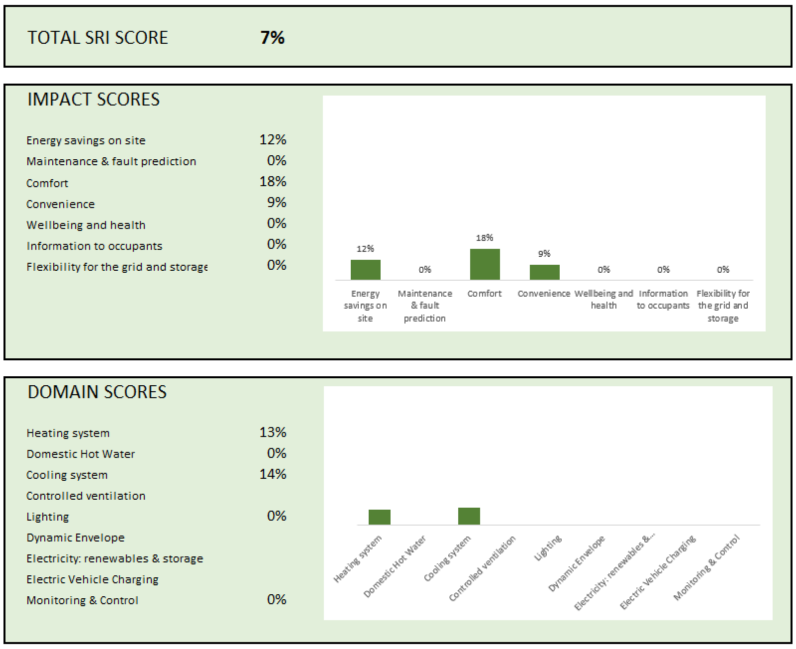

Figure 31. SRI assessment for the Greek archetype (baseline situation).

Further information on the simulation model and the SRI detailed evaluation for the baseline is included as an annex.

The referred scenarios and the outcomes from the simulations are shown in Table 6 below. This table includes the referred scenarios, the consumption [kWh/m^2·year] of that scenario and, the economic savings of the scenario with respects to the baseline situation and the payback of the investment thanks to that economic saving.

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Table 6. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	415	-	-
	>15%	No	232	134,689	7 months
		Yes	193	164,246	6 months
Renovated	<15%	No	223	160,760	5.54 years
	>15%	No	104	235,135	4.13 years
		Yes	104	235,635	4.12 years

Conclusions

The evaluated hotel building has a very high potential due to its high consumption, due to the poorly insulated envelope and lack of building management strategies (absence of intelligent thermostats or occupancy control for indoor lighting).

Two different strategies have been followed to increase the efficiency of the building:

- Passive strategies, achieved exclusively by improvements on the envelope and the replacement of old equipment and lights for higher efficient ones.
- Active strategies, by improvements on the management of the building.
- Furthermore, DR is applied to the building for two hours each day.

The outcomes of the simulation suggest that this type of buildings are very good candidates, showing large energy consumption patterns and very high potential energy savings. The higher demand of cooling (covered with electricity) compared to heating demand (covered with gas), positively influences on the potential for EPC as electricity has a higher cost than gas.

Regarding the best performing strategy, the outcomes of the simulation suggest that passive strategies have higher potential but at higher cost, resulting on lower paybacks than those obtained for active strategies. The combination of active and passive strategies result on high performing buildings with important revenues. On the other side, DR has very little impact when applied to high performing buildings.

5.3 SPAIN

A mall complex with six stores of one floor and 174m^2 plus three stores with double size on end and middle of ≈2,000m^2 built before 1990, with rectangle shape is taken as baseline. South wall is the only wall with glazing. The HVAC system is served by roof-tops based on gas for heating and heat pump for cooling. The SRI is <15%.

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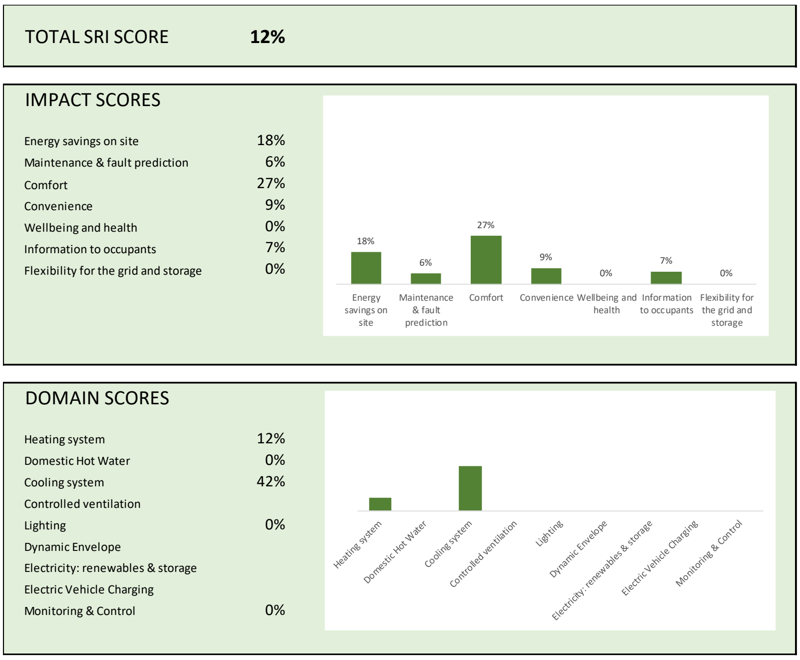

Figure 32. **SRI assessment for the Spanish archetype (baseline situation).**

Further information on the simulation model and the SRI detailed evaluation for the baseline is included as an annex.

The referred scenarios and the outcomes from the simulations are shown in Table 7 below. This table includes the referred scenarios, the consumption [kWh/m²·year] of that scenario and, the economic savings of the scenario with respects to the baseline situation and the payback of the investment thanks to that economic saving.

Table 7. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	413	-	-
	>15%	No	198	31,105	1.34 years
		Yes	189	32,530	1.28 years
Renovated	<15%	No	148	47,837	10.91 years
	>15%	No	101	54,753	10.3 years
		Yes	97	56,344	10.01 years

Conclusions

The outcomes of the simulation suggest that this type of buildings are very good candidates to be renovated with active strategies, showing large energy savings by the implementation of building management systems. However, passive strategies need periods over 10 years to payback, a period that could be considered too high for financial standards. This is mainly caused by the following:

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- the lower floor area considered for the Spanish building in comparison with the Irish and Greek case studies. Lower floor area is translated on higher ratios volume/envelope, and therefore higher investments per conditioned volume for envelope renovations.
- Lower price of the energy carriers considered for Spain in comparison with the previous cases.
- Use of gas to cover the predominant heating demand, with lower cost than electricity.

The same case applies to the combination of passive and active strategies, with a payback period over 10 years. As in the previous case studies analysed, DR has very little impact when applied to high performing buildings.

5.4 ADDITIONAL SIMULATIONS

The simulations models prepared for the quantitative analysis of EPC potential for the specific case studies are further used to estimate the potential in every country considered.

5.4.1 IRELAND

Hotel

Table 8. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	620	-	-
	>15%	No	396	142,781	7 months
		Yes	321	189,652	5 months
Renovated	<15%	No	303	213,389	4.18 years
	>15%	No	138	305,912	3.17 years
		Yes	138	306,241	3.17 years

Mall

Table 9. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	488	-	-
	>15%	No	217	44,821	2.23 years
		Yes	217	48,366	2.07 years
Renovated	<15%	No	180	62,202	16.88 years
	>15%	No	120	71,389	16.11 years
		Yes	116	73,253	15.70 years

5.4.2 GREECE

Office

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

Table 10. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	384	417,458	-
	>15%	No	139	268,407	4 months
		Yes	129	278,750	4 months
Renovated	<15%	No	200	201,079	5.22 years
	>15%	No	85	328,147	3.50 years
		Yes	77	337,361	3.41 years

Mall

Table 11. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	343	94,043	-
	>15%	No	158	35,138	2.85 years
		Yes	148	39,728	2.52 years
Renovated	<15%	No	118	58,511	17.95 years
	>15%	No	77	67,229	17.11 years
		Yes	72	69,705	16.50 years

5.4.3 SPAIN

Office

Table 12. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	404	396,791	-
	>15%	No	160	245,075	5 months
		Yes	150	254,522	5 months
Renovated	<15%	No	202	199,710	5.26 years
	>15%	No	84	320,014	3.59 years
		Yes	76	328,017	3.51 years

Hotel

Table 13. **Outcomes for the referred scenarios.**

Construction period	SRI	DR	Consumption [kWh/m²·year]	EPC potential (€/year savings)	EPC payback
Before 1990	<15%	No	502	257,735	
	>15%	No	308	100,910	10 months
		Yes	249	131,561	7 months
Renovated	<15%	No	257	138,669	6.43 years
	>15%	No	121	200,654	4.48 years

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

		Yes	120	200,970	4.83 years

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

6 CONCLUSIONS

The work carried out in task 4.1 has been presented. This includes the development of an interactive web-app that presents the most suitable "target" market across Europe for the SmartSPIN split-incentives business model based on EPC.

The information published in the interactive web-app is based on a two-stages analysis performed within task 4.1 and hereby presented.

Qualitative analysis

Different European countries and typologies of commercial buildings have been analysed to identify those buildings with the highest potential for EPC and energy management based on literature review such as public databases, statistics and surveys of the existing building stock. The exploratory qualitative analysis particularly focuses on:

- Building specific parameters that can be directly used to characterize and evaluate the EPC potential of different building classes
  - Floor area available for EPC;
  - Construction period;
  - Energy consumption;
  - SRI.
- Country specific parameters, which are independent among types of commercial buildings and provide useful information, primarily regarding the potential at different European regions and countries:
  - Maturity of the ESCO market;
  - Demand response potential of the building stock;
  - Availability of dynamic TOU tariffs;
  - Maturity of the DR market;
  - Existence of incentives.

Based on these parameters, the top candidates are identified in a two-layered classification, with the first layer being the building type (size, SRI, age), and the second the geographical division. It can be observed that specific typologies of buildings will rank high independently of the country. Large, non-renovated buildings constructed before 1990 will have high potential even if the country lacks a mature DR market.

On the next step, the potential of these top candidates is quantitatively analysis.

Quantitative analysis

The potential of the most suitable building typologies (large office, large hotel and large commercial centre) is evaluated via simulation under different boundary conditions and scenarios of renovation, taking into account:

- Climate;
- Price of energy carriers;
- Performance of the building envelope;

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- SRI and,
- existence of demand response.

The simulation models allow to assess the energy and monetary benefits from the following retrofitting scenarios:

- Passive strategies, achieved exclusively by improvements on the envelope and the replacement of old equipment and lights for higher efficient ones.
- Active strategies, by improvements on the management of the building.
- Combination of both strategies.
- Furthermore, DR is applied to the building for two hours each day.

The quantitative analysis confirms the great potential of the top candidates for both improvements on the envelope and on the smartness of the building, mainly due to their poorly insulated envelope and lack of building management strategies (absence of intelligent thermostats or occupancy control for indoor lighting), what drives to high energy demand. This potential is higher than 75% if a complete upgrade of the building is performed, improving the performance of the envelope and increasing the SRI from <15% to >15%.

Regarding the best performing strategy, the outcomes of the simulation suggest that active strategies have higher potential at lower cost, while the combination of active and passive strategies result on high performing buildings with important revenues. On the other side, DR has very little impact when applied to high performing buildings.

Regarding the economic potential of the evaluated retrofitting scenarios, active strategies present lower paybacks due to the relative low investment needed for their implementation. On the other hand, the large investments needed for envelope renovation causes higher paybacks. In any case, large offices and large hotels present very attractive paybacks for all the considered retrofitting scenarios, as it’s the case of SRI improvements on large malls. On the other hand, large commercial centres need periods over 10 years to payback the renovation of the envelope, a period that could be considered too high for financial standards. This is mainly caused by the following:

- the lower floor area considered for the mall in comparison with the Irish and Greek case studies. Lower floor area is translated on higher ratios volume/surface, and therefore higher investments per conditioned volume for envelope renovations.
- Use of gas to cover the predominant heating demand, with lower cost than electricity.

Results must be considered as reference and not as a detailed calculation. This top-down approach, going from a general case rather than taking into consideration specific factors, is adequate for the purpose of the present work, focusing on macro variables affecting the EPC market rather than in specific building cases.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101033744.

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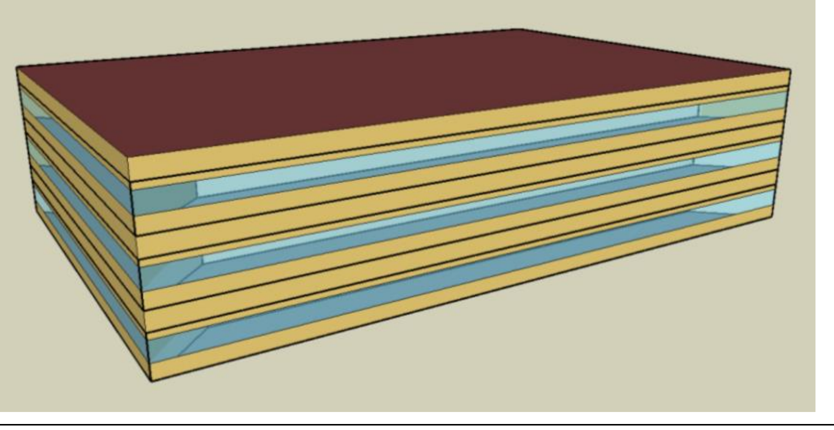
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

8 ANNEX A: DETAIL INFORMATION OF THE SIMULATION MODELS

8.1 IRELAND

Below are described the main characteristics of the simulated building model, archetype medium hotel.

Table 14. **Building characteristics for the baseline scenario [based on DOE reference model]**.

Items	Description
Available fuel types	Electricity
Building Type (Principal Building Function)	Offices
Building Prototype	**Medium office**
Total Floor Area (m^2)	4,982
Building shape	
Aspect Ratio	1.5
Number of Floors	3 above-ground floors
Window Fraction (Window-to-Wall Ratio)	33.0%
Characteristics of window	U-Factor: 3 $W/m^2 \cdot K$ Solar Heat Gain Coefficient: 0.39
Construction – exterior walls (from outside to inside layer)	Wood Siding; Steel Frame Res Wall Insulation; 1/2IN Gypsum U-value: 0.52
Construction – roof	Roof Membrane; IEAD Res Roof Insulation: Metal Decking U-value: 0.38
Construction - foundation	20 cm heavy-weight concrete with carpet
Infiltration - flow per Exterior Surface Area	0.0025 $m^3/s \cdot m^2$
HVAC system	Multi-zone constant volume system with electric heat

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

Thermostat Setpoint	24°C Heating
Thermostat Operation Schedule	Always on

The evaluation of the SRI for the building is as follows:

Code		Service	Main functionality level as inspected by SRI assessor	share (default = 100% means applicable throughout the building)	Optional: additional functionality level in part of the building	Share of additional functionality level	Warnings	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Service to be assessed?
Heating-S1	Heat control - demand side	Heat emission control	1	100%		0%		No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Heating-S2a	Control heat production facilities	Heat generator control (all except heat pump)	0	100%		0%		Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (e.g. depending on supply water temperature set point)			1
Heating-S2b	Control heat production facilities	Heat generator control (for heat pumps)											0
Heating-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Heating-S4	Reporting	Report information regarding heating system performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
DHW-S1	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	100%		0%		Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management			1
DHW-S2	Flexibility DHW production facilities	Control of DHW storage charging	0	100%		0%		None	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)			1
DHW-S3	Information to occupants	Report information regarding domestic hot water performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Cooling-S1	Cooling control - demand side	Cooling emission control	1	100%		0%		No automatic control	Central automatic control	Individual room control REF	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Cooling-S2	Control cooling production facilities	Generator control for cooling	0	100%		0%		Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load			1
Cooling-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Cooling-S4	Reporting	Report information regarding cooling system performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Ventilation-S1	Air flow control	Air flow control al the room level	0	100%		0%		No ventilation system or manual control	Clock control	Occupancy detection control	Central Demand Control based on air quality sensors (CO2, VOC,...)	Local Demand Control based on air quality sensors (CO2, VOC,...) with local flow from/to the zone regulated by dampers	1
Ventilation-S3	Feedback - Reporting information	Reporting information regarding IAQ	0	100%		0%		None	Air quality sensors (e.g. CO2) and real time autonomous monitoring	Real time monitoring & historical information of IAQ available to occupants	Real time monitoring & historical information of IAQ available to occupants + fault/maintenance detection based on internal sensors	Real time monitoring, historical & predictive information of IAQ (incl. external data eg outside temperature, ambient air...) available to occupants + fault/maintenance detection based on internal sensors and historical data	1
Lighting-S1	Artificial lighting control	Occupancy control for indoor lighting	0	100%		0%		Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)		1
DE-S1	Window control	Window solar shading control											0
DE-S3	Feedback - Reporting information	Reporting information regarding performance	0	100%		0%		No reporting	Position of each product & fault detection	Position of each product, fault detection & predictive maintenance	Position of each product, fault detection, predictive maintenance, real-time sensor data (wind, lux, temperature...)	Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature...)	1
Electricity-S1	Storage	Storage of locally generated energy											0
Electricity-S2	Electricity Loads	Electricity Monitoring Systems											0
Electricity-S3	Renewables	Reporting information regarding energy generation											0
Electricity-S4	Storage	Reporting information regarding stored electricity											0
EV-S1	EV Charging presence & capacity	Number of charging spaces											0
EV-S3	EV Charging - Grid	EV Charging Grid balancing											0
EV-S4	EV Charging - connectivity	EV charging information and connectivity											0
MC-S1	TBS interaction control	Interaction between TBS and/or BACS	0	100%		0%		None	Single platform that allows manual control of multiple TBS	Single platform that allows automated control & coordination between TBS	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals		1
MC-S2	Smart Grid Integration	Smart Grid Integration	0	100%		0%		None - No harmonization between grid and building energy systems; building is operated independently from the grid load	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting				1
MC-S3	Feedback - Reporting information	Central reporting of TBS performance and energy use	0	100%		0%		None	Real time indication of energy use per energy carrier	Real time indication of sub-metererd energy use or other performance metrics for at least 2 domains	Real time indication of sub-metererd energy use or other performance metrics for all main TBS		1

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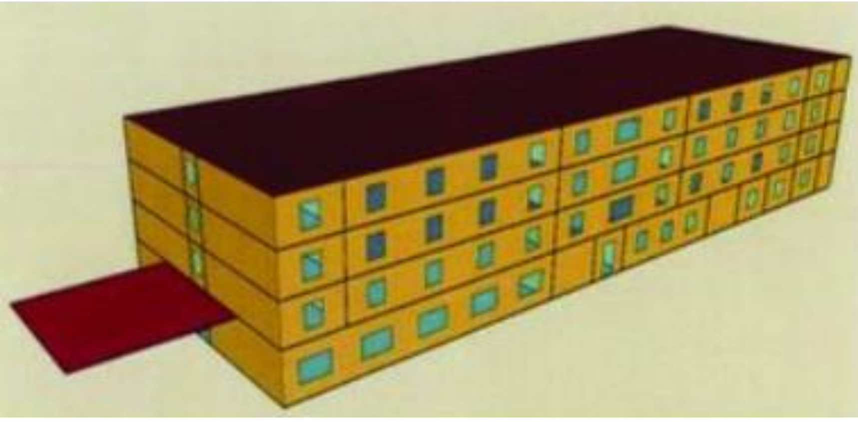
8.2 GREECE

Below are described the main characteristics of the simulated building model, archetype medium hotel.

Table 15. **Building characteristics for the baseline scenario [based on DOE reference model]**.

Items	Description
Available fuel types	Gas, electricity
Building Type (Principal Building Function)	Lodging
Building Prototype	**Small Hotel**
Total Floor Area (m^2)	4,004
Building shape	
Aspect Ratio	3
Number of Floors	4 above-ground floors
Window Fraction (Window-to-Wall Ratio)	Total: 10.9%
Characteristics of window	U-Factor: 4.23646 $W/m^{2}\cdot K$ Solar Heat Gain Coefficient: 0.39
Construction – exterior walls (from outside to inside layer)	Wood Siding; Steel Frame Res Wall Insulation; 1/2IN Gypsum U-value: 2.67
Construction – roof	Roof Membrane; IEAD Res Roof Insulation: Metal Decking U-value: 3.29
Construction - foundation	20 cm heavy-weight concrete with carpet
Infiltration - flow per Exterior Surface Area	0.0102 $m^3/s\cdot m^2$
HVAC system	Independent terminal units based on gas for heating and heat pump for cooling, while electric unit heaters are used in stairs and storage areas.
Thermostat Setpoint	22°C Cooling/ 21.9°C Heating

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

Thermostat Operation Schedule	Always on

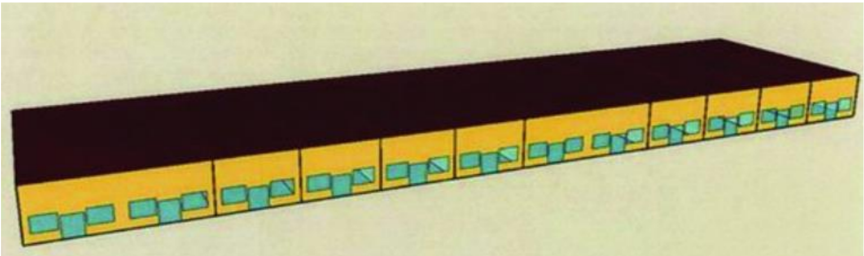
The evaluation of the SRI for the building is as follows:

Code		Service	Main functionality level as inspected by SRI assessor	share (default = 100% means applicable throughout the building)	Optional: additional functionality level in part of the building	Share of additional functionality level	Warnings	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Service to be assessed?
Heating-S1	Heat control - demand side	Heat emission control	1	100%		0%		No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Heating-S2a	Control heat production facilities	Heat generator control (all except heat pump)	0	100%		0%		Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (e.g. depending on supply water temperature set point)			1
Heating-S2b	Control heat production facilities	Heat generator control (for heat pumps)											0
Heating-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Heating-S4	Reporting	Report information regarding heating system performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
DHW-S1	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	100%		0%		Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management			1
DHW-S2	Flexibility DHW production facilities	Control of DHW storage charging	0	100%		0%		None	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)			1
DHW-S3	Information to occupants	Report information regarding domestic hot water performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Cooling-S1	Cooling control - demand side	Cooling emission control	1	100%		0%		No automatic control	Central automatic control	Individual room control REF	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Cooling-S2	Control cooling production facilities	Generator control for cooling	0	100%		0%		Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load			1
Cooling-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Cooling-S4	Reporting	Report information regarding cooling system performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Ventilation-S1	Air flow control	Air flow control al the room level											0
Ventilation-S3	Feedback - Reporting information	Reporting information regarding IAQ											0
Lighting-S1	Artificial lighting control	Occupancy control for indoor lighting	0	100%		0%		Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)		1
DE-S1	Window control	Window solar shading control											0
DE-S3	Feedback - Reporting information	Reporting information regarding performance											0
Electricity-S1	Storage	Storage of locally generated energy											0
Electricity-S2	Electricity Loads	Electricity Monitoring Systems											0
Electricity-S3	Renewables	Reporting information regarding energy generation											0
Electricity-S4	Storage	Reporting information regarding stored electricity											0
EV-S1	EV Charging presence & capacity	Number of charging spaces											0
EV-S3	EV Charging - Grid	EV Charging Grid balancing											0
EV-S4	EV Charging - connectivity	EV charging information and connectivity											0
MC-S1	TBS interaction control	Interaction between TBS and/or BACS	0	100%		0%		None	Single platform that allows manual control of multiple TBS	Single platform that allows automated control & coordination between TBS	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals		1
MC-S2	Smart Grid Integration	Smart Grid Integration	0	100%		0%		None - No harmonization between grid and building energy systems; building is operated independently from the grid load	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting				1
MC-S3	Feedback - Reporting information	Central reporting of TBS performance and energy use	0	100%		0%		None	Real time indication of energy use per energy carrier	Real time indication of sub-metererd energy use or other performance metrics for at least 2 domains	Real time indication of sub-metererd energy use or other performance metrics for all main TBS		1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

8.3 SPAIN

Table 16. **Building characteristics for the baseline scenario [based on DOE reference model]**.

Items	Description
Available fuel types	Electricity, gas
Building Type (Principal Building Function)	Retail
Building Prototype	**Strip mall, shopping stores**
Total Floor Area (m^2)	2,090
Building shape	
Number of Floors	Single story
Window Fraction (Window-to-Wall Ratio)	10.5%, only in south wall (26.2%)
Characteristics of window	U-Factor: 4.7 $W/m^{2}\cdot K$ Solar Heat Gain Coefficient: 0.69
Construction – exterior walls (from outside to inside layer)	Wood Siding; Steel Frame Res Wall Insulation; 1/2IN Gypsum U-value: 1.06
Construction – roof	Roof Membrane; IEAD Res Roof Insulation: Metal Decking U-value: 1.34
Construction - foundation	20 cm heavy-weight concrete with carpet
Infiltration - flow per Exterior Surface Area	0,000302 $m^3/s\cdot m^2$
HVAC system	Roof-tops based on gas for heating and heat pump for cooling
Thermostat Setpoint	24°C Cooling/ 23.6°C Heating
Thermostat Operation Schedule	Always on

The evaluation of the SRI for the building is as follows:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.

Code		Service	Main functionality level as inspected by SRI assessor	share (default = 100% means applicable throughout the building)	Optional: additional functionality level in part of the building	Share of additional functionality level	Warnings	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Service to be assessed?
Heating-S1	Heat control - demand side	Heat emission control	1	100%		0%		No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Heating-S2a	Control heat production facilities	Heat generator control (all except heat pump)											0
Heating-S2b	Control heat production facilities	Heat generator control (for heat pumps)	0	100%		0%		On/Off-control of heat generator	Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)			1
Heating-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Heating-S4	Reporting	Report information regarding heating system performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
DHW-S1	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	100%		0%		Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management			1
DHW-S2	Flexibility DHW production facilities	Control of DHW storage charging	0	100%		0%		None	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)			1
DHW-S3	Information to occupants	Report information regarding domestic hot water performance	0	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Cooling-S1	Cooling control - demand side	Cooling emission control	1	100%		0%		No automatic control	Central automatic control	Individual room control REF	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1
Cooling-S2	Control cooling production facilities	Generator control for cooling	1	100%		0%		Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load			1
Cooling-S3	Control heat production facilities	Storage and shifting of thermal energy											0
Cooling-S4	Reporting	Report information regarding cooling system performance	1	100%		0%		None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1
Ventilation-S1	Air flow control	Air flow control al the room level											0
Ventilation-S3	Feedback - Reporting information	Reporting information regarding IAQ											0
Lighting-S1	Artificial lighting control	Occupancy control for indoor lighting	0	100%		0%		Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)		1
DE-S1	Window control	Window solar shading control											0
DE-S3	Feedback - Reporting information	Reporting information regarding performance											0
Electricity-S1	Storage	Storage of locally generated energy											0
Electricity-S2	Electricity Loads	Electricity Monitoring Systems											0
Electricity-S3	Renewables	Reporting information regarding energy generation											0
Electricity-S4	Storage	Reporting information regarding stored electricity											0
EV-S1	EV Charging presence & capacity	Number of charging spaces											0
EV-S3	EV Charging - Grid	EV Charging Grid balancing											0
EV-S4	EV Charging - connectivity	EV charging information and connectivity											0
MC-S1	TBS interaction control	Interaction between TBS and/or BACS	0	100%		0%		None	Single platform that allows manual control of multiple TBS	Single platform that allows automated control & coordination between TBS	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals		1
MC-S2	Smart Grid Integration	Smart Grid Integration	0	100%		0%		None - No harmonization between grid and building energy systems; building is operated independently from the grid load	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting				1
MC-S3	Feedback - Reporting information	Central reporting of TBS performance and energy use	0	100%		0%		None	Real time indication of energy use per energy carrier	Real time indication of sub-metererd energy use or other performance metrics for at least 2 domains	Real time indication of sub-metererd energy use or other performance metrics for all main TBS		1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033744.