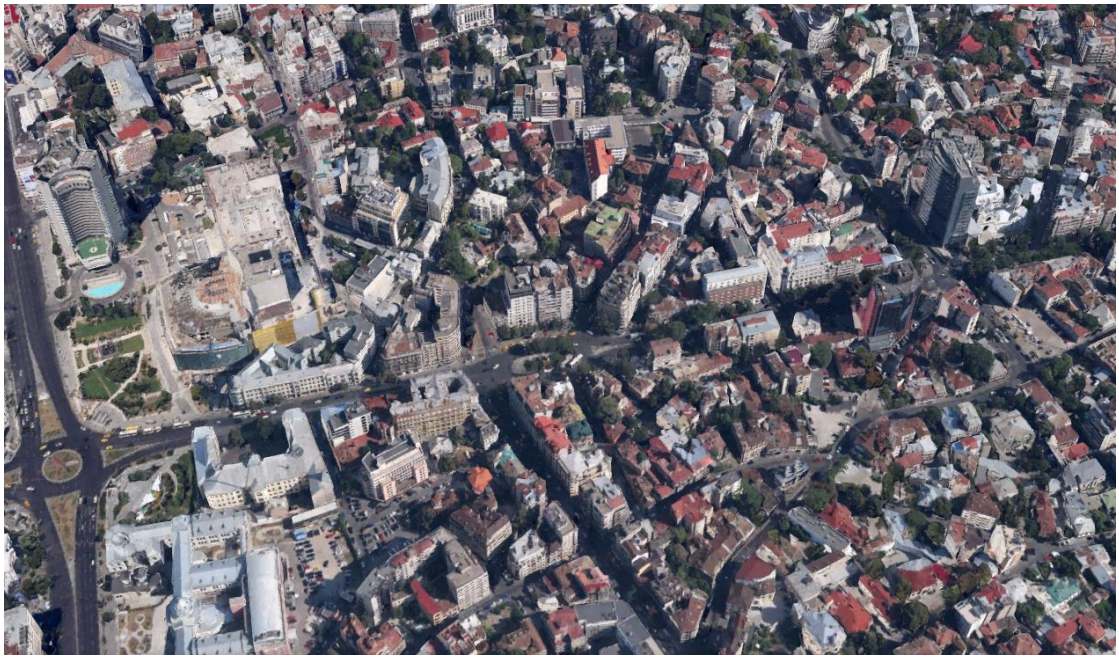
RePublic_ZEB
ZEROING IN ON ENERGY

Co-funded by the Intelligent Energy Europe Programme of the European Union

D2.1 REPORT ON THE PRELIMINARY ASSESSMENT OF PUBLIC BUILDING STOCK



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Project consortium

	BME	WP3 Leader
	BRE	WP6 Leader
	BSERC	WP2 Leader
	CRES	Partner
	CTI	WP1-WP7 Leader Coordination
	EIHP	Partner
	URBAN-INCERC	Partner
	IREC	Partner
	LNEG	WP5 Leader
	MACEF	Partner
	POLITO	WP 4 Leader
	ZRMK	Partner

Project overview

The RePublic_ZEB project is focused on the energy and CO_2 emissions associated with existing public buildings and their refurbishment towards nZEB.

The **core objective** of the project is to:

- Define costs-benefit optimized "packages of measures" based on efficient and quality-guaranteed technologies for the refurbishment of the public building stock towards nZEB that are standardized and adopted by builders and building owners.

From this stems three **basic objectives:**

(i) State-of-the-art assessment of the public building stock through a country-specific evaluation of the energy consumption and CO_2 emissions;

(ii) Define reference buildings; and;

(iii) Develop a common framework and a harmonized methodology for the definition of a nZEB concept for public buildings.

Acknowledgement

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CONTENTS

1. SUMMARY

This report represents the deliverable D2.1 of work package WP 2 (Analysis of the public building stock and definition of reference buildings) and presents key data concerning the general features and total energy consumption of public buildings in the countries or regions covered by the project consortium, with a view to define classes of buildings to be used as a basis for future project developments.

In the reporting countries, available data sources and the knowledge about the public building stock differ. In general, data from official statistics are fairly limited in the depth of their coverage. For this reason, further knowledge is generated through national and European projects, energy performance certificates and various energy efficiency studies, e.g. in the framework of consulting activities.

This report aims at collecting and analysing, as far as possible, the public building stocks in countries addressed in the RePublic_ZEB project, namely Bulgaria, Croatia, Former Yugoslav Republic of Macedonia, Greece, Hungary, Italy, Portugal, Romania, Slovenia, Spain (Catalonia Region) and United Kingdom. Starting from previous IEE projects as well as regional studies and bibliographies, each partner collected and analysed data concerning the general features and total energy consumption for heating, DHW, cooling and lighting referred to all types of public buildings.

In general, the analysis shows that the current state of knowledge of the European public building stock (and non-residential building stock in general), and current retrofit processes is not very well known. It is therefore important to gather more information about energy related characteristics of buildings, their quantities and the state of retrofit through further studies and surveys. Using existing available databases to analyse and evaluate energy certificates seems to be one promising approach.

First, in order to perform a co-ordinated analysis of the public building stock, a common methodology was defined, which included setting of necessary key information and considering challenges, the definition of building categories and sub-categories (taking into account potential compatibilities in participant countries), and the setting of an indicative list of information sources (with conditions to be satisfied). Furthermore, the main indicators for statistical analysis of the building stock were proposed and an indicative approach/methodology for defining reference buildings was recommended. The methodology is presented in chapter 2 and the indicative table structure for collecting public buildings stock data in each country is presented in the Annex to this report.

Based on the defined methodology, national data collected and processed for the 11 participant countries are presented in chapter 3 of this report, including and overall picture of the building stock, the structure of the public building stock by construction year, heating system, geometry (e.g., compactness ratio and number of floors), share of fuel type per building category, main thermal characteristics of the building envelope, energy performance indicators of public building stock per building category.

Chapter 4 summarises the main findings of the analysis. The results of the analysis serve to define classes of public buildings and selection of the most relevant ones. This was done through a country cross-comparison of processed data, enabling the identification of indicators to group buildings in different classes to which the same approach for the renovation/refurbishment can be applied (e.g. building use, size, energy performance). The buildings' energy saving potential was also considered. Finally, 2-3 classes per country are selected for further analysis.

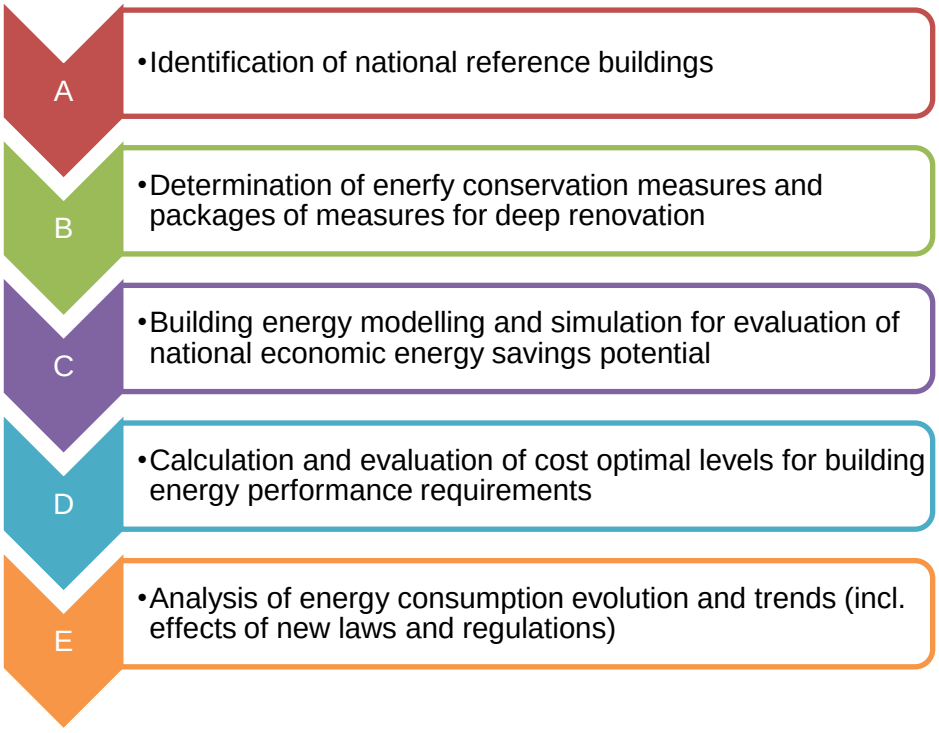
2. METHODOLOGY

2.1 Starting point

The current analysis was performed in the framework of WP2 focusing on data collection and statistical analysis concerning the general features and total energy consumption for heating, DHW, cooling and lighting of public building stocks in eleven countries, in order to define the state-of-the-art of energy performance. In this context, the starting point of the analysis was the collection of useful data from worldwide, European and Regional projects, publications and technical bibliography on this topic, with the aim to further define a set of reference buildings for each public building class considered. These will be used as prototype buildings in the analysis of the assessment of standardized and costs/benefits effective "packages of measures" fitted to the real refurbishment process

2.2 Methodology for performing of building stock analysis [57][1]

The building stock analysis is designed to collect and provide the necessary information for realisation of the following five step procedure:



Source: [57]

Several challenges should be considered when design a methodology for new building stock inventory:

- Existing data do not follow the classification of Annex I of EPBD.
- Definitions and terms – a common definition for all partner countries (using standardised definitions where available) would facilitate the comparison of data; incl. floor area, name of energy carriers etc.
- Collection of energy data can normally only be done at the level of delivered energy (by energy carrier), and not directly as energy performance (energy use) for heating, cooling,

[1] Excerpts from the study [57], in which Prof. Kaloyanov is co-author, are used in this chapter.

ventilation, domestic hot water preparation, lighting etc. (expert recalculations will be needed).

- Which are the important categories and subcategories, meaning floor area ratio of total building stock or ratio related to energy consumption? Most probably some sub-categories of buildings will have negligible influence on the final energy consumption, and this will normally be clear after at least the initial input of information has been entered into the building stock inventory.
- Climatic zones: diverse climatic zones for energy performance calculations might differ from the statistical regions used for data collection and categorisation.

The information needed just for the building stock inventory is less than what would be needed for the energy performance calculations (Reference building). The approach proposed is therefore to develop a two-step procedure:

- Collection and statistical analysis of data for the building stock. Identification of reference building/buildings for each building category;
- Additional information about energy calculations (reference building).

2.2.1 Building categories for building stock statistical analysis

The categorization of buildings should as a minimum cover the categories listed in Annex I of the EPBD. The following categories should be considered:

1. Residential (e.g. social housing, service housing, student/campus housing etc.);
2. Offices;
3. Education buildings;
4. Hospitals;
5. Hotels and restaurants;
6. Sports facilities;
7. Wholesale and retail trade services buildings;
8. Other types of energy-consuming buildings

When developing a building stock inventory, it is necessary to find a good balance between collecting enough information to support the purpose of the building stock inventory and reducing the efforts needed to collect and analyse the information.

In most countries, in existing or drafted building regulations, the building categorization is close or similar to what is used by EUROSTAT.

Therefore, the recommendation for categorization and sub-categorization of buildings in the building stock inventory is based on Annex I of the EPBD and EUROSTAT.

Consequently, the following categorization and sub-categorization is recommended for non-residential buildings (Table 1):

Table 1: Categorization of public buildings

Main category	Subcategory	Definition according to EUROSTAT
Offices	-	Buildings used as places of business, for clerical and administrative purposes, e.g. banks, post offices, municipal offices, government department offices, conference and congress centres, law courts, parliament buildings etc.
Educational	Kindergartens	Buildings used for pre-primary education.

Main category	Subcategory	Definition according to EUROSTAT
buildings	Schools	Buildings used for primary and secondary education (e.g. nursery schools, primary schools, secondary schools, colleges, grammar schools, technical schools etc.), formal education schools, vocational training schools.
	Universities/High schools	Buildings used for higher education and research; research laboratories; higher educational establishments.
Health care facilities	Hospitals	Institutions providing medical and surgical treatment and nursing care for ill or injured people. University hospitals, hospitals of penitentiaries, prisons or armed forces.
	Other institutional care buildings	Sanatoria, long-stay hospitals and nursing homes, psychiatric hospitals, dispensaries, maternity facilities, maternal and child welfare centres. Institutional buildings with combined residential/lodging services and nursing or medical care for the elderly, for handicapped people etc. Buildings used for thermal treatment, therapy, functional rehabilitation, blood transfusion, breast milk collection, veterinary treatment etc.
Hotels and restaurants	Hotels	Hotels, motels, inns, pensions and similar lodging buildings, with or without restaurants, detached restaurants and bars.
	Other short-stay accommodation buildings	Youth hostels, mountain refuges, children's or family holiday camps, vacation bungalows, holiday and rest homes, other lodging buildings for holiday makers, not elsewhere classified.
Sport facilities	-	Buildings used for indoor sports (basketball and tennis courts, swimming pools, gymnastic halls, skating or ice-hockey rinks etc.) providing facilities for spectators (stands, terraces etc.) and for participants (shower and changing rooms etc.)
Wholesale and retail trade service buildings	-	Shopping centres, shopping malls, department stores, detached shops and boutiques, halls used for fairs, auctions and exhibitions, indoor markets, service stations etc.
Other types of energy consuming buildings	-	The following building types defined in EUROSTAT, and can thus be considered: ○ Buildings and installations of civil and military airports, rail stations, bus stations and harbour terminals, cable car and chairlift stations. ○ Radio and television broadcast buildings, telephone exchange buildings, telecommunication centres etc. ○ Garages (over- or underground) and roofed car parks. ○ Industrial buildings. ○ Cinemas, concert halls, opera houses, theatres etc. ○ Meeting halls and multi-purpose halls mainly used for public entertainment. ○ Casinos, circuses, music halls, dance-halls and discotheques, bandstands etc. ○ Museums, art galleries, libraries and resource centres. ○ Farm buildings and storage buildings used for agriculture farming, e.g. cowsheds, stables, pig

Main category	Subcategory	Definition according to EUROSTAT
		○ houses, sheep-folds, studs, kennels, industrial hen-houses, granaries, hangars and agricultural outhouses, cellars, wine making plant, wine vats, greenhouses, agricultural silos etc. ○ Churches, chapels, mosques, synagogues. ○ Historic or protected buildings, of any kind, not used for other purposes. ○ Penitentiaries, prisons and remand centres, barracks for armed forces, police or fire services

For reporting and comparison purposes, it could be useful if all the partners are using the same building categorization in their national building stock inventory. There might be a need for differentiation at the level of sub-categories, but reporting on the main building category level could be maintained.

Indicative list of information sources

- Odyssee (http://www.odyssee-mure.eu/) Building stock (by type, sector and fuel), floor areas, energy use, consumption of buildings by fuel, energy consumption indicators (e.g. space heating unit consumption)
- BPIE Data Hub (http://www.buildingsdata.eu/) BPIE data hub for the energy performance of buildings mainly used in building stocks
- TABULA IEE Project (http://www.building-typology.eu/) National building typologies from TABULA have been use for the following countries: Belgium; Czech Rep.; Denmark; Spain; France; Italy, Poland and Slovenia
- EUROSTAT (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/) Ownership & tenure according to income class and to age of occupant
- Statistical offices in each country (e.g. for Romania The National Institute of Statistics, http://www.insse.ro/cms/)
- ENTRANZE IEE Project (http://www.entranze.eu/publications/, http://www.entranze.eu/tools/interactive-data-tool)
- BUILD UP Skills National Status Quo reports (http://www.buildupskills.eu/en/national_projects) – downloadable in English on the page of each national project
- National/Regional EPC Databases

2.2.2 Indicators for statistical analysis

The following main indicators for statistical analysis of the building stock are proposed:

- Total floor area (built-up area), m² (defined by outer dimensions),
- Total useful conditioned floor area (heated and/or cooled), m² (defined by internal / overall / outer dimensions – please specify),
- Land area occupied by the building(s), m²
- Compactness ratio/factor (area of the exterior walls/building gross volume),
- Number of (above ground) floors (including Ground-floor),
- Type of building construction (as defined at national level),

- Age (year of construction / commissioning),
- Building energy services/uses (e.g. heating, cooling, mechanical ventilation, DHW, artificial lighting),
- Type of heating/cooling system,
- Climatic zone,
- Energy performance (split by energy carrier).

(proposed structured table in Public-Building-Stock_Data.xls file, presented in Annex)

2.2.3 Main parameters of the statistical analysis

The following main parameters will be included in the statistical analysis:

- Total number of public buildings,
- Number of buildings in the category,
- Total conditioned area of all buildings,
- Relative share of the conditioned area of the buildings from a given category of the total conditioned area of the public buildings,
- Relative share of the number conditioned area of the buildings in a given sub-category of the total number/total conditioned area for the category,
- Average energy performance in the category.

The results of the derived classification with regard to the distribution of the different building categories should lead to the definition of major categories/sub-categories for a follow-up analysis (share of sub-categories in the total balance of public buildings).

For each major building category/sub-category statistical analysis is performed using the proposed main indicators. Median value is identified for each of the indicators and reference value/values should be proposed.

A very important part of this process is the realistic assessment and choice of the expedient necessary number of reference buildings for each category/sub-category. This number shall be defined as an optimal number:

$$n_{opt} \in \{n_{min}; n_{max}\}$$

where:

n_{min} - minimum number of reference buildings defined for the needs of the assessment of the economic feasibility, focussing on the renovation of existing buildings (but could include also the construction of new buildings). Furthermore, it is defined as a minimum requirement according to Annex I to the EU Delegated Regulation No.244/2012 – at least two existing buildings (and one new building) for each building category,

n_{max} - maximum number of reference buildings. In practice, it is equal to the number of all buildings in the category/subcategory.

Moving from lower to upper limit is concerned both with the increase of the necessary volume of calculations in geometric progression, and with occurrence of significant subsequent difficulties in summing up the results, formulating of multitude scales of energy consumption classes and the following practical use of the assessment of conformity with energy efficiency.

In order to make a reliable classification according to the proposed indicators, the following consistent steps should be taken:

1. Identification of the existing building stock in the country alternative and complementary data bases for the attainment of the goals;
2. Investigation and verification of the identified data-bases for the quality and reliability of information;
3. Adoption of indicators and criteria for formulation of multitude data regarding buildings of the different sub-categories;
4. Hierarchical processing of data for identification of reference groups and reference buildings.

2.2.4 Principles to be followed while choosing information sources

The information sources have to satisfy the following conditions:

- regular provision of data, data maintenance and level of updating in a reasonable time horizon;
- consistency and relevancy of data classification with the national approach for defining building types in the partner's country;
- possibilities for horizontal and vertical sections of multitude data, selected by specific characteristics for the needs of the analysis;
- availability of up to date information;
- possibility to use the data for defining of "base scenario";
- flexibility of data bases from one source to combine and/or supplement data bases of other source for the needs of the analysis;
- accessible data processing for analysis purposes.

2.2.5 Recommended approach/methodology for defining reference buildings

The output of the current analysis should permit the identification of buildings categories with the largest share in each country and the selection of 2-3 representative categories per country. Furthermore, based on the results of the current analysis, the representative buildings will be detailed in order to permit simulation analysis of the energy performances in current state and with the application of the defined set of technical solutions for building renovation.

The reference buildings will be used for at least three purposes:

- Evaluation/calculation of cost-optimal levels for energy performance requirements;
- Proposal of improved minimum energy performance requirements;
- Evaluation/calculation of the national economic energy savings potential.

The main purpose of a reference building is to represent the typical and average building stock in a certain country, since it is impossible to calculate the cost-optimal situation for every individual building. Hence, the reference buildings established ought to reflect as accurately as possible the actual national building stock so that the methodology can deliver representative calculation results.

As sufficient information to prepare such reference buildings is lacking, the development of reference buildings should be done in two steps:

- Define first version of reference buildings based on existing information and expert evaluations;
- Develop the reference buildings based on information collected in the new building stock inventory (and information from energy certification).

A reference building will be defined by its:

- Geometry, including window area, and orientation;
- Thermal properties;
- Occupant behaviour;

- Technical systems/installations;
- Operational pattern;
- Energy carriers used.

There is an indefinite number of combinations in the existing buildings stock, and no "correct average" exists.

Regarding building geometry, we recommend creating a typical reference building for each building category (virtual/notional building) – typical in the sense of size, number of floors and compactness.

It might be useful to have 2-3 reference geometries (sub-categories) for some of the most important building categories (depending on the purpose of the use of the reference buildings, important related mainly to share of the countries building stock/energy consumption).

Such reference geometries should be developed by experts based on their knowledge of the building stock, e.g.:

- existing building stock inventories or statistics;
- design documentation (of typical buildings constructed some years ago);
- energy audit reports;
- pilot projects (with input data for calculations available);
- projects within international donor programmes; and
- data collected in the energy performance certification schemes (if applicable).

If only one reference building for a building category is being developed, the area should be close to the average building area for this building category obtained from statistics/inventories including form factor close to the median.

For each building geometry, several sets of input values can be defined and variations evaluated (sensitivity analysis) to find the yearly results in kWh/m^2, depending on the purpose of the calculations.

Several of these input data can be collected for existing and previous building regulations and norms, and from the same sources as listed above for the defining the building geometry.

When evaluating and defining typical or average input values, it is necessary to define what will be the baseline. Related to indoor climate and operation of technical systems and installations, should the baseline be based on the actual situation or normalised? If the "actual" is the preferred approach, maybe a "mixture" should be used, assuming that the operation will be more normalised as the living standard and national economy is developing.

Regarding for instance defining the thermal properties, several approaches are possible. As the building stock will be divided into groups based on years of construction, which for instance could follow the periods for changes in building regulations (or other changes of importance for the assessments to be done), the corresponding U-value requirements are specified. For each building category, reference buildings could be defined with U-values for each of these time periods.

For some building categories, there could be one reference building using the resulting average U values.

3. COUNTRY DATA

3.1 BULGARIA

3.1.1 Overall picture of the building stock in Bulgaria

The available data base of public buildings, which can be used for classification and ex-post selection of reference buildings by categories, has been maintained by the Sustainable Energy Development Agency (SEDA).

The data base includes buildings with heated/cooled area equal to or larger than 1000 m^2, subject to obligatory certification by March 2013.

During the second half of 2013, following the enacted in March 2013 amendments to the Energy Efficiency Act and in line with the provisions of the Directive 2010/32/EC, the data base has been updated and already includes information regarding buildings with heated/cooled area above 250 m^2.

For the goals of the current project, the existing data base of buildings with heated/cooled area above 1000 m^2 has been used.

4611 buildings have been analysed with total built-up area of 18 258 445 m^2 and total heated/cooled area of 17 779 923 m^2.

Figure BG 1 depicts the distribution of the analysed buildings by total built-up floor area.

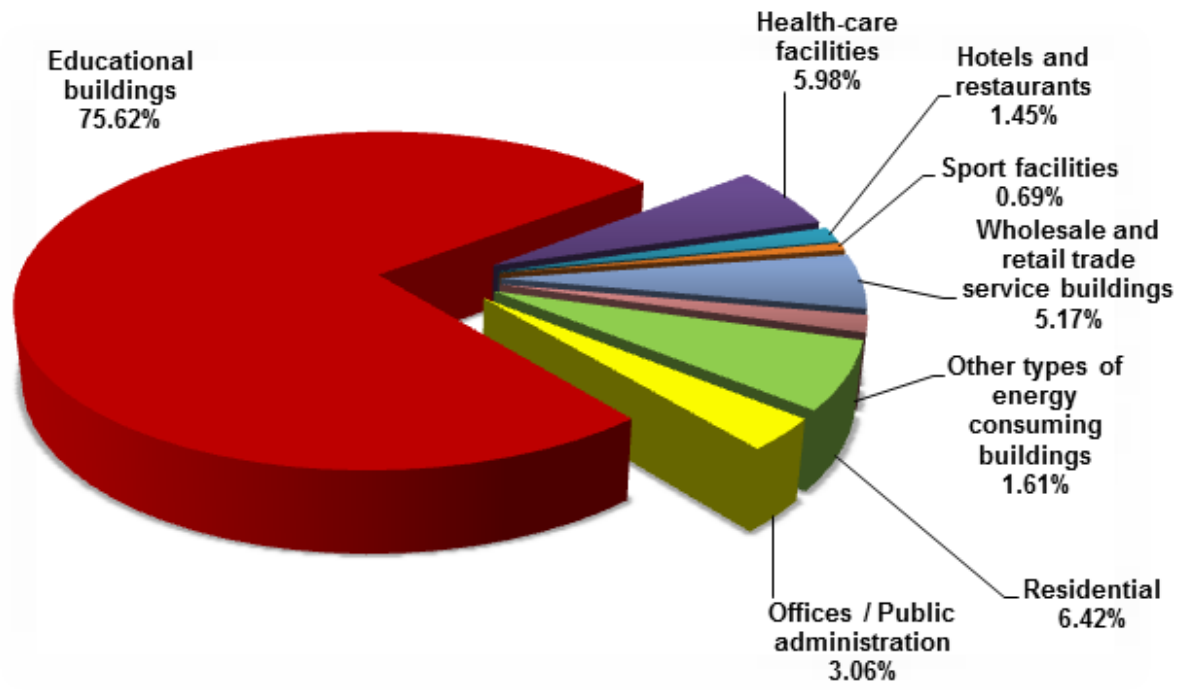


Figure BG 1: Structure of the public building stock registered for energy certification
(Source: Sustainable Energy Development Agency)

3.1.2 Public building stock data

Table BG 1 contains parameters of the main building categories and sub-categories, given in the analysed data-base.

Table BG 1

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	Residential	193	1 172 546	1 169 909
1.1	Social housing	0	0	0
1.2	Service housing	18	63 837	61 200
1.3	Student housing	175	1 108 709	1 108 709
2	Offices / Public administration	211	558 347	551 290
2.1	Central Authorities	211	558 347	551 290
2.2	Regional Local Authorities	0	0	0
3	Educational buildings	3617	13 806 933	13 398 225
3.1	Kindergartens	1014	1 916 912	1 889 405
3.2	Schools	2173	8 030 020	7 708 820
3.3	Universities/ High schools	430	386 000	3 800 000
4	Health-care facilities	321	1 091 229	1 063 100
4.1	Hospitals	207	851 829	834 500
4.2	Other institutional care	114	239 400	228 600
5	Hotels and restaurants	26	265 000	243 000
5.1	Hotels	26	265 000	243 000
5.2	Other short-stay accommodation buildings	0	0	0
6	Sport facilities	54	126 800	122 000
7	Wholesale and retail trade service buildings	32	944 000	941 000
8	Other types of energy consuming buildings	157	293 590	291 400
	Without detailed data	0	0	0
1	**TOTAL**	**4 611**	**18 258 445**	**17 779 924**

The share of building structure of the buildings (masonry walls, concrete frames and masonry walls, large prefabricated panels etc.) is illustrated in Figure BG 2.

The distribution of the building stock by age band, based on construction year or major rehabilitation year, is presented in Figure BG 3.

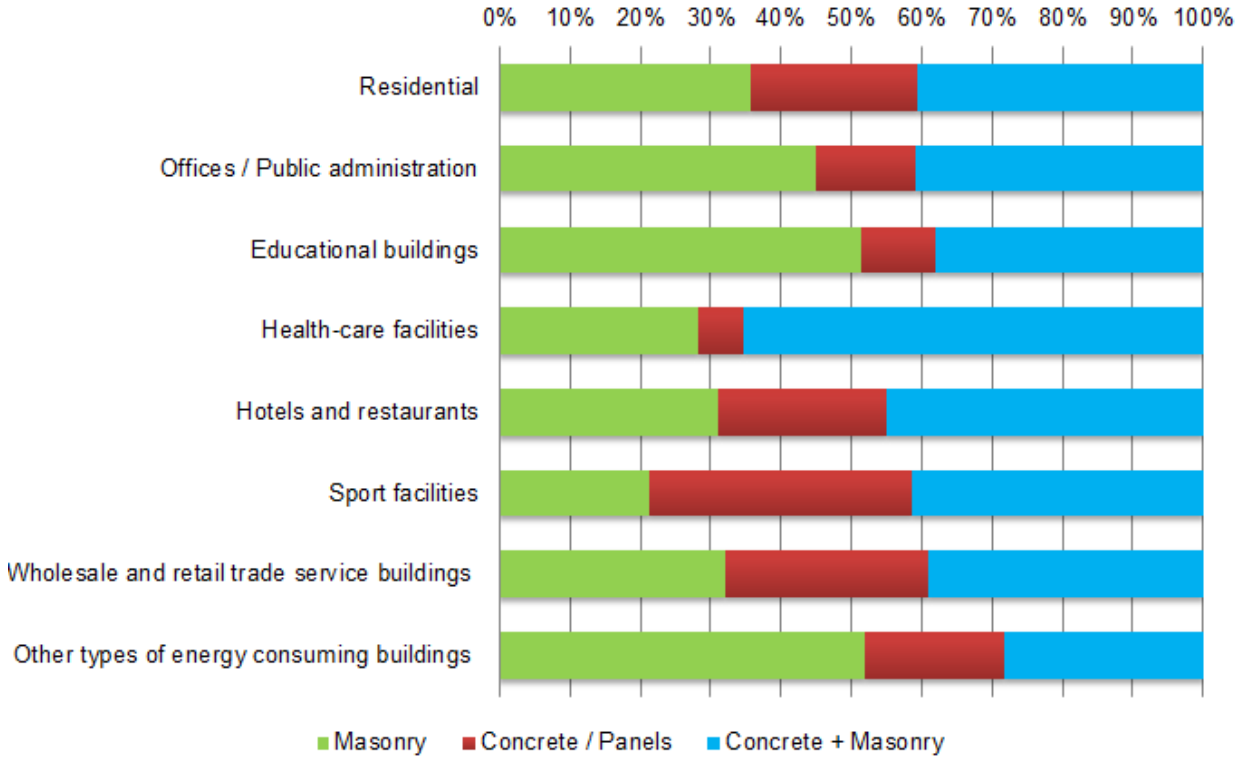


Figure BG 2: Structure of public building stock
(Source: SEDA)

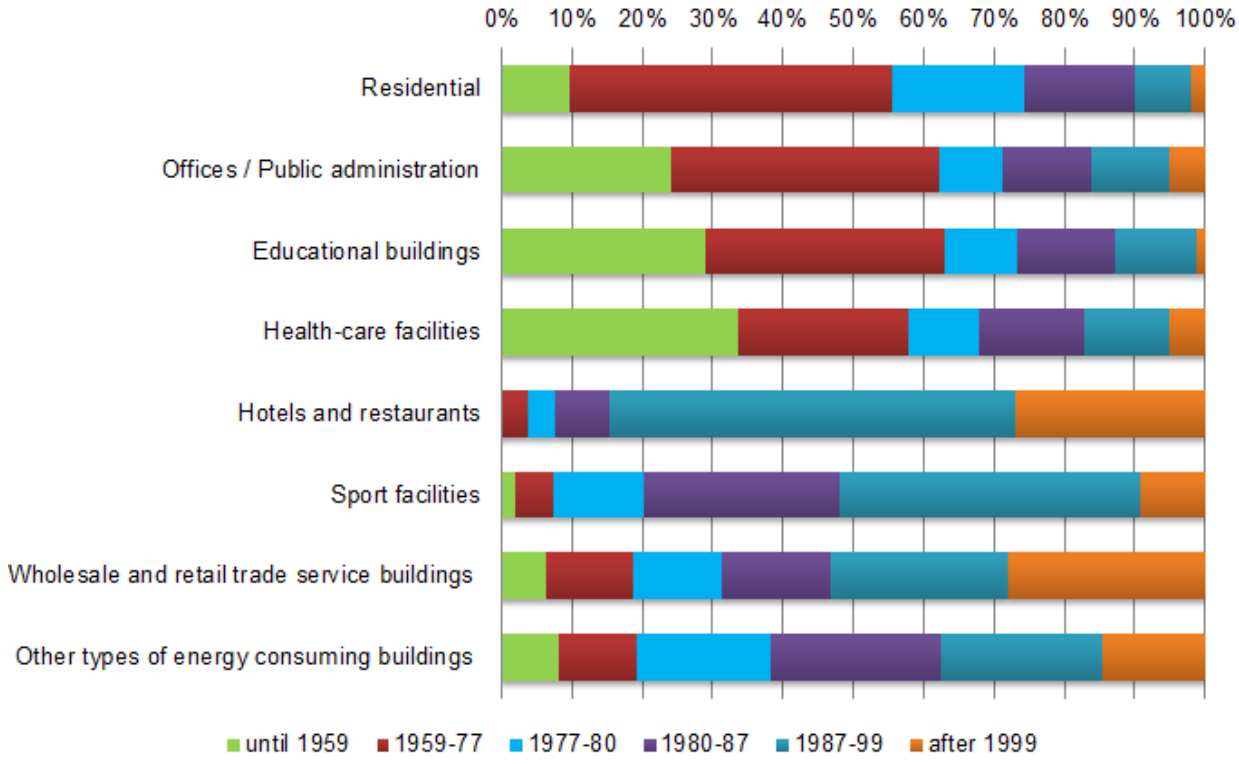


Figure BG 3: The public building stock by construction year
(Source: SEDA)

The ratio of building envelope area to building volume (compactness ratio), which influences the heating and cooling need of a building, was estimated for each building category based on the number of floors above ground (including Ground-floor), built-in area occupied by the building (area at ground level) and total constructed area of the building. The shape characteristics are presented in Table BG 2.

Table BG 2

No.	Category / sub-category	Compactness ratio [m^{-1}]	Number of (above ground) floors (including Ground-floor)
1	Residential	0,20	4,58
2	Offices / Public admin.	0,30	4,30
3	Education	0,34	3,23
4	Health-care facilities	0,35	4,13
5	Hotels & restaurants	0,32	4,10
6	Sport facilities	0,30	1,80
7	Commercial	0,11	2,30
8	Other types	0,36	2,10

(Source: SEDA)

The heating system of the building stock is predominantly central heating, connected to district heating or to a heating plant in or nearby the building. The heating system type per building category is presented in Figure BG 4.

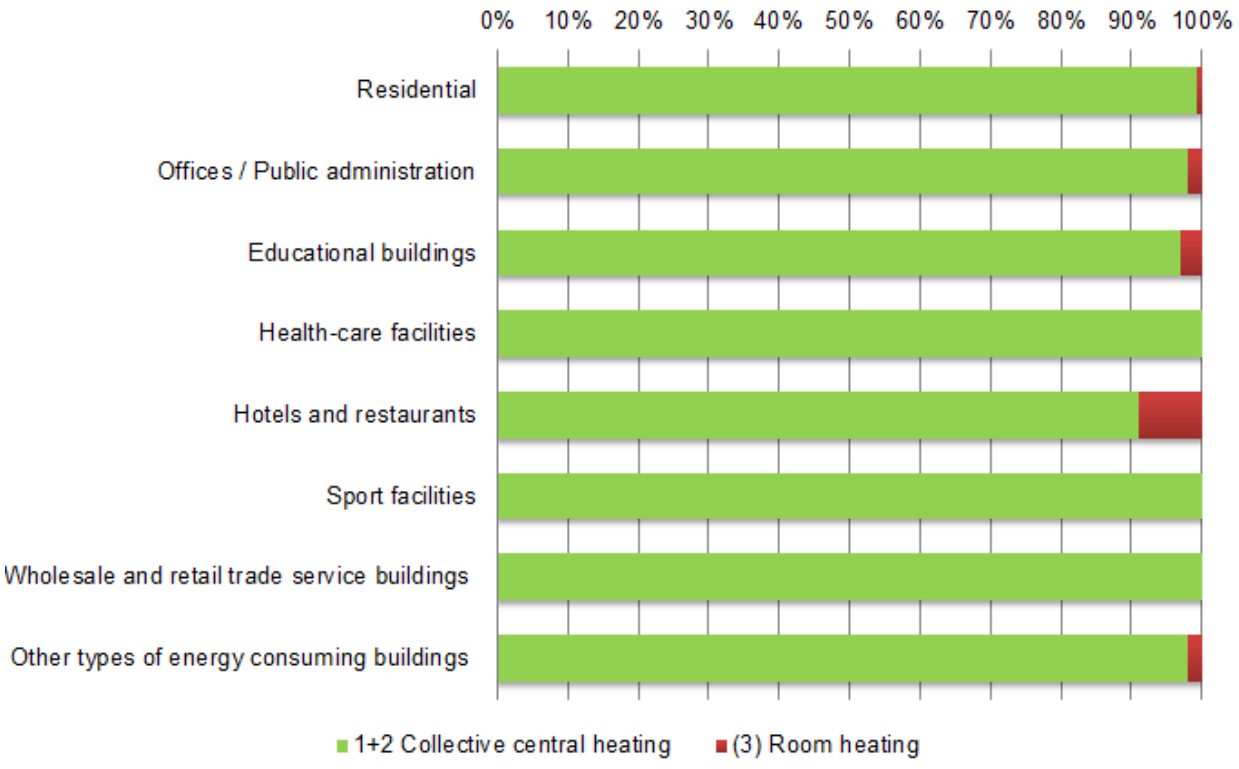


Figure BG 4: Heating system in the public buildings

(Source: SEDA)

The fuel type used for heating and DHW generation is presented in Figure BG 5.

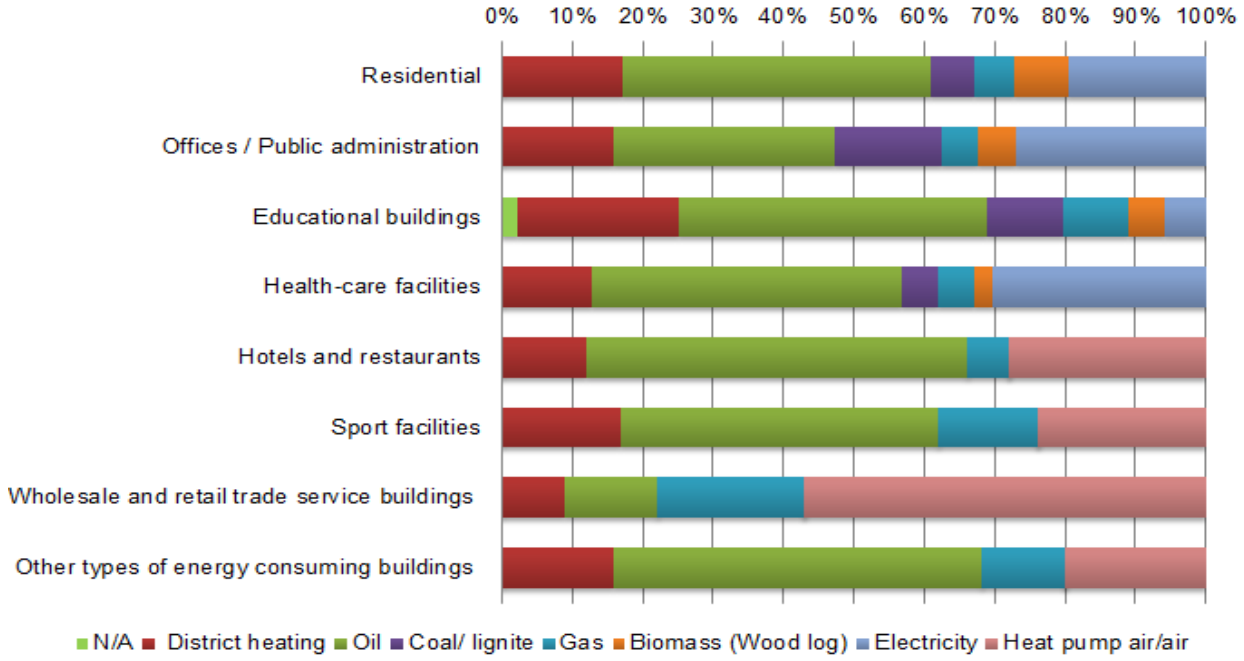


Figure BG 5: Share of fuel type per building category – public building stock
(Source: SEDA)

Regarding the energy performance of existing public building stock, Table BG 3 presents the main thermal characteristics of the building envelope as defined in the national ordinances for the reference year 1999.

Table BG 3

No	Category/ Subcategory	Reference values – baseline year 1999			
		Wall, W/m2K	Roof, W/m2K	Floor, W/m2K	Windows, W/m2K
1	Residential	0,50	0,30	0,2	2,65
2	Offices/Public administration	0,50	0,30	0,2	2,65
3	Educational buildings	0,50	0,30	0,2	2,65
4	Health care facilities	0,50	0,30	0,2	2,65
5	Hotels and restaurants	0,50	0,30	0,2	2,65
6	Sporting facilities	0,50	0,30	0,2	2,65
7	Wholesale and retail selling buildings	0,50	0,30	0,2	2,65
8	Other types of energy consuming buildings	0,50	0,30	0,2	2,65

(Source: SEDA)

3.1.3 Energy performance of public building stock (EPC Database)

Based on the classification of the building stock, several representative (reference) buildings have been selected/generated. They have been modelled and the energy consumption simulated by applying the monthly energy balance methodology described in BDS EN ISO 13790.

The energy performance of the reference buildings, expressed as specific final energy consumption is shown on Figure BG 6.

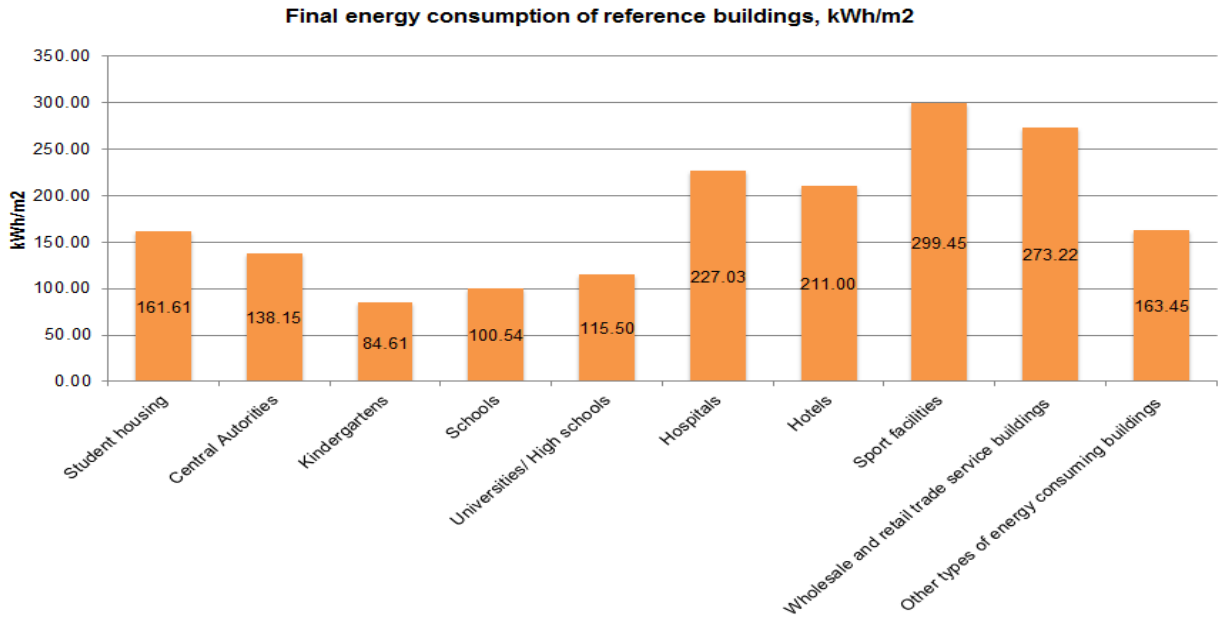


Figure BG 6: Final energy consumption in the reference buildings
(Source: SEDA, TU-Sofia)

Figure BG 7 presents the share of energy consumption for the main energy consuming technologies in the reference buildings.

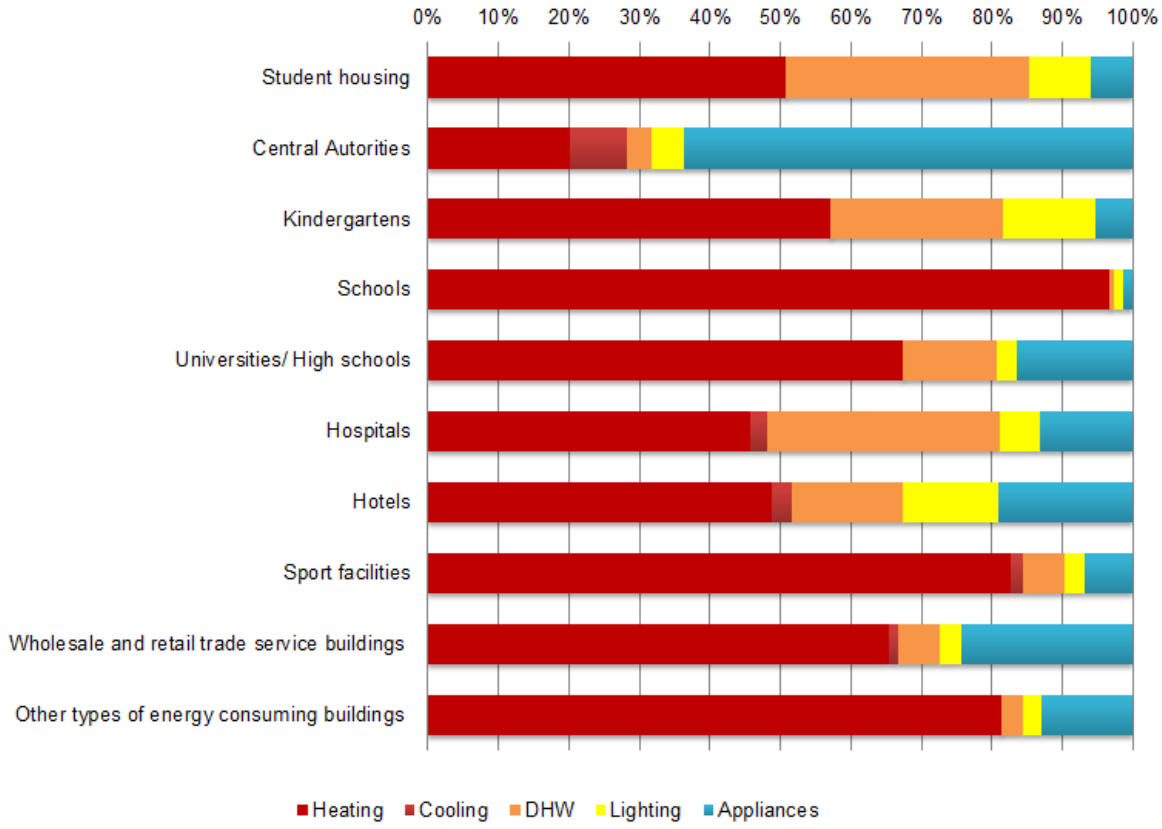


Figure BG 7: Share of the energy consumption in the reference buildings
(Source: SEDA, TU-Sofia)

3.2 CROATIA

3.2.1 Overall picture of the building stock in Croatia

The Database of public buildings owned by central government is run by the government Agency for Transactions and Mediation in Immovable Properties. The Database is incomplete in terms of building properties, so for the purpose of this project information has been combined with reference buildings data which covers the entire building stock in Croatia.

Several limitations in application of reference buildings data apply: due to the very large range of building properties because of climate differences (coastal to continental Croatia) average values for the entire building stock cannot be used. Instead, the reference public building stock is represented by the continental building stock constructed between 1971 and 2005 – the period of the highest construction rate in Croatia, and these buildings are the most representative of the stock today. The older stock might not be well represented as many heritage buildings are in the pre 1971 stock).

Further, information on the energy consumption and energy carriers for reference buildings doesn't give the distribution of energy carriers in the total stock energy consumption, but most significant energy carriers for each building use.

Sub-categories of the buildings within the database are not identified – and information can be accessed only at the top level, i.e. the major building categories.

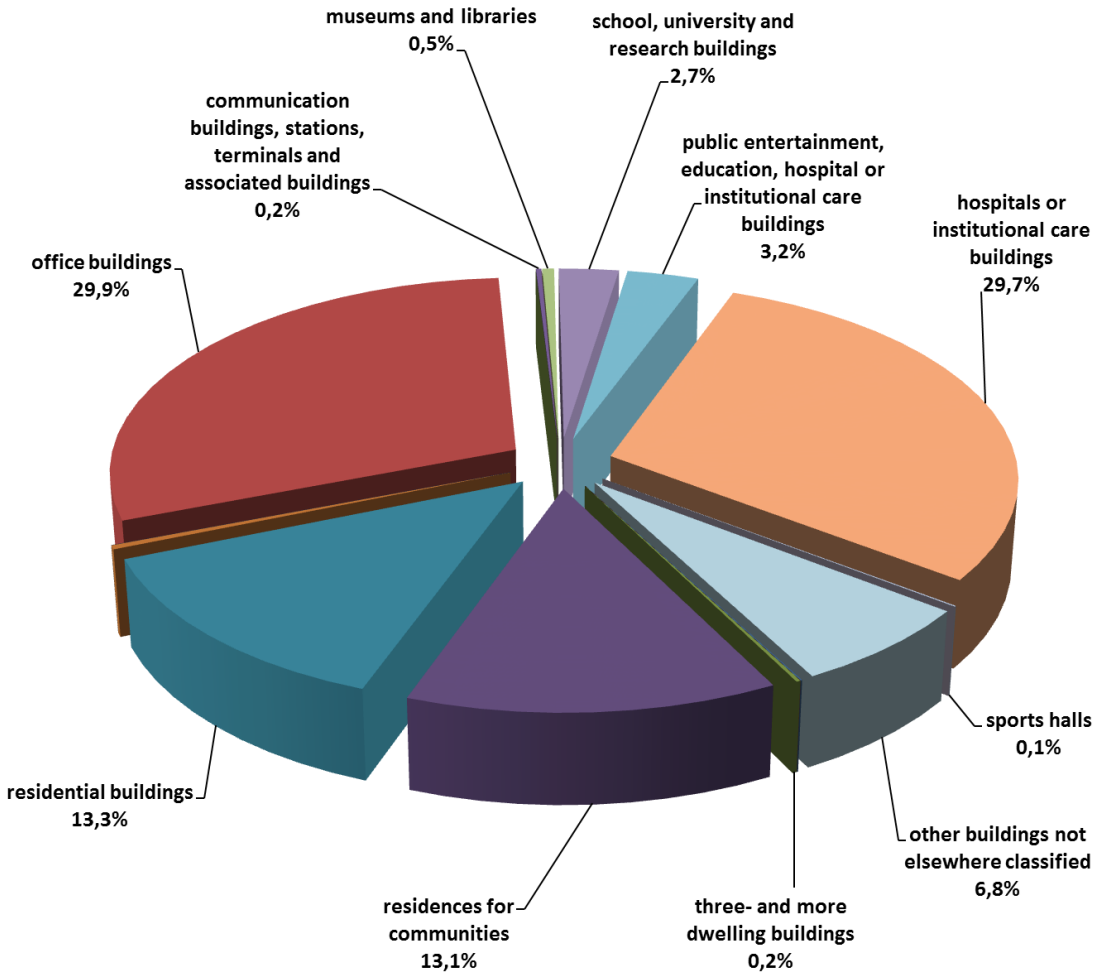


Figure CR 1: Structure of the public building stock database

3.2.2 Public building stock data

Table CR 1 contains parameters of the main building categories and sub-categories, given in the analysed database.

Table CR 1: Structure of the public building stock

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m² of heated building part	Total useful conditioned floor area (heated and/or cooled), m²
1	**Residential**	**173**	**249 298**	**211 269**
1.1	Social housing			
1.2	Service housing			
1.3	Student housing			
2	**Offices / Public administration**	**260**	**559 554**	**474 198**
2.1	Central Autorities			
2.2	Regional Local Authorities			
3	**Educational buildings**	**25**	**49 799**	**42 203**
3.1	Kindergartens			
3.2	Schools			
3.3	Universities/ High schools			
4	**Health-care facilities**	**178**	**555 598**	**470 845**
4.1	Hospitals			
4.2	Other institutional care			
5	**Hotels and restaurants**	**5**	**6 017**	**5 099**
5.1	Hotels			
5.2	Other short-stay accommodation buildings			
6	**Sport facilities**	**1**	**1 290**	**1 093**
7	**Wholesale and retail trade service buildings**			
8	**Other types of energy consuming buildings**	**126**	**132 421**	**112 221**
1	**TOTAL**	**768**	**1 553 976**	**1 316 929**

The majority of the public buildings were constructed in the period 1971 – 2005. The distribution of fuel type per building category – public building stock is presented in Figure CR 2.

3.2.3 Energy performance of public building stock (EPC Database)

Based on the classification of the building stock, several representative (reference) buildings have been selected/generated. They have been modelled and the energy consumption simulated by applying the monthly energy balance methodology described in BDS EN ISO 13790.

The energy performance of the reference buildings, expressed as specific final energy consumption is shown in Figure CR 3.

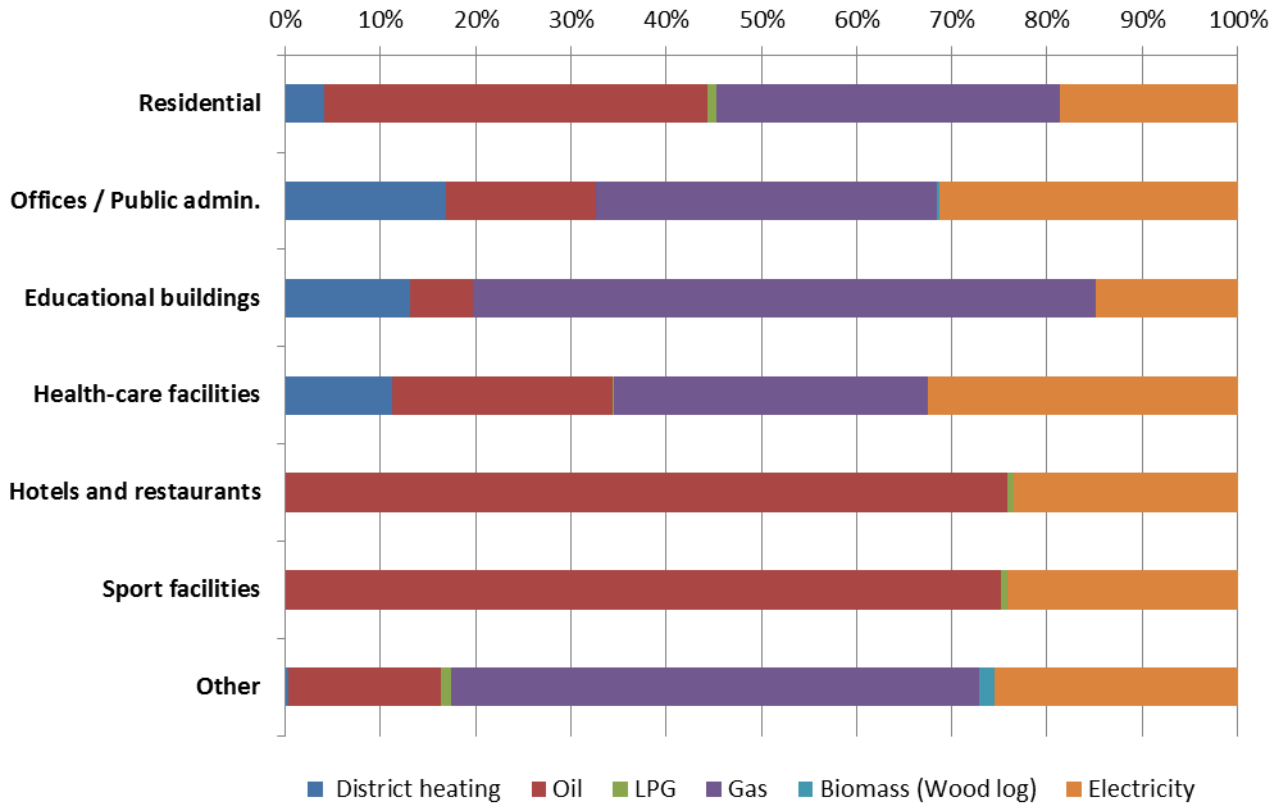


Figure CR 2: Share of fuel type per building category – public building stock

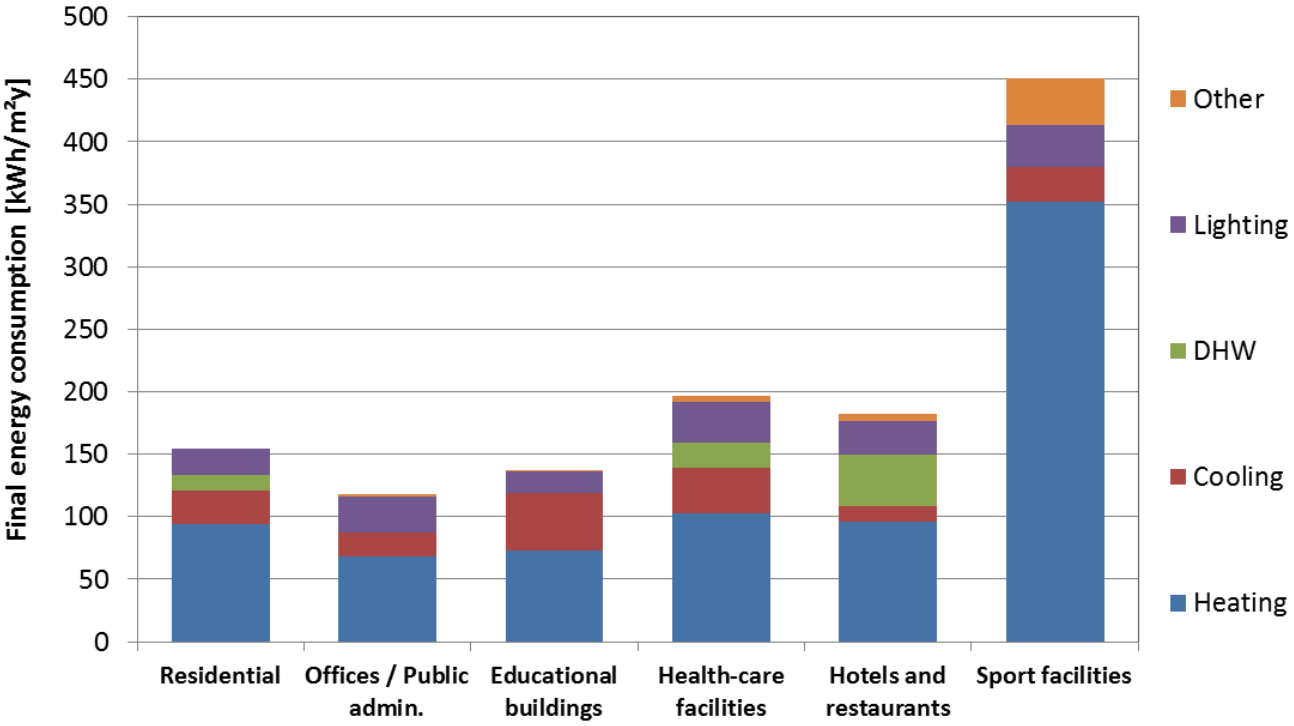


Figure CR 3: Energy performance of the public building stock

3.3 GREECE

3.3.1 Overall picture of the building stock in Greece

The available data base of public buildings, which can be used for classification and ex-post selection of reference buildings by categories, has been maintained by the National Statistical Service of Greece.

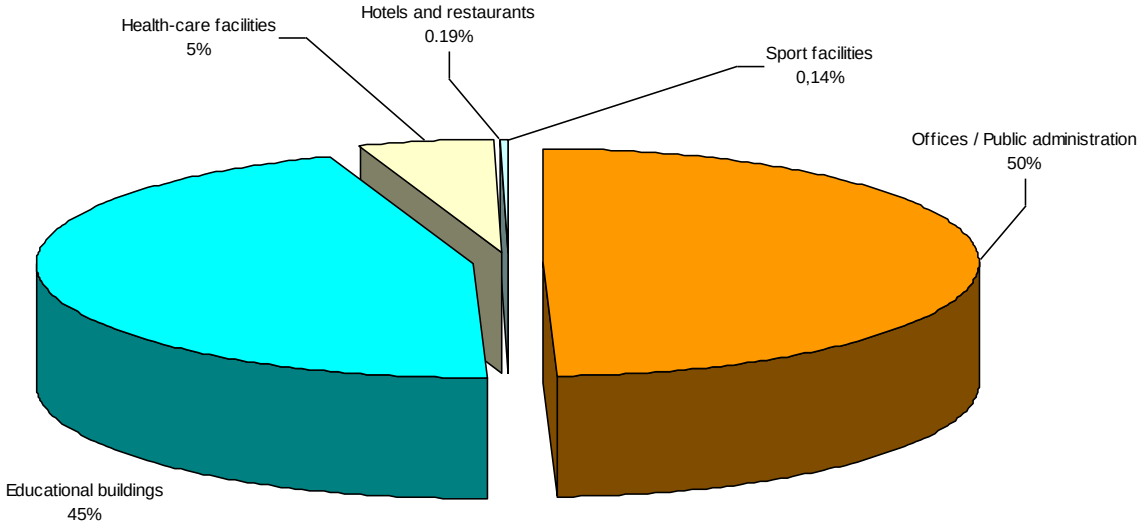


Figure GR 1: Structure of the public non-residential building stock registered for energy certification

It is noticed that 46 190 residences (of a total amount of 5 476 162 residences in Greece) are owned by central or local authorities (as presented in Table GR-1) and are rented as households. As a result, these data are not included in Figure GR 1, considering their non-public use.

3.3.2 Public building stock data

Table GR 1 contains parameters of the main building categories and sub-categories, given in the analysed data-base.

It is noticed that the total useful conditioned floor area of "Educational Buildings" and "Health care facilities" is assumed equal with the total floor area.

Table GR 1: Public building stock data

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	**Residential**	**46 190**	data not available	data not available
1.1	Social housing	46 190		
1.2	Service housing			
1.3	Student housing			
2	**Offices / Public administration**	**15 682**	**4 709 200**	**4 709 200**
2.1	Central Autorities	82	310 000	310 000
2.2	Regional Local Authorities	15 600	4 399 200	4 399 200
3	**Educational buildings**	**14 446**	**10 772 913**	**10 772 913**
3.1	Kindergartens	5 489	1 093 707	data not available

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
3.2	Schools	8 957	9 679 206	data not available
3.3	Universities/ High schools	data not available	data not available	data not available
4	**Health-care facilities**	**1 566**	**4 979 169**	**4 979 169**
4.1	Hospitals	314	900 000	data not available
4.2	Other institutional care	1 252	4 079 169	data not available
5	**Hotels and restaurants**	**61**	**data not available**	**data not available**
5.1	Hotels	31	data not available	data not available
5.2	Other short-stay accommodation buildings	30	data not available	data not available
6	**Sport facilities**	**44**	**124 498**	**112 838**
7	**Wholesale and retail trade service buildings**	**0**	**0**	**0**
8	**Other types of energy consuming buildings**	**0**	**0**	**0**
1	**TOTAL**	**31 799**	**20 585 780**	**20 574 120**

Regarding the total floor area (built-up area) of buildings owned from local authorities, the "Hellenic Agency for Local Development and local government SA" presents a categorization of buildings as described in the table below:

Table GR 2: Buildings owned by local authorities in Greece

percentage of buildings	range of area (m^2)	average area (m^2) (CRES assumption)	number of buildings	average total area of buildings (m^2)
42%	<100	75	6 552	491 400
27%	100-200	150	4 212	631 800
27%	200-1 000	600	4 212	2 527 200
4%	>1 000	1 200	624	748 800
			15 600	**4 399 200**

Regarding the sport facilities, the total building area is the count of the building facilities' areas of "Olympic Assets" and the building facilities' areas of national basketball courts, gymnastic halls, and swimming pools.

The total number of Sport facilities buildings is 44 and is presented in the table below:

Table GR 3: Sport facilities in Greece

	Number of buildings	Total floor area	Total useful condition floor area heated or cooled, m^2
Olympic Assets	3*	77037	77037
Basketball courts, gymnastic halls	31*	24900	13240
Swimming pools	10	22561	22561
Total	44	124498	112838

* Building complex

According to the information provided from "Public Properties Company", there are 31 public hotels and 30 short stay accommodation buildings.

The distribution of the building structure for the whole building stock of 3 990 970 buildings in Greece is illustrated in Figure GR 2.

(There are not available data for each category of buildings)

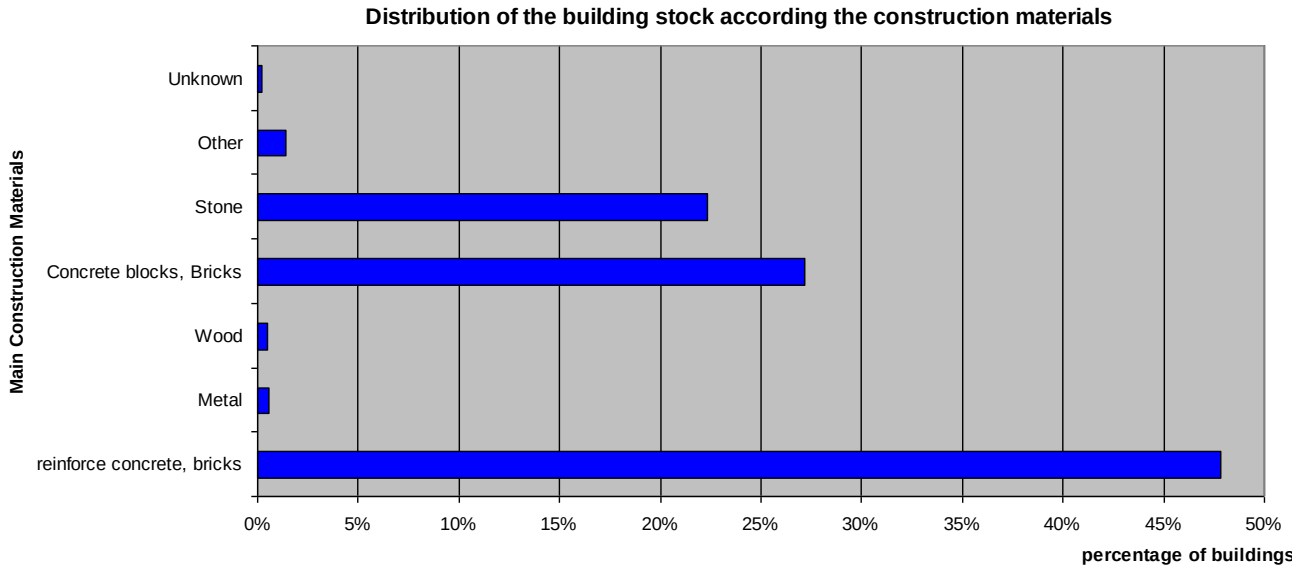


Figure GR 2: Structure of public building stock
(Source: [25], Hellenic Statistical Authority, http://www.statistics.gr/portal/page/portal/ESYE)

The distribution of the building stock by age band, based on construction year or major rehabilitation year, is presented in Figure GR 3.

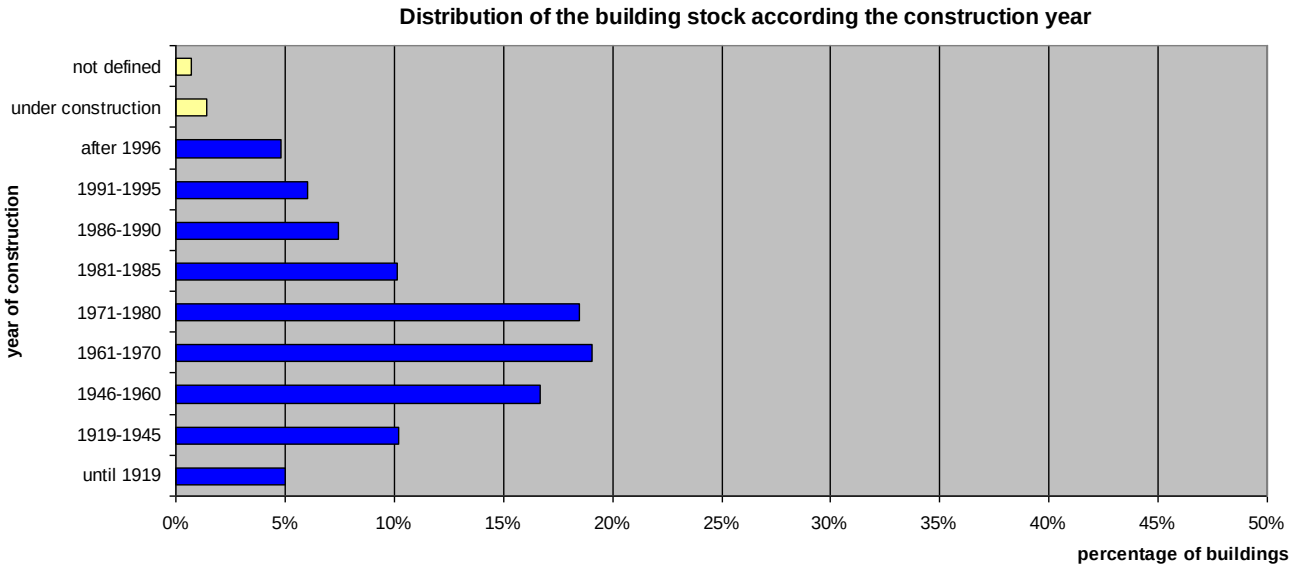


Figure GR 3: The public building stock by year of construction
(Source: [25], Hellenic Statistical Authority, http://www.statistics.gr/portal/page/portal/ESYE)

The heating system of the building stock is predominantly central heating. The fuel used for space heating and DHW generation is predominantly diesel, while for cooling is electricity.

Table GR 4 and Table GR 5 present the minimum requirements (max U values) for the building components and the whole building envelope respectively as defined in the Greek Regulation of Energy Performance of Buildings (KENAK).

Table GR 4: Maximum permissible U-values (W/(m2.K) of building components

	Climatic zone			
	A	B	C	D
Roof	0,50	0,45	0,40	0,35
External wall(*)	0,60	0,50	0,45	0,40
External floor	0,50	0,45	0,40	0,35
Floor over ground	1,20	0,90	0,75	0,70
External wall in contact with the ground	1,5	1,00	0,80	0,70
Opening(*)	3,20	3,00	2,80	2,60
Glass facade	2,20	2,00	1,80	1,80

(*) Not applied to passive systems except the 'direct solar gain' system

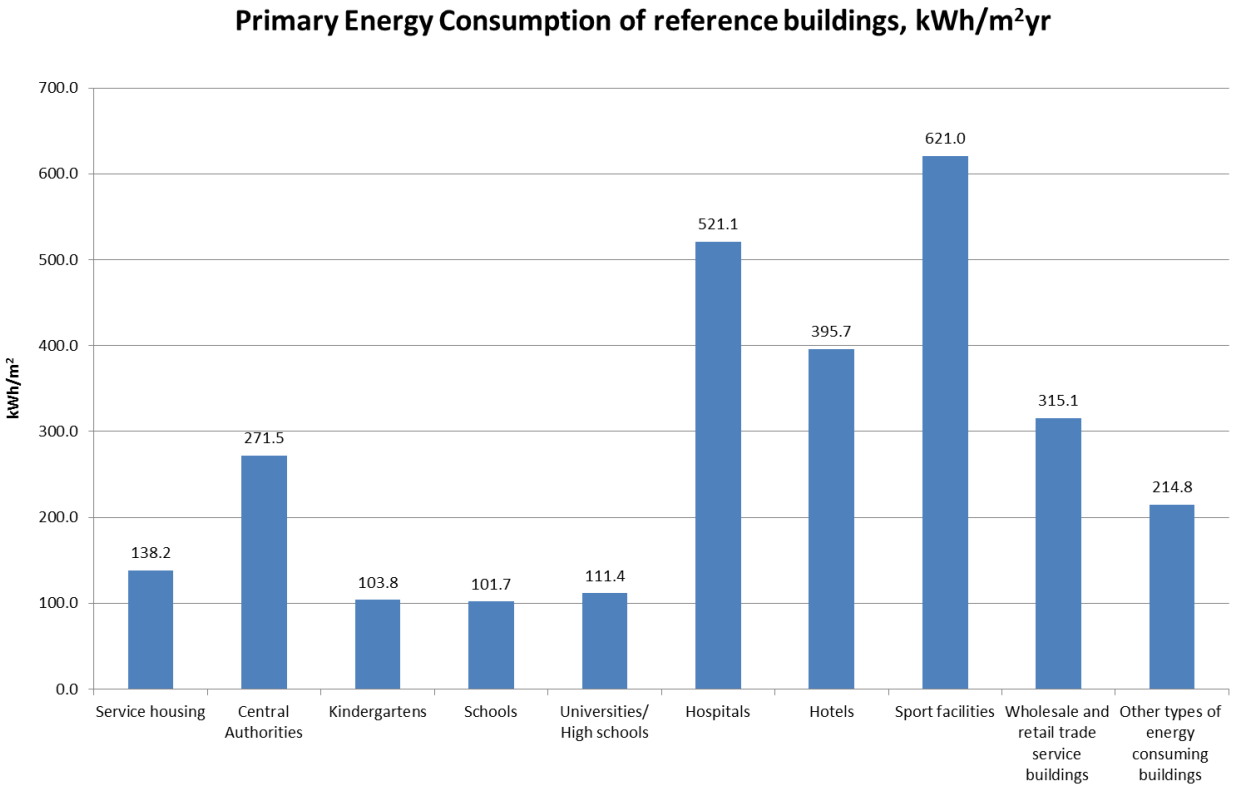
Table GR 5: Maximum permissible Um (W/(m^2.K) of the building envelope

Compactness ratio F/V (m^{-1})	Climatic zone			
	A	B	C	D
≤0,2	1,26	1,14	1,05	0,96
0,3	1,20	1,09	1,00	0,92
0,4	1,15	1,03	0,95	0,87
0,5	1,09	0,98	0,90	0,83
0,6	1,03	0,93	0,86	0,78
0,7	0,98	0,88	0,81	0,73
0,8	0,92	0,83	0,76	0,69
0,9	0,86	0,78	0,71	0,64
≥1,0	0,81	0,73	0,66	0,60

3.3.3 Energy performance of public building stock (EPC Database)

Up to date approx. 580 800 EPCs have been issued, 1 263 EPCs of which concern public buildings. 924 EPCs (which corresponds to 73%) of the certificates have been issued for the building energy-efficient refurbishment in the framework of national funding programmes. The certificate include basic data of the building (such as location, owner, building use/category, climatic zone, total surface area), the classification which is done based on the primary energy consumption of the building compared to the primary energy consumption of a reference building, calculated and actual energy data (such as primary energy consumption, CO_2 emissions), data for the proposed energy saving measures (cost, energy saving, CO_2 reduction, and payback period) and energy auditors' information (name, registration number).

Figure GR 4 presents the results of the analysis regarding the calculated primary energy consumption for heating, cooling, lighting and DHW (not appliances) and CO_2 emissions indicators, but without having a statistical representation value due to the low number of analysed certificates.



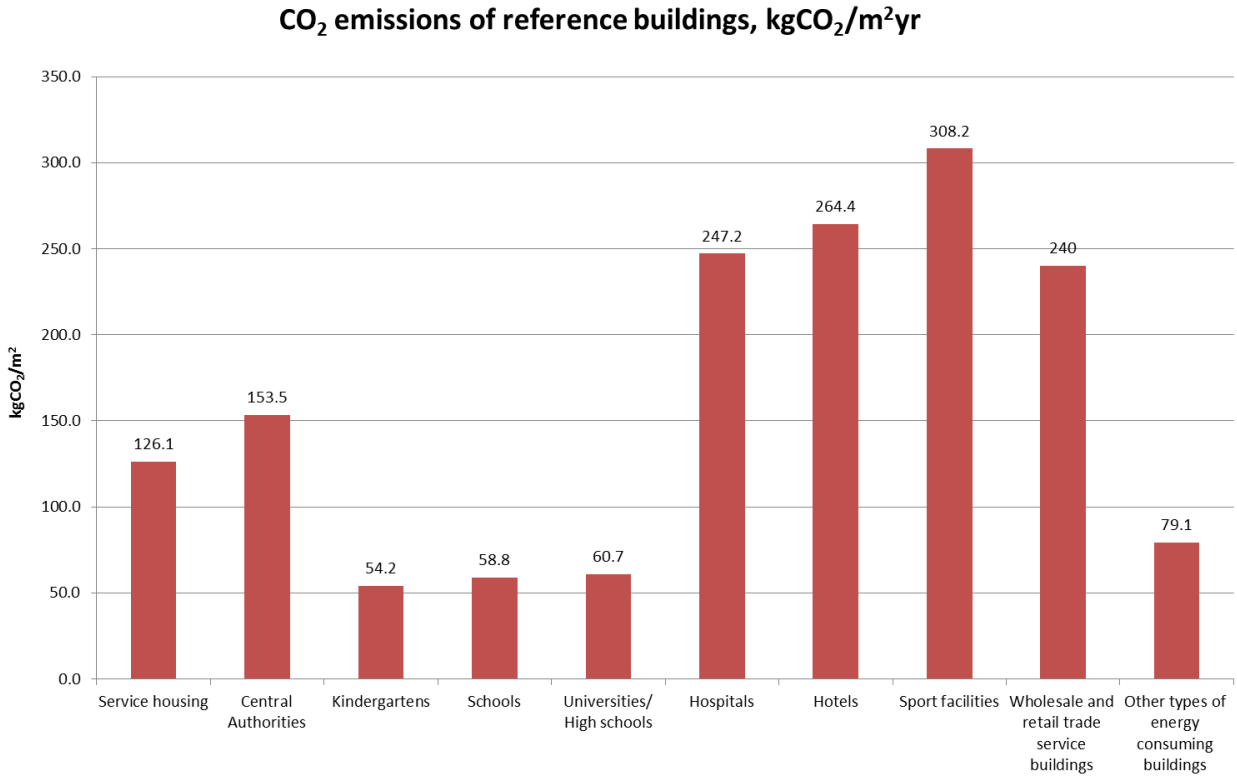


Figure GR 4: Calculated primary energy consumption and CO_2 emissions
(Source: EPC database)

Figure GR 5 presents the share of each use in the primary energy consumption for each public building category.

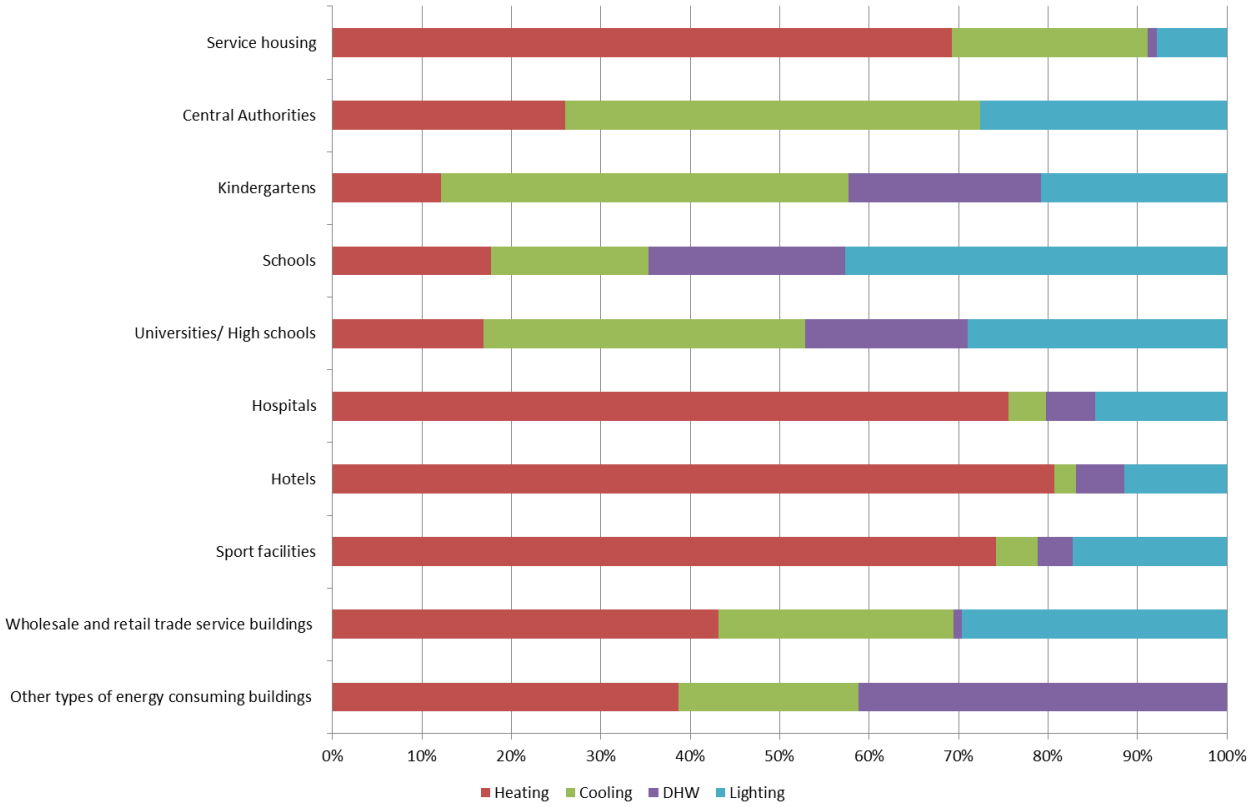


Figure GR 5: Share of each use in the primary energy consumption for each public building category
(Source: EPC database)

3.4 HUNGARY

3.4.1 Overall picture of the building stock in Hungary

The Hungarian Building Energy Strategy was prepared in 2014, now it is in public review. That document contains reliable information about the buildings: it presents the existing status of residential and public buildings, including data about number of the buildings, building structures, calculated primary energy consumption etc. and it proposes several building retrofitting measures in different levels of refurbishments. Consequently, the National Building Energy Strategy was used as main source in order to gather the necessary information for creating the public building stock database for this report.

The Hungarian Building Energy Strategy is available in Hungarian language on the following website: http://www.kormany.hu/hu/nemzeti-fejlesztesi-miniszterium/fejlesztes-es-klimapolitikaert-valamint-kiemelt-kozszolgaltatasokert-felelos-allamtitkarsag/hirek/tarsadalmi-egyeztetesen-a-nemzeti-epuletenergetikai-strategia-tervezete-es-a-kapcsolodo-kornyezeti-vizsgalati-jelentes

Besides the Hungarian Building Energy Strategy, some other important sources have also been taken into account:

- Zoltan Magyar, Gabor Nemeth, Robert Ispan, Miklos Osztroluczky: Defining building typology for modelling the Hungarian public building stock, 2012. (Part of the task to prepare the Hungarian Building Energy Strategy).
- Hungarian Central Statistical Office (KSH): Building data of Regional Local Authorities, 2011.
- ÉMI Nonprofit Llc: Building data of Central Authorities, 2012.

According to the Hungarian Building Energy Strategy document, there are five main building categories in the public building sector in Hungary:

1. Offices;
2. Educational buildings;
3. Health-care facilities;
4. Wholesale and retail trade service buildings;
5. Cultural buildings.

In Hungary, the above five building categories definitely dominate in the public building sector. However, the Local municipalities have some residential buildings, and also some sport facilities, but unfortunately there is no reliable, representative information about these buildings.

There are 37 871 public buildings in Hungary, from which there are 6 571 office buildings, 14 548 educational buildings, 9 111 health-care facilities, 2 312 wholesale and retail trade facilities, and 5 329 other types of energy consuming buildings (cultural buildings). The distribution of public building stock in Hungary regarding the dominant public building categories is presented in Figure HU 1. It can be seen in Figure HU 1 that the educational buildings represents the biggest part, since these are 60% of the public building stock.

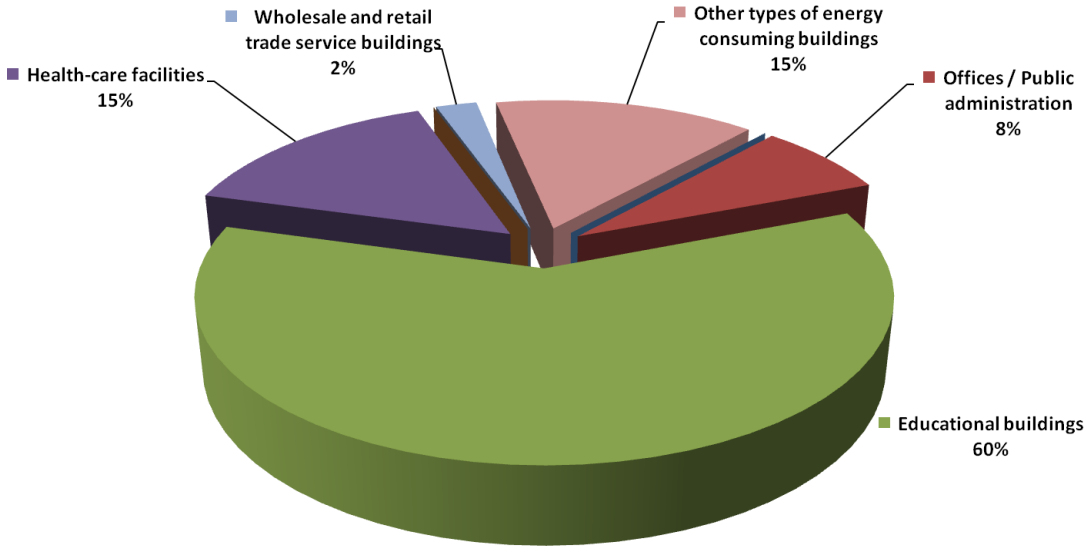


Figure HU 1: Structure of non-residential building stock

3.4.2 Public building stock data

The Hungarian Energy Strategy does not present sub-categories of public buildings; therefore the relevant public buildings' data (number of buildings, floor areas etc.) is described in this report regarding the above mentioned five main building categories. Table HU 1 presents the number of the public buildings, and the total floor area. As it is mentioned earlier, there are 37 871 public buildings in Hungary, summarizing 52,9 million m^2 floor area.

Table HU 1: Public building stock data

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	**Residential**	**N/A**	**N/A**	**N/A**
1.1	Social housing	N/A	N/A	N/A
1.2	Service housing	N/A	N/A	N/A
1.3	Student housing	N/A	N/A	N/A
2	**Offices / Public administration**	**6 571**	**3 969 238**	**3 572 314**
2.1	Central Authorities	1 961	1 863 349	1 677 014
2.2	Regional Local Authorities	4 610	2 105 889	1 895 300
3	**Educational buildings**	**14 548**	**31 811 036**	**28 629 932**
3.1	Kindergartens	N/A	N/A	N/A
3.2	Schools	N/A	N/A	N/A
3.3	Universities/ High schools	N/A	N/A	N/A
4	**Health-care facilities**	**9 111**	**8 068 513**	**7 261 661**
4.1	Hospitals	N/A	N/A	N/A
4.2	Other institutional care	N/A	N/A	N/A
5	**Hotels and restaurants**	**0**	**0**	**0**
5.1	Hotels	0	0	0
5.2	Other short-stay accommodation buildings	0	0	0
6	**Sport facilities**	**N/A**	**N/A**	**N/A**
7	**Wholesale and retail trade service buildings**	**2 312**	**1 222 264**	**1 100 037**
8	**Other types of energy consuming buildings**	**5 329**	**7 837 663**	**7 053 897**
1	**TOTAL**	**37 871**	**52 908 714**	**47 617 841**

The share of building structure of public buildings (masonry walls, concrete frames and masonry walls, large prefabricated panels) is illustrated in Figure HU 2. As it can be seen in that figure, usually the masonry walls, and concrete frames with masonry walls are the most common building structures.

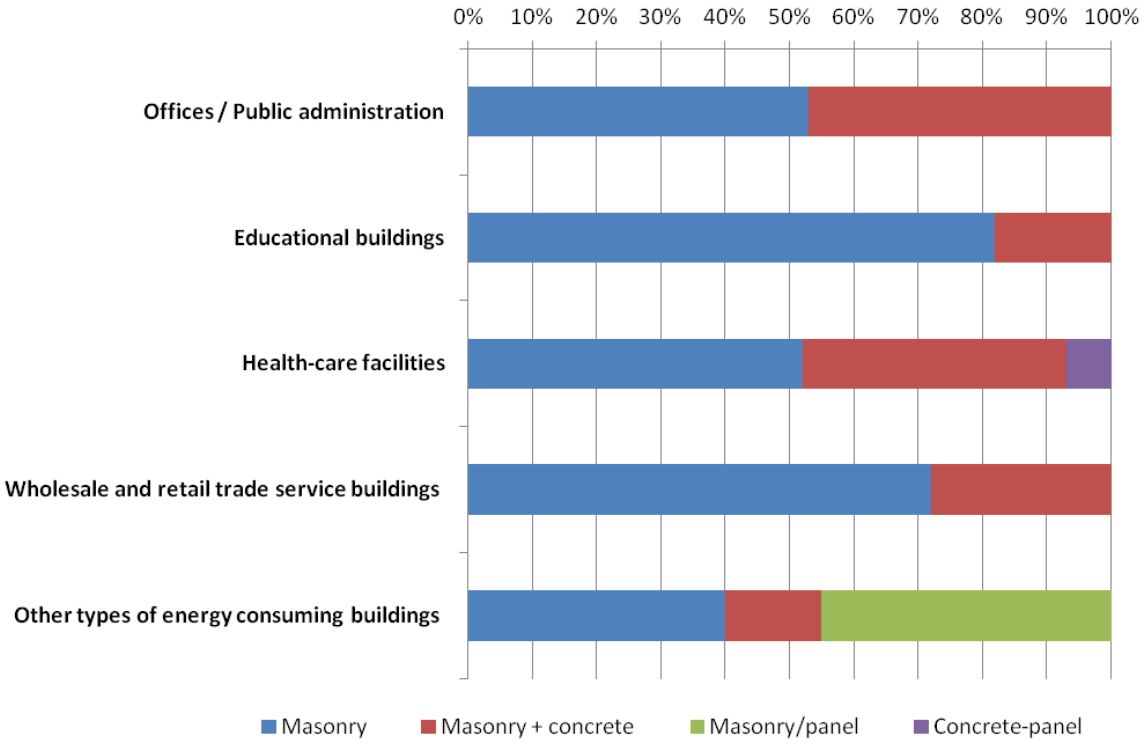


Figure HU 2: Structure of public building stock

The ratio of building envelope area to building volume (A/V, compactness ratio) influences the heating and cooling need of a building. In the Hungarian Building Energy Strategy, there were considered 42 public building types in the building typology, based on statistical data from Hungarian Central Statistical Office and ÉMI Llc. These 42 public building types were defined taking into account the function of the building and the year of construction. For all 42 public building types the A/V ratio was calculated and presented in the document named as "Defining building typology for modelling the Hungarian public building stock, 2012" written by Zoltan Magyar, Gabor Nemeth, Robert Ispan, Miklos Osztroluczky. Taking into account these calculated A/V values for 42 types of public buildings, and the total floor areas of each building type, the average A/V values were calculated for the main public building categories, which are presented in Table HU 2.

Table HU 2: Public building compactness data

Category	Compactness ratio (building envelope area/building volume) [m^2/m^3]
Offices / Public admin.	0,33
Education	0,45
Health-care facilities	0,32
Commercial	0,38
Other types	0,34

The public building stock by age band, based on construction year is presented in Figure HU 3. It can be concluded the public building stock is rather old in Hungary, since 30-40% of the office, the educational buildings, and the health-care facilities were constructed between 1901 and 1945, as well as 10-20% of commercial- and other types of buildings.

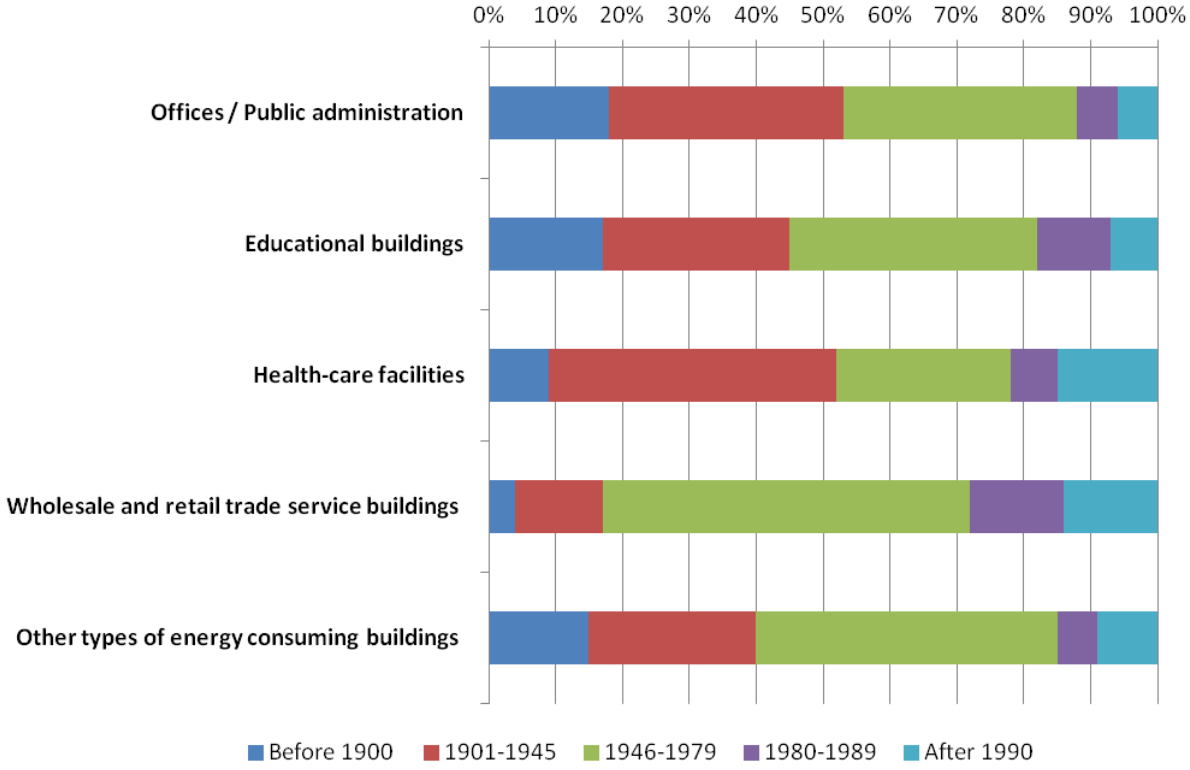


Figure HU 3: The public building stock by construction year

In Hungary, the heating system is central heating in public buildings, i.e. gas boiler or district heating. Practically there is no individual, or room heating system, such as electric heater. Unfortunately, there is no representative database how many public buildings have condensing boiler, and how many have conventional boiler. In Hungary, there has been many implemented retrofitting projects in the recent years (EU funded KEOP projects from 2007 to 2013), so with an estimation we considered that 25% of the public buildings' heating systems are equipped with condensing boiler.

Regarding the thermal characteristic of the buildings, Table HU 3 to Table HU 7 presents the heat transfer coefficients of the main building envelope structures, such as wall, roof, windows and floor. The heat transfer coefficients are presented concerning five different time periods, because the date of the construction has a great influence on the building envelope elements.

Table HU 3: U values, offices

U values, Offices - public administration, W/m^{2}K					
	Year of construction				
Structure	**before 1900**	**1901-1945**	**1946-1979**	**1980-1989**	**after 1990**
Wall	1,6 - 1,8	1,43 - 2,0	1,2 - 2,0	1,20	0,9 - 1,0
Roof	1,1 - 1,2	1,0 - 1,3	0,95 - 1,76	0,50	0,50
Windows	2,50	2,50	2,5 - 3,0	2,50	1,8 - 2,0
Floor	1,0	1,0 - 1,10	1,75	1,15	0,7 - 1,1

Table HU 4: U values, Educational buildings

U values, Educational buildings, W/m^{2}K					
	Year of construction				
Structure	before 1900	1901-1945	1946-1979	1980-1989	after 1990
Wall	1,6 - 1,8	1,43 - 2,0	1,2 - 2,0	1,20	0,9 - 1,0
Roof	1,1 - 1,2	1,0 - 1,3	0,95 - 1,75	0,50	0,50
Windows	2,50	2,50	2,5 - 3,0	2,50	1,8 - 2,0
Floor	1,0	1,0 - 1,1	1,65 - 1,75	1,00	0,70

Table HU 5: U values, Health-care facilities

U values, Health-care facilities, W/m2K					
	Year of construction, and subtype of the building				
Structure	before 1900	1901-1945	1946-1979	1980-1989	after 1990
Wall	1,43 - 1,8	1,80	0,8 - 2,0	1,20	1,00
Roof	1,20	1,0 - 1,2	0,7 - 0,8	0,60	0,50
Windows	2,50	2,50	2,5 - 2,6	2,50	2,0
Floor	1,0	1,0	1,6 - 1,75	1,0 - 1,15	0,7 - 1,15

Table HU 6: U values, Wholesale and retail trade services

U values, Wholesale and retail trade services, W/m^{2}K					
	Year of construction, and subtype of the building				
Structure	before 1900	1901-1945	1946-1979	1980-1989	after 1990
Wall	1,43 - 2,0	1,43-2,0	1,43-2,0	1,10	1,10
Roof	0,7 - 0,9	0,7 - 0,9	0,7 - 0,9	0,70	0,70
Windows	2,50	2,50	2,50	2,50	2,50
Floor	1,75	1,75	1,75	1,15	1,15

Table HU 7: U values, Other types of buildings

U values, Other types of buildings, W/m^{2}K					
Structure	Year of construction, and subtype of the building				
	before 1900	1901-1945	1946-1979	1980-1989	after 1990
Wall	1,43	1,43	1,2 - 2,1	1,20	1,00
Roof	1,0	1,0	0,8 - 1,0	0,60	0,50
Windows	2,50	2,50	2,5 - 2,65	2,50	2,0
Floor	1,0	1,0	1,5 - 1,75	1,55	1,25 - 1,55

3.4.3 Energy performance of public building stock

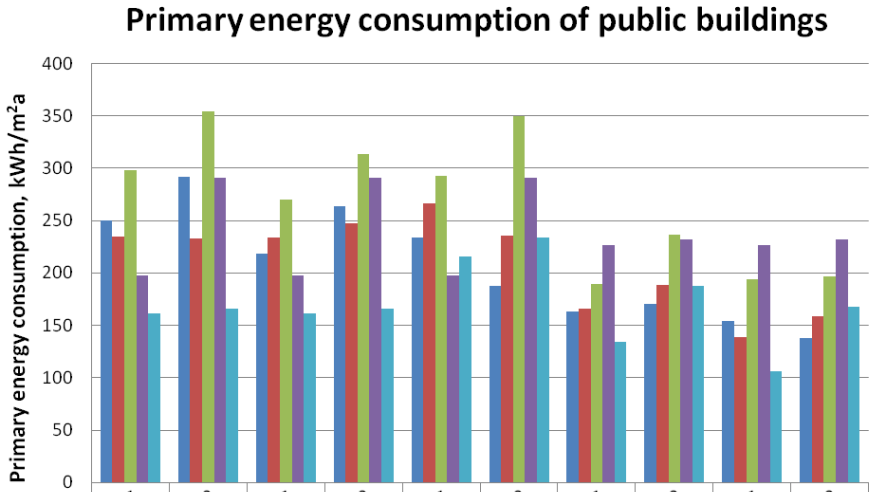
The information contained in the energy performance certificates would permit the evaluation of average energy performances by building type, provided that the number of issued certificates,

location of building and compactness ratio (A/V) ensure a representative statistical sample in terms of conditioned space floor area of building type.

In Hungary, ÉMI Llc. developed a questionnaire in 2013 in order to gather all the relevant information from public buildings' operators regarding the building envelope, HVAC system, lighting, real energy consumption and calculated primary energy consumption. By now, only approximately 20% of those responsible could give these data, because many of the public buildings have not been analyzed, and do not have energy certification yet.

Therefore, regarding the primary energy consumption of Hungarian public buildings, the Hungarian Building Energy Strategy was used again, because it contains the calculated primary energy consumption for the characteristic public building types. In Hungary, the primary energy factors, which were taken into account, are the following:

- electricity: 2,5
- natural gas: 1,0
- district heating: natural gas source 1,26 (0.83 if the rate of the combined heat production is more than 50%)



	1 before 1900	2 before 1900	1 1901-1945	2 1901-1945	1 1946-1979	2 1946-1979	1 1980-1989	2 1980-1989	1 after 1990	2 after 1990
Offices / public administration	251	292	218	264	234	187	163	171	154	138
Educational buildings	235	233	234	247	267	236	166	189	139	159
Health-care facilities	298	354	270	313	293	350	189	237	194	196
Wholesale and retail trade service buildings	198	291	198	291	198	291	227	232	227	232
Other types of energy consuming buildings	161	166	161	166	216	234	134	188	106	168

Figure HU 4: The primary energy consumption of public building stock

The primary energy consumption of five main categories of public buildings in Hungary is presented in Figure HU 4. As it can be seen, the health-care facilities contribute the highest primary energy consumption, since this kind of buildings even have 300-350 kWh/m^{2}a primary energy need.

There are some office, commercial, and health-care facilities, which have 250-300 kWh/m^{2}a primary energy demand, while many of the educational buildings contribute 230-250 kWh/m^{2}a consumption. Approximately half of the public building types consume 130-230 kWh/m^{2}a primary energy.

The educational buildings have relatively high primary energy consumption, and it represents 60% of the public building stock, consequently the educational buildings have high energy saving potential among the others.

3.5 ITALY

3.5.1 Overall picture of the public building stock in Italy

The main collected and processed data refer to offices/public administration and schools. These categories concern buildings owned and occupied by Public Authorities.

Last official documents published by the Italian Ministry of Economic Development MISE in June 2014 estimates the total floor area of the central public building administration in 13 763 975 m² by considering only buildings with floor area > 500 m². According to art. 5 of the 2012/27/EU Directive, buildings with floor area in between 250 m² and 500 m² are considered too, for a total amount of total floor area of the central public building administration of 14 201 202 m².

In order to define the amount of the public offices and schools building floor area and number of units, CRESME 2014 (Economic Social Market for construction and land Research Center) and ENEA 2009 (National Agency for New Technologies, Energy and the Environment) sources were considered [Report RSE/2009/165 and RIUSO03].

For hotels only the number of facilities and beds is known [Report RSE/2009/162], while for social houses only the number of buildings. These categories concern buildings frequently visited by the public but not usually owned by Public Authorities (hotels) or at the opposite buildings owned by Regional and Local Authorities (social housing) but used by privates.

Table IT 1 shows the number of buildings and the total floor area according to the available data. The total useful floor area could be considered equal to the total floor area.

Table IT 1

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²
1	Residential	90 000	-
1.1	Social housing	90 000	-
1.2	Service housing		
1.3	Student housing		
2	Offices / Public administration	13 700	23 600 000
2.1	Central Autorities	4 080	14 201 202
2.2	Regional Local Authorities	9 620	9 398 798
3	Educational buildings	52 000	73 400 000
3.1	Kindergartens		
3.2	Schools		
3.3	Universities/ High schools		
4	Health-care facilities	26 082	-
4.1	Hospitals	1165	-
4.2	Other institutional care	24917	-
5	Hotels and restaurants	25 845	48 593 059
5.1	Hotels	25 845	48 593 059
5.2	Other short-stay accommodation buildings		
6	Sport facilities		
7	Wholesale and retail trade service buildings		
8	Other types of energy consuming buildings		
	TOTAL	**207 627**	**(145 593 059)**

3.5.2 Public building stock data

Table IT 2 shows, if available, the land area occupied by the buildings, the compactness ratio and the number of floors. The collected data are defined for Italian climatic zones and/or for building period of construction: as to aggregate the collected data, mean values weighted on the floor area and/or on the number of buildings were used. When information was not available, the following assumptions were used in order to fill in the WP2 data tables:

- storey height: 3,5 m for offices and 3 m for schools;
- buildings are considered rectangular, with long wing of 10 m;
- ground floor and roof are heat transfer surfaces and a flat roof is considered.

Table IT 2

No.	Category / sub-category	Land area occupied by the building(s), m²	Compactness Ratio (area of the exterior walls/building volume)	Number of (above ground) floors (including Ground-floor)
1	Residential	-	-	-
2	Offices / Public administration	237	0,23	3,2
3	Educational buildings	335	0,30	3
5	Hotels	480	0,19	4

Figure IT 1 shows the Public offices building stock correlation between the period of construction and the Italian climatic zones, while for schools only disaggregated data are available and Figure IT 2 and Figure IT 3 are provided.

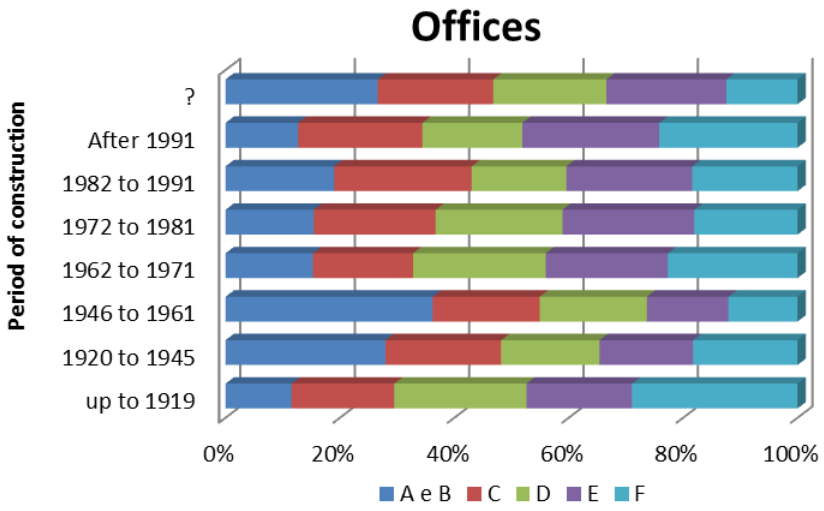


Figure IT 1

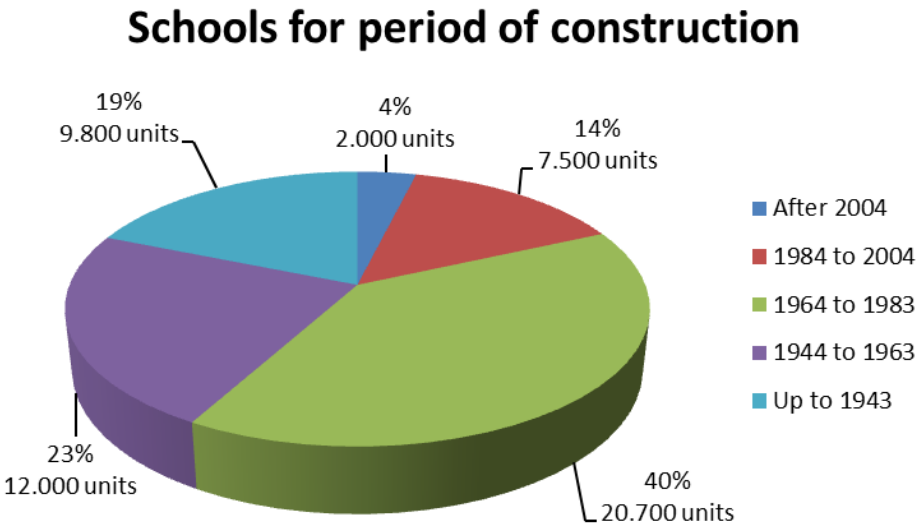


Figure IT 2

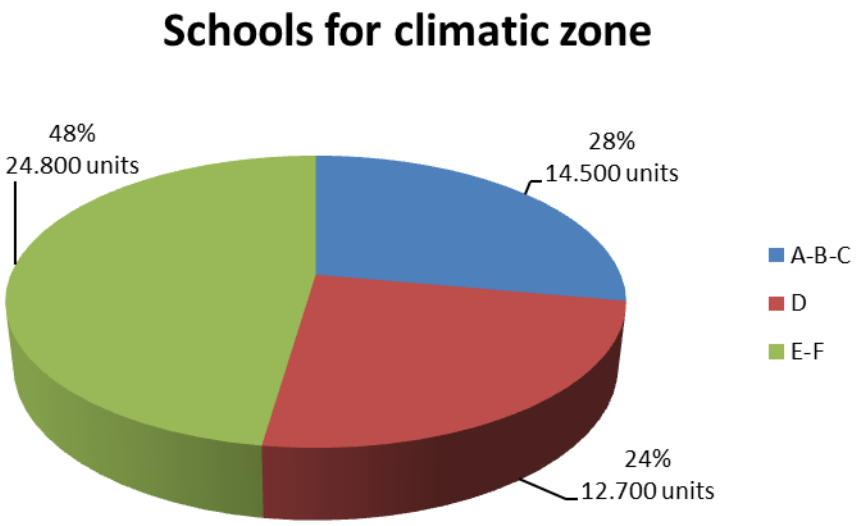


Figure IT 3

Materials used for building are reported for climatic zones in Figure IT 4 and for period of construction in Figure IT 5. Data can be used for all the building categories. As shown, the Concrete + Masonry typology is the most used, regardless of the historical period or the climate.

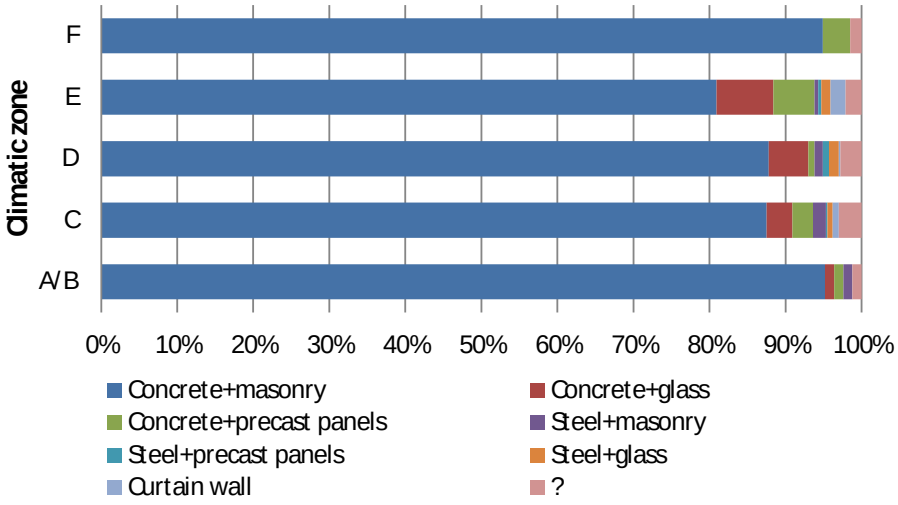


Figure IT 4

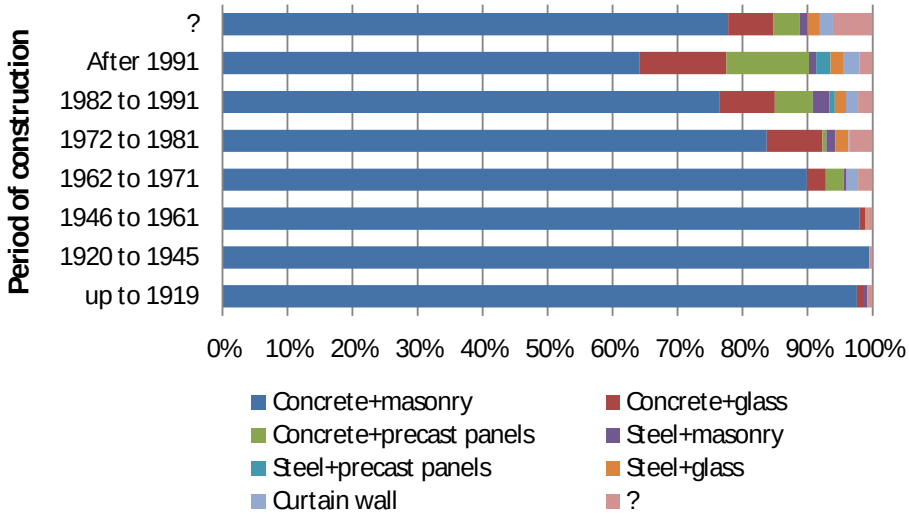


Figure IT 5

Concerning U-values, data filled in WP2 Data Table refers to an ENEA research [Report RSE/2009/161], in which reference building offices were defined departing from CRESME data. In Figure IT-6 data refers to opaque components, while in Figure IT-7 to windows. Values can be considered for all the building categories.

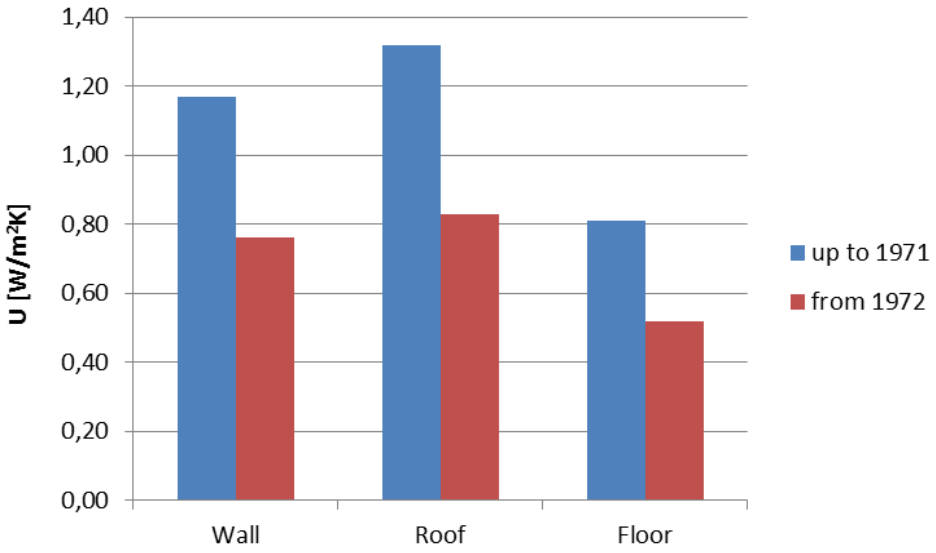


Figure IT 6

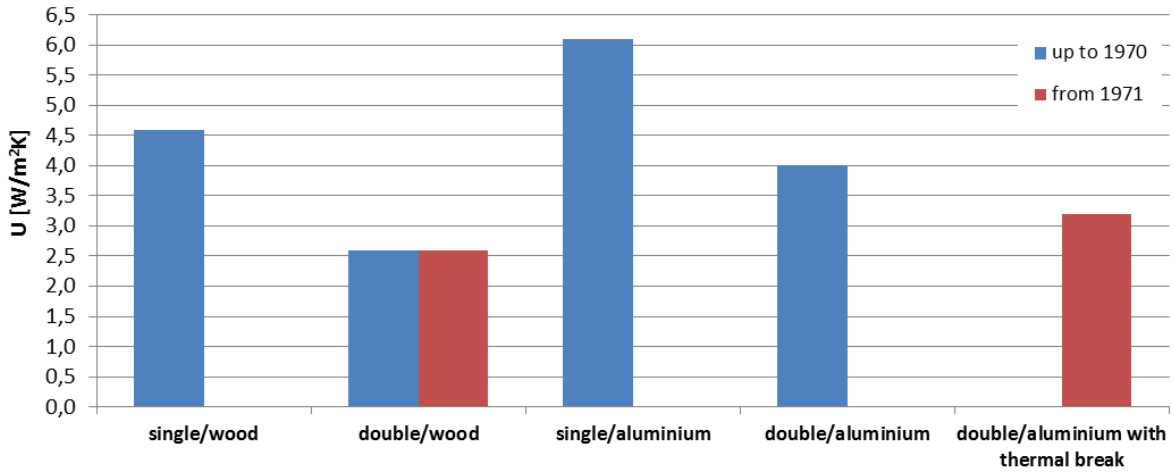


Figure IT 7

The energy carriers used for heating are defined for schools in Figure IT 8, while for public offices data are referred to the climatic zones in Figure IT 9 and for period of construction in Figure IT 10.

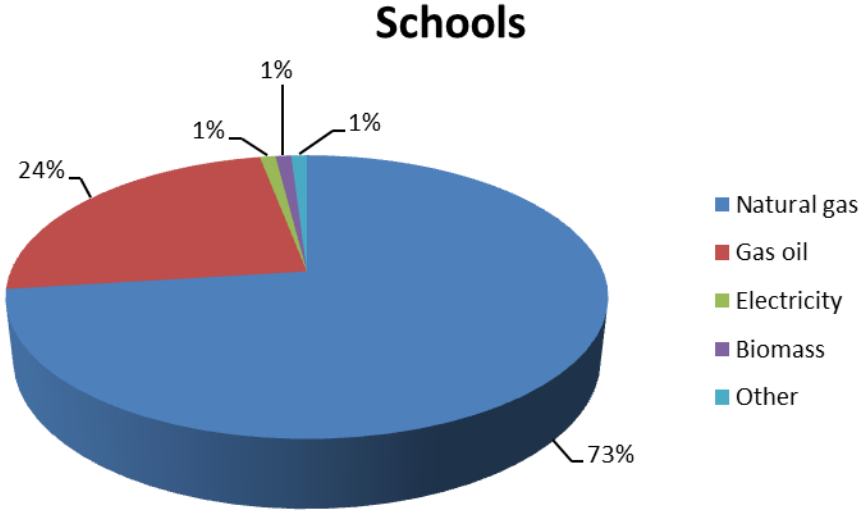


Figure IT 8

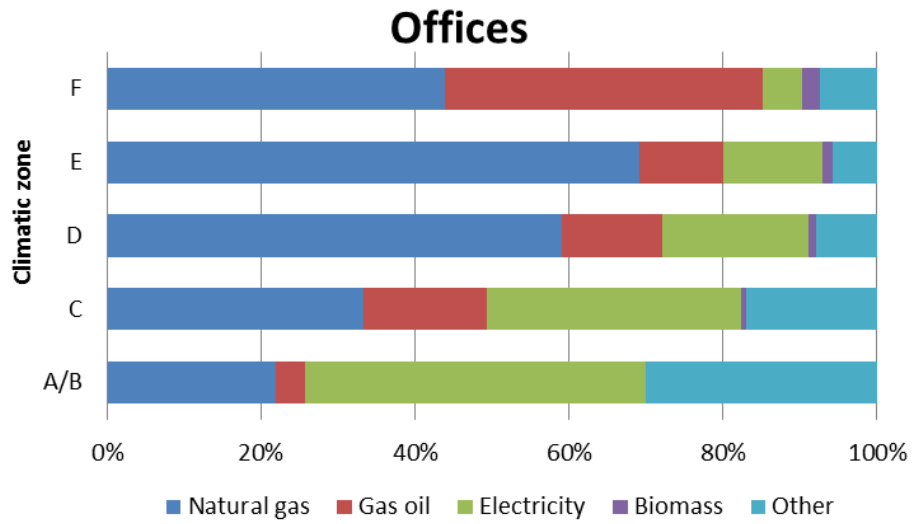


Figure IT 9

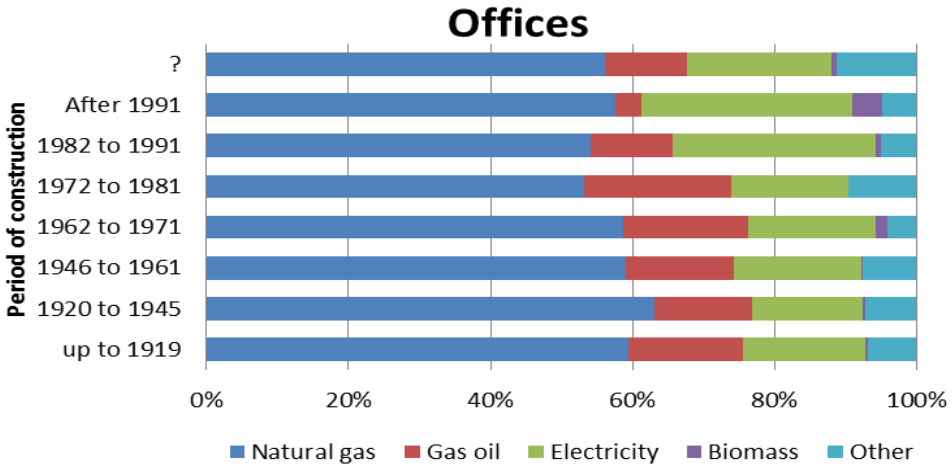


Figure IT 10

Data concerning the use of renewable sources are only available for the public offices stock for different period of building construction, as shown in Figure IT 11.

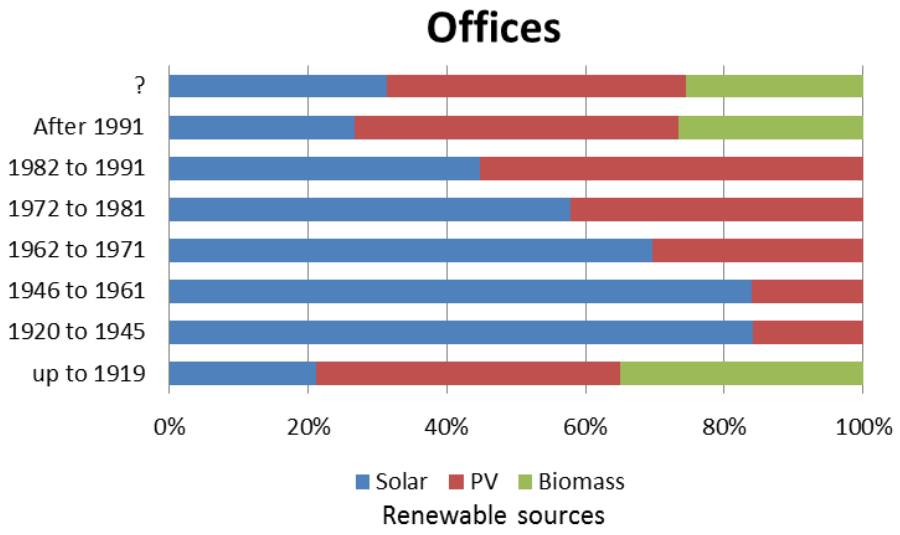


Figure IT 11

Concerning the cooling system, only data on the facility presence or not and the used emission subsystem typology are available:

- only the 20% of schools has a cooling system and the 85% of this is of splits;
- the 80% of public offices in climatic zones A, B and C has a cooling system; the percentage decreases to 70% in climatic zones D and E, while in the Northern Italy (climatic zone F) only the 20%. The amount of cooling systems is increasing since 1920 nowadays, from 60% up to 82%;
- from 1920 to present day the split is generally used as cooling system in offices, while heat pumps reach the 40% in Southern Italy.

Concerning hotels, a survey carried out in 2005 pointed out in the seasonal hotels (especially located in mountain, in the North of Italy) diesel seems to be the predominant source of energy (56%) and solar systems are often used (14,5%); while for annual facilities the natural gas (53%) and the electricity (36,5%) are prevalent, and there is a greater presence of electrical heat pumps (22%). Cogeneration plants and district heating are minor.

3.5.3 Energy performance of public building stock

Concerning the office buildings energy consumption, many different sources and values are available. In Figure IT 12 a comparison of the data elaborations from MISE [2014], CRESME [2014] and ENEA [2009] is given. Values are considered as final primary energy; the Italian primary energy conversion factor has been used (1 for fossil fuels and 2,17 for electrical energy), the final use is not specified.

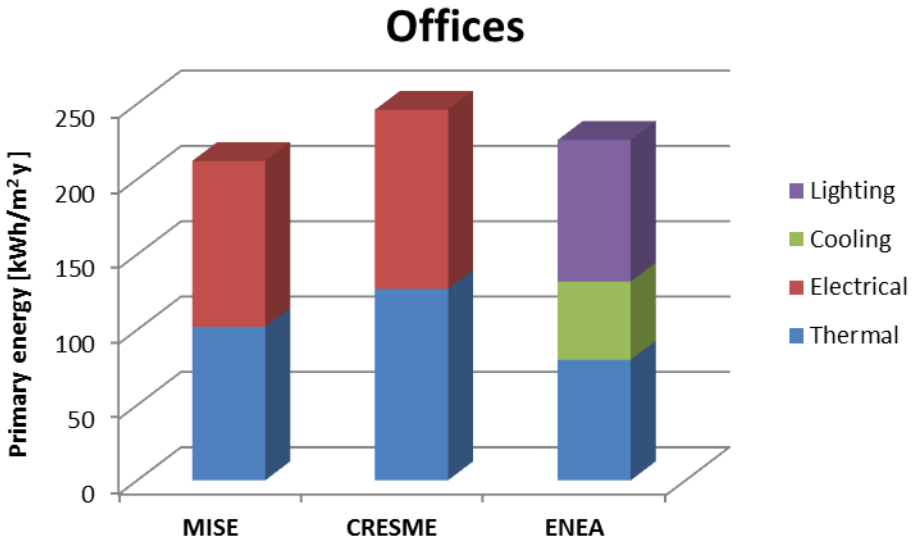


Figure IT 12

Figure IT 13 shows the total primary energy consumption for different end uses, according to available data, for the building categories analysed.

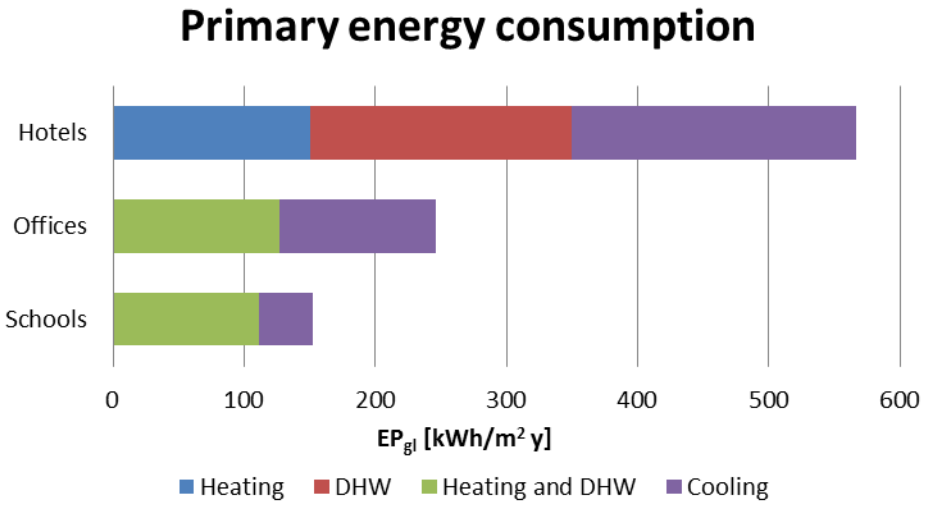


Figure IT 13

Another public building sector extremely interesting for the RePublic_ZEB goals is the residential, as social housing counts around 90 000 units and an energy consumption of about 240 kWh/m^2 year. Data at national level estimate an yearly energy consumption of 1 02 Mtep of thermal energy and 0 02 Mtep of electrical energy.

3.6 PORTUGAL

The analysis representing the preliminary assessment of the public building stock is based on the information from the data base of National Energy Certification System (SCE). Other information has been used in order to support the analysis, e.g the analysis of the residential reference building developed for “cost optimal” analysis regarding residential buildings and the ICESD [21], report on Energy Consumption in Residential Buildings.

3.6.1 Overall picture of the building stock in Portugal

The overall building stock information analysed for Portugal summarizes more than 10.734 buildings with more than 2 764 460,34m². It is important to recognise that this is only a sample of the total building stock. The distribution of the residential and non-residential building stock is presented in Figure PT 1.

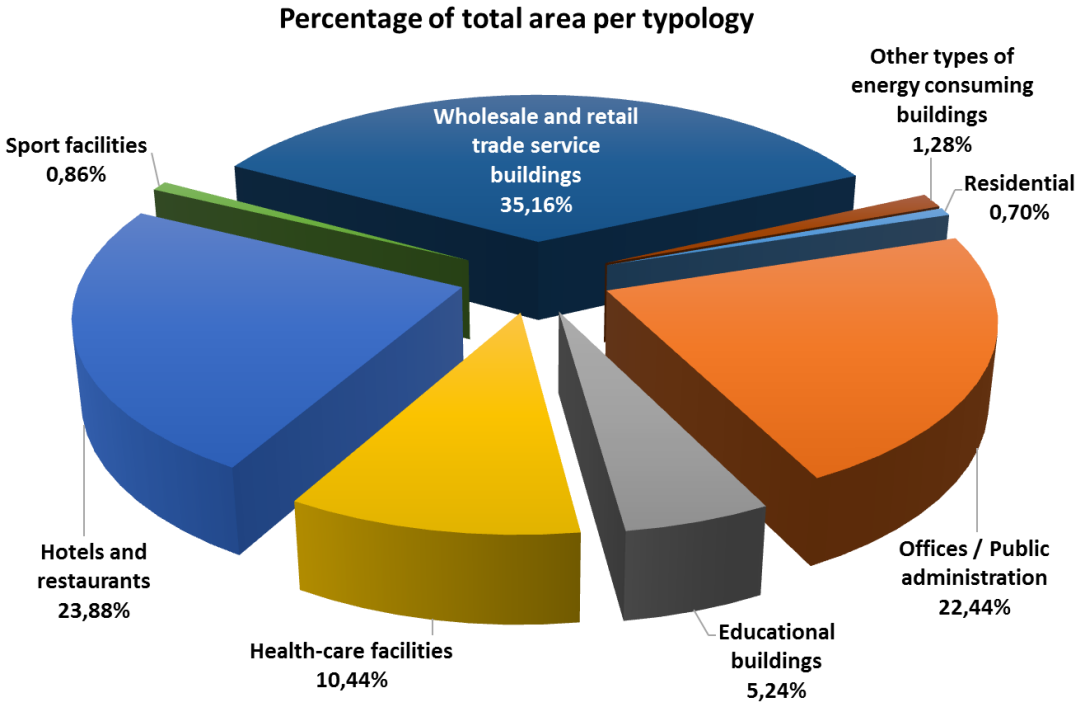


Figure PT 1: Structure of building stock
(Source: ADENE)

3.6.2 Public building stock data

An inventory of the existing buildings is being created through the National Energy Certification System (SCE) directed by the Agency for Energy (ADENE). The inventory is for public and non-public buildings.

The existing sample provided by ADENE for analysis demonstrates that the sample for public stock consists in 339 buildings divided in each building categories defined in the annex of this report is presented in Table PT 1.

Table PT 1: Public building stock data

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	Residential	246	N/A	19 260
2	Offices / Public administration	42	N/A	18 553
2.1	Central Authorities	36		12 719
2.2	Regional Local Authorities	6		5 834
3	Educational buildings	11	N/A	19 424
3.1	Kindergartens	1		599
3.2	Schools	10		18 825
3.3	Universities/ High schools	N/A	N/A	N/A
4	Health-care facilities	9	N/A	12 202
4.1	Hospitals	4		8 174
4.2	Other institutional care	5		4029
5	Hotels and restaurants	6	N/A	1342
5.1	Hotels	6		1 342
5.2	Other short-stay accommodation buildings	N/A		N/A
6	Sport facilities	1	N/A	2 196
7	Wholesale and retail trade service buildings	17	N/A	2 620
8	Other types of energy consuming buildings	7	N/A	7 395
	TOTAL	**339**		**82 991**

The data presented in Table PT 1 is illustrated in the Figure PT-2. It is possible to distinguish that residential and offices and public administration buildings are the largest portion of the sample. The inventory includes local and central administration buildings.

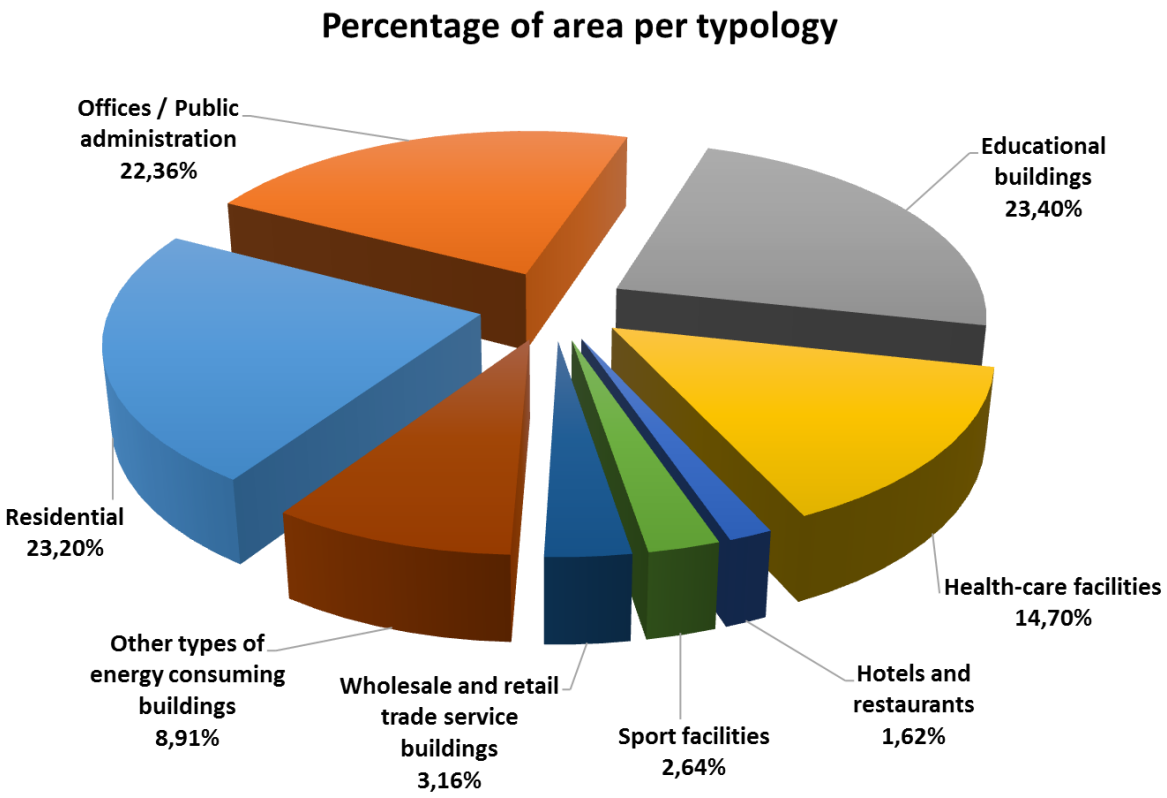


Figure PT 2: Structure of public building stock
(Source: ADENE)

It is important to recognise that there is not complete information about the constructive form used, but commonly it is concrete frames and masonry walls.

Figure PT 3 shows the distribution of building stock by age band based on construction year. The age band categories are based on the introduction of major alterations to the Portuguese legislation.

The heating and cooling systems commonly used are presented in Figure PT 4. According to the sample analysed in Portugal there is a great diversity in the systems used.

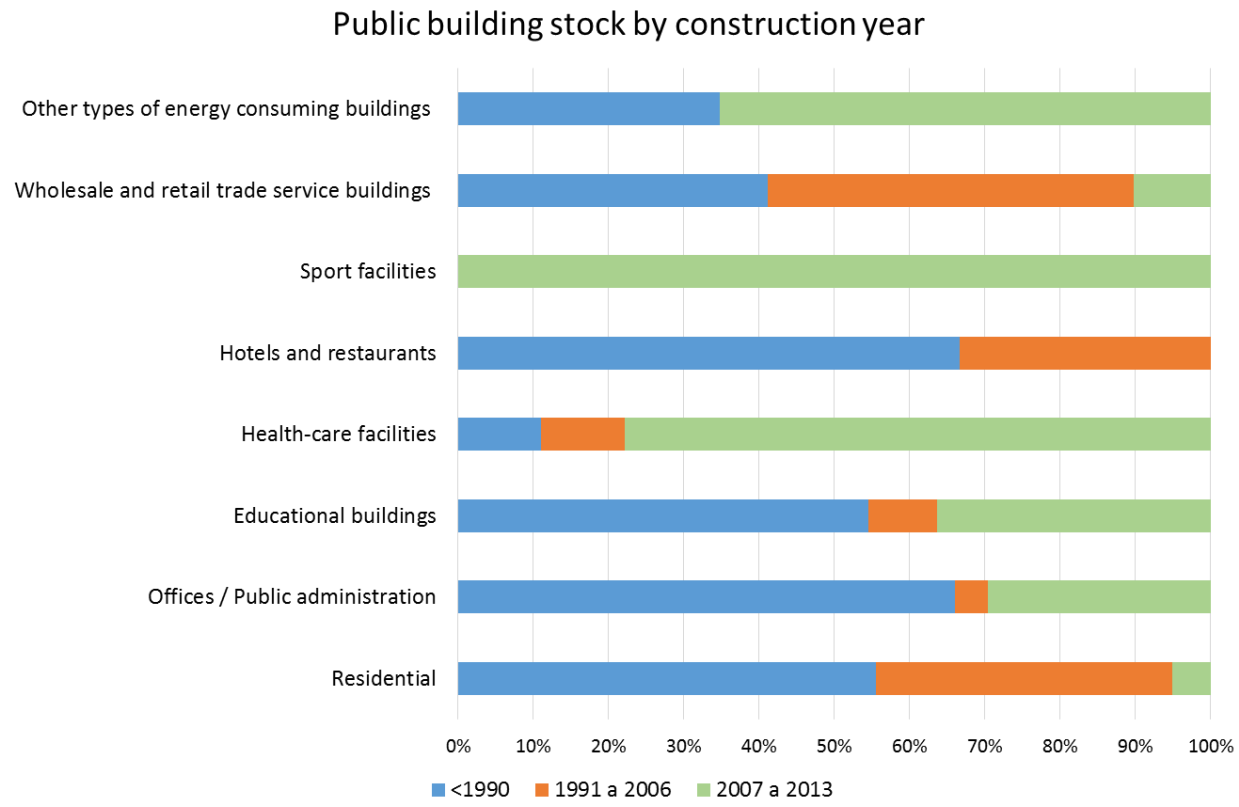


Figure PT 3: Public building stock by construction year
(Source: ADENE)

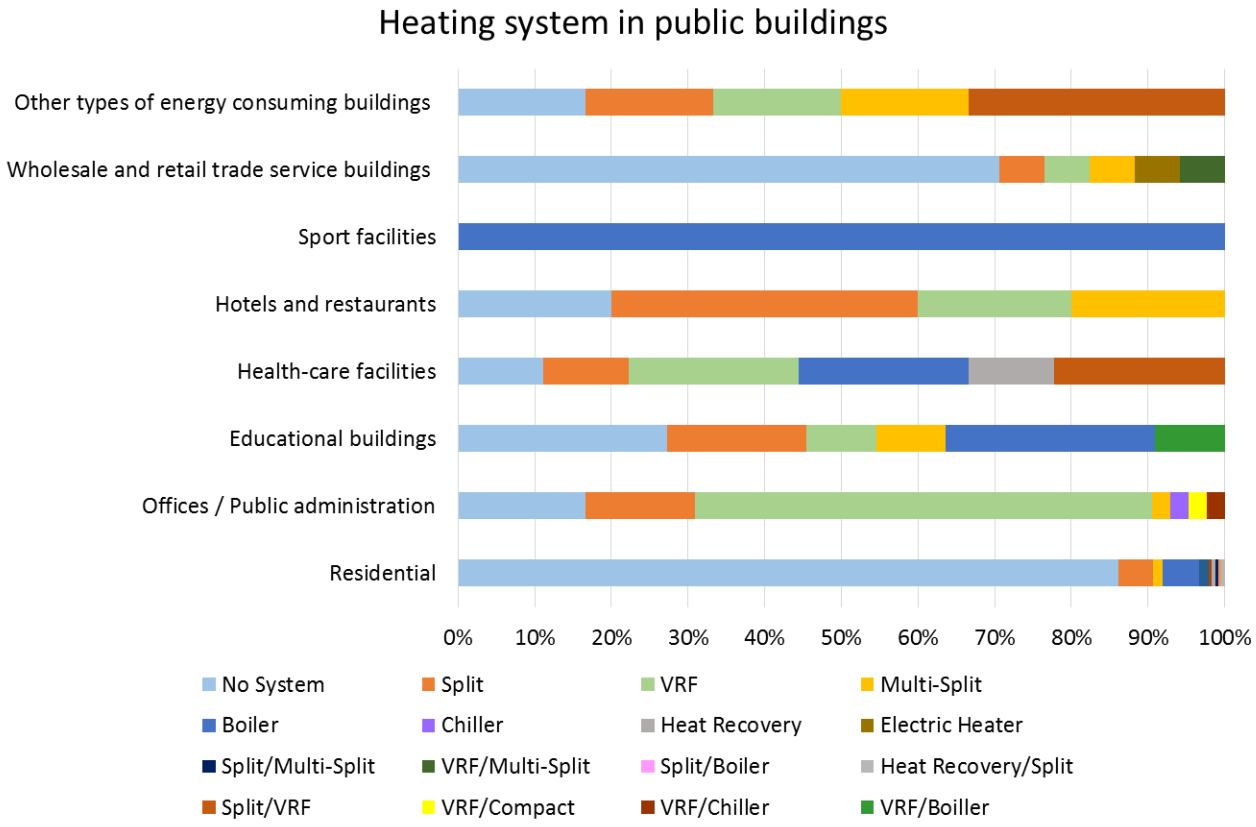


Figure PT 4: Heating and cooling systems in public buildings
(Source: ADENE)

The fuel type used for heating and DHW generation is presented in Figure PT 5.

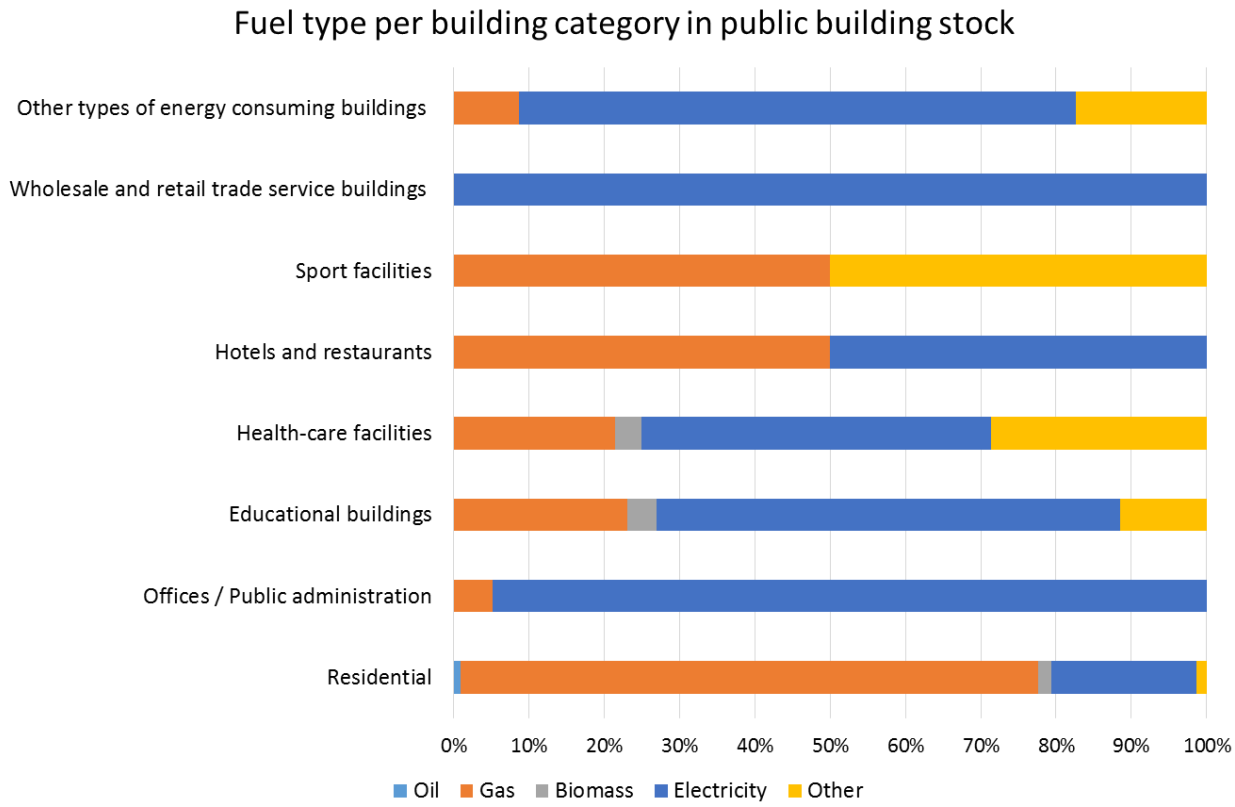


Figure PT 5: Fuel type per building category in public building stock
(Source: ADENE)

Regarding the energy performance of existing public building stock, Table PT 2 presents the main thermal characteristics (building envelope) as well as normal specific consumption per building category.

Table PT 2

No.	Building category	Wall, W/m^{2}K	Roof, W/m^{2}K	Floor, W/m^{2}K	Windows, W/m^{2}K	Final Energy, Use, kWh/m^{2}yr
1	Residential <1990 1991 to 2006 2007 to 2013	 1,70 0,96 0,96	 2,60 2,60 0,39	 3,10 2,50 0,37	 4,80 4,10 3,90	129,02
2	Offices Public admin. <1990 1991 to 2006 2007 to 2013	 1,76/1,3 2,3 1,60/0,32	 1,25 1,25 0,43	 1,25 1,25 2,21	 6 6,2 2,2	48,60

No.	Building category	Wall, W/m²K	Roof, W/m²K	Floor, W/m²K	Windows, W/m²K	Final Energy, Use, kWh/m²yr
3	Education <1990 1991 to 2006 2007 to 2013	 1,3 0,47 0,66	 2,25 0,53 0,40	 2,21 N/A 0,58	 3,90 3,14 4,06	195,76
4	Health-care Facilities <1990 1991 to 2006 2007 to 2013	 2,4 0,96 0,62	 2,8 2,25 0,72	 N/A N/A 0,56	 5,10 4,05 3,30	81,12
5	Hotels Restaurants <1990 1991 to 2006 2007 to 2013	 0,96 1,10 N/A	 2,60 2,60 N/A	 3,1 2,21 N/A	 5,1 6,0 N/A	109,11
6	Sport facilities <1990 1991 to 2006 2007 to 2013	 N/A N/A 0,6	 N/A N/A 0,59	 N/A N/A N/A	 N/A N/A 1,41	118,69
7	Commercial <1990 1991 to 2006 2007 to 2013	 0,96 0,96 0,54	 2,60 N/A 0,42	 2,25 3,1 N/A	 6,2 6,0 2,3	70,91
8	Other types <1990 1991 to 2006 2007 to 2013	 0,43 N/A 0,46	 2,60 N/A 0,44	 0,75 N/A 0,45	 5,12 N/A 1,6	48,34

(Source: ADENE)

3.6.3 Energy performance of public building stock (EPC Database)

Figure PT 6 and Figure PT 7 demonstrates the final energy use and CO_2 emissions indicators, respectively, but is probably not statistically representative due to the very low number of analysed certificates.

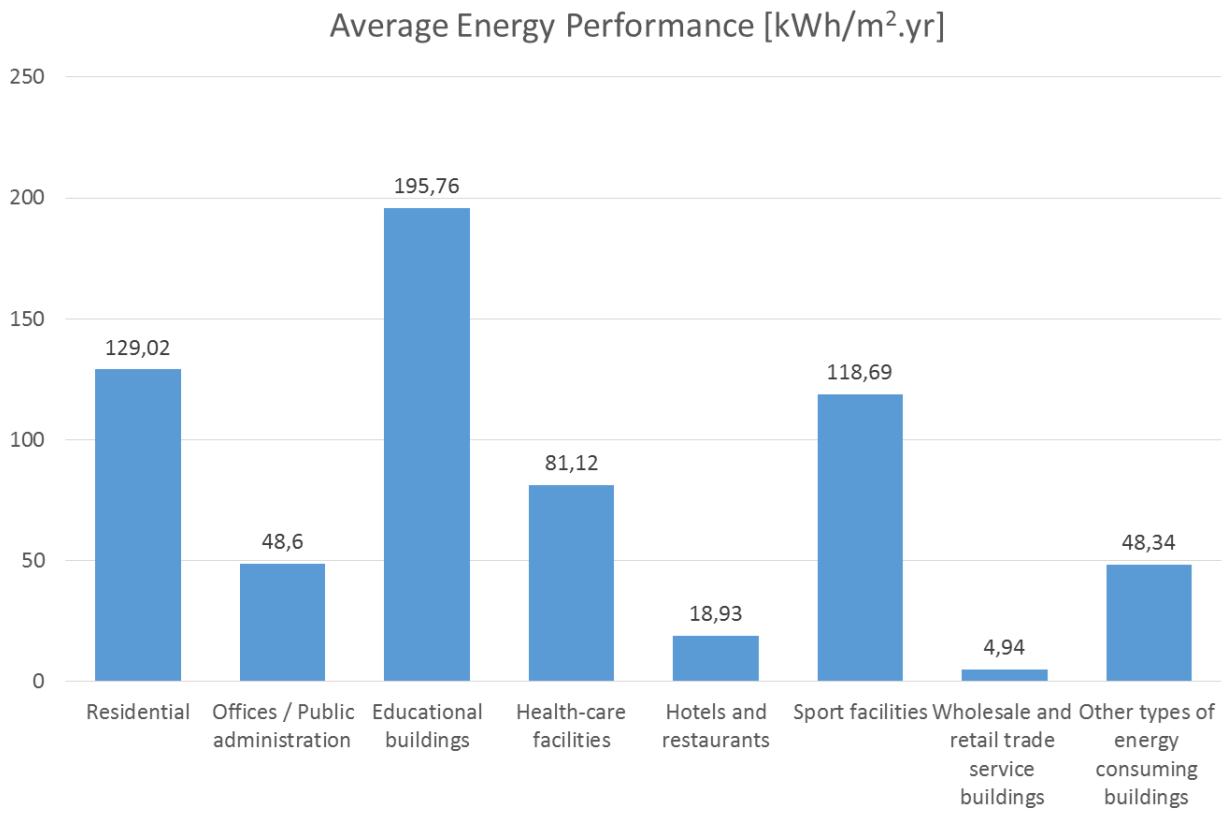


Figure PT 6: Fuel type per building category in public building stock
(Source: ADENE)

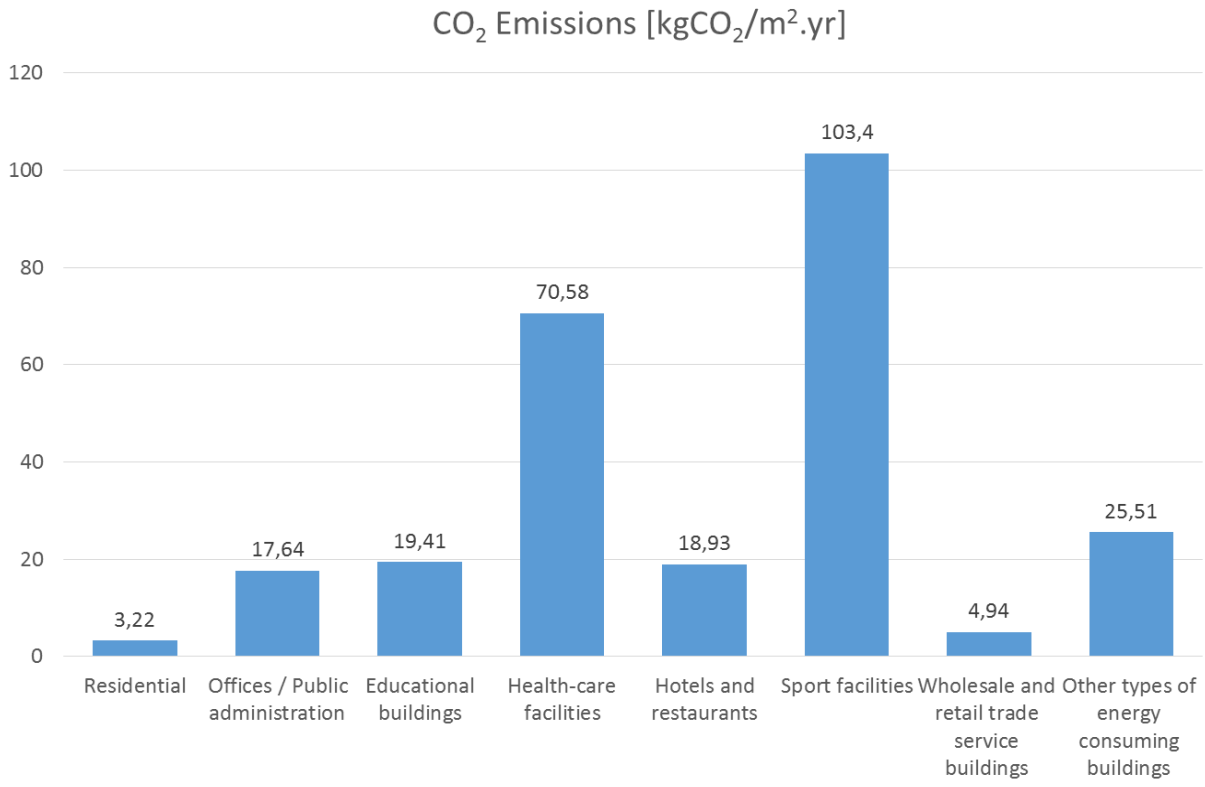


Figure PT 7: Estimated evaluation of energy performance of existing buildings
(Source: ADENE)

Figure PT 8 presents the share of each use (building service) in the final energy consumption for each public building category, excluding appliances, which we do not have information.

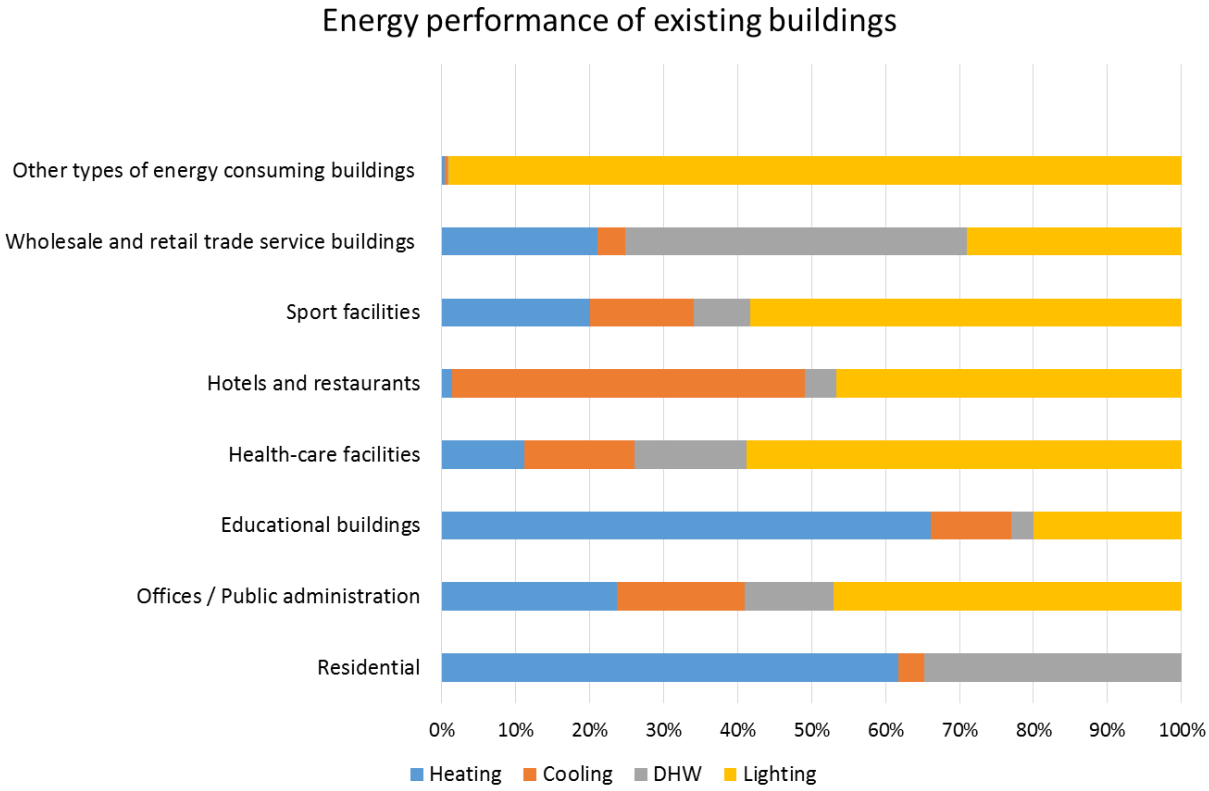


Figure PT 8: Estimated evaluation of energy performance of existing buildings
(Source: ADENE)

Assumptions related to the analysis:

The information is obtained from the database of certified buildings, according to the new building legislation in Portugal, starting at the end of 2013, transposing the EPBD-recast (2010/31/EU directive). For this reason some of data required in the spreadsheet are not available.

Category/sub-category:

The data considered for analysis represents the buildings belonging to Public administration, Central authorities and Regional Local Authorities.

Year of construction:

Office buildings have been considered as those built before 1990, and between 1991 and 2006, when requirements were introduced in the building regulation, especially in residential buildings. Between 2007 and 2013 new requirements were introduced regarding construction quality, systems and methodology to calculate energy performance.

Heat system type:

For the calculation of the primary energy, national building regulation assumes that for a building/space that don´t have any specified system or any information about the existing system, a default system is considered depending on the energy carrier type.

Consumption levels by different building types

The data available are representing the final energy value, not the primary. The conversion factors are 2,5 for electricity and 1 for gas.

U values of components and air-tightness levels

U-values are obtained by the calculation of the statistical function mode that will return the most representative value found in the sample studied for each typology and sub-typology. The following Table PT 3 to Table PT 10) present the U-values and respective constructive solutions for each typology.

Note

With respect to U values presented in the following tables, it is worth mentioning that since 2006 the national regulation fulfil the EPBD (2002/91/EC) requirements concerning major renovation.

Table PT 3: Constructive solutions of building elements and U-values (Residential)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Residential	< 1990	**1,70** (Single brick wall uninsulated)	**2,60** (Horizontal without thermal insulation)	**3,10** (Uninsulated)	**4,80** (Single glazing metal frame without thermal break)
	1991-2006	**0,96** (Single brick wall or double brick wall (post 1960))	**2,60** (Horizontal without thermal insulation)	**2,50** (Uninsulated)	**4,10** (Single glazing metal frame without thermal break)
	2007-2013	**0,96** (Single brick wall or double brick wall (post 1960))	**0,39** (Horizontal with thermal insulation in exterior)	**0,37** (Insulated in exterior)	**3,90** (Single glazing metal frame without thermal break)

Table PT 4: Constructive solutions of building elements and U-values (Offices)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Offices / Public administration	< 1990	**1,76/1,3** (Single brick wall uninsulated/ Single brick wall or double brick wall (post 1960))	**1,25** (Horizontal without thermal insulation)	**1,25** (Uninsulated)	**6** (Single glazing metal frame without thermal break)
	1991-2006	**2,3** (Single brick wall or double brick wall (post 1960))	**1,25** (Horizontal without thermal insulation)	**1,25** (Uninsulated)	**6,2** (Single glazing metal frame without thermal break)
	2007-2013	**1,60/0,32** (Single brick wall or double brick wall (post 1960)/double brick wall with insulation in cavity)	**0,43** (Horizontal with thermal insulation in exterior)	**2,21** (Insulated in exterior)	**2,2** (Single glazing metal frame with thermal break)

Table PT 5: Constructive solutions of building elements and U-values (Educational Buildings)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Educational buildings	< 1990	**1,3** (Single brick wall or double brick wall (post 1960))	**2,25** (Horizontal without thermal insulation)	**2,21** (Uninsulated)	**3,90** (Single glazing metal frame without thermal break)
	1991-2006	**0,47** (Single brick wall with insulation in exterior)	**0,53** (Horizontal with thermal insulation in exterior)	N/A	**3,14** (Single glazing metal frame with thermal break)
	2007-2013	**0,66** (Single brick wall with insulation in exterior)	**0,40** (Horizontal with thermal insulation in exterior)	**0,58** (Insulated in interior)	**4,06** (Single glazing metal frame with thermal break)

Table PT 6: Constructive solutions of building elements and U-values (Health Care Facilities)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Health-care facilities	< 1990	**2,40** (Single brick wall uninsulated)	**2,80** (Pitched roof without insulation)	N/A	**5,10** (Single glazing metal frame without thermal break)
	1991-2006	**0,96** (Single brick wall or double brick wall (post 1960))	**2,25** (Horizontal without thermal insulation)	N/A	**4,05** (Double glazing metal frame without thermal break)
	2007-2013	**0,62** (Double brick wall with insulation in cavity)	**0,72** (Horizontal without thermal insulation)	**0,56** (Insulated)	**3,30** (Double glazing metal frame with thermal break)

Table PT 7: Constructive solutions of building elements and U-values (Hotels and restaurants)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Hotels and restaurants	< 1990	**0,96** (Single brick wall or double brick wall (post 1960))	**2,60** (Horizontal without thermal insulation)	**3,10** (Uninsulated)	**5,10** (Single glazing wood frame)
	1991-2006	**1,10** (Single brick wall or double brick wall (post 1960))	**2,60** (Horizontal without thermal insulation)	**2,21** (Uninsulated)	**6,00** (Single glazing metal frame without thermal break)
	2007-2013	N/A	N/A	N/A	N/A

Table PT 8: Constructive solutions of building elements and U-values (Sport facilities)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Sport facilities	< 1990	N/A	N/A	N/A	N/A
	1991-2006	N/A	N/A	N/A	N/A
	2007-2013	**0,60** (Double brick wall with insulation in cavity)	**0,59** (Horizontal with thermal insulation in exterior)	N/A	**1,41** (Single glazing plastic frame)

Table PT 9: Constructive solutions of building elements and U-values (Wholesale and retail trade service buildings)

Category	Period	Envelope Element			
		Walls	Roofs	Floor	Windows
Wholesale and retail trade service buildings	< 1990	**0,96** (Double brick wall uninsulated)	**2,60** (Horizontal without thermal insulation)	**2,25** (Uninsulated)	**6,20** (Single glazing metal frame without thermal break)
	1991-2006	**0,96** (Single brick wall or double brick wall (post 1960))	N/A	**3,10** (Uninsulated)	**6,00** (Single glazing metal frame without thermal cut)

	2007-2013	**0,54** (Double brick wall with insulation in cavity)	**0,42** (Horizontal with thermal insulation in exterior)	N/A	**2,30** (Double glazing metal frame with thermal break)

Table PT 10: Constructive solutions of building elements and U-values (Other types of energy consuming buildings)

Category	Period	Envelope Element			
		Walls	**Roofs**	**Floor**	**Windows**
Other types of energy consuming buildings	< 1990	**0,43** (Single brick wall with insulation in exterior)	**2,60** (Horizontal without thermal insulation)	**0,75** (Insulated in interior)	**5,12** (Single glazing wood frame)
	1991-2006	N/A	N/A	N/A	N/A
	2007-2013	**0,43** (Single brick wall with insulation in exterior)	**0,44** (Horizontal with thermal insulation in exterior)	**0,45** (Insulated in exterior)	**1,60** (Double glazing metal frame with thermal break)

Ventilation and air-tightness levels

According to Portuguese building legislation residential buildings have to respect a minimum air change rate of $0,4h^{-1}$, which is based on the calculations and methodologies of EN 15424. For service buildings the minimum air flow value is calculated using a calculation sheet and the values are expressed in m3/h/occupant.

3.7 ROMANIA

3.7.1 Overall picture of the building stock in Romania

The overall building stock in Romania comprises more than 5,344 thousand buildings with more than 626,08 mil. m², of which around 89% are residential buildings.

While for the residential building stock reliable detailed data are provided by censuses in 1992, 2002 and 2011 as well as by the statistical yearbooks published by the Romanian National Institute of Statistics, for buildings in the tertiary sector, detailed or aggregated data are not available, for types of buildings and their characteristics. Starting from the buildings typology in Romania, an estimation of total non-residential building stock was performed [22], by grouping buildings by destination and building type, aiming to comply with the categories of buildings established by the Energy Performance Calculation Methodology. The estimated number of non-residential buildings was 226,1 thousand buildings, comprising more than 67,21 million m², based on the data from the Statistical Yearbook of Romania 2011 and updated in the BPIE buildings data hub [24]. The distribution of the non-residential building stock is presented in Figure RO 1

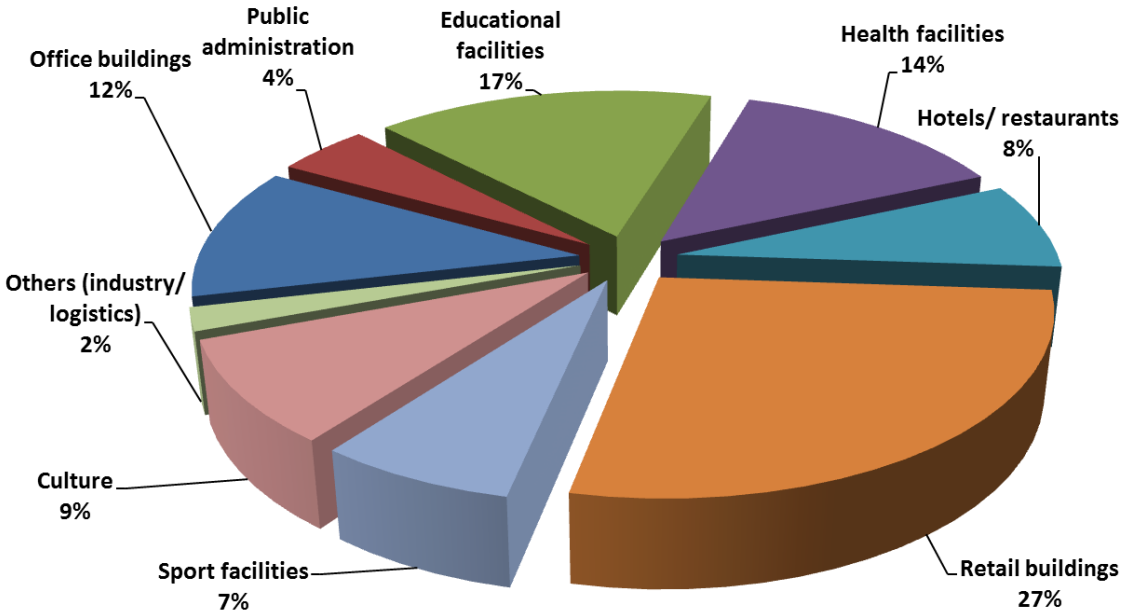


Figure RO 1: Structure of non-residential building stock
(Source: Romanian National Institute of Statistics, [23], [24], INCD URBAN-INCERC)

3.7.2 Public building stock data

Starting from the obligation in Article 5 (5) of the Energy Efficiency Directive 2012/27/EU), an inventory of buildings heated and / or cooled with a useful floor area of 500 square meters, owned and occupied by central government, was performed at the end of 2014 (based on data / information submitted by central public authorities - ministries and other bodies subordinated to the Government or Ministries or autonomous administrative authorities) and the summary was published on 25/03/2014 [25].

Table RO 1: Public building stock data

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	Residential	174	510 616	470.819

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1.1	Social housing	-	-	-
1.2	Service housing	49	88 705	77 099
1.3	Student housing	125	421 911	393 720
2	Offices / Public administration	1 770	4 163 792	3 670 931
2.1	Central Authorities	1 770	4 163 792	3 670 931
2.2	Regional Local Authorities	-	-	-
3	Educational buildings	213	566 650	488 539
3.1	Kindergartens	-	-	-
3.2	Schools	64	85 841	83 973
3.3	Universities/ High schools	149	480 809	404 566
4	Health-care facilities	125	684 707	585 994
4.1	Hospitals	98	538 161	466 751
4.2	Other institutional care	27	146 545	119 243
5	Hotels and restaurants	73	210 176	172 730
5.1	Hotels	22	65 567	55 599
5.2	Other short-stay accommodation buildings	51	144 609	117 131
6	Sport facilities	162	362 148	324 572
7	Wholesale and retail trade service buildings	39	334 329	292 260
8	Other types of energy consuming buildings	328	515 564	482 287
	Without detailed data	63	337 415	269 932
TOTAL		2 947	7 685 397	6 758 063

The central government includes Chamber of Deputies, ministries, specialized bodies under the subordination or authority of the Government, central autonomous authorities and comprise public administration offices, universities, hospitals, residential (service housing), protocol houses and other building types.

The distribution of the central public building stock per building categories defined in the annex of this report is presented in Figure RO 2.

The inventory does not include local administration buildings and most of the education buildings (from kindergarten to high schools and VET units), which are under the authority of regional/local scholar inspectorates and local councils responsibility. For these buildings no detailed reliable data is available.

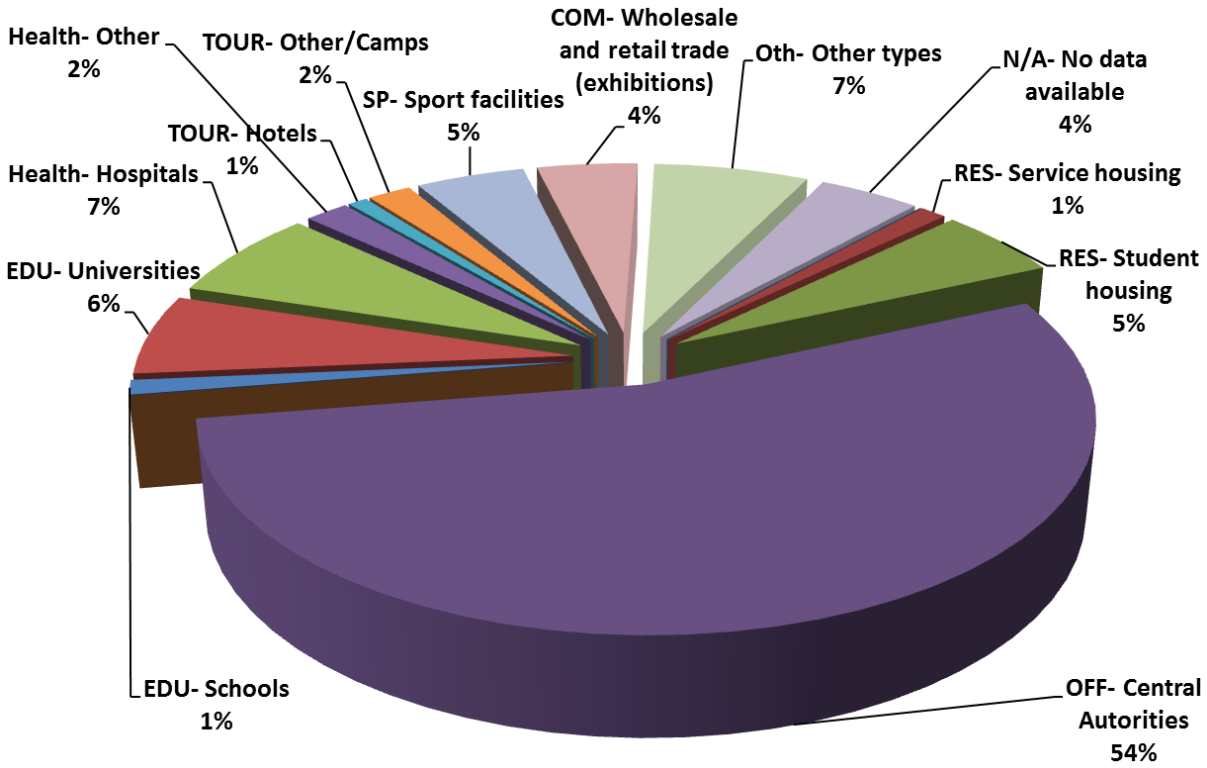


Figure RO 2: Structure of central government building stock
(Source: [25], INCD URBAN-INCERC)

The total number of local public administration buildings could be estimated starting from the information available from the Statistical Yearbook of Romania 2011 (Table RO 2). The total useful area is estimated based on typical building size for selected categories and on the analysis of energy performance certificates database (around 350 education buildings).

Table RO 2: Estimative number of public buildings (local administration)

Building use	Type	Number of units
Education	Schools and high schools	5 982
	Kindergarten	1 498
	Tertiary education	624
Public administration	Prefectures, county councils	84
	Town halls, local councils – urban area	326
	Town halls, local councils – rural area	2 861
	Public central administration (ministries, governmental institutions)	43
	Other units of central administration	1 786

(Source:[22], INCD URBAN-INCERC)

Taking into account the results of the inventory of central government buildings and the estimations for public buildings under the local administration, the distribution of public building stock in Romania is estimated at 13 698 buildings, comprising 17 846 623 m². The distribution of buildings by categories is presented in Table RO 3 (number of buildings, total built-up area and total useful conditioned floor area) and is illustrated in Figure RO 3 (useful area).

Table RO 3

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	Residential	174	510 616	470 819
1.1	Social housing	0	0	0
1.2	Service housing	49	88 705	77 099
1.3	Student housing	125	421 911	393 720
2	Offices / Public administration	5 041	6 208 167	5 306 431
2.1	Central Autorities	1 770	4 163 792	3 670 931
2.2	Regional Local Authorities	3 271	2 044 375	1 635 500
3	Educational buildings	7 693	12 382 975	9 941 599
3.1	Kindergartens	1 498	1 123 500	898 800
3.2	Schools	6 046	10 778 666	8 638 233
3.3	Universities/ High schools	149	480 809	404 566
4	Health-care facilities	125	684 707	585 994
4.1	Hospitals	98	538 161	466 751
4.2	Other institutional care	27	146 545	119 243
5	Hotels and restaurants	73	210 176	172 730
5.1	Hotels	22	65 567	55 599
5.2	Other short-stay accommodation buildings	51	144 609	117 131
6	Sport facilities	162	362 148	324 572
7	Wholesale and retail trade service buildings	39	334 329	292 260
8	Other types of energy consuming buildings	328	515 564	482 287
	Without detailed data	63	337 415	269 932
	TOTAL	13 698	21 546 097	17 846 623

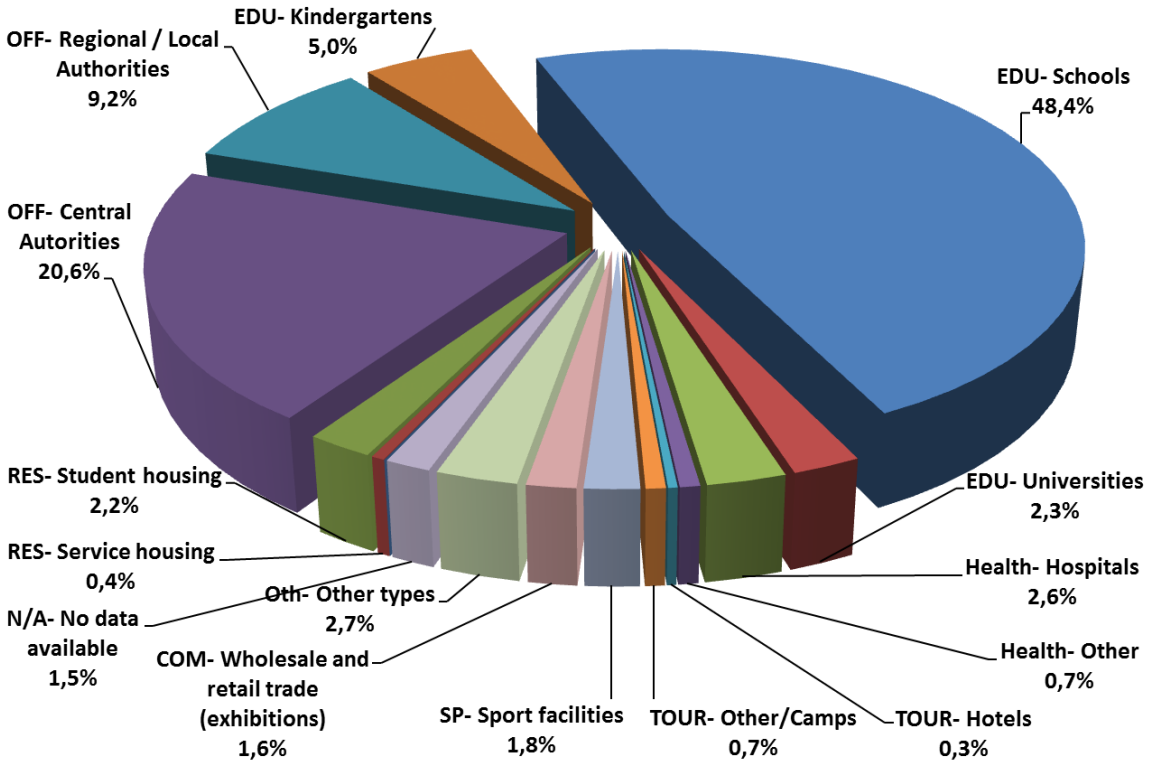


Figure RO 3: Structure of public building stock
(Source:[25], INCD URBAN-INCERC)

The distribution of building structure of central public buildings (masonry walls, concrete frames and masonry walls, large prefabricated panels and other, i.e wood, metal, curtain walls etc.) is illustrated in Figure RO 4.

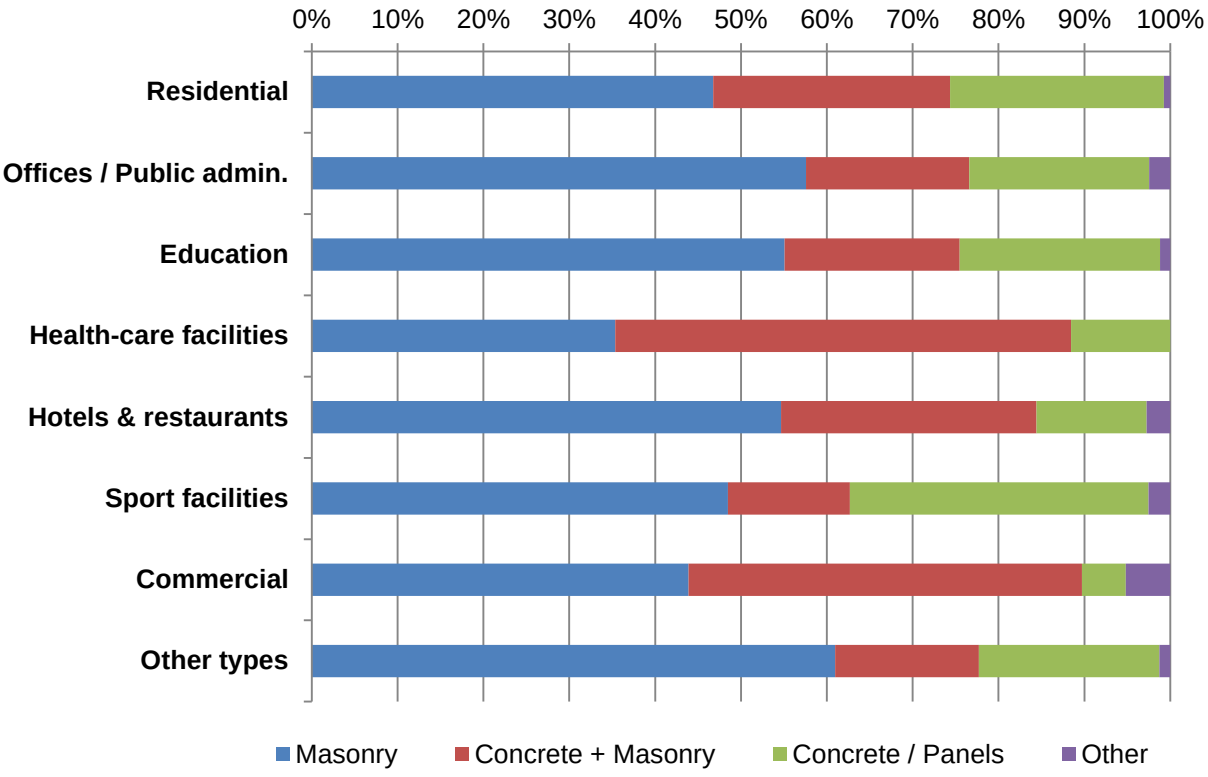


Figure RO 4: Structure of public building stock
(Source:[25], INCD URBAN-INCERC)

The central government building stock by age band, based on construction year or major refurbishment year, is presented in Figure RO 5.

The ratio of building envelope area to building volume (Compactness Ratio), which influences the heating and cooling need of a building, was estimated for each building category based on the number of floors above ground (including Ground-floor), built-in area occupied by the building (area at ground level) and total constructed area of the building. For the calculation, a length-width ratio of 1,6 (regardless of building type) and an average floor height of 2,75 m were assumed, together with the average number of floors per building category.

The calculated shape characteristics (Compactness Ratio) are presented in Table RO 4.

The heating system of the central public stock is predominantly central heating, connected to district heating or to a heating plant or one in a nearby the building. The heating system type per building category is presented in Figure RO 6.

Almost all buildings connected to a heating plant are equipped with heating systems with conventional boiler.

The fuel type used for heating and DHW generation is presented in Figure RO 7.

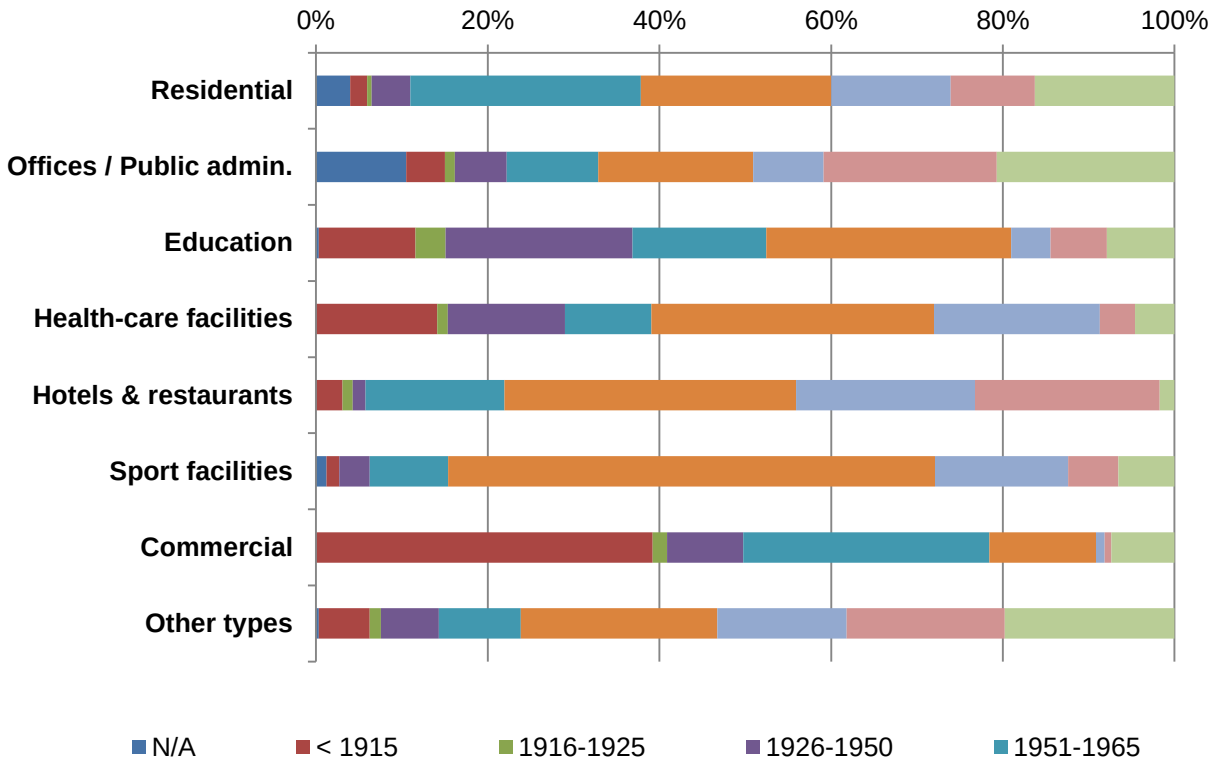


Figure RO 5: The public building stock (Central Gov.) by construction year
(Source:[25], INCD URBAN-INCERC)

Table RO 4

No.	Category / sub-category	Compactness Ratio (area of the exterior walls/building volume), m^{-1}	Number of (above ground) floors (including Ground-floor)
1	Residential	0,25	4,6
2	Offices / Public admin.	0,26	4,6
3	Education	0,25	3,2

No.	Category / sub-category	Compactness Ratio (area of the exterior walls/building volume), m^{-1}	Number of (above ground) floors (including Ground-floor)
4	Health-care facilities	0,20	4,1
5	Hotels & restaurants	0,23	4,1
6	Sport facilities	0,34	1,6
7	Commercial	0,20	3,3
8	Other types	0,36	1,8

(Source: [25], INCD URBAN-INCERC)

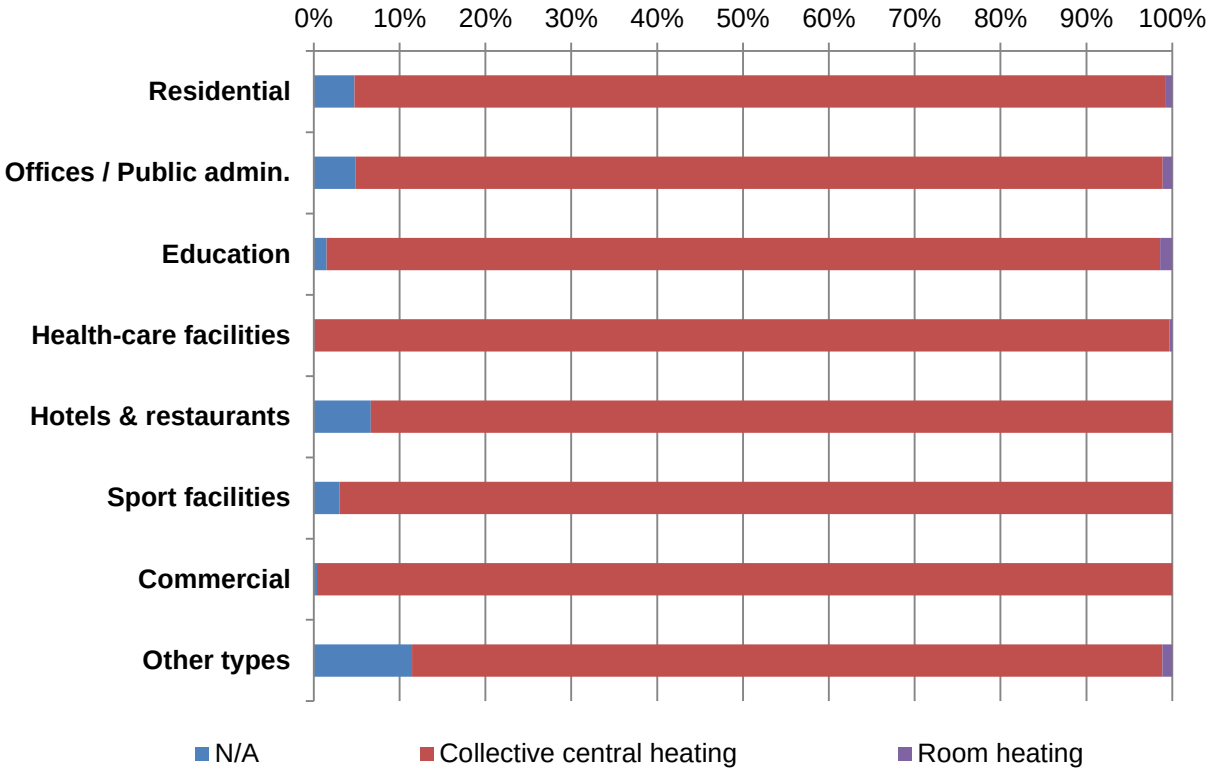


Figure RO 6: Heating system in public buildings
(Source:[25], INCD URBAN-INCERC)

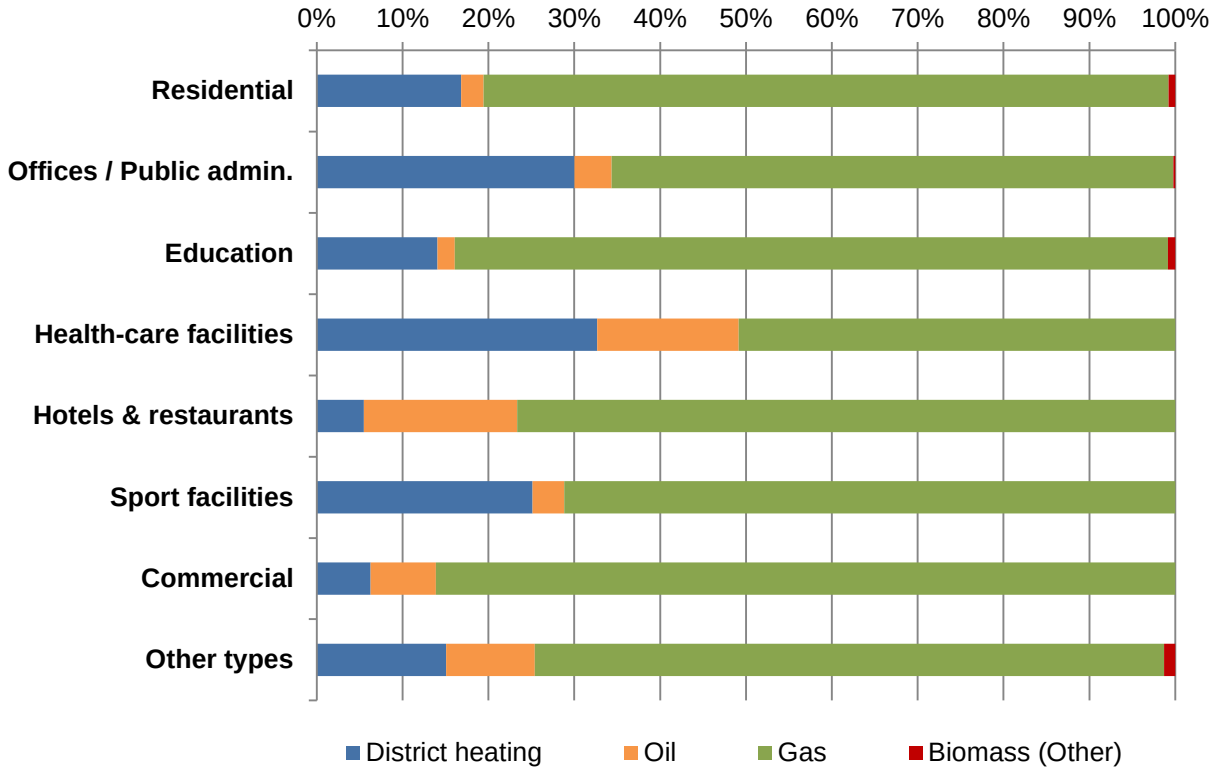


Figure RO 7: Share of fuel type per building category - public building stock
(Source:[25], INCD URBAN-INCERC)

Regarding the energy performance of existing public building stock, Table RO 5 presents the main thermal characteristics (building envelope) as well as normal specific consumption per building category.

Table RO 5

No.	Building category	Wall, W/m²K	Roof, W/m²K	Floor, W/m²K	Windows, W/m²K	Final Energy Use, kWh/m²yr
1	Residential	Avg: 1,30 Min: 0,56 Max: 1,70	Avg: 1,40 Min: 0,20 Max: 1,70	Avg: 1,10 Min: 0,22 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	120 – 300
2	Offices / Public admin.	Avg: 1,10 Min: 0,59 Max: 1,30	Avg: 0,9 Min: 0,25 Max: 1,4	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	120 – 350
3	Education	Avg: 1,10 Min: 0,59 Max: 1,30	Avg: 0,9 Min: 0,25 Max: 1,4	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	150 – 350
4	Health-care facilities	Avg: 1,10 Min: 0,57 Max: 1,30	Avg: 0,9 Min: 0,22 Max: 1,4	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	200 – 400
5	Hotels & restaurants	Avg: 1,10 Min: 0,57 Max: 1,30	Avg: 0,9 Min: 0,22 Max: 1,4	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	150 – 300
6	Sport facilities	Avg: 1,10 Min: 0,59 Max: 1,30	Avg: 0,9 Min: 0,25 Max: 1,4	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	150 – 350

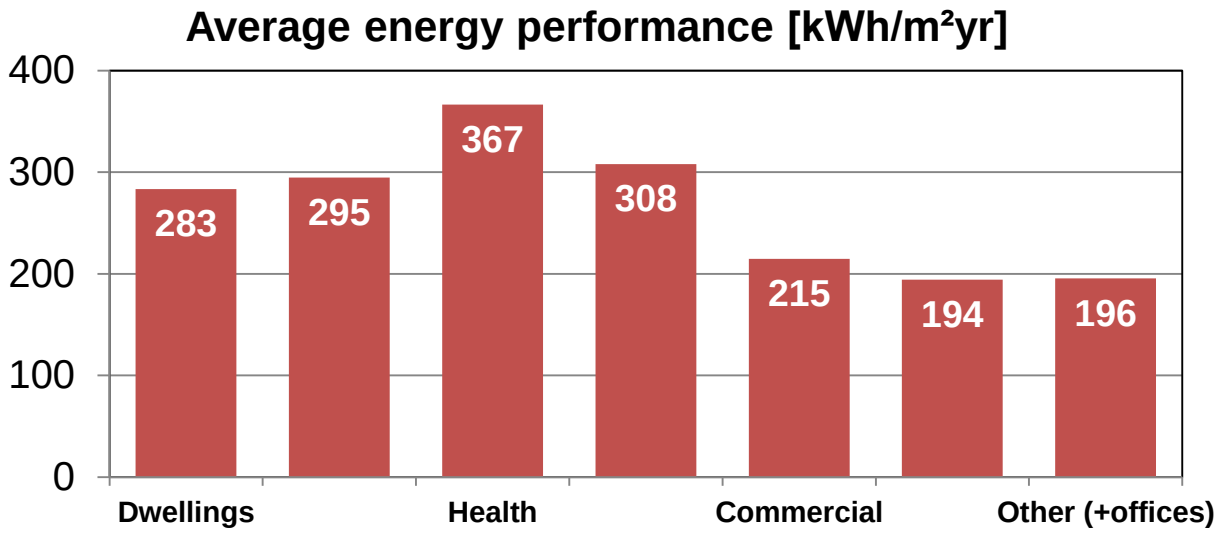
No.	Building category	Wall, W/m²K	Roof, W/m²K	Floor, W/m²K	Windows, W/m²K	Final Energy Use, kWh/m²yr
7	Commercial	Avg: 1,40 Min: 0,91 Max: 1,70	Avg: 0,90 Min: 0,25 Max: 1,40	Avg: 0,95 Min: 0,40 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	150 – 300
8	Other types	Avg: 1,40 Min: 0,91 Max: 1,70	Avg: 1,00 Min: 0,33 Max: 1,40	Avg: 1,0 Min: 0,83 Max: 1,40	Avg: 2,0 Min: 1,3 Max: 2,5	120 – 250

(Source: [22], [24], [25], INCD URBAN-INCERC)

3.7.3 Energy performance of public building stock (EPC Database)

The information contained in issued energy performance certificates permits the evaluation of average energy performances by building type, provided that the number of issued certificates, location of building and shape factor (building envelope to internal volume ratio) ensure a representative statistical sample in terms of conditioned space floor area of building type and climatic consistency.

The central database with energy performance certificates (EPCs), issued by energy auditors for buildings, is managed by INCD URBAN-INCERC and by the end of April 2014 more than 150,000 EPCs have been transmitted in electronic format, while only approx. 31,000 EPCs have been processed by manually entering key EP data in the structured database (of which 29,500 EPCs are for residential buildings). The preliminary analysis of approx. 1,500 of these EPCs permits a provisional evaluation of the energy performance of existing public buildings. Figure RO 8 presents the result of this analysis regarding the final energy use and CO_2 emissions indicators, but is not statistically representative value due to the very low number of analysed certificates.



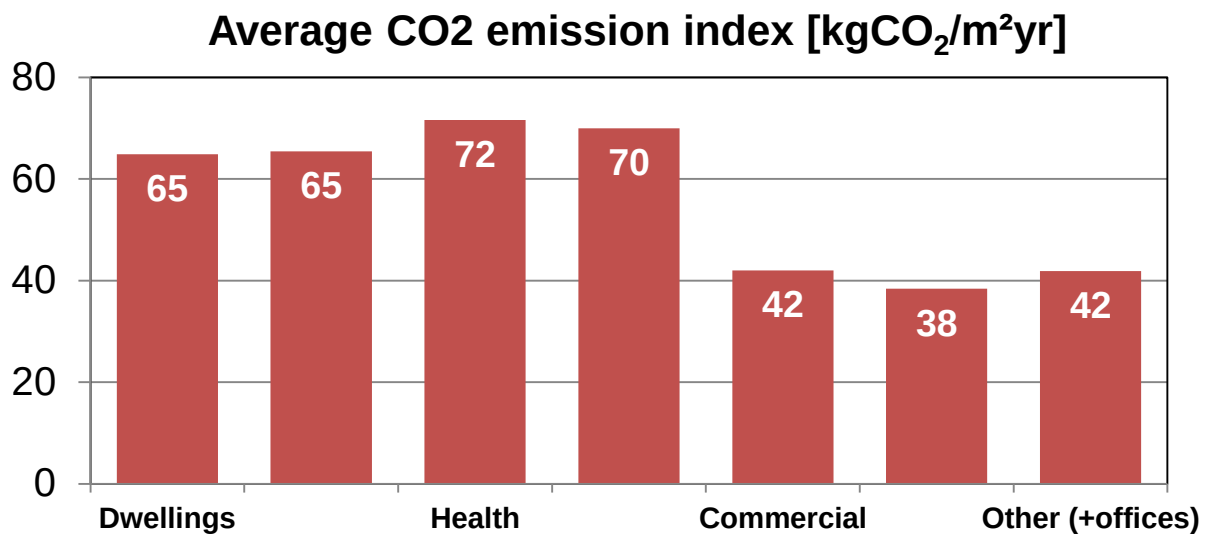


Figure RO 8: Estimative evaluation of energy performance of existing buildings
(Source: INCD URBAN-INCERC)

Figure RO 9 presents the share of each use (building service) in the final energy consumption for each public building category, including appliances.

The energy performance of buildings as presented reflects the actual status and the existing systems in each building category.

Regarding education buildings, which is the building category with the highest share in the total building stock in Romania (along public office/administration buildings), one should mention the lack of mechanical ventilation systems, which lead to inadequate ventilation in many classrooms (considered to be the main cause of students' performance reduction and health symptoms). Moreover, it is a usual practice in schools renovation to increase the air tightness of building envelope without installing controlled ventilation systems (*Source: INCD URBAN-INCERC)*. This could be the focus of the package of technical solutions which will be provided within the RePublic_ZEB project.

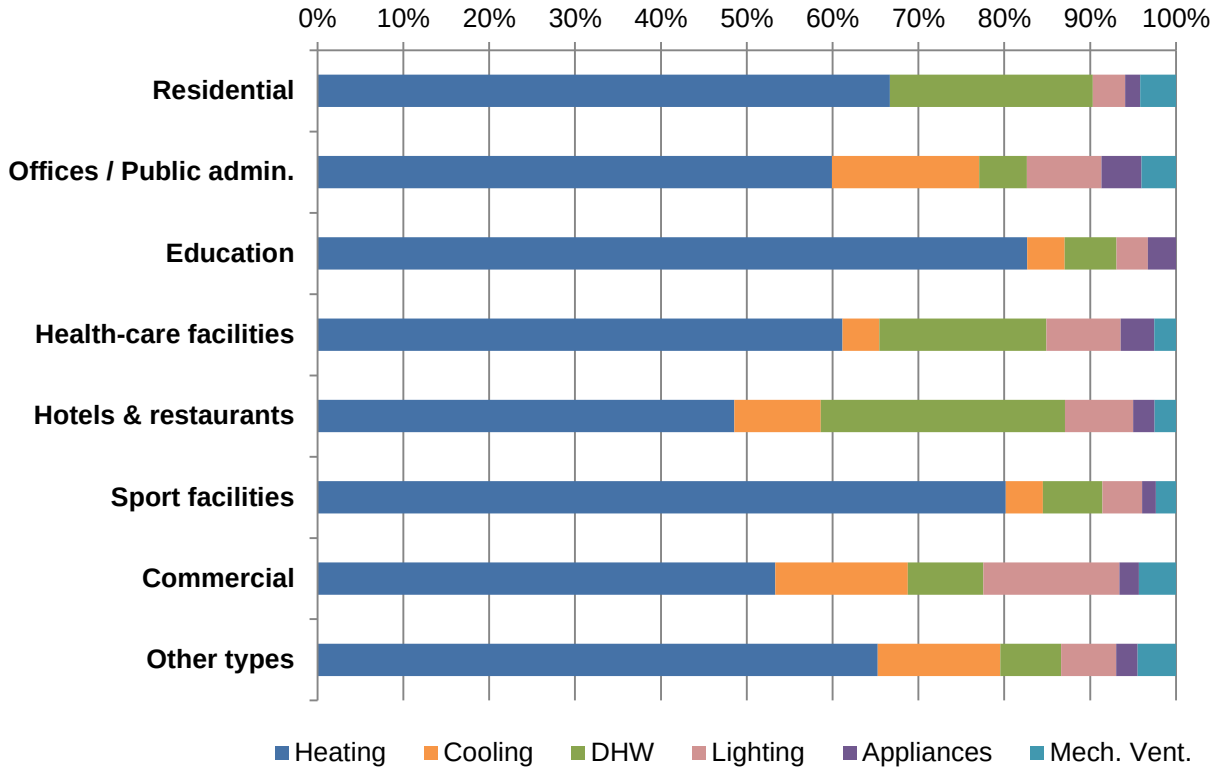


Figure RO 9: Estimative evaluation of energy performance of existing buildings
(Source: INCD URBAN-INCERC)

3.8 SLOVENIA

3.8.1 Overall picture of the building stock in Slovenia

Actual use of the buildings is adapted to CC-SI classification of objects by the Regulation on the introduction and use of a common classification of facilities and establishing facilities of national importance (CC-SI, Uradni list RS, št. 33/03). The available data on buildings in Slovenia are available on publicly available databases, which are maintained by the Geodetic Administration of the Republic of Slovenia. The most important one is Registry of Real Estates, where data on classification of the buildings for the entire building stock can be found (Table SI 1).

Table SI 1: The total floor area of buildings according to CC-SI uniform classification of buildings in Slovenia [REN 2014]

CC-SI code	CC-SI code explanation	Total floor area [1000 m²]
CC-SI 111	Apartments in the building with one part buildings	4 5351,71
CC-SI 112	Apartment in the building with two parts of buildings	4 285,78
CC-SI 112	Apartment in the buildings with more parts of the building	17 001,45
CC-SI 113	Residential units in the special purpose buildings	1 001,06
CC-SI 121	Restaurant use	2 748,10
CC-SI 122	Administrative and office use	6 728,44
CC-SI 123	Commercial activity and other service activities	5 960,63
CC-SI 124	Use of the marketing, the implementation of electrical. Communication	5 263,04
CC-SI 125	Industrial use and storage	19 400,33
CC-SI 126	Use for general public significance	7 265,34
CC-SI 127	Agricultural land use, land use for religious rituals, ...	42 225,49
CC-SI 13	Joint share	267,44

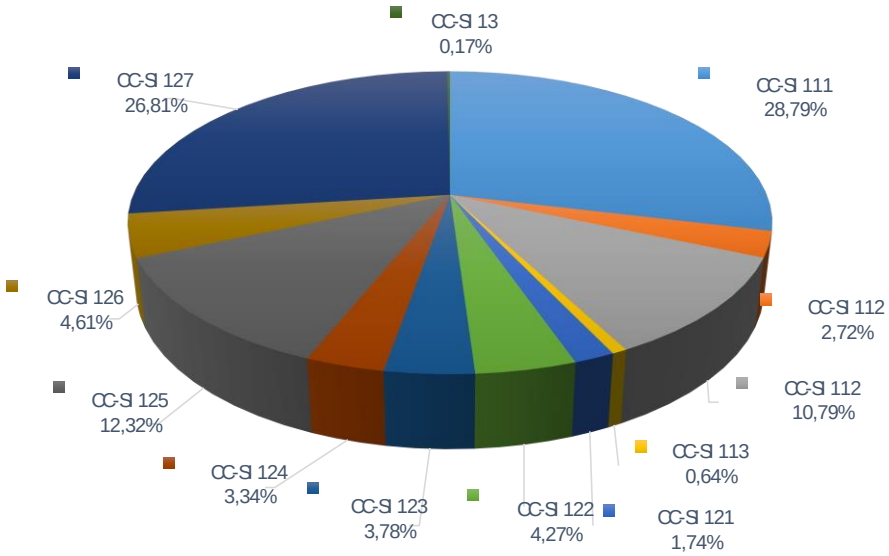


Figure SI 1: The percentage of buildings classifications representation for the Slovenian building stock

3.8.2 Buildings stock data

Public buildings cover 10% of the entire building stock; this includes kindergartens, schools, universities, hospitals, building for culture and entertainment, sport halls and others. In 2013, an

extensive survey was conducted related to public and service sector. The building owners are aware that even simple measures can reduce the use of energy. Almost 60% of all organizations are already investing in measures that lead to lower energy consumption. Only 15% of all respondents is familiar with EPC, 29% of them states their building facade is without any insulation and a quarter of them have an insulation thickness up to 10cm. Results of the survey indicate awareness and willingness to invest in energy savings measures in the non-residential building sector.

3.8.2.1 Public and service sector

An overview of the non-residential building sector is seen in Table SI 2. According to the building category, a CC-SI classification code was attributed to each. Each building in the databases has a unique identification code. The identification code was used as a primary key, and the CC-SI code as the secondary key while searching the total number of buildings and floor areas for each category. Over 4000 buildings are owned and/or occupied by central or regional authorities. Among these, the buildings of central government were identified (further explained in section 3.8.2.2 below).

Table SI 2: Total number of buildings and surfaces per each category (REN 2014)

No.	Category	Number of buildings	Total floor area
1	Offices / Public administration	4 178	1 050 095
2	Educational buildings	4 513	3 632 263
3	Health-care facilities	2 337	1 263 939
4	Sport facilities	303	1 029 328
5	Other types of energy consuming buildings	5 397	2 324 369

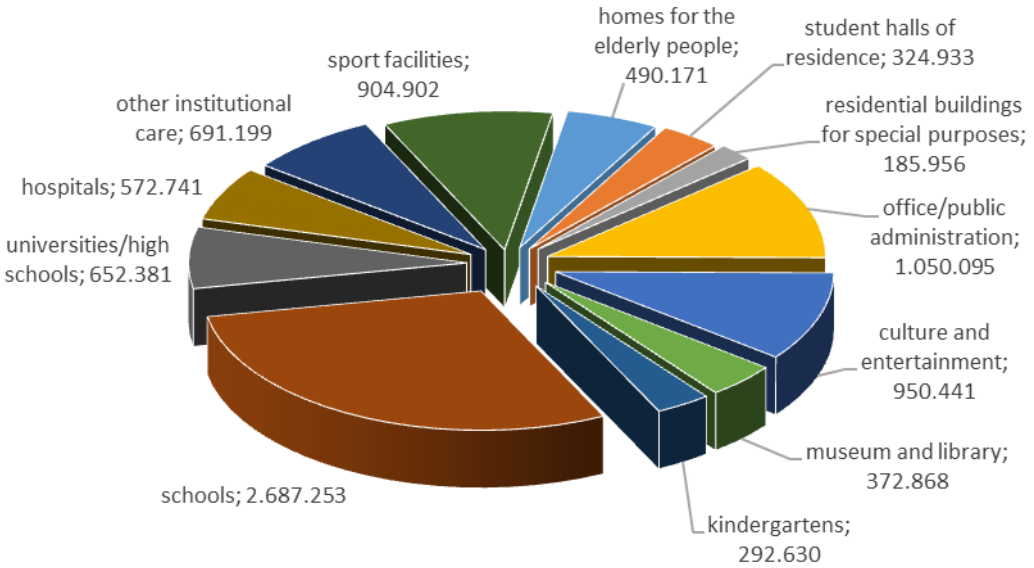


Figure SI 2: Structure of Slovenian public building sector (type, total floor area)

Taking into account the structure of Slovenian public buildings stock, the proposed reference buildings to be further detailed for simulation of energy performance in various scenarios are:

- office building,
- school,
- kindergarten

- hospital.

Figure SI 3 shows the proportion of buildings that already have established energy bookkeeping with energy agencies. A vast majority does not have it yet; the biggest percentage lies with buildings for educational purposes, offices and buildings of public administration.

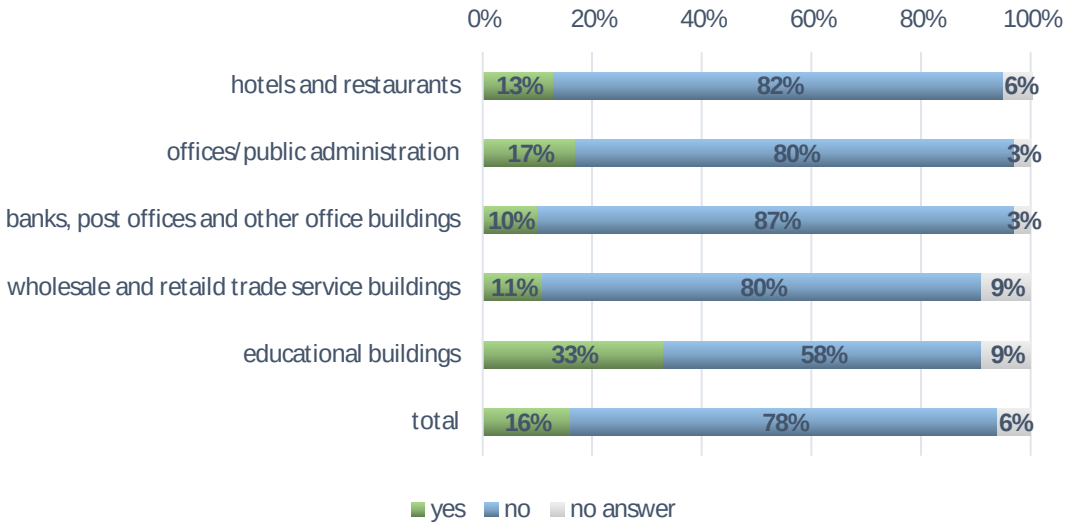


Figure SI 3: Cooperation with outer institution in the field of energy management
(REUS, 2013)

A large proportion in each category of non-residential buildings has not had a conducted energy audit yet, presented in Figure SI 4.

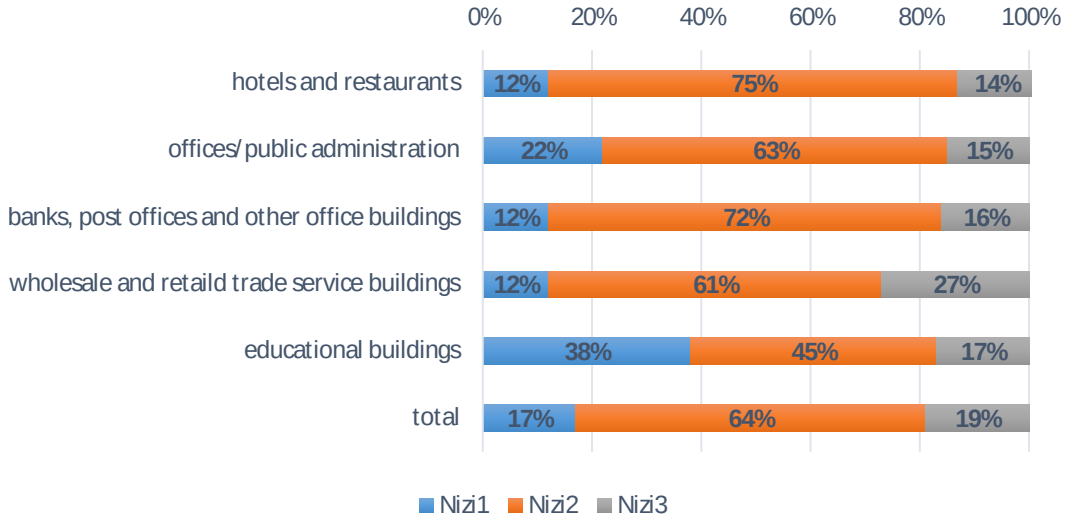


Figure SI 4: Conducted Energy Audit
(REUS 2013)

Among the ones that have not yet conducted an energy audit, almost 50% in each category is interested in doing so.

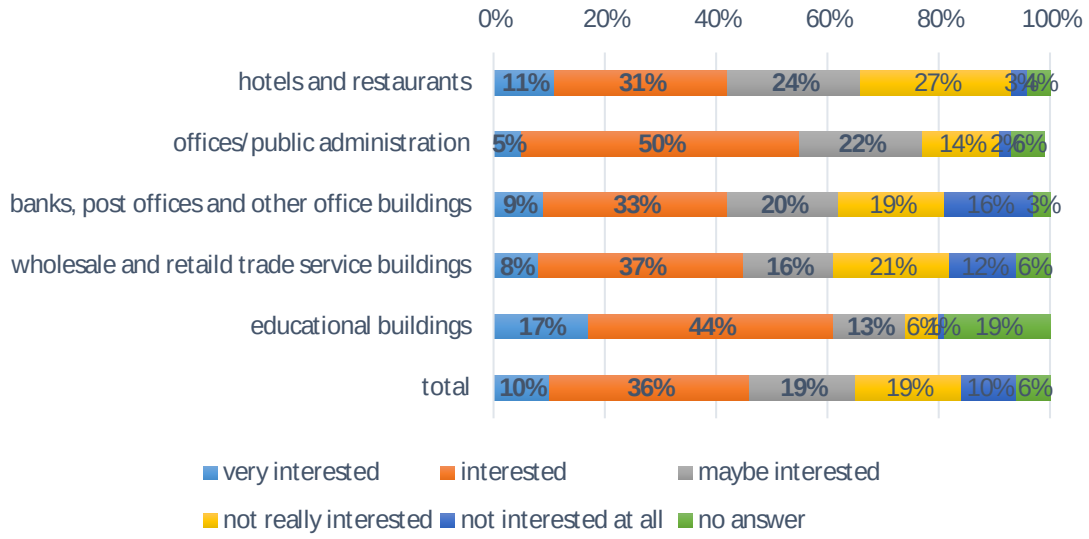


Figure SI 5: Interest to carry out an energy audit *(REUS 2013)*

A relatively small number of buildings use renewable energy sources for any kind of purposes.

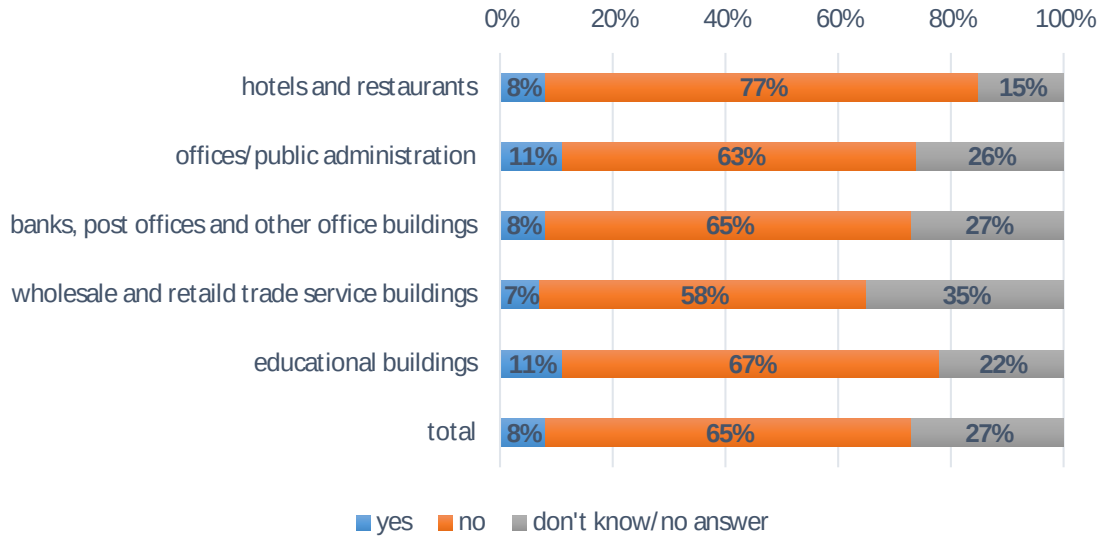


Figure SI 6: Use of RES *(REUS 2013)*

Figure SI 7 illustrates the percentage of buildings managers who are interested to purchase electricity produced from renewable energy sources in the next three years.

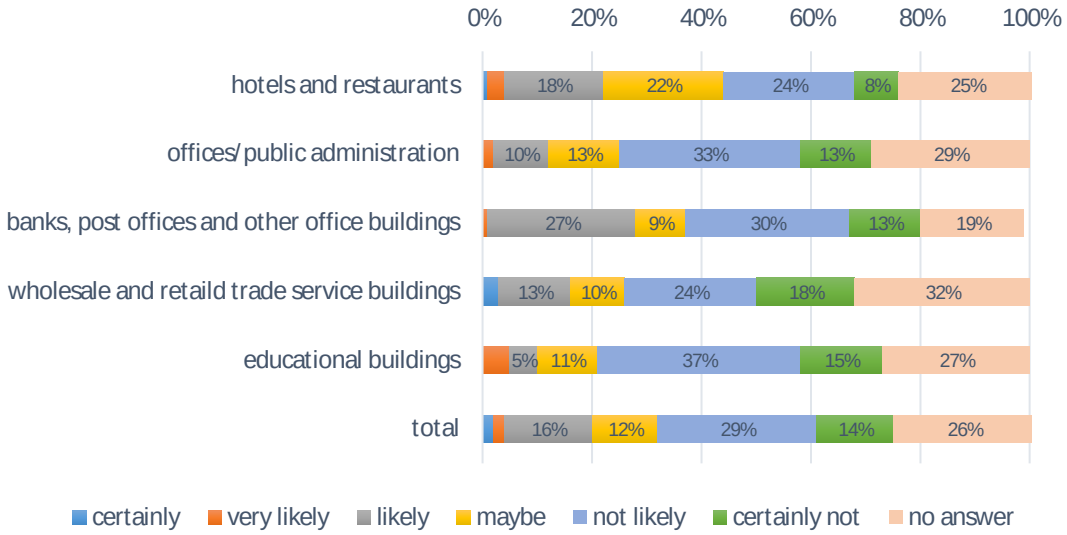


Figure SI 7: Probability of purchasing electricity produced from renewable energy sources in the next three years *(REUS 2013)*

Natural gas, district heating and oil are the most common used energy carriers for the system heating and the preparation of DHW (Figure SI 8).

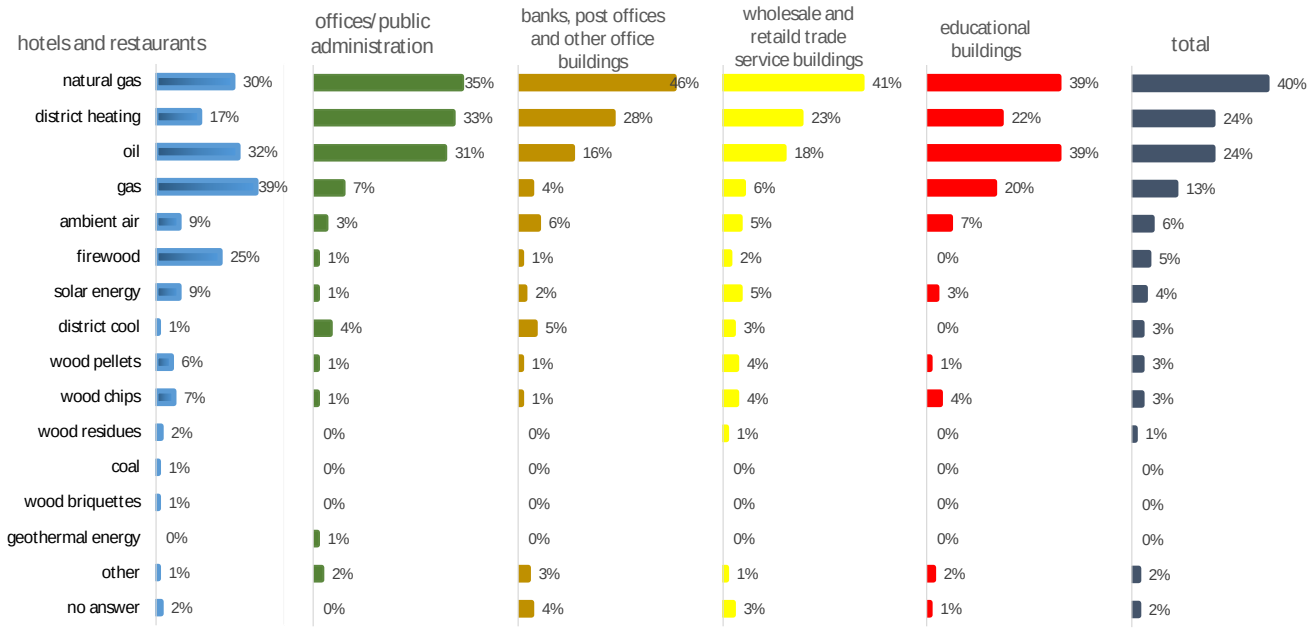


Figure SI 8: Use of energy carriers in non-residential building sector *(REUS 2013)*

Figure SI 9 presents the most likely used energy carrier, when replacing the entire heating system.

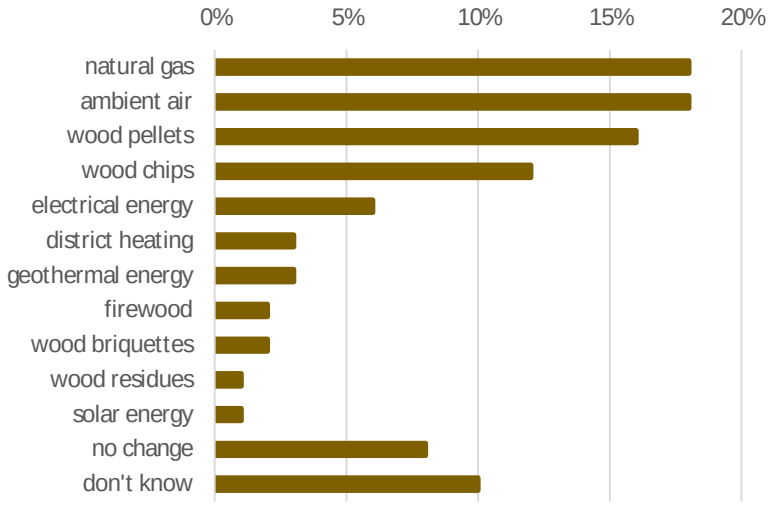


Figure SI 9: The choice of energy carrier when replacing the heating system
(REUS 2013)

3.8.2.2 Central government buildings

Article 5 in the Directive on Energy Efficiency (2012/27/EU) requires that each Member State shall renovate 3% of the total floor area of buildings owned by the central government from 1st January 2014 every year or adopt alternative cost effective measures in order to achieve the same improvements in energy efficiency of government buildings. The member state is obliged to prepare and publish an inventory of these buildings, which must contain information about the area and energy efficiency of these buildings.

The Ministry responsible for energy prepared records, resulting from the national registry for Real Estate Cadastre by the Surveying and Mapping Authority of the Republic. Census represents buildings of this register, which is owned by the Republic of Slovenia (RS) or legal person, which is assumed to represent the ownership of the Republic of Slovenia (ministries, funds, institutions, ...) and whose registered manager of state property in accordance with the Regulation on mode of entry managers of real estate in the Land Cadastre and cadastre (Ur. l. RS, št. 121/2006 and 104/2013).

Of these buildings that comply with the provisions of the Directive in the records (link) only those buildings designated for business use and with a floor area greater than 500 m² are included. Energy efficiency of buildings is defined by an estimate of primary energy consumption per m². The assessment took into account the age of the building and property of the object and renovation year of the building envelope.

The records of government buildings are derived from the state register of real estate on the 18th April 2014. Since the registry continues to be compiled, the records will be updated in the future. In addition, the Ministry of Justice next year intends to establish an information system upgrade to CEN (Central Register of real estate owned by RS), which will replace the existing record.

3.8.3 Energy performance of public building stock

The energy performance of public building stock is presented in Figure SI 10 based on the information available from EPC Database [bal. on 03.2014]. Category "Other" correlates to delivered energy for electricity.

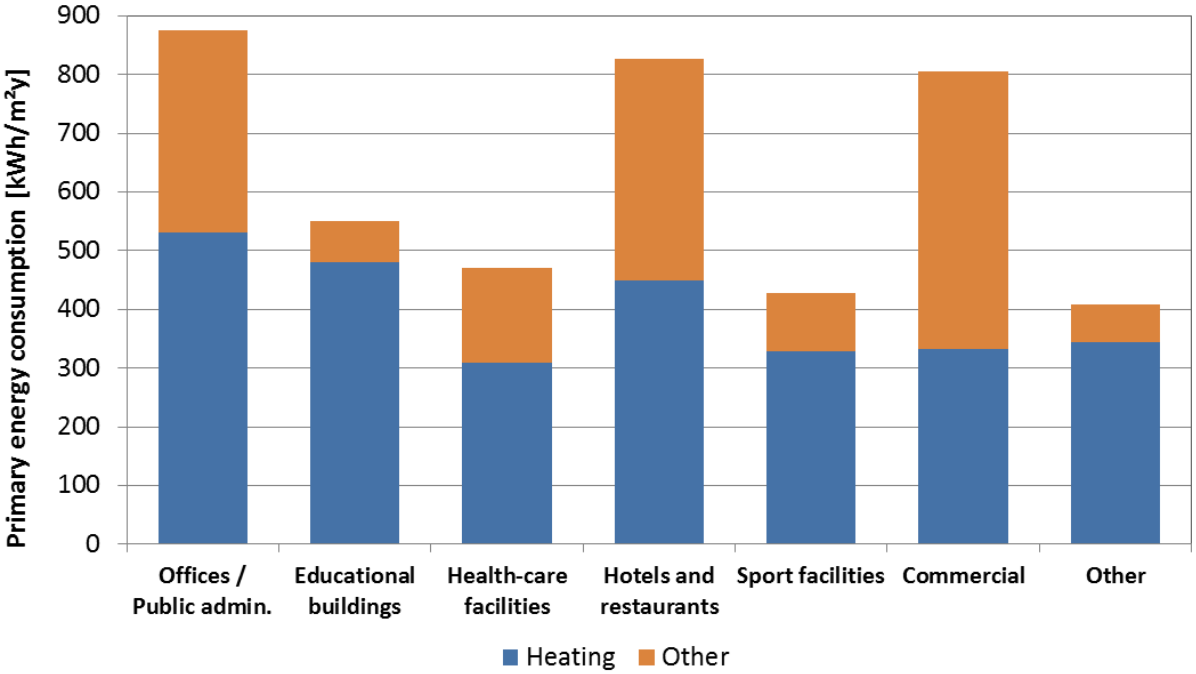


Figure SI 10: Estimative evaluation of energy performance of existing buildings
(Source: EPC Database 03.2014)

3.9 SPAIN (Catalonia Region)

3.9.1 Overall picture of the building stock in Spain and Catalonia Region

According to the national population and building census, in 2011 there were 9 814 785 buildings in Spain.

The number of total residential buildings in Catalonia region was 1 192 463 buildings according to the 2011 national population census (IDESCAT and INE, 2011). In the 2001 national census 87% of residential buildings were owned privately (IDESCAT and INE, 2001).

The total floor area for residential buildings in 2001 in Catalonia was 212 146 966 m². For the year 2010, Peters estimated a total floor area of 276 030 851 m^2 (Christoph Peters et al., 2011) by adding the area of newly completed dwellings.

The number of non-residential buildings in Catalonia are 105 803, according to Peters based on data from IDESCAT and INE (Christoph Peters et al., 2011). The information regarding non-residential categories is only available by establishments, considering an establishment as an independent unit inside a building where some economic activity is done. The 2001 population and building census accounted for 405 351 units or establishments.

The Population and buildings census 2001, (IDESCAT and INE, 2001) shows 405 351 non-residential establishments in Catalonia in different categories (including public and private establishments), of which: 19% Offices, 2% Education buildings, 2% Health care facilities, 1% Social Welfare, 1% Sport Facilities and Cultural, 42% Commercial and 33% Others (industry, agriculture etc..).

There have been difficulties to find recent data on building stock especially on energy consumption, particularly for the tertiary sector and specifically for public buildings. Other studies have highlighted these difficulties as Peters (Christoph Peters et al., 2011) and Mata (Mata et al., 2013).

3.9.2 Public building stock data

3.9.2.3 Number of buildings and surface

The Spanish government performed an energy inventory of central government buildings which is presented in the report to the Commission on the transposition of article 5 and 6 of Directive 2012/27/EU (Spanish Government. Ministry of Industry, Energy and Tourism, 2013).

This inventory lists the heated and/or cooled buildings that are occupied and owned by the central government with a floor area of more than 500 m². This inventory groups the building by ministry and do not specify its use. There were 1 763 buildings identified with a floor of 11 200 244 m2.

In the current document, a more in depth analysis has been done regarding the buildings owned by regional authorities. The study has been focused in the Catalonia Region.

The public building stock analysis includes social housing, offices, health centres, sport facilities and schools. Hotels and trade centres have been excluded from the analysis as they are mainly under private ownership.

Table SP 1 presents the number of buildings and their floor area for different categories in Catalonia

Table SP 1: Number of public buildings and areas for categories of public buildings in Catalonia

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²
1	Residential	88 660	6 061 595

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²
1.1	Social housing	88 660	6 061 595
1.2	Service housing		
1.3	Student housing		
2	Offices / Public administration	7 853	3 187 013
2.1	Central Autorities		
2.2	Regional Local Authorities		
3	Educational buildings	2 813	9 057 860
3.1	Kindergartens		
3.2	Schools	2 813	9 057 860
3.3	Universities/ High schools		
4	Health-care facilities	65	1 251 634
4.1	Hospitals	65	1 251 634
4.2	Other institutional care		
5	Hotels and restaurants	-	-
5.1	Hotels		
5.2	Other short-stay accommodation buildings		
6	Sport facilities	2 645	1 445 309
6,1	Swimming pools	228	107 205
6,2	Sportive halls	2 417	1 338 104
7	Wholesale and retail trade service buildings		
8	Other types of energy consuming buildings		
	TOTAL	**102 036**	**21 003 411**

Different sources have been consulted to obtain the number of public buildings and their floor area.

The social housing stock managed by the Housing Agency (Agencia d´habitatge) comprises 88,660 dwellings according to the regional benchmarking analysis done in the framework of the MARIE project in 2011 (Christoph Peters et al., 2011). According to this study, the social housing represents a 2% of the total number of dwellings in Catalonia. Therefore it has been assumed that the surface of social housing is also a 2% of the total building surface: 6 061 594 m^2

The number of offices in Catalonia and its surface has been obtained from the Cadastral Register Statistical Yearbook 2013 (Cadastral register, 2013). An 18% of the offices is assumed to be public owned offices, in line with the objectives of the Catalan Strategy for the Energy Renovation of Buildings 2014-2020 (Catalan Government, 2014) where the tertiary public buildings are considered to be 18% of all total tertiary buildings.

The number of public hospitals in Catalonia was obtained from statistical data from the Spanish Health Ministry (Spanish Health Ministry, 2014). However there was no available floor area data. An average floor area of 19 255,9 m^2 per hospital was used to estimate the total floor area, according to the Energy, Climate Change and Air Quality Plan from Barcelona, 2011-2020 (Ajuntament de Barcelona, 2011).

The number and the area of swimming pools and pavilions have been obtained from the Sportive Equipment Census from the Sports Catalan Centre of the Catalan Government (Sports Catalan Centre, Catalan Government, 2014).

The number of public schools has been obtained from the statistical data from Education Catalan Ministry 2014 (Catalan Education Ministry, 2014). As floor area data was not available an average

area for schools has been calculated from a set of energy audits in schools in the European project: EURONET 50/50 (Euronet 50/50, 2012).

Figure SP 1 shows the distribution of the total useful floor area occupied by public buildings (Table SP 1) for different building categories for Catalonia.

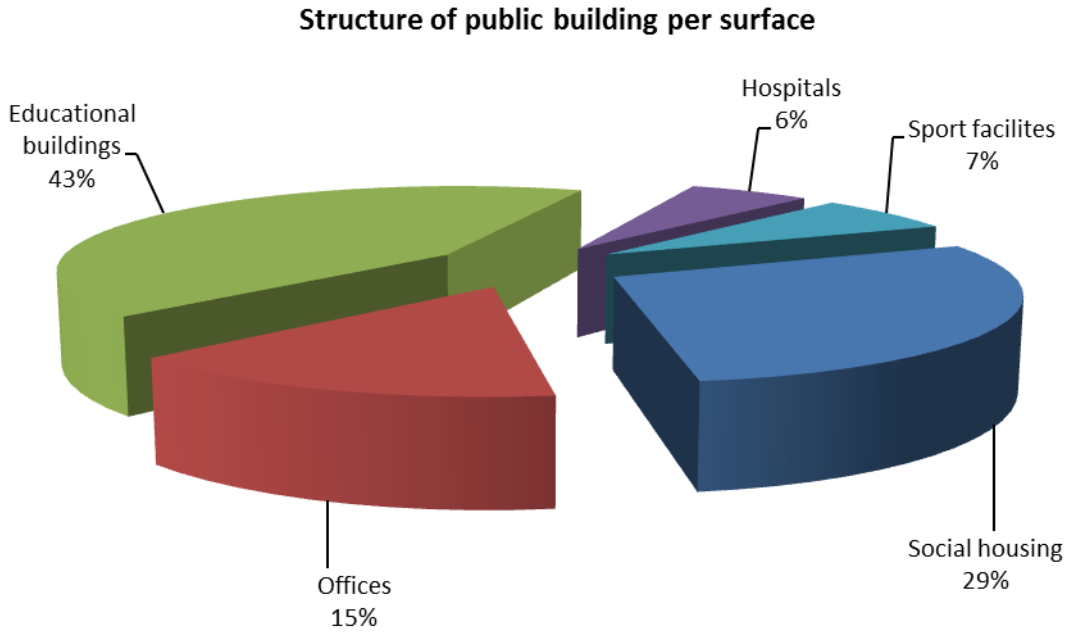


Figure SP 1: Structure of the public building stock
Source: (Christoph Peters et al, Cadastral register, Spanish Health Ministry, Ajuntament de Barcelona, Sports Catalan Centre, Euronet 50/50)

3.9.2.4 Construction year

The Spanish Government, in its Cost Optimal Report, regarding EPBD, has selected 6 different construction periods in Spain (Ministry of Development of Spain. Directorate for Architecture, Housing and Planning, 2013):

- Before 1900: Traditional building construction
- 1901 – 1940: Traditional / First modern movement experiences
- 1941 – 1960: 1st Period after civil war (reconstruction)
- 1961 – 1980: 2nd period (expansion)
- 1981 – 2006: 1st energy regulation for buildings (NBE-CT-79)
- After 2006: New Building Code (CTE) in force

The national population and building census, has a classification of the residential buildings by construction year, however this information is not available for non-residential buildings.

60% of the residential buildings were constructed before 1980 (30% between 1961-1980) and a 40% after 1980 (36% before 2006)

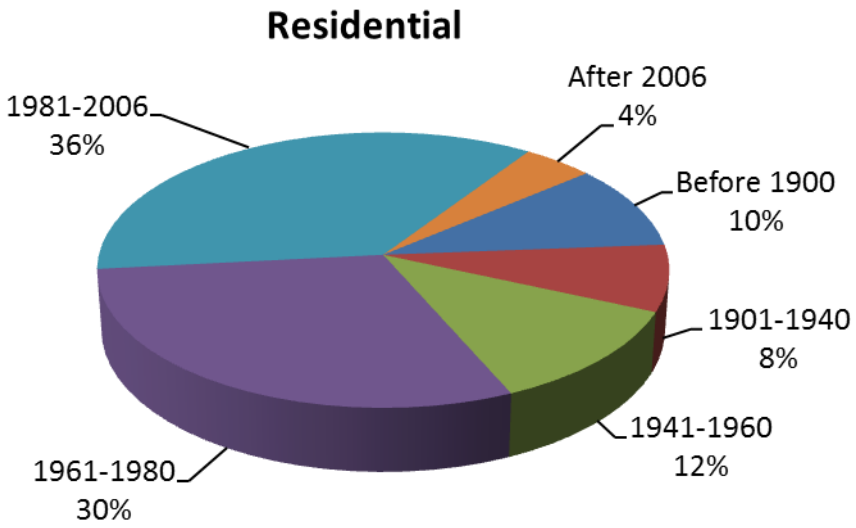


Figure SP-2: Distribution of the Catalan residential buildings stock according construction year

Source: (National statistic Institute (INE), 2011)

Regarding non-residential public buildings there is some information available in a study from the Spanish Municipalities Federation (FEMP). They performed a study of 324 municipal public buildings all over Spain (Federación Española de Municipios y Provincias (FEMP), 2011). Figure SP 3 shows the distribution of those 324 buildings as a function of the construction year, almost 50% of public buildings were constructed between 1981 and 2006.

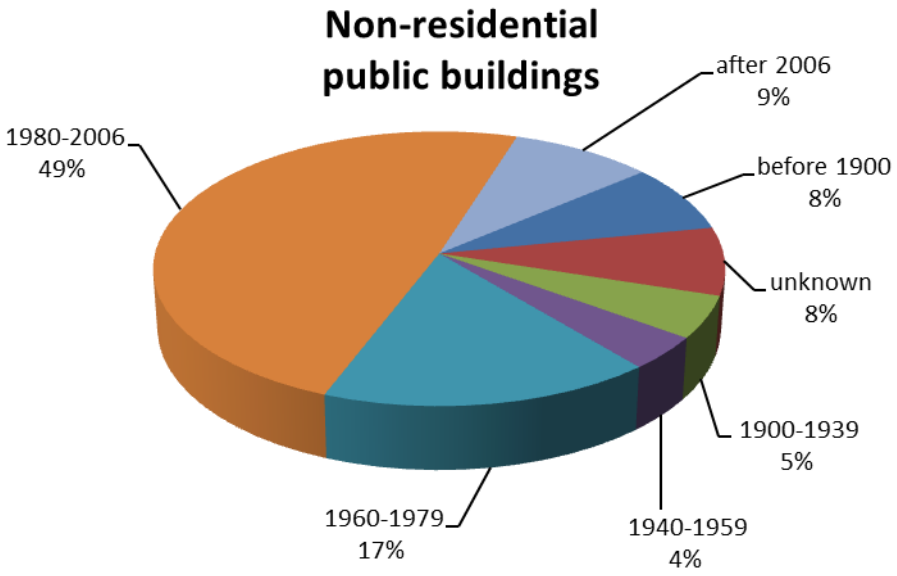


Figure SP 3: Construction year of municipal public buildings (based on 324 buildings)

Source: FEMP(Federación Española de Municipios y Provincias (FEMP), 2011)

3.9.2.5 Construction materials

The characteristic materials of the reference buildings selected by the Ministry of Development of Spain, to perform the cost optimal calculations are used here. The reference buildings have been identified as representatives for the most typical categories in Spain (Ministry of Development of Spain, Directorate for Architecture, Housing and Planning. 2013).

From the six reference buildings selected by the Ministry, one is a subsidized housing and two are non-residential buildings: an office building and an educational building.

The subsidized housing reference building is an isolated multifamily block constructed in the 1960s. The building was done with concrete slabs and brick load bearing walls. The office reference building was constructed in the 1960s with a concrete structure with lightweight, uninsulated cladding. The education reference building was constructed in the 1980s with concrete structure and brick half foot enclosure with thermal insulation according to NBE-CTE-79.

In Table SP 2 more detail of the construction materials for each of the three references buildings is presented.

Table SP 2: Construction materials for the reference buildings
Source: (Ministry of Development of Spain. Directorate for Architecture, Housing and Planning, 2013)

	Residential (multifamily)	Offices	Education
Façade	Vertical walls finished with cement plaster. 1/2' brick wall with air space solutions and hollow brick + 1/2' plaster or solid brick wall with plaster inside	Main facade of perforated brick with interior single hollow brick wall and no vent tube + coated stone or granite. 1/2' brick walls without plaster enclosing for exterior stair walls	1/2' brick facade with cladding + unventilated chamber with thermal insulation
Cover	Cover of Catalan ceramic tiles without insulation. Forged health on poorly ventilated air chamber.	Catalan cover with water stop sheet over ventilated chamber.	Ceramic tile pitched roof on concrete deck supported on hollow brick walls and thermal insulation between partitions. Flat roof with mortar slope, asphalt + gravel;
Horizontal partitions	Horizontal partitions ceramic tile cement mortar	Ceramic unidirectional slab	Unidirectional slab with ceramic elements. Ceramic tile flooring and plaster coating.
Vertical partitions	Partitions 1/2' vertical partitions of hollow brick + plaster.	1/2' hollow brick vertical partitions + plastering and tiling.	Hollow brick vertical partitions + plaster.
Glazing and frame	Wooden window frame + 6 mm monolithic glazing.	Steel window frame + 4/12/4mm glazing.	Aluminium frame sliding windows + 4/6/4mm glazing.
Flooring	Prestressed concrete beams slabs with cement infill.	Plain concrete slab on the ground	

In the same publication the surface to volume ratio of the reference buildings is presented, 0.69 for the residential building, 0.35 for the office building and 0.78 for the educational building. The number of floors for the office building is 11 floors considering ground floor and mezzanine. The education building has 2 floors including ground floor. The subsidized housing has 4 floors including ground floor.

The National Statistical Institute provides the number of floors for the tertiary buildings in Catalonia, but not divided by subcategory (IDESCAT and INE, 2001). The weighted average is 1,51 floors per tertiary building.

3.9.2.6 Heating system of the building stock

There is no specific information regarding the heating system in the public building stock. The National Statistical Institute (INE) has information of the heating and cooling systems for residential

buildings, but not for non-residential buildings. In Figure SP 4 and Figure SP 5, the type of heating system and the percentage of different fuel for heating for residential buildings is presented. Regarding cooling, 36% of the Catalan dwellings have cooling systems according to INE (National Statistical Institute (INE), 2008).

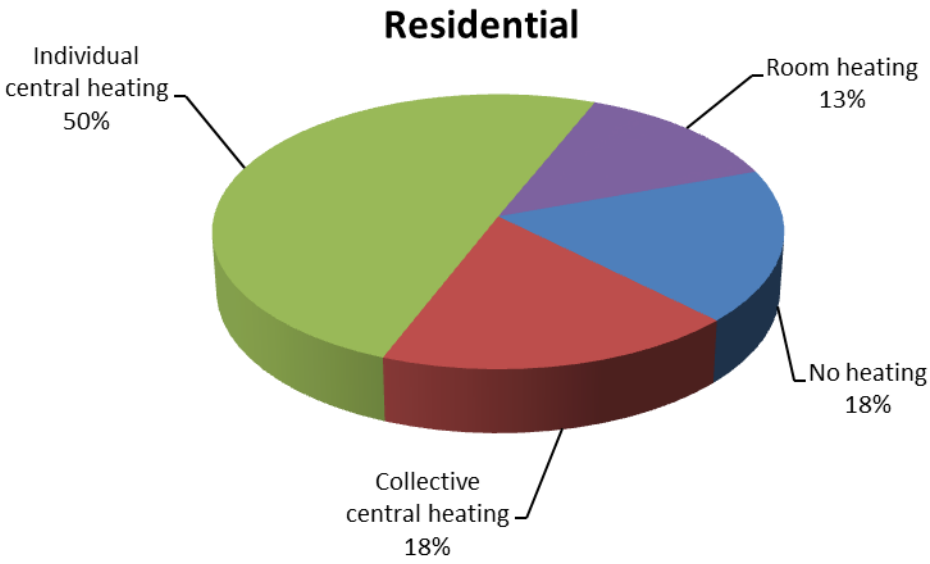


Figure SP 4: Heating system in residential dwellings
Source: (National statistic Institute (INE), 2008)

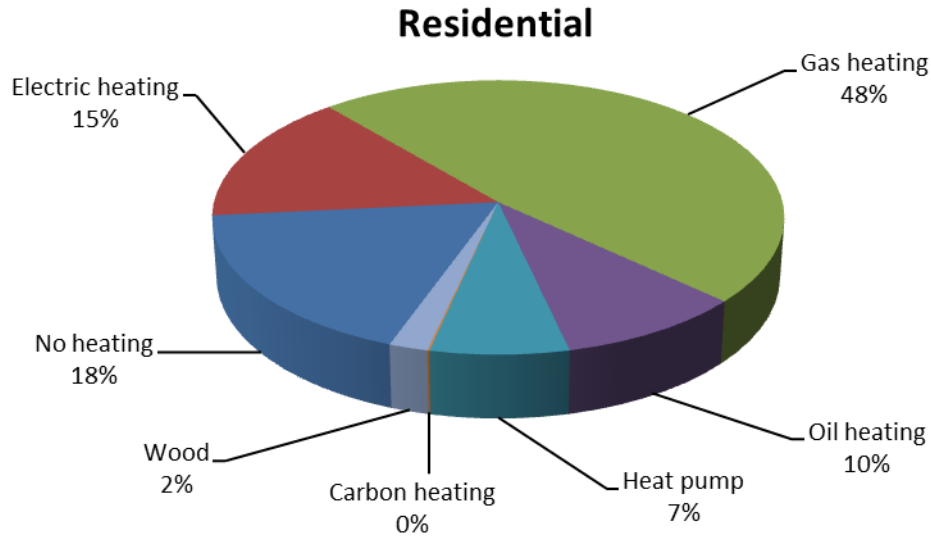


Figure SP 5: Share of fuel type per heating only residential category
Source: (National Statistical Institute (INE), 2008)

The study from the Spanish Municipalities Federation (FEMP) contains some information regarding non-residential public buildings heating systems as a function of the Spanish climatic zone (Federación Española de Municipios y Provincias (FEMP), 2011). The study analyses 324 buildings. The colder the climatic zone is, the more fuel is used for heating. In contrast, warmer climatic zones use electric heating instead. The Code climatic zones are defined by a combination of a letter (α1, A, B, C, D and E, from warmest to coldest) which represents the climate severity of winter and a figure which represents the climate severity of summer (1, 2, 3 and 4, from coldest to warmest).

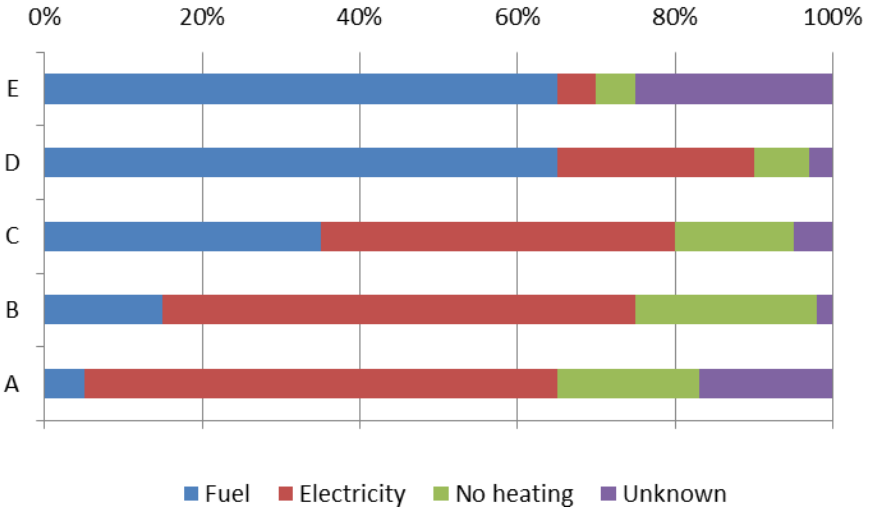


Figure SP-6: Share of fuel type per heating for non-residential public buildings in function of heating climatic zone

Source: (Federación Española de Municipios y Provincias (FEMP), 2011).

Regarding refrigeration, the warmer climatic zones have approximately the same percentage of central and individual air conditioning systems (30% each system). The percentage of buildings without air conditioning is 20%. The colder climatic zones have low percentage of air conditioning systems. (Federación Española de Municipios y Provincias (FEMP), 2011).

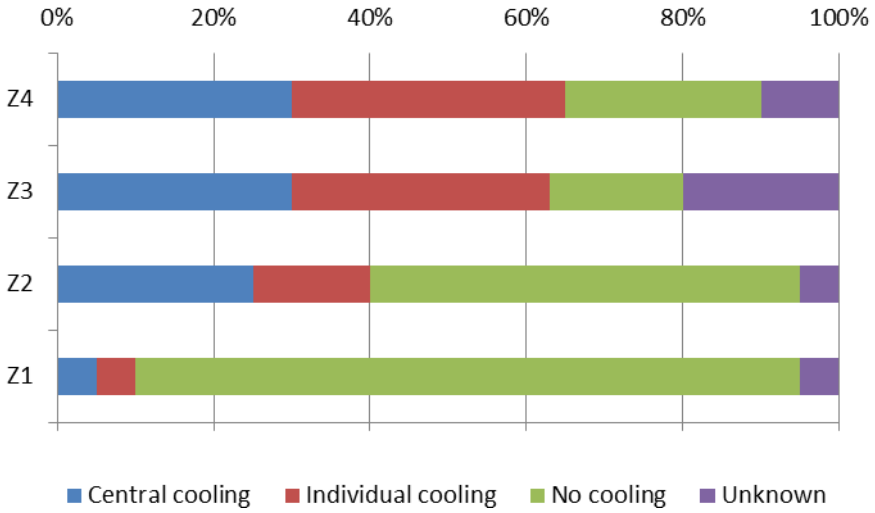


Figure SP-7: Type of cooling for non-residential public buildings in function of cooling climatic zone

Source: (Federación Española de Municipios y Provincias (FEMP), 2011).

3.9.2.7 Thermal characteristics of the envelope

The thermal characteristics of the envelope are dependent of the climatic zone as per the first energy regulation for buildings (NBE-CT-79) in 1979

The thermal characteristics of the building envelope for the reference buildings selected by the Ministry of Development of Spain can be seen in Table SP 3 (Ministry of Development of Spain. Directorate for Architecture, Housing and Planning, 2013)

Table SP 3: Thermal characteristics of the building envelope for the reference buildings

No.	Building category	Wall, W/m2K	Roof, W/m2K	Floor, W/m2K	Windows, W/m2K	Source
1	Residential (multifamily)	1,42/1,20	1,76	2,35	5,70	(Ministry of Development of Spain. Directorate for Architecture, Housing and Planning., 2013)
2	Offices.	1,51/2,44/1,53	0,89	3,20	2,15/3,52	(Ministry of Development of Spain. Directorate for Architecture, Housing and Planning., 2013)
3	Education	0,63	0,57	1,73	3,59	(Ministry of Development of Spain. Directorate for Architecture, Housing and Planning., 2013)

3.9.3 Energy performance of public building stock (EPC Database)

The energy consumptions for the tertiary buildings were studied in the Marie Project (Joana Ortiz et al., 2012) following a forecast tertiary calculation approach. The building floor area was estimated by the number of employees, in Spain the estimation of public buildings' area was 390 200 000 m^2 of tertiary floor. In Catalonia there was an estimation of 63 350 000 m^2 of tertiary floor according to the study. The specific primary energy consumption according this study was 419 kWh/m^2. These energy consumption values consider the energy consumption of not only public buildings, but also hotels, trade centres, restaurants and other categories of buildings which are normally under private ownership.

To determine the energy consumption only for public building categories, a sectorial and bibliographic research has been done. The primary energy consumption can be seen in Figure SP 8 and the distribution of energy uses for the different categories can be seen in Figure SP 9

The final energy consumption of social housing is assumed to be the one presented by Peters for residential use and its distribution among different uses (Christoph Peters et al., 2011).

The final energy consumption of offices has been calculated as the average consumption of the central government buildings compiled in the energy inventory of central government buildings in Spain compiled by the Spanish government for the transposition of the Article 5 of the Directive 2012/27/EC on Energy Efficiency (Spanish Government - Ministry of Industry, Energy and Tourism, 2013). The distribution among different uses is taken from a study of the Catalan Energy Institute (ICAEN, 2004).

An analysis on energy use in Spanish hospitals undertaken for an official report prepared by the Institute for Energy Diversification and Saving (IDAE), presented an average value of final energy consumption of 293 kWh/m^2 in 2011. The distribution of the energy consumption is based in an energy audit of a hospital (Gas Natural Fenosa, n.d.).

For pavilions and swimming pools, the final energy consumption has been calculated using the ratios of energy consumption for different kinds of pavilions and swimming pools according to a study of the Diputació de Barcelona (Regional Authority of Barcelona) (Andreu Corominas Renter. Diputació de Barcelona, 2011). The energy distribution of pavilions and swimming pools was provided by Salas (Albert Salas et al.,2012). The DHW in swimming pools accounts also for dehumidification and for the heating of the water from the swimming pool vase.

The final energy consumption of schools has been calculated as an average of the schools which participated in an energy audit of the Euronet 50/50 project (Euronet 50/50, 2012). The distribution among different uses is taken from a study of the Catalan Energy Institute (ICAEN, 2004).

The primary energy consumption has been calculated using the following primary energy factors: 2,461 $kWh_{primary}/kWh_{final}$ for electricity and 1,195 $kWh_{primary}/kWh_{final}$ for the fuel (assuming natural gas only) (IDAE, 2014).

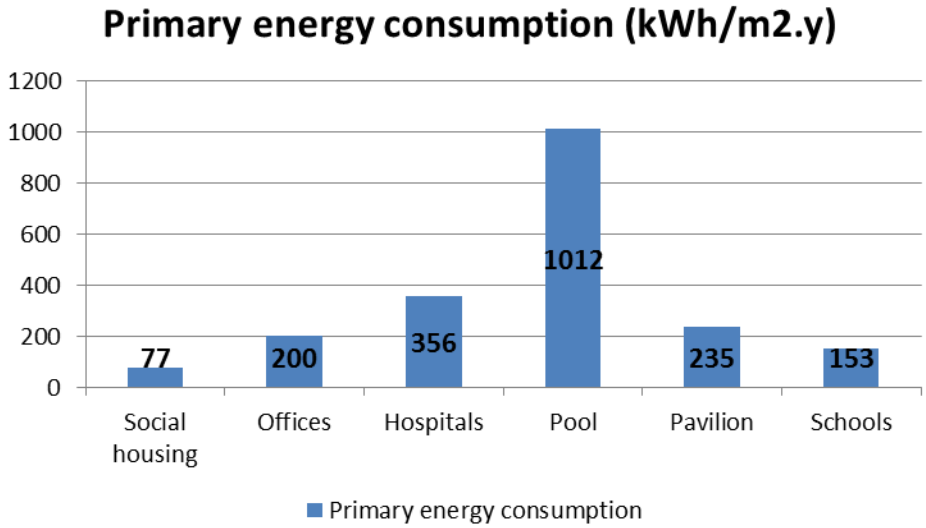


Figure SP 8: Public building primary energy consumption according sectorial bibliographic research

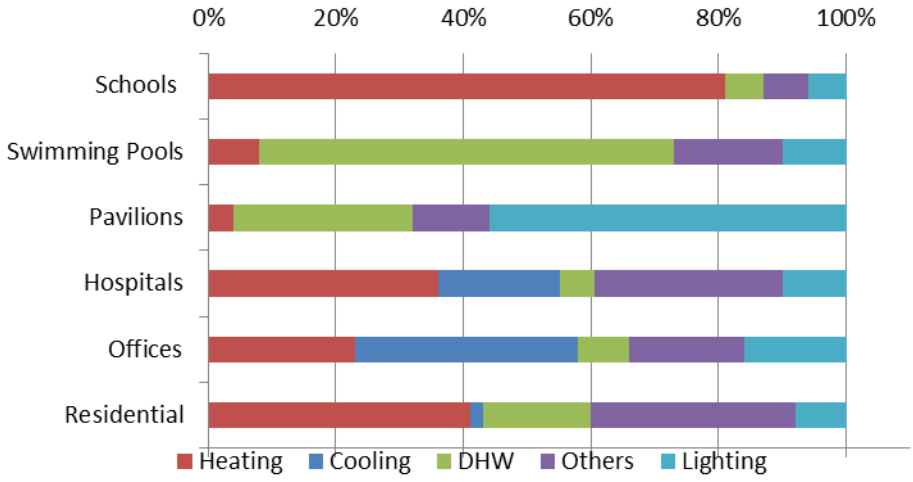


Figure SP 9: Percentage of distribution of energy uses

Source: (ICAEN, 2004)(Christoph Peters et al., 2011)(Gas Natural Fenosa, n.d.) (Andreu Corominas Renter. Diputació de Barcelona, 2011)

Figure SP 10 shows the average primary energy consumption of different building categories registered from the energy performance certificates provided by the Catalan Energy Institute (ICAEN) responsible for the Energy Certificates in Catalonia. The data refers only to energy performance certificates of 150 public buildings since 3 February 2014 until June 2014. The database contains existing and new buildings. Only general energy consumption for sport facilities was provided by the EPC database. For coherence with Figure SP-9, the division between pools and pavilions has been done in Figure SP-10.

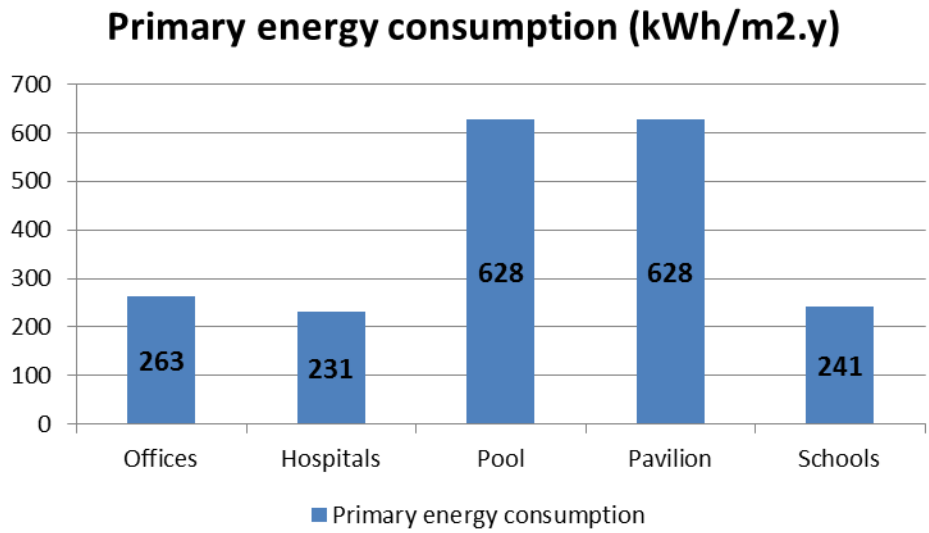


Figure SP 10: Public building energy consumption according energy performance certificates since 3rd February 2014
Source: ICAEN

3.10 Former YUGOSLAV REPUBLIC OF MACEDONIA

3.10.1 Overall picture of the building stock in the former Yugoslav Republic of Macedonia

The available data used in the preparation of the public building stock includes 2 441 buildings with total floor area of 2 564 116 m^2.

The main sources for the data were the National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018 and the System for monitoring of energy efficiency (ExCITE), which is database operated by Association of the units of local self -government of the Republic of Macedonia – ZELS, and the input data in the database is from the municipalities.

Not all of the buildings are covered in the Public Building Stock. The estimation is that 70% of the buildings are covered by the current analysis.

Figure MC 1 depicts the distribution of the analysed buildings by total built-up floor area.

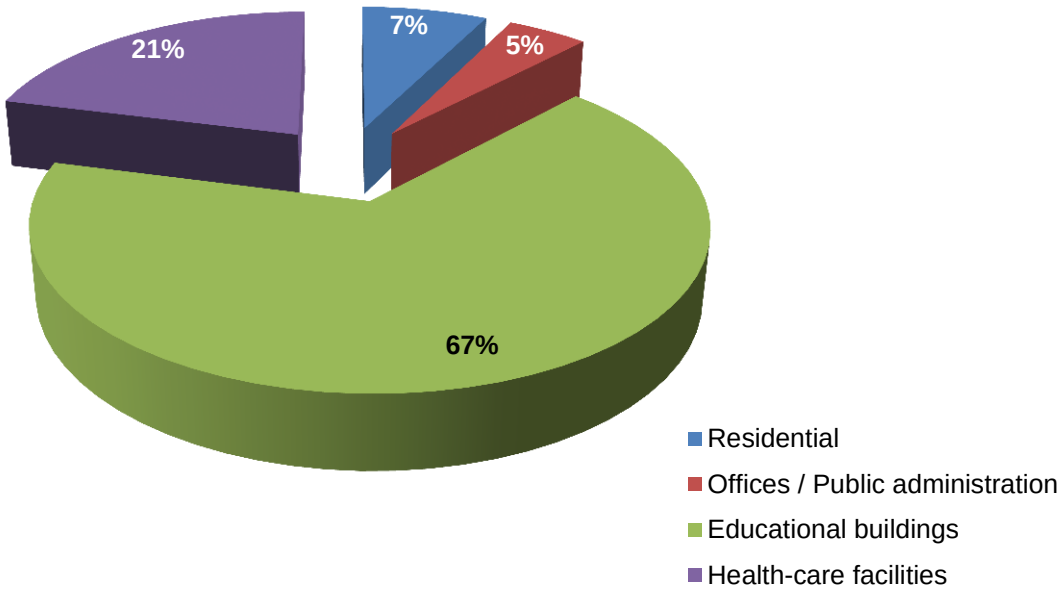


Figure MC 1: Structure of the building stock registered for energy certification

(Source: National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018)

3.10.2 Public building stock data

Table MC 1 contains parameters of the main building categories and sub-categories, given in the analysed data-base.

Table MC 1

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
1	Residential	154	189 542	174 249
1.1	Social housing	72	50 454	46 287
1.2	Service housing			
1.3	Student housing	82	139 088	127 962
2	Offices / Public	195	121 804	92 783

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²
	administration			
2.1	Central Authorities	28	18 714	17 363
2.2	Regional / Local Authorities	167	103 090	75 420
3	Educational buildings	1 607	1 713 569	1 510 945
3.1	Kindergartens	174	185 460	174 172
3.2	Schools	1 159	960 260	816 220
3.3	Universities/ High schools	274	567 849	520 553
4	Health-care facilities	485	539 201	487 967
4.1	Hospitals	471	528 810	478 321
4.2	Other institutional care	14	10 391	9 646
5	Hotels and restaurants	0	0	0
5.1	Hotels	0	0	0
5.2	Other short-stay accommodation buildings	0	0	0
	TOTAL	**2 441**	**2 564 116**	**2 265 944**

The share of the type of construction in the buildings is illustrated in the Figure MC 2.

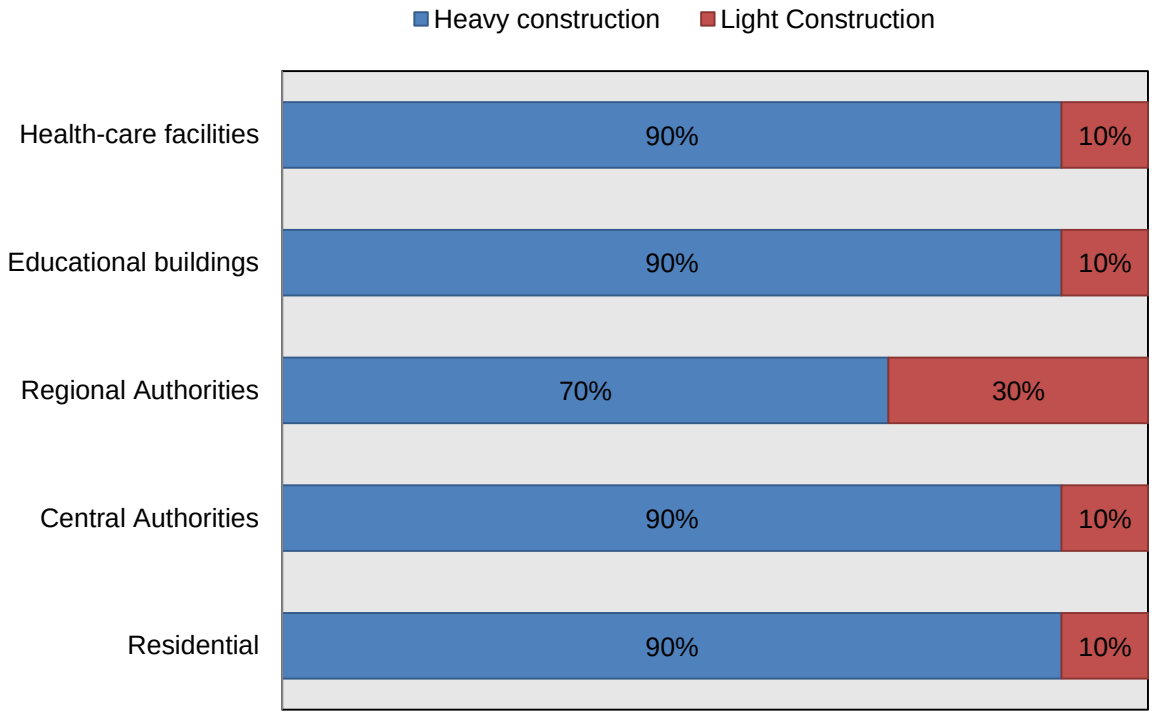


Figure MC 2: Type of construction in the public building stock

The distribution of the building stock by age band, based on construction year or major rehabilitation year, is presented in Figure MC 3.

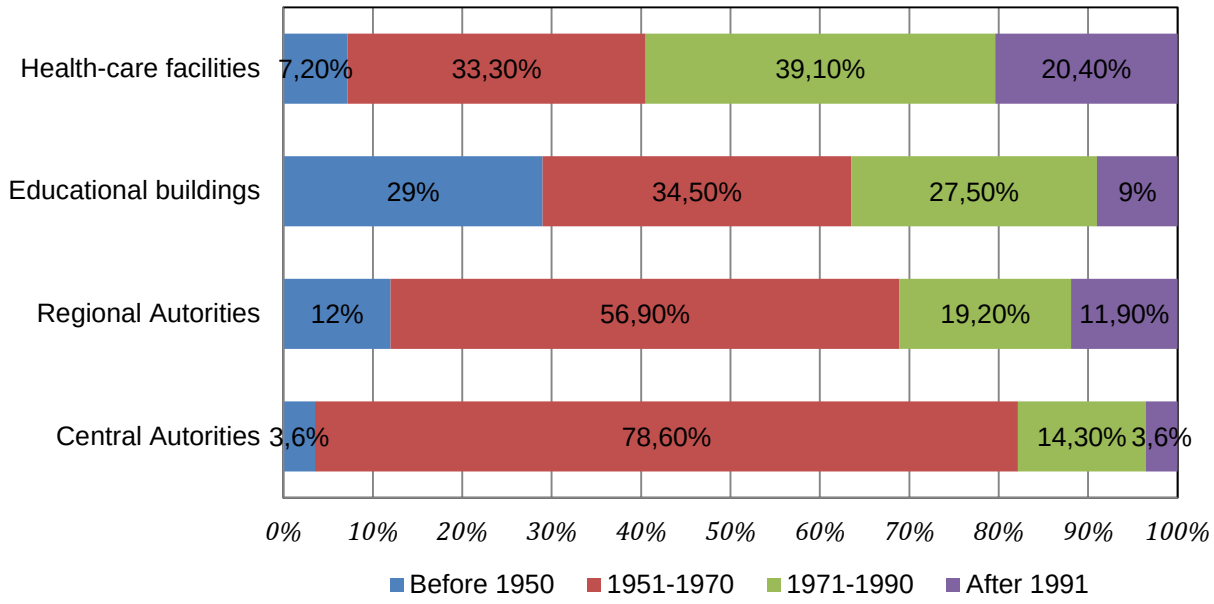


Figure MC 3: The public building stock by construction year
(Source: National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018)

The heating system of the building stock is predominantly central heating, connected to district heating or to a heating plant in or nearby the building.

Regarding the energy performance of existing public building stock, Table MC 2 presents the main thermal characteristics of the building envelope as defined in the national ordinances for the reference year 2008.

Table MC 2

No.	Category / sub-category	Reference values – baseline year 2008			
		Wall [W/m²K]	Roof [W/m²K]	Floor [W/m²K]	Windows [W/m²K]
1	Residential	1,3	0,8	0,6	3,5
2	Offices / Public administration	1,3	0,8	0,6	3,5
3	Educational buildings	1,3	0,8	0,6	3,5
4	Health-care facilities	1,3	0,8	0,6	3,5

(Source: National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018)

3.10.3 Energy performance of public building stock

The energy performance of the reference buildings, expressed as specific final energy consumption (all end uses except appliances) is shown on Figure MC 4.

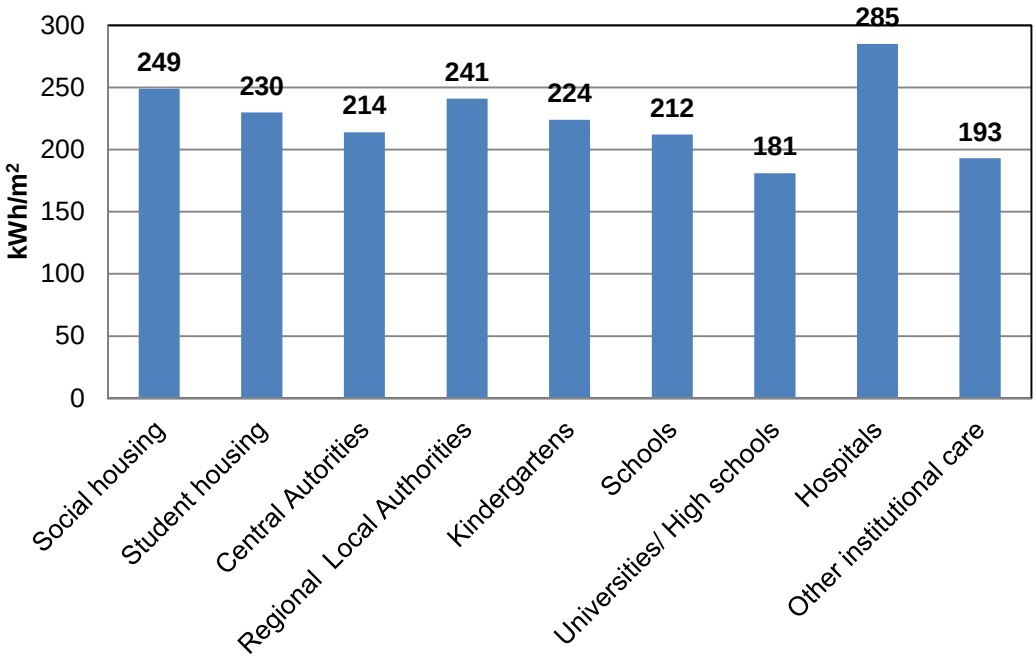


Figure MC 4: Energy consumption in reference buildings, in kWh/m²
(Source: National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018)

The Figure MC 5 shows the share of the electrical and heating energy in the energy consumption of the buildings.

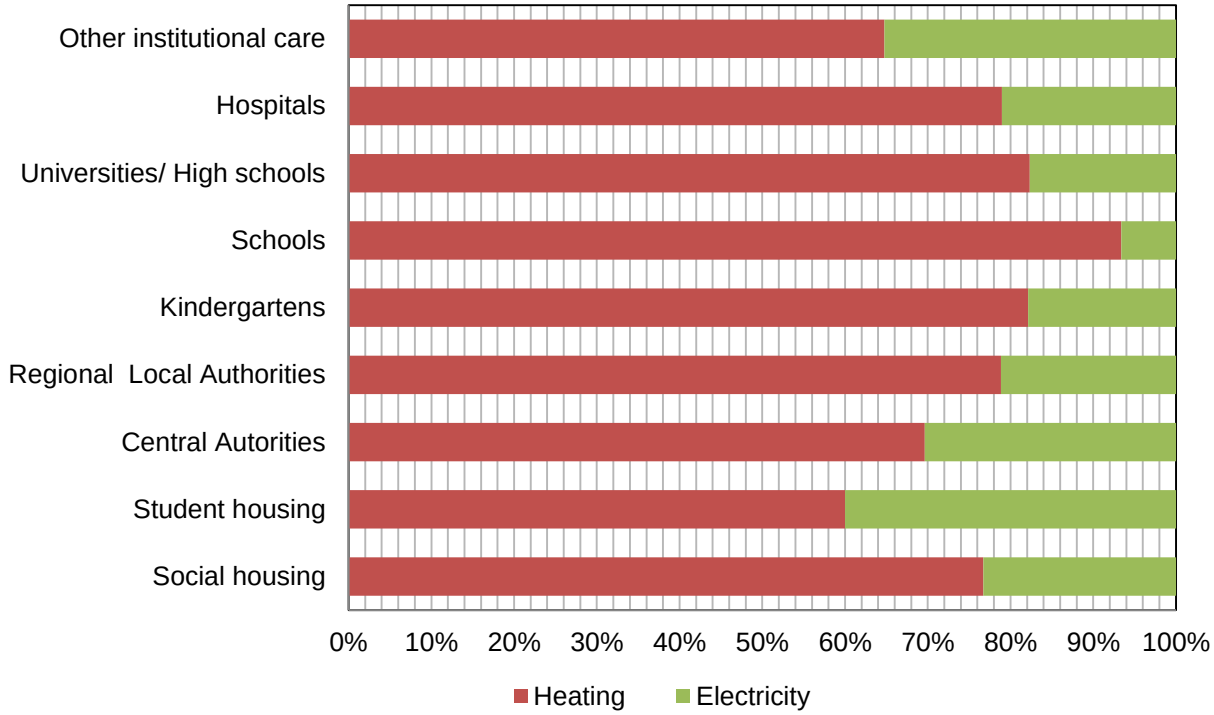


Figure MC 5: Share of the energy consumption in the reference buildings
(Source: National Programme for Energy Efficiency in Public Buildings in Macedonia 2012-2018)

3.11 United Kingdom

3.11.1 Overall picture of the building stock in UK

The overall building stock in the UK comprises about than 4,5 million buildings, with more than 606 mil. m² floor area, of which around 85% (43% of floor area) are in residential and office buildings. The overall structure of UK building stock is illustrated in Figure UK 1.

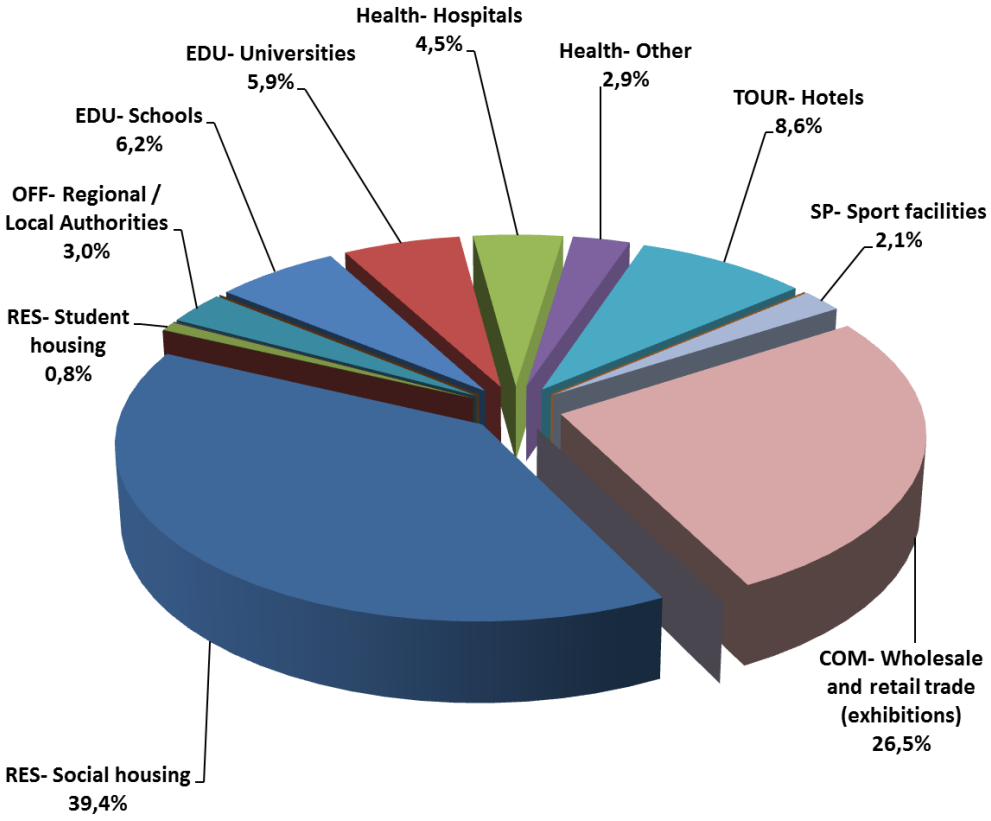


Figure UK 1: Structure of building stock in the UK
Does not include industrial buildings, Source: BRE

3.11.2 Public building stock data

The values presented in Figure UK 1 and Table UK 1 refer to the total non-residential building stock to which social rented housing (residential) was added.

The effective public building stock in the UK is difficult to define in detail, however it can be reasonably estimated by excluding some of the building sectors that would not normally be considered public buildings, i.e. the hotels and retail sectors, social rented housing as well as half of 'Other institutional care' (under Health-care facilities).

Thus, the public building stock in the UK could be estimated at 86,450 buildings, comprising 140.44 mil. m². The overall distribution of UK building stock per building categories is illustrated in Figure UK 2.

Further on, the main characteristics of the UK building stock is presented, including also some of the building sectors which were excluded from the assumption of the public building stock, in order to offer a better picture of the performance of existing buildings in the UK as well as of the quality of existing data.

Table UK 1: Building stock in the UK

No.	Category / sub-category	Number of buildings	Total floor area (built-up area), m²
1	Residential	3 816 790	243 980 000
1.1	Social housing	3 816 790	238 900 000
1.2	Service housing		
1.3	Student housing		5 080 000
2	Offices / Public administration	36 800	18 500 000
2.1	Central Autorities	500	250 000
2.2	Regional Local Authorities	36 300	18 250 000
3	Educational buildings	32 671	73 331 900
3.1	Kindergartens		
3.2	Schools	15 107	37 731 900
3.3	Universities/ High schools	17 564	35 600 000
4	Health-care facilities	27 138	44 510 000
4.1	Hospitals	1 638	27 110 000
4.2	Other institutional care	25 500	17 400 000
5	Hotels and restaurants	103 408	52 260 000
5.1	Hotels	103 408	52 260 000
5.2	Other short-stay accommodation buildings		
6	Sport facilities	2 587	12 800 000
7	Wholesale and retail trade service buildings	522 412	160 950 000
8	Other types of energy consuming buildings		
	TOTAL	**4 541 806**	**606 331 900**

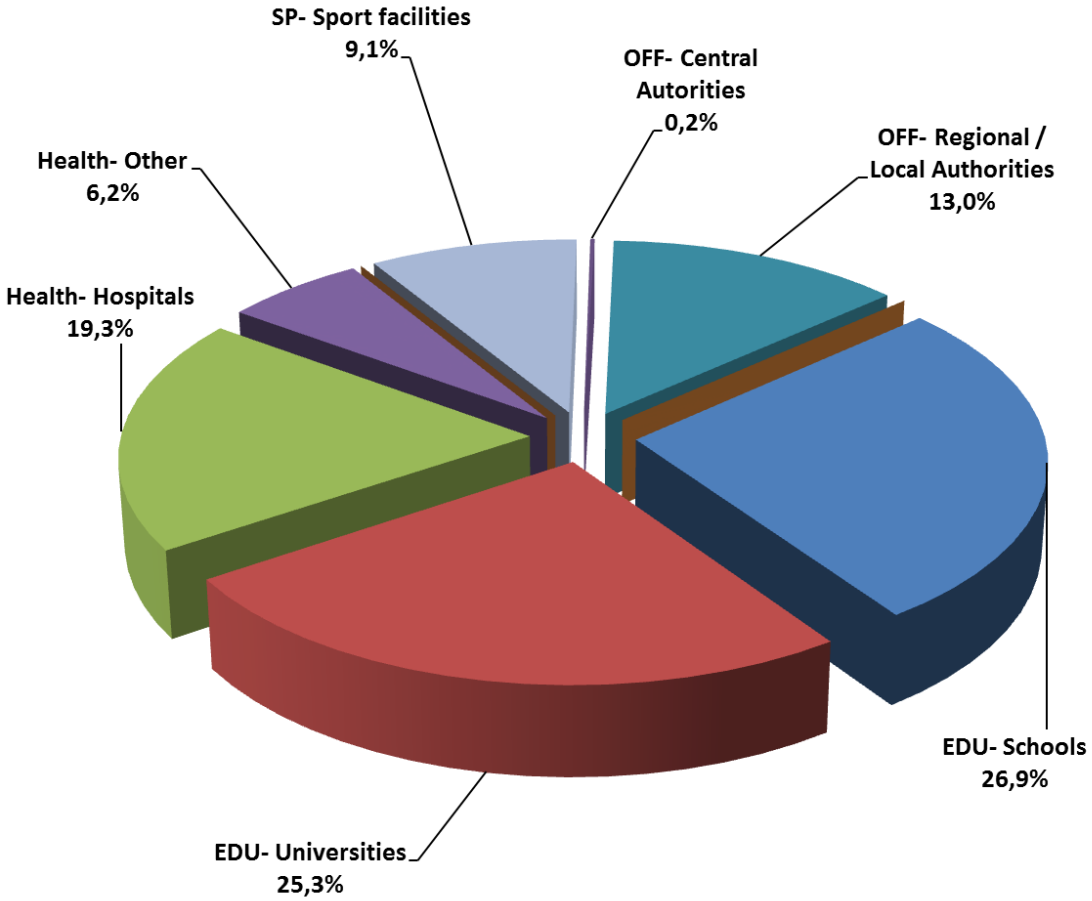


Figure UK 2: Structure of public building stock in the UK

Table UK 2: Shape factors and heights of main building categories in the UK

Category / sub-category	Compactness Ratio (area of the exterior walls/building volume)	Number of (above ground) floors (including Ground-floor)
Residential		
Social housing Service housing Student housing	- 0.43 for bungalow (412,000 dwellings) - 0.29 for mid terrace (492,000) - 0.47 for end terrace (743,000) - 0.47 for semi detached (630,000) - 0.39 for flat (1,773,000)	1 for bungalow (412,000 dwellings) 2 for house (1,654,000) 3 to 6 for low-rise flat (1,407,000) 7+ for high rise flat (207,000)
Offices / Public administration		
Central Autorities Regional Local Authorities	0,16	1 storey (5% offices) 2 storeys (38%) 3 storeys (22%) 4 storeys (12%) 5 storeys (10%) >5 storeys (13%)
Educational buildings		
Kindergartens		
Schools	0,18	1 storey (48% schools) 2 storeys (42%) 3 storeys (8%) >3 storeys (2%)
Universities/ High schools		1 storey (43%) 2 storeys (41%) 3 storeys (11%) >3 storeys (4%)
Health-care facilities		
Hospitals	0,24	1 storey (42% hospitals) 2 storeys (37%) 3 storeys (15%) 4 storeys (4%) 5 storeys (1%) >5 storeys (0.5%)
Other institutional care	similar to residential buildings	1 storey (20%) 2 storeys (59%) 3 storeys (31%)
Hotels and restaurants		
Hotels	0,12	1 storey (9% hotels) 2 storeys (36%) 3 storeys (27%) 4 storeys (18%) 5 storeys (7%) >5 storeys (4%)
Other short-stay accommodation buildings		
Sport facilities	0,1	1 storey (39%) 2 storeys (56%) 3+ storeys (5%)
Wholesale and retail trade service buildings	0,16	1 storey (34%) 2 storeys (36%) 3 storeys (16%) >3 storeys (14%)
Other types of energy consuming buildings		
TOTAL		

Table UK 3: Representative types of building construction and age

No.	Category / sub-category	Type of building construction (as defined at national level)	Year of construction / commissioning
1	**Residential**	Houses and bungalows: - solid (25cm) walls (pre 1930) - cavity (brick-brick or brick-block) - timber frame - steel frame etc. - suspended timber floors, solid or suspended concrete - tiled roofs Flats: - Concrete frame	Houses: Mostly 1890s to present day Flats: Mainly 1960s to present day
2	**Offices / Public administration**	**Type 1 Office** (Naturally ventilated cellular office)**:** Walls: - Stone walls - Solid brick - Brick/brick and brick /lightweight aggregate block cavity - Timber frame Roofs: - Flat timber - Pitched timber (ceiling level insulation) Floors: - Solid concrete - Suspended timber **Type 2** (Naturally ventilated open plan)**, 3** (Air conditioned office - standard) **& 4** (Air conditioned office - prestige) **Offices:** Walls: - Brick/brick and brick /lightweight aggregate block cavity - Rainscreen cladding Roofs: - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete - Suspended timber	
3	**Educational buildings**		
3.1	Kindergartens		
3.2	Schools	Walls: - Solid brick - Pre-cast concrete - Brick/brick and brick /lightweight aggregate block cavity - Rainscreen cladding Roofs: - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete	Significant range over last 200-250 years, although many build post WW II

No.	Category / sub-category	Type of building construction (as defined at national level)	Year of construction / commissioning
3.3	Universities/ High schools	Walls: - Stone walls - Solid brick - Pre-cast concrete - Rainscreen cladding Roofs: - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete	Significant range over last 200-250 years, although many build post WW II
4	**Health-care facilities**		
4.1	Hospitals	Walls: - Solid brick - Dense concrete - Pre-cast concrete - Brick/brick and brick /lightweight aggregate block cavity - Rainscreen cladding Roofs: - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete	
4.2	Other institutional care	Walls: - Solid brick - Brick/brick and brick /lightweight aggregate block cavity - Timber frame Roofs: - Flat timber - Pitched timber (ceiling level insulation) Floors: - Solid concrete - Suspended timber	
5	**Hotels and restaurants**	Walls: - Stone walls - Brick/brick and brick /lightweight aggregate block cavity - Timber frame Roofs: - Flat timber - Pitched timber (ceiling level insulation) Floors: - Solid concrete - Suspended timber	

No.	Category / sub-category	Type of building construction (as defined at national level)	Year of construction / commissioning
6	**Sport facilities**	Walls: - Brick/brick and brick /lightweight aggregate block cavity - Rainscreen cladding Roofs: - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete - Suspended timber	
7	**Wholesale and retail trade service buildings**	Walls: - Solid brick walls - Brick/brick and brick /lightweight aggregate block cavity - Rainscreen cladding Roofs: - Flat concrete - Flat timber - Pitched timber (ceiling level insulation) - Sheet metal Floors: - Solid concrete - Suspended timber	

Heating system type

Residential buildings:

- About 4-5% of social housing has some form of district heating [These would have gas and/or biomass as a fuel],
- Central heating (90%), Storage heating (7%), Fixed room/portable heating (3%),
- 45% dwellings have conventional boiler (standard, back or combi), 10% have no boiler, 45% dwellings have condensing boiler (standard or combi),
- 4% of dwellings use Oil as fuel for heating, 1,5% use Coal / lignite, 85% use Gas, while 9% use Electricity.
- The number of biomass appliances in UK homes is currently low, perhaps about 3 000 boilers, although this is growing significantly following recent grant programmes and now the Renewable Heat Incentive (RHI) where owners are paid for the heat generated,
- The number of air source and ground source heat pumps in UK homes is currently low, perhaps about 10 000, although this is growing significantly following recent grant programmes and now the Renewable Heat Incentive (RHI) where owners are paid for the heat generated,

Offices / Public administration

- The number of biomass appliances in non-domestic buildings is growing fast as a result of the RHI - there are currently some 5 000 across all buildings but this is from a low base. Only a handfull of these are in the government office sector,
- The number of heat pumps in non-domestic buildings is growing steadily as a result of the RHI - there are currently only a few hundred across all buildings. Only a very small number are in the government office sector

Schools:

- About 15% of school floor area is served by some form of district heating,
- Balance of heating is individual central heating.

- About 15% of schools have some form of district heating, <1% are using coal for heating, while >80% are using gas,
- The number of biomass appliances in non-domestic buildings is growing fast as a result of the RHI - there are currently some 5,000 across all buildings but this is from a low base. About 200 of these are in the education sector
- The number of heat pumps in non-domestic buildings is growing steadily as a result of the RHI - there are currently only a few hundred across all buildings. Only a very small number are in the education sector

Universities/ High schools:

- About 25% of further education floor area is served by some form of district heating
- Balance of heating is individual central heating, using mostly gas

Hospitals:

- About 65% of hospital floor area is served by some form of district heating
- About 42% of care home floor area is served by some form of district heating,
- Balance of heating is individual central heating,
- About 65% of hospital floor area is served by some form of district heating, <1% use coal for heating and >80% use gas,
- About 42% of care home floor area is served by some form of district heating, 1% use coal for heating and >80% use gas,
- The number of biomass appliances in non-domestic buildings is growing fast as a result of the RHI - there are currently some 5 000 across all buildings but this is from a low base. About 30 of these are in the hospital sector, while about 100 of these are in the residential care sector,
- The number of heat pumps in non-domestic buildings is growing steadily as a result of the RHI - there are currently only a few hundred across all buildings. Only a very small number are in the hospital sector and in the residential care sector.

Hotels:

- The number of biomass appliances in non-domestic buildings is growing fast as a result of the RHI - there are currently some 5 000 across all buildings but this is from a low base. About 1 500 of these are in the hotel sector,
- The number of heat pumps in non-domestic buildings is growing steadily as a result of the RHI - there are currently only a few hundred across all buildings. Only a small number are in the hotel sector,

3.11.3 Energy performance of public building stock

Table UK 4: Consumption levels by different building types (kWh/m²/year)

No.	Category / sub-category	Heat.	Cool.	DHW	Light.	Appl.	All end uses except appl.	All end uses	Year of data	Notes
1	Residential [kWh/m2/yr]	130	0	50	10	25	190	215	2014	These figures relate to a typical house (mid terrace property, 84 m² total floor area) in the social housing sector that has been improved under the Decent Homes programme and so has reasonable levels of fabric insulation (loft and cavity walls), double glazed windows and a condensing boiler.
2	Offices / Public administration	65%	2%	6%	10%	11%	89%	100%	2005	Breakdown presented is average for offices in the government sector. See Table UK-6 for typical kWh/m^2/year for offices (Type 1 to 4) This also shows differences between fossil fuels and electricity See Table UK-7 for kWh/m²/year for each end use for each office type.
3	Educational buildings	69%	0%	8%	8%	12%	88%	100%	2005	See Table UK-6 for typical kWh/m^2/year for school buildings This also shows differences between fossil fuels and electricity
4	Health-care facilities	71%	1%	11%	12%	4%	96%	100%	2005	See Table UK-6 for typical kWh/m^2/year for different types of hospital buildings, residential and care homes This also shows differences between fossil fuels and electricity
5	Hotels and restaurants	42%	3%	19%	10%	23%	77%	100%	2005	See Table UK-6 for typical kWh/m^2/year for different hotel types This also shows differences between fossil fuels and electricity
6	Sport facilities	46%	3%	13%	14%	8%	92%	100%	2005	See Table UK-6 for typical kWh/m^2/year for different sports and recreation buildings This also shows differences between fossil fuels and electricity
7	Wholesale and retail trade service buildings	39%	5%	5%	28%	17%	83%	100%	2005	See Table UK-6 for typical kWh/m^2/year for different retail buildings This also shows differences between fossil fuels and electricity

Table UK 5: U values of components and air-tightness levels

Category / sub-category	Wall, W/m2K	Roof, W/m2K	Floor, W/m2K	Windows, W/m2K	Air-tightness levels n50 in h-1 [-]	Notes
Residential	Avg: 0,6 Min: 0,3 Max: 2,1	Avg: 0,16 Min: 0,16 Max: 0,16	Avg: 0,5 Min: 0,2 Max: 0,8	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 10 m3/m2/hr Min: 3 m3/m2/hr Max: 15 m3/m2/hr all at 50Pa	These values relate to a house in the social housing sector (average figures for house improved through Decent Homes) as well as minimum and maximum. The range is very broad reflecting the different forms of construction
Offices / Public administration	**Type 1:** Avg: 1,4 Min: 0,39 Max: 2,09 **Type 2,3 & 4:** Avg: 0,52 Min: 0,25 Max: 1,5	**Type 1:** Avg: 0,42 Min: 0,17 Max: 2,3 **Type 2,3 & 4:** Avg: 0,23 Min: 0,17 Max: 0,53	?	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 14 m3/m2/hr Best 10%: <7 m3/m2/hr Worse 10%: >34 m3/m2/hr all at 50Pa	
Educational buildings - Schools	Avg: 1,44 Min: 0,25 Max: 2,09	Avg: 0,42 Min: 0,17 Max: 2,35	?	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 14 m3/m2/hr Best 10%: <7 m3/m2/hr Worse 10%: >34 m3/m2/hr all at 50Pa	Lower prevalence of double glazed windows
Educational buildings - Universities/ High schools	Avg: 1,07 Min: 0,25 Max: 2,09	Avg: 0,42 Min: 0,17 Max: 2,35	?	Avg: 1,8 Min: 1,4 Max: 2,8		Lower prevalence of double glazed windows
Health-care facilities - Hospitals	Avg: 1,44 Min: 0,25 Max: 3,02	Avg: 0,42 Min: 0,17 Max: 2,30	?	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 14 m3/m2/hr Best 10%: <7 m3/m2/hr Worse 10%: >34 m3/m2/hr all at 50Pa	
Health-care facilities - Other institutional care	Avg: 1,44 Min: 0,39 Max: 2,09	Avg: 0,42 Min: 0,17 Max: 2,30	?	Avg: 1,8 Min: 1,4 Max: 2,8		
Hotels	Avg: 0,52 Min: 0,39 Max: 1,44	Avg: 0,64 Min: 0,17 Max: 2,35	?	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 14 m3/m2/hr Best 10%: <7 m3/m2/hr Worse 10%: >34 m3/m2/hr all at 50Pa	
Sport facilities	Avg: 0,52 Min: 0,25 Max: 2,09	Avg: 0,42 Min: 0,17 Max: 0,35	?	Avg: 1,8 Min: 1,4 Max: 2,8	Avg: 14 m3/m2/hr Best 10%: <7 m3/m2/hr Worse 10%: >34 m3/m2/hr all at 50Pa	
Wholesale and retail trade service buildings	Avg: 1,44 Min: 0,25 Max: 2,09	Avg: 0,64 Min: 0,17 Max: 2,19	?	Avg: 1,8 Min: 1,4 Max: 5,8		High proportion of single glazed windows in retail sector

Table UK 6: Energy benchmarks for existing buildings
(Source CIBSE Concise Handbook)

	Energy consumption (kWh/m2/year)				Basis of benchmark
	Good practice		Typical practice		
	Fossil fuel	Electricity	Fossil fuel	Electricity	
Further & Higher Education					
Catering, bar/restaurant	182	137	257	149	Gross floor area
Catering, fast food	438	200	618	218	Gross floor area
Lecture rooms, arts	100	67	120	76	Gross floor area
Lecture room, science	110	113	132	129	Gross floor area
Library, air conditioned	173	292	245	404	Gross floor area
Library, naturally ventilated	115	46	161	64	Gross floor area
Residential, halls of residence	240	85	290	100	Gross floor area
Residential, self-catering/flats	200	45	240	54	Gross floor area
Science laboratory	110	155	132	175	Gross floor area
Education (schools)					
Primary	113	22	164	32	Gross floor area
Secondary	108	25	144	33	Gross floor area
Secondary (with swimming pool)	142	29	187	36	Gross floor area
Hospitals					
Teaching and specialist	339	86	411	122	Heated floor area
Acute and maternity	422	74	510	108	Heated floor area
Cottage	443	55	492	78	Heated floor area
Long stay	401	48	518	72	Heated floor area
Hotels					
Holiday	260	80	400	140	Treated floor area
Luxury	300	90	460	150	Treated floor area
Small	240	80	360	120	Treated floor area
Offices					
Naturally ventilated, cellular (Type 1)	79	33	151	54	Treated floor area
Naturally ventilated, open plan (Type 2)	79	54	151	85	Treated floor area
Air conditioned, standard (Type 3)	97	128	178	226	Treated floor area
Air conditioned, prestige (Type 4)	114	234	210	358	Treated floor area
Residential and nursing homes	247	44	417	79	Gross floor area
Sports and recreation					
Combined centre	264	96	598	152	Treated floor area
Dry sports centre (local)	158	64	343	105	Treated floor area
Fitness centre	201	127	449	194	Treated floor area
Ice rink	100	167	217	255	Treated floor area
Leisure pool centre	573	164	1,321	258	Treated floor area
Sports ground changing facility	141	93	216	164	Treated floor area
Swimming pool (25m) centre	573	152	1,336	237	Treated floor area
Retail					
Department store	194	237	248	294	Sales floor area
Department store (all electric)	-	209	-	259	Sales floor area
Supermarket (all electric)	-	1,034	-	1,155	Sales floor area
Distribution warehouse	103	53	169	67	Sales floor area

Distribution warehouse (all electric)	-	55	-	101	Sales floor area	

Table UK 7: Office end-use
(Source BRE)

Delivered energy (kWh/m²/year)	Type 1		Type 2		Type 3		Type 4	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Gas/oil heating	79	151	79	151	97	178	107	201
Catering gas	0	0	0	0	0	0	7	9
Cooling	0	0	1	2	14	31	21	41
Fans, pumps and controls	2	6	4	8	30	60	36	67
Humidification	0	0	0	0	8	18	12	23
Lighting	14	23	22	38	27	54	29	60
Office equipment	12	18	20	27	23	31	23	32
Catering electricity	2	3	3	5	5	6	13	15
Other electricity	3	4	4	5	7	8	13	15
Computer room	0	0	0	0	14	18	87	105
Total gas or oil	**79**	**151**	**79**	**151**	**97**	**178**	**114**	**210**
Total electricity	**33**	**54**	**54**	**85**	**128**	**226**	**234**	**358**

Information sources:

The sources of information for residential buildings were various, but mainly the government's English Housing Survey (https://www.gov.uk/government/collections/english-housing-survey) and the source quality is very good.

The sources of information for Offices / Public administration, Educational buildings, Health-care facilities, Hotels and restaurants, Sport facilities and Wholesale and retail trade service buildings are various (see below) and could be considered as reasonable. The non-domestic sector is not as well documented as the domestic one because of its diverse nature. Data is taken from various sources so there is a risk that information compiled for different requirements may not be consistent with each other. Some data (e.g. floor areas) is up to 10 years old, although it is probably still reasonably representative.

- Non-domestic building energy fact file, BRE Report 339 (Shape factor, energy use, occurrence of a/c etc.)
- DfES Schools AMP data (Floor areas and nos. buildings)
- CO_2 emissions from non-domestic buildings: 2000 and beyond, BRE report 442 (End use energy consumption etc.)
- Potential for reducing carbon emissions from commercial and public-sector buildings, BRE Information Paper (IP) 3/12 (End-use energy consumption etc.)
- Local authority planning and contract data (number of storeys)
- Desk study on heat metering, Defra report (District heating information)
- RHI application data (DECC website) - biomass and heat pumps
- CIBSE Concise Handbook (Energy benchmarks)
- CIBSE Environmental Design (U-values)
- Airtightness and commercial buildings, BRE Report 448 (Envelope airtightness)
- Airtightness specifications, BSRIA Specification 10/98
- Testing buildings for air leakage, CIBSE Technical Memoranda TM23: 2000
- https://www.gov.uk/government/collections/renewable-heat-incentive-renewable-heat-premium-payment-statistics

Data for buildings used for pre-primary education are not known separately, many of these buildings are likely to be included as nursery schools.

Hotels and restaurants and Wholesale and retail trade service buildings would probably not be classified as 'public' buildings, while for the other short-stay accommodation buildings data are not available. Rest homes were included in the Health-care facilities category, while Sport facilities are generally local authority Sports Centres. Other types of energy consuming buildings (e.g. industrial, warehouses, civil and military facilities, historical buildings etc.) are building types too diverse to provide robust data. Some warehouses are included in the Wholesale and retail trade service buildings.

Figure UK 3 presents data on Display Energy Certificates (DECs) for public buildings (covering categories 2, 3, 4 & 6 from Table UK 4) registered in 2009 to 2013 in England & Wales.

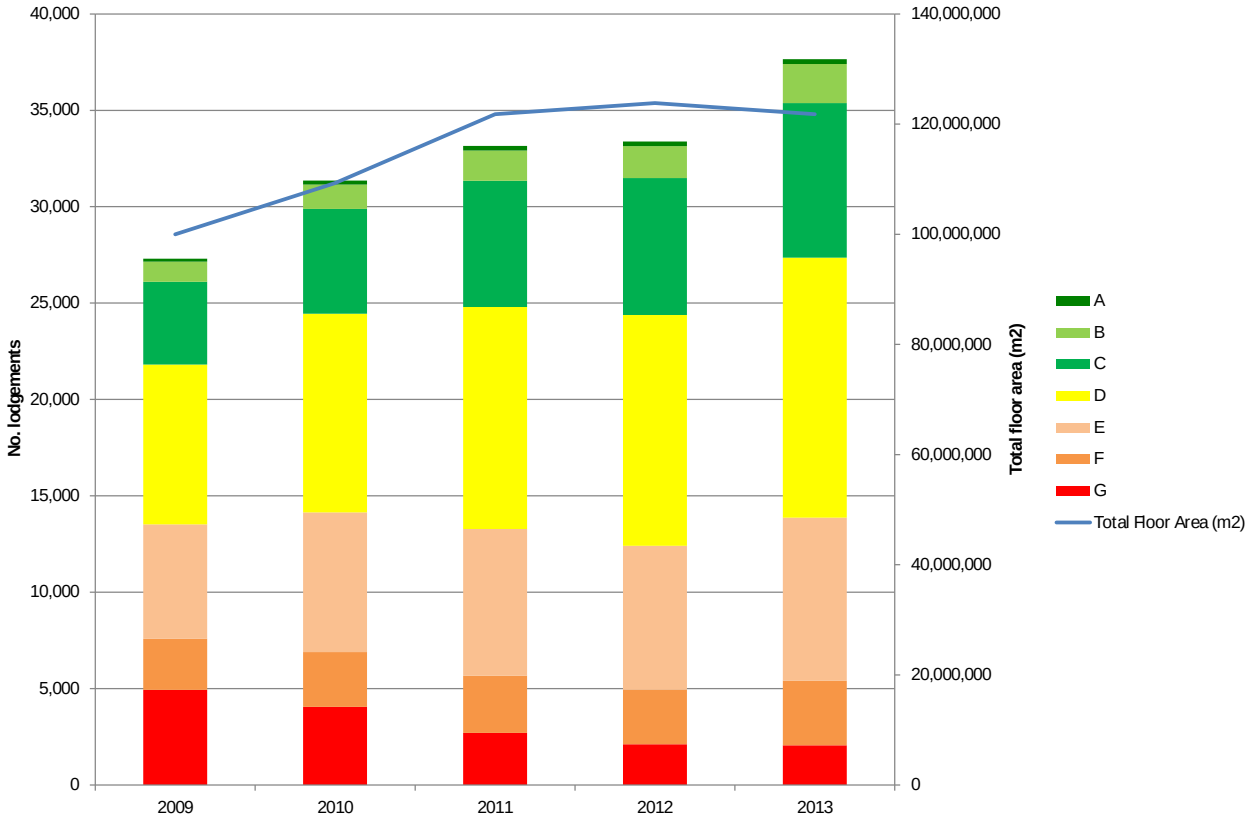


Figure UK 3: Display Energy Certificates (DECs) for public buildings
(Source DCLG)

4. CONCLUSION

The main objective of the report was to analyse the existing public building stock in the countries or regions covered by the project consortium, with the view to assess key data concerning the general features and the public buildings total energy consumption, in order to permit the definition of public buildings classes as a basis for project developments.

While Article 5 of the Energy Efficiency Directive (EED) focuses only on buildings owned and occupied by central government, setting a 3% annual renovation target for this, the activities performed under task T2.1 of work package WP 2 (Analysis of the public building stock and definition of reference buildings) were to evaluate the whole public building stock by analysing available data for buildings owned and/or occupied by central and local authorities. Thus, taking into account the exemplary role that public buildings should have in the transformation of the existing building stock to a high energy performance one (targeting the nearly zero energy level), the analysis also addressed educational and health care buildings which in some countries are under local government administration.

The starting point of the analysis was the collection of useful data from European and Regional projects, publications and technical bibliography on this topic as well as other sources of statistical data or summarised information, with the aim to build a realistic image of the public building stock and its performance in the selected countries. Among these sources, the most useful ones were the BPIE Data Hub, BUILD UP Skills reports and National EPC databases in the selected countries. EUROSTAT and Statistical offices in each country lacked relevant data on non-residential building stock in general and public building stock in particular. This emphasises once more the need to develop viable tools for collecting and processing data in order to ensure specific and robust databases useful for developing strategies in building sector.

Other relevant sources of information used were previous studies performed at national level and inventories of existing central government building stock recently undertaken in some participant countries.

The collection of data in each country participating in RePublic_ZEB project was designed starting from a comprehensive template which included detailed data required for the evaluation of energy performance of the existing public building stock. The effective gathering of existing data showed that in some countries, available data sources and the knowledge about the public building stock differ.

From country to country, different numbers of buildings and mixed categories (total non-residential, public / non-public, central / local administration) were found. It was a challenge to select or aggregate relevant appropriate building categories, due to the lack of a clear common basis for analysis. It was found that not all partners have available data according to defined requirements (template) and to EPBD building categories. Various types of data were still missing in some countries (age of buildings for different categories, constructive structure, height / shape factor (compactness ratio), systems, fuel/energy agent), making difficult a clear decision regarding the clear-cut selection and detailed definition of reference buildings. Moreover, the energy consumption [kWh/m².year] was given either in primary or final (end-use / delivered) energy and the split of energy performance indicator in all types of services to reflect the requirements from Annex I of EPBD (heating, cooling, ventilation, DHW, lighting and appliances) is not sufficiently clear / uniform in all countries in order to transform EPB in comparable values. In some countries the energy performance data came from the simulation of predefined reference buildings (e.g. from cost optimal reports), while in others the available data from central EPC registers was not always statistically representative due to the small sample of buildings in each category).

Although the above mentioned aspects could constitute limitations in the assessment of existing building stocks in the group of 11 countries addressed by the current analysis, the findings could be considered as sufficient to the scope of the study, i.e. the selection of classes of buildings in

each country with the highest share of total floor area and with the highest impact in terms of energy performance (primary energy consumption).

The key findings of the preliminary cross country analysis performed on the available data collected are presented in Table 2. The total number of public buildings analysed in each country and the total analysed floor area are presented along with the values of total floor area included in the updated set of performance indicators to assess the RePubli_ZEB project impact (D7.1).

Table 2: Consumption levels by different building types (kWh/m²/year)

Country	Total analysed buildings	Total analysed floor area [1000 m²]	Floor area D7.1 [1000 m²]	Primary Energy TOTAL minus appliances [kWh/m²yr]	Primary Energy TOTAL [TWh/yr]	Share TFA	Share PE
Bulgaria	4 611	17 780	10 919	136	2,43	4,2%	1,8%
Croatia	768	1 317	1 326	254	0,33	0,3%	0,2%
the FYR Macedonia	2 441	2 266	1 333	298	0,68	0,5%	0,5%
Greece	31 738	20 574	310	203	4,19	4,9%	3,0%
Hungary	37 871	47 618	400	232	11,04	11,2%	8,0%
Italy	91 545	145 593	23 600	306	44,51	34,4%	32,2%
Portugal	339	83	680	156	0,01	0,0%	0,0%
Romania	13 698	17 847	6 739	392	7,00	4,2%	5,1%
Slovenia	16 728	9 300	708	527	4,90	2,2%	3,5%
Spain	102 036	21 003	5 000	170	3,57	5,0%	2,6%
UK	86 446	140 442	404 755	426	59,77	33,1%	43,2%
Total (without UK)	**388 221**	**423 823**	**455 770**	**326,6**	**138,42**	**100,0%**	**100,0%**

The biggest share of the analysed building stock in terms of total floor area and primary energy consumption is occupied by Italy and UK, due to the size of the considered stock and partially to the consideration of a part of building categories which are shared between private and public ownership or occupation (which could also be the case of Slovenia). On the other hand, the low values reported for Portugal could be explained by the lack of reliable data for the overall building stock, as only a limited sample of public buildings are available through the inventory of the existing buildings at the National Energy Certification System (SCE).

Figure 1 presents the total analysed floor area of public buildings analysed in each country and the values of total floor area included in the updated set of performance indicators (D7.1).

The differences between the public building stocks included in the updated set of performance indicators D7.1 (basically the values from central government buildings inventories) and the values of building stocks identified and analysed in the current report, in terms of total floor areas (TFA), are overall explained by the fact that in the first case only buildings owned and occupied by central public authorities were included, while in the latter also buildings owned and/or occupied by local public authorities were included.

At country level, the analysis of total floor area share per building category is presented in Figure 2 and the analysis of primary energy consumption share per building category is presented in Figure 3, enabling a first evaluation of representative classes for further analysis.

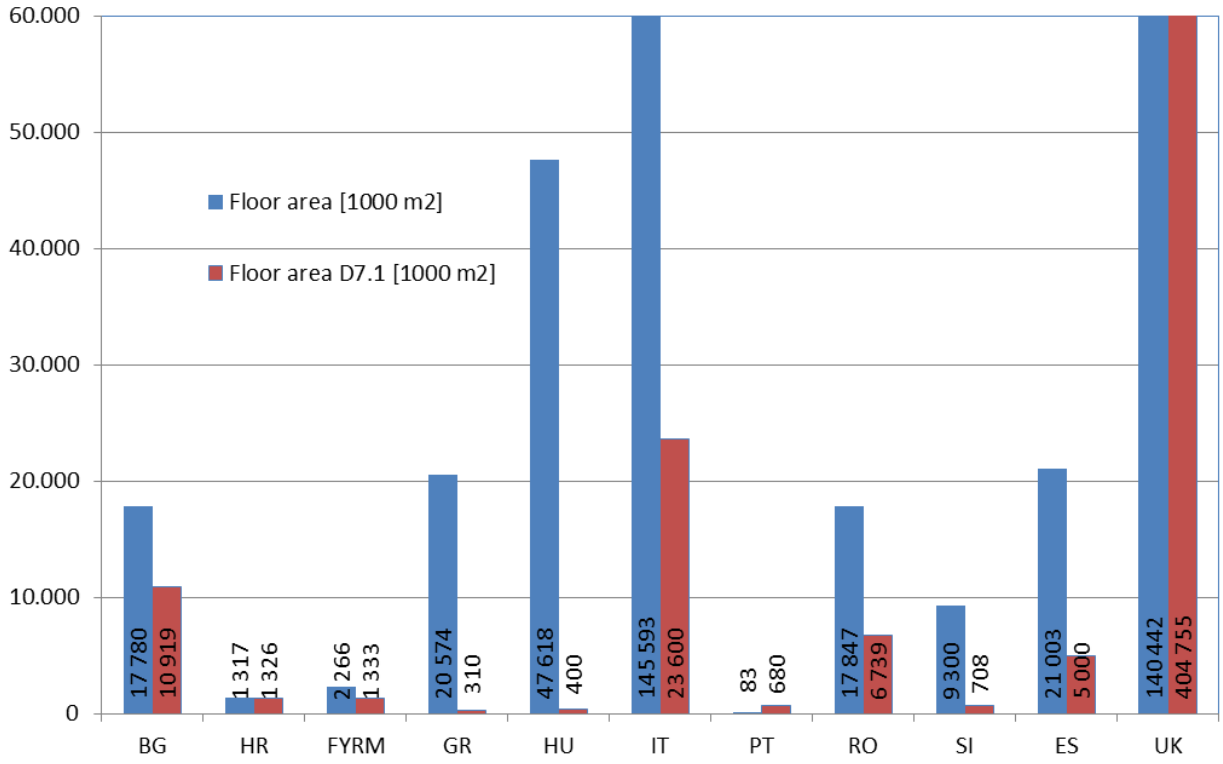


Figure 1: Total Floor Area per analysed countries

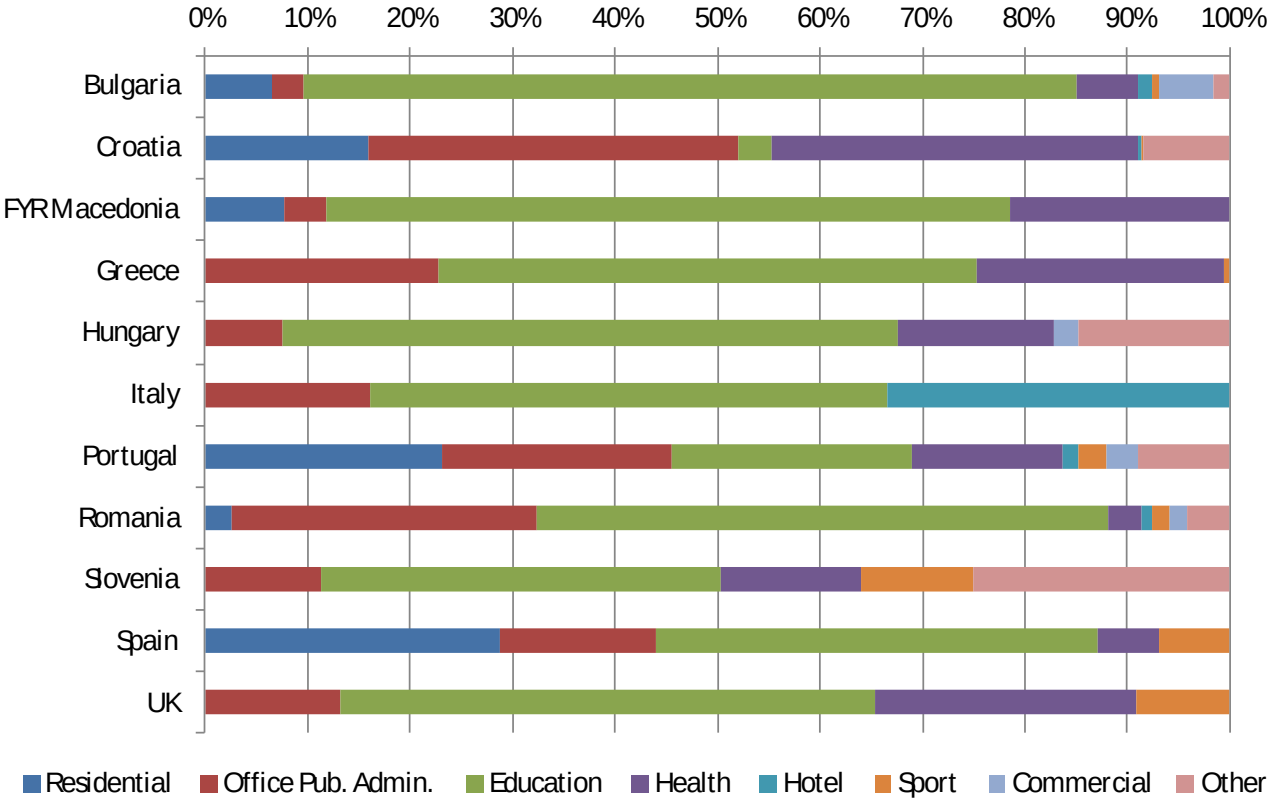


Figure 2: Impact assessment (share of total floor area) for preliminary selection of reference buildings

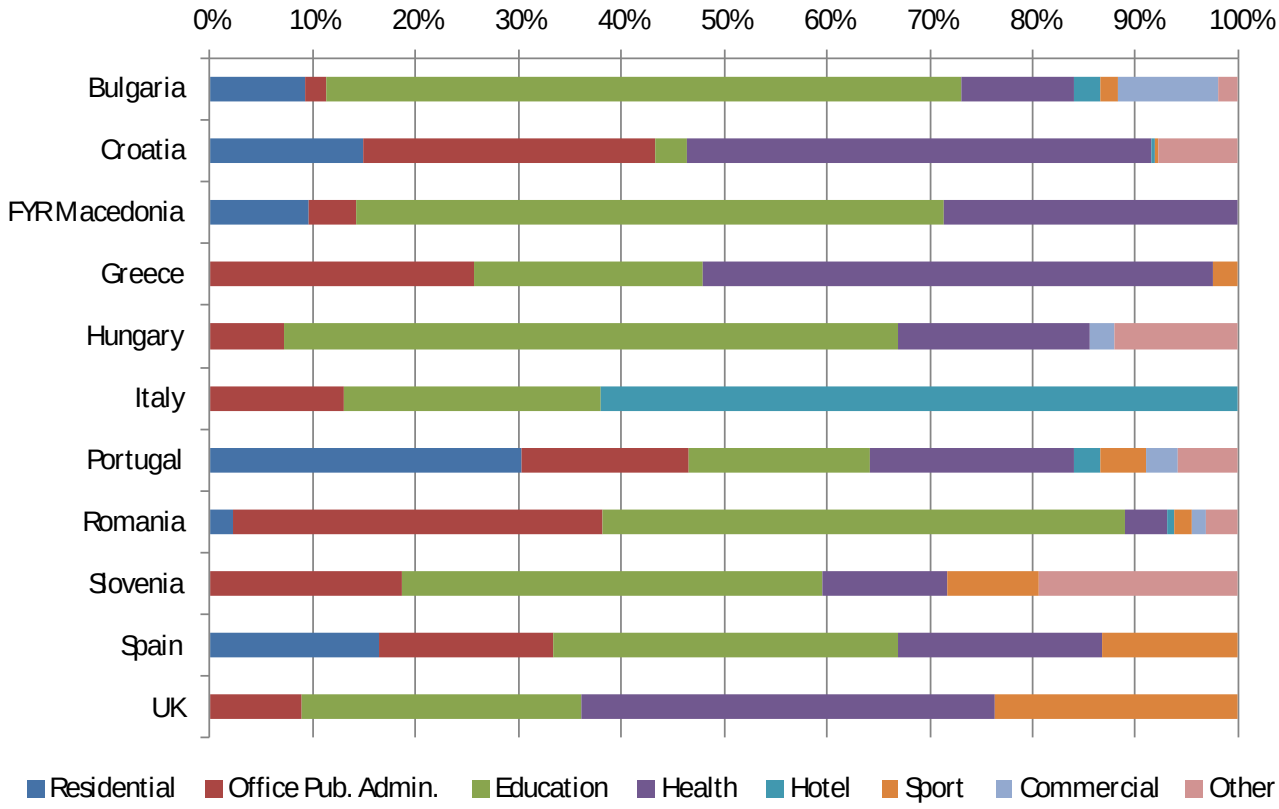


Figure 3: Impact assessment (share of total primary energy consumption) for preliminary selection of reference buildings

In terms of CO_2 emissions and saving potential, the most interesting classes of buildings are the ones with the highest values of specific primary energy consumption, however the selection of building categories for which reference buildings will be defined is strongly influenced by the impact that the major renovation of the considered building categories will bring at building stock level. Figure 4 presents the primary energy consumption (both as specific consumption [kWh/m²year] and total consumption [TWh/year]) as cumulative values for all addressed countries and per building category.

Taking into account the values of TFA and PE consumption as impact on public building stock in each country, the preliminary selection of reference buildings is presented in Table 3.

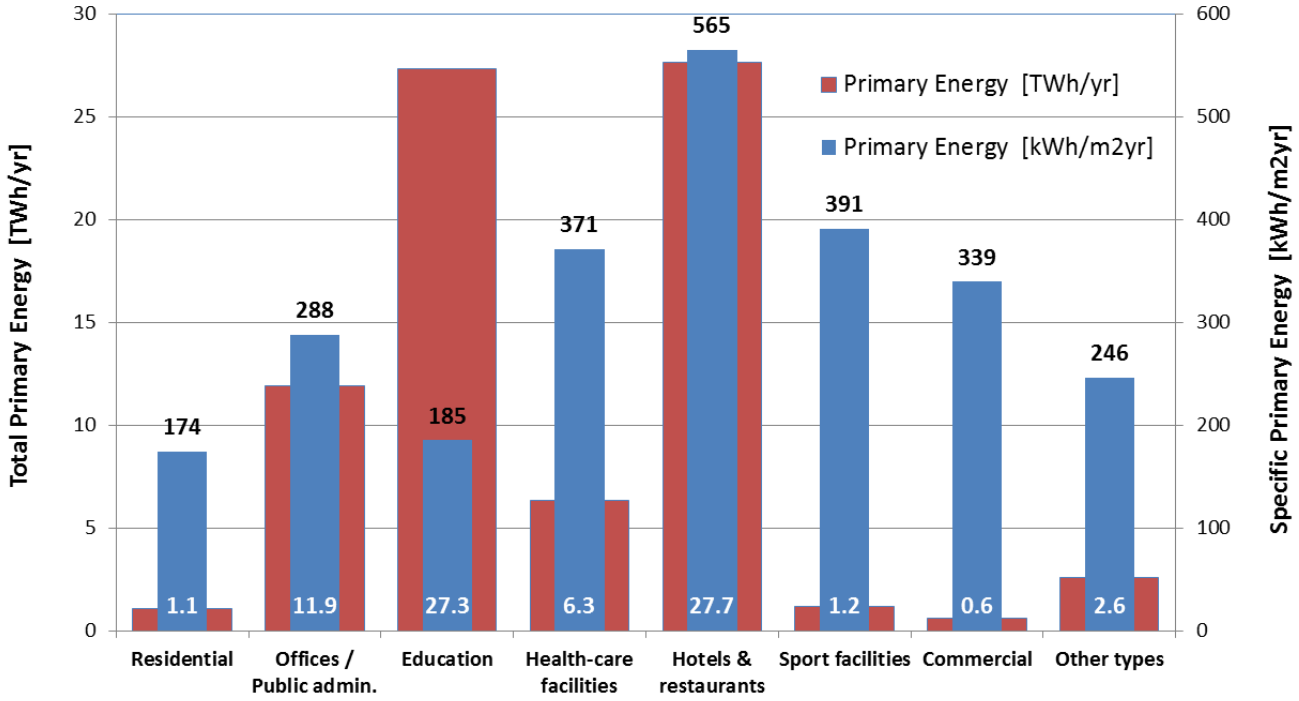


Figure 4: Total primary energy per building category in analysed countries

Table 3: Buildings with impact on public building stock in each country – preliminary selection of reference buildings

Country	Residential	Offices Public Admin.	Educa-tion	Health	Hotel	Sport	Com-mercial	Other
Bulgaria	O	O	●	●	-	-	O	-
Croatia	O	●	O	●				
the FYR Macedonia	O	O	●	●	-	-	-	-
Greece	-	●	●	●	-	-	-	-
Hungary	-	O	●	●	-	-	-	O
Italy	-	●	●	-	O	-	-	-
Portugal	O	●	●	O			-	O
Romania	-	●	●	O	-	-	-	-
Slovenia	-	●	●	●	-	O	-	O
Spain	O	●	O	●	-	O	-	-
UK	-	●	●	●	-	O	-	-

Key

● - Should be considered taking into account a significant impact in terms of building floor surface and energy consumption at the level of building stock,

O - Could be considered taking into account the impact in terms of building floor surface and energy consumption at the level of building stock.

The objectives of the report were overall achieved, by defining the classes of buildings as the most relevant ones (in terms of major renovation impact) to be analysed further during the project implementation. The report offers enough information to select building categories and sub-categories (e.g. Education buildings – school), providing for most of the countries detailed information which could be considered either as identification keys for the construction of 'statistical representative buildings' or as checking indicators for the verification of an actual building selected as a reference building for a specific category/sub-category (e.g., average conditioned area, compactness ratio, number of floors, EP indicators, age, systems, fuel type etc.).

For the selected reference buildings in each country the corresponding necessary geometrical data, building energy use, base heat supply regime (type of the heating system, energy resource/carrier etc.) should be detailed, allowing the simulation of the energy consumption and the estimation of different major renovation strategies and packages of solutions. This report together with the defined reference buildings will be presented to the national stakeholders and submitted for their validation.

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6. ACRONYMS

ACRONYM	Description
A/V	building area/building volume
ADENE	Portuguese Energy Agency
BAPV	Building Applied Photovoltaics
BDS	Bulgarian Institute of Standardization
BIPV	Building Integrated Photovoltaics
BPIE	Building Performance Institute Europe
BSRIA	The Building Services Research and Information Association
CC-SI	Classification of Types of Construction
CDI	Research, Development, Innovation
CIBSE	Chartered Institution of Building Services Engineers
CO_2	Carbon dioxide
CRESME	Economic Social Market for Construction and Land Research Center, Italy
DEC	Display Energy Certificates
DHW	Domestic hot water
EASME	Executive Agency for Small and Medium-sized Enterprises
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EE	Energy Efficiency
EED	Energy Efficiency Directive
ENEA	National Agency for New Technologies, Energy and the Environment of Italy
EPB	Energy Performance of Buildings
EPBD	Energy Performance of Buildings Directive
EPC	Energy performance characteristics/Energy Performance Certificate
ESCO	Energy Services Company
ESF	European Social Fund
EU	European Union
FEMP	Spanish Municipalities Federation
GD	Government Decision
GO	Government Ordinance
Heat.	Heating
HVAC	Heating, ventilation and air-conditioning
ICAEN	Catalan Energy Institute
ICESD	International Conference on Environmental Science and Development
IDESCAT	Statistical Institute of Catalonia
INE	National Statistical Institute, Spain
KENAK	Greek Regulation of Energy Performance of Buildings

ACRONYM	Description
KEOP	Environment and Energy Operative Programme
kWh	Kilowatt hour
kWh/m^2	Kilowatt hours per square meters
MDRAP	Ministry of Regional Development and Public Administration
ME	Ministry of Economy
MISE	Ministry of Economic Development of Italy
Mtep	Million-ton equivalent of petroleum
nZEB	Nearly Zero Energy Buildings
PE	Primary energy
RES	Renewable Energy Sources, as per the definition in Directive 2001/77/EC of the European Parliament and of the Council
RHI	Renewable Heat Incentive
SCE	Portuguese National System for Energy and Indoor Air Quality Certification of Buildings
SEDA	Sustainable Energy Development Agency
TFA	Total floor area
TU-Sofia	Sofia Technical University
TWh/yr	Terawatt hour per year
UK	United Kingdom of Great Britain
VAT	Value Added Tax
VET	Vocational Education and Training
VRF	Variable refrigerant flow
W/m^{2}K	Watts per metres squared kelvin
WP	Work package
ZELC	Association of the Units of the Local-self Government of the Republic of Macedonia

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BULGARIA

CROATIA

GREECE

HUNGARY

ITALY

the FYROM

PORTUGAL

ROMANIA

SLOVENIA

SPAIN

UK

Appendix

Indicative table structure for collecting Public Buildings Stock Data in each country

No.	Category / sub-category	Description	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²	Land area occupied by the building(s), m²
1	Residential	Total, of which:				
1.1	Social housing	Residential buildings owned by central/local authorities (usually rented)				
1.2	Service housing	Buildings/Dwellings owned by central/local authorities and used by public servants in their duty				
1.3	Student housing	Residential buildings in campus areas, owned by central/local authorities				
2	Offices / Public administration	Total, of which:				
2.1	Central Autorities	Buildings owned and/or occupied by central authorities				
2.2	Reg. Local Authorities	Buildings owned and/or occupied by regional of local authorities				
3	Educational buildings	Total, of which:				
3.1	Kindergartens	Buildings used for pre-primary education.				
3.2	Schools	Buildings used for primary and secondary education (e.g. nursery schools, primary schools, secondary schools, colleges, grammar schools, technical schools etc.), formal education schools, vocational training schools				
3.3	Universities/ High schools	Buildings used for higher education and research; research laboratories; higher educational establishments.				
4	Health-care facilities	Total, of which:				
4.1	Hospitals	Institutions providing medical and surgical treatment and nursing care for ill or injured people. University hospitals, hospitals of penitentiaries, prisons or armed forces				

No.	Category / sub-category	Description	Number of buildings	Total floor area (built-up area), m²	Total useful conditioned floor area (heated and/or cooled), m²	Land area occupied by the building(s), m²
4.2	Other institutional care	Sanatoria, long-stay hospitals and nursing homes, psychiatric hospitals, dispensaries, maternity facilities, maternal and child welfare centres. Institutional buildings with combined residential/lodging services and nursing or medical care for the elderly, for handicapped people etc. Buildings used for thermal treatment, therapy, functional rehabilitation, blood transfusion, breast milk collection, veterinary treatment etc.				
5	Hotels and restaurants	Total, of which:	0	0	0	0
5.1	Hotels	Hotels, motels, inns, pensions and similar lodging buildings, with or without restaurants, detached restaurants and bars.				
5.2	Other short-stay accommodation buildings	Youth hostels, mountain refuges, children's or family holiday camps, vacation bungalows, holiday and rest homes and other lodging buildings for holiday makers, not elsewhere classified				
6	Sport facilities	Buildings used for indoor sports (basketball and tennis courts, swimming pools, gymnastic halls, skating or ice-hockey rinks etc.) providing facilities for spectators (stands, terraces etc.) and for participants (shower and changing rooms etc.)				
7	Wholesale and retail trade service buildings	Shopping centres, shopping malls, department stores, detached shops and boutiques, halls used for fairs, auctions and exhibitions, indoor markets, service stations etc.				
8	Other types of energy consuming buildings	e.g. industrial, warehouse, civil and military facilities, historical buildings etc.				
TOTAL			0	0	0	0

					Heating system type			Boiler type [% (1+2)]	
No.	Factor of the shape / Compactness Ratio (area of the exterior walls / building volume)	Number of (above ground) floors (including Ground-floor)	Type of building construction (as defined at national level)	Year of construction / commissioning	(1) Collective central heating (building boilers/heating plant)	(2) Individual central heating (incl. electric heating)	(3) Room heating	Conventional boiler	Condensing boiler
1									
1.1									
1.2									
1.3									
2									
2.1									
2.2									
3									
3.1									
3.2									
3.3									
4									
4.1									
4.2									
5									
5.1									
5.2									
6									
7									
8									
Total									

	Fuel / energy agent type												Cooling system
No.	District heating	Oil	Coal/ lignite	Gas	Biomass (Wood log)	Biomass (Wood chips)	Biomass (Wood pellets)	Biomass (Other)	Electricity	Heat pump air/air	Heat pump air/water	Heat pump water/water	(No system, individual/split, central)
1													
1.1													
1.2													
1.3													
2													
2.1													
2.2													
3													
3.1													
3.2													
3.3													
4													
4.1													
4.2													
5													
5.1													
5.2													
6													
7													
8													
Total													

	Consumption levels by different building types (kWh/m²/year)									
No.	Heating	Cooling	DHW	Lighting	Appliances	Other	All end uses except appliances	All end uses	Year of data	Notes
1										
1.1							0	0		
1.2							0	0		
1.3							0	0		
2										
2.1							0	0		
2.2							0	0		
3										
3.1							0	0		
3.2							0	0		
3.3							0	0		
4										
4.1							0	0		
4.2							0	0		
5										
5.1							0	0		
5.2							0	0		
6							0	0		
7							0	0		
8							0	0		
Total										

	U values of components and air-tightness levels						Comments / other information			
	Wall, W/m2K	Roof, W/m2K	Floor, W/m2K	Windows, W/m2K	Air-tightness levels n50 in h-1 [-]	Notes	Source	Source URL	Source quality rating	Please describe data quality issues if relevant
1										
1.1										
1.2										
1.3										
2										
2.1										
2.2										
3										
3.1										
3.2										
3.3										
4										
4.1										
4.2										
5										
5.1										
5.2										
6										
7										
8										
Total										