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# D3.2 – CATALOGUE OF REFERENCE BUILDINGS CLASSES IN MED COUNTRIES

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## TABLE OF CHANGES

| Date | Change | Author | Resulting Document Version |
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| 24/10/2018 | First review-addition proposals | José Manuel Salmerón Lissén (USE) | V1.1 |
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# PUBLISHABLE EXECUTIVE SUMMARY

This report represents deliverable D3.2: ''Catalogue of reference buildings classes in MED countries'' of Work Package 3 (Optimal Solutions) and presents key data concerning the general features of residential buildings in HAPPEN project's involved countries and the identification of reference buildings for a future cost/benefit analysis.

This report aims at collecting and analysing, as much as possible, the residential building stocks in countries addressed in the HAPPEN project (Greece, Croatia, Cyprus, Italy, Slovenia, Spain and France). Starting from previous EU projects as well as regional studies and experts' knowledge, each partner collected and analysed data concerning the general features for heating, DHW, cooling, construction and geometrical details referred to all types of residential buildings.

In order to perform a co-ordinated analysis of the residential building stock, a specific procedure was followed. The main indicators for statistical analysis of the building stock were proposed and a methodology for defining reference buildings was presented. Based on the defined methodology, national data were collected and analysed for the seven participant countries.

The results of the analysis define six different reference buildings in each country. Moreover through a cross-country comparison of the obtained data, the most representative buildings were identified, after grouping the buildings in different classes to which the same approach for the renovation/refurbishment can be applied (e.g. building use, size, and energy performance).

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# ACRONYMS AND ABBREVIATIONS

All acronyms and abbreviations (AAs) used in the report should be listed in alphabetical order in the table below (other than symbols for units of measurement) in the following way:

AAs must be defined the first time they are used in the text of the report, and AAs should not be introduced if they are not used again in the document.

| | |
|---|---|
| **ACs** | Air Conditioners |
| **BPIE** | Building Performance Institute Europe |
| **DD** | Degree Days |
| **DHW** | Domestic Hot Water |
| **DOE** | Department of Energy |
| **EU** | European Union |
| **EPBD** | Energy Performance of Buildings Directive |
| **HDD** | Heating Degree Days |
| **HVAC** | Heating, Ventilating, Air Conditioning systems |
| **IEE** | Intelligent Energy Europe |
| **MED** | Mediterranean |
| **MS** | Member States |
| **MFH** | Multi-Family House |
| **RB** | Reference Buildings |
| **SFH** | Single Family House |
| **WP** | Work Package |

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# 1 INTRODUCTION

## 1.1 Aims and objectives

The current analysis aims to achieve the categorisation of existing building stock of MED countries through six different reference buildings types. Furthermore, based on the results of the current analysis, the representative buildings will be described in detail in order to permit simulation analysis of the energy performances in their current state and with the application of the defined set of technical solutions for building renovation.

## 1.2 Relations to other documents

### 1.2.1 Other Project Documents

This deliverable is in very close relation with next deliverables:

**WP3: Optimal Solutions**

D3.3 – Abacus of "renovation measures" at building and district scale

D3.4 – Report on optimal packages of solutions targeted on building and climates

The deliverable is related to, or has repercussions over the results of the deliverables:

**WP3: Optimal Solutions**

D3.5 - Report on the holistic impacts on renovation integrated solutions

**WP5: Integrated Platform**

D5.3.6 – Validated HAPPEN platform

**WP7: Communication, Dissemination, Exploitation**

D 7.2 – Articles, publications on the platform, other diss. and comm. materials

D 7.3n – Dissemination, workshop/meetings – reports

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## 2 BASIC INFORMATION ON COST OPTIMAL

The European Union is committed to reducing greenhouse gas emissions by 80–95 % below 1990 levels by 2050. Higher energy performance buildings and the use of renewable energy sources in existing and new buildings are expected to play a major role in achieving this aim. This focus is well grounded, as energy consumption in buildings accounts for roughly 40 % of Europe's total final energy consumption and the share of households being 27 % of the total.

In order to have a practical impact on the reduction of building energy consumptions, the Energy Performance of Buildings Directive (EPBD) obliges Member States (MS) to define minimum requirements of energy performance of buildings and buildings components with a view to achieving cost-optimal levels.

The term "cost-optimal" is defined as the energy performance that entails the lowest cost during the estimated economic lifecycle. At the same time, it enlarges the concept from cost optimal to cost effectiveness, as graphically shown in Fig. 1.

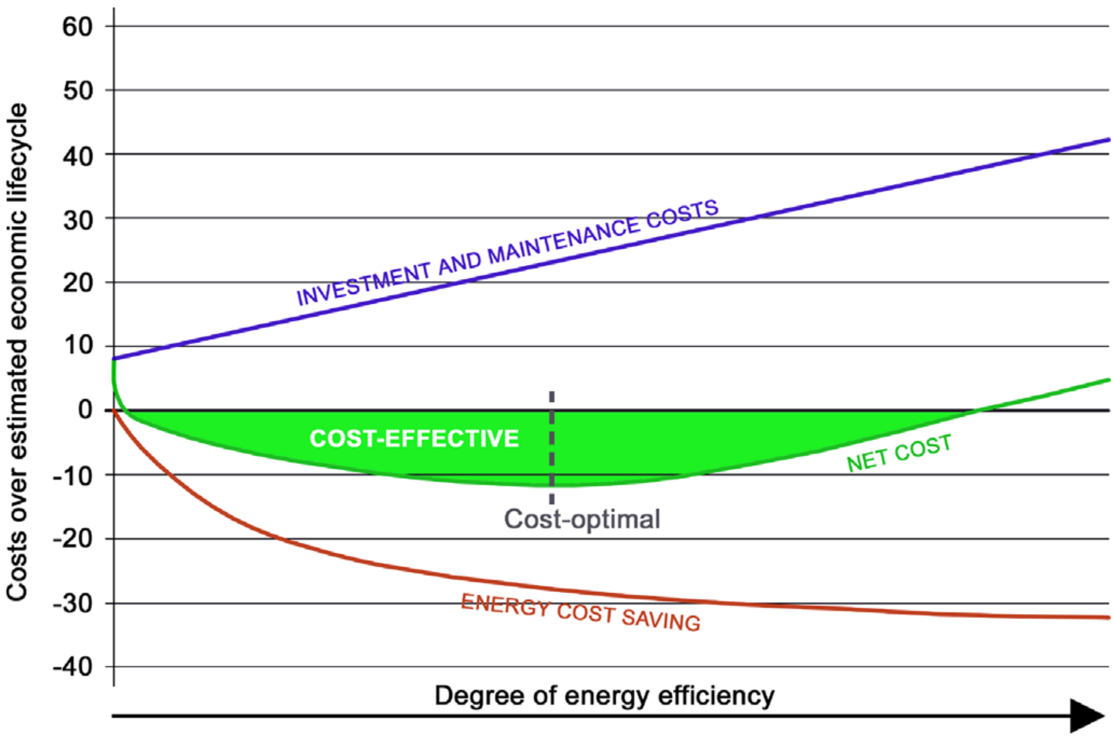


Fig. 1. Cost-optimal point and cost-effective range (Ballarini et al. 2014)

Since building stocks are characterised by a large diversity of houses and heat supply systems, it is not possible to calculate the cost-optimality for every single building. For this reason, the comparative framework illustrated in the accompanying Guidelines of the EPBD requires of the MS to define a set of reference buildings (RBs), as typical national or regional buildings. Due to the EPBD request, RBs have hence become a crucial topic for studies assessing the energy performance.

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Once the RBs are defined, the investigation procedure can include the following steps: 1.energy performance calculation of the reference buildings to assess the baseline of the energy performance; 2. definition of energy retrofit measures to be applied to the reference buildings; 3. Energy performance calculations to evaluate the energy performance after the retrofit measures; 4.calculation of the life cycle costs using net present valuation; and 5. finally, assessment of the cost optimal (and cost-effective) set of measures to optimise (and increase) the energy performance of the reference buildings.

The choice and assessment of different RBs lead to multiple curves in the results of the cost-optimal methodology. Depending on the type of the selected RB in any particular situation, this may result in different recommendations for energy-efficient measures.

# 3 STATE OF THE ART

The definition of "reference building" is not clearly standardized and harmonized between the different MSs. According to the Commission Delegated Regulation No.244/ 2012 (European Commission, 2012a) and to its accompanying Guidelines (European Commission, 2012b), Member States are required to define "reference buildings" that should represent the typical and average building stock in each Member State, in order to obtain general results consistent with the characteristics of the analysed building stock.

Several studies, at EU and international level, are being developed in order to define RB.

## 3.1 European projects on RBs

The one most known EU project concerning the RBs is TABULA ("Typology Approach for Building Stock Energy Assessment"). It is a project, supported by the Intelligent Energy Europe (IEE), which is aimed to pursuit a harmonized structure to create building national typologies able to facilitate cross-country comparison of building stocks.

In the TABULA project, emphasis is given on the assessment and improvement of the energy performance of buildings: thus, the typology concept focuses on building parameters related to the energy consumption.
Therefore, residential building typologies were developed in 13 European countries following a common methodological structure by defining a set of five parameters related to building classification.

These parameters are the following: country, region or climate zone, construction year class (different construction periods should be defined for each country separately, reflecting shifts in building practice and energy requirements by building regulations), building size class (four different building sizes are considered in the project: single-family houses, terraced houses, multi-family houses, apartment blocks) and further energy-relevant parameters (U-values, heating system, etc.), as well as a set of exemplary buildings representing the respective building types.

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Of course, each country could, according to the specific features of given groups of buildings, examine categories, which do not entirely meet the proposed indicators but are important for the country due to other specific reasons.

Another one is the ASIEPI project (Assessment and Improvement of the EPBD Impact – for new buildings and building renovation), aims at developing an instrument for making meaningful comparisons of minimum energy performance requirements in the individual MSs and to test this instrument with a limited selection of RBs.

A single family house, varying from row house to detached house, was defined for each participant country. The single family house was chosen as a valuable RB mainly for two reasons. Firstly, because, it represents the most typical residential building in Europe and secondly small and simple houses were preferred to perform comparison studies in order to minimize the errors of a complex geometry.

The Buildings Performance Institute Europe (BPIE) has undertaken an extensive survey across all EU MSs. This survey provides an EU-wide picture of European building stock. BPIE used in its survey a building characterization based on the building typology (function type), building age, building size and building location. This characterization corresponds to the statistical data provided by the participating EU countries.

Within the IMPRO- Building project, data were collected from several sources and harmonized in order to define an appropriate building stock typology based on several aspects (e.g. population, building type, age, structure). The overall objective of the project was the analysis of the environmental improvement potentials of residential buildings. The database covered 25 MSs of EU and defined 72 building types (53 existing buildings and 19 new building types).

This led to building models distributed into three building types: single-family houses (including two-family houses and terraced houses), multi-family houses (buildings with fewer than 9 floors), and high-rise buildings (buildings that are higher than 8 floors). The buildings were also defined in such a way as to be distributed into three main zones in Europe that roughly represent three climate zones according to heating degree days (HDD). Three age categories for buildings are set as the highest aggregated level for each country: until 1945 (old buildings), between 1946 until 1990 (post war buildings) and after 1991 (current and new buildings). The description also covered the material composition of the different building elements (roofs, external and interior walls, basement/foundation, floors, windows/doors).

The analysis of the use phase implied using data referring to the heating and cooling energy demand. Since the focus was on the analysis of improvement potentials of building design rather than HVAC (Heating, Ventilating, and Air Conditioning) systems, a standard heating system was defined for all building types. The differences of the space heating demand of the different building types only result from each building's design, construction material composition and from the climatic region.

The COST Action C16 "Improving the quality of existing urban building envelopes" is directed to multi-storey residential blocks from the period after World War II, especially those built during the period

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when the need for housing in Europe was at its greatest. That is why the COST Action C16 focussed on the period 1950 to 1980.

In Passive house retrofit, social housing companies in 14 countries were given the chance to benefit from a tool kit designed to help them carry out retrofitting in such a way as to considerably reduce primary energy consumption. The tool kit includes best practices, "Passivhaus" standards and a methodology. Retrofitting methods include better insulation, air-tightness and balanced ventilation which encompass cooling in southern climes. This information source is used as the basis for evaluation the possibilities for Passive House Retrofitting. The typologies of the 5 partner-countries (Austria, Denmark, Lithuania, Spain and The Netherlands) are different concerning the number of building types and the way the typology is made. For all building typologies focus has been put on buildings from 1950's to around 1980-90.

RePublic_ZEB is a European Commission funded project that brings together partners from the South-Eastern European Countries to develop and promote Near Zero Energy Building (nZEB) tools. The RePublic_ZEB project aims to assist in achieving the huge potential for energy savings by focusing on the energy and $CO_2$ emissions associated with existing public buildings and their refurbishment towards nZEB.

Resting on the above considerations, the basic approach proposed for selection of categories of buildings, for which representative buildings for further cost-benefit analysis were to be determined, includes assessment of the building classes identified at the previous stage, observing the importance and the magnitude of the following indicators: Building conditioned area ($m^2$), specific final/primary energy consumption ($kWh/m^2.year$) and/or quantity of $CO_2$ emission equivalent of the specific energy consumption ($kg/m^2.year$). Each partner had to select 2-3 or more building categories.

The ENTRANZE project provides data analysis and guidelines to promote the introduction of nearly zero energy buildings in the existing building stock in EU. Among the collected data that are available by means of an online tool, the percentage of dwellings by period of construction and by type of building (single or multi-family) and the average floor area by type of building are useful for risk assessment studies.

The GE2O project defines geo-clusters across EU countries with a view to deploy the potential of energy efficient buildings. Geo-clusters are wide trans-national areas with similar building typologies, climatic conditions, macroeconomic situation and regulatory framework. A well-based mapping tool was developed for the visualization of data regarding the age of construction and use (residential or non-residential) of buildings.

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## 3.2 US Example

In the United States, the Department of Energy (DOE) created 16 RB models that characterize more than 60% of the commercial building stock in the U.S. These models aim to represent in a realistic way building characteristics and construction practices. They included 15 commercial buildings and one multi-family residential building and were classified under three construction periods (pre-1980, post-1980 and new buildings). The data collected for creating RBs can be collated into four main areas that constitute a wider set of features: form (building type, size and general geometry), envelope (construction technologies and material), system (heating and cooling systems, mechanical ventilation systems, generation systems and production from renewable sources) and operation (operational parameters affecting the usage of the building). The research carried out aimed at assessing new technologies, optimizing designs, analysing advanced controls, developing energy codes and standards and at conducting lighting, day lighting, ventilation, and indoor air quality studies

## 3.3 National Studies

There are also several national works, aimed at assessing the energy consumption, emissions and potential energy savings of building stocks. Although there is no standard regarding the process to determine reference buildings, most studies apply similar procedures to obtain it.

For example, Balaras et al. 2011 and Dascalaki et al. 2010 examined Hellenic residential buildings. The classification was carried out using the construction period (pre 1980, 1981–2001 and 2002–2012), type of building (low-rise buildings with one or two floors, high rise buildings with more than two floors) and climatic zone (four zones). Additional sub-categories were defined with common characteristics including thermal properties of the building and HVAC systems. The methodology adopted to establish these categories of residential buildings assigns to each of them a real existing building considered to be representative of all buildings in the given class. On the other hand, Theodoridou et al. 2011 examined Greek residential buildings stock. The classification proposed is based on only the construction period and they identified five classes, that is: class A (1919–1945), class B (1946–1980), class C (1981–1990), class D (1991–2010) and class E (2010–2011). Such a choice relies on the consideration that the building age provides further information about the buildings typologies, the building materials, plants and appliances used and the construction practice applied. Researchers actually followed similar characterization schemes adopted in countries like Germany and Switzerland (Hassler 2009).

Furthermore, a wider analysis on the energy consumption of 193 residential buildings stocks involving five European countries has been performed by Balaras et al. 2004. Tommerup and Svendsen 2006 examined Danish residential building stock. They referred to two typical buildings: single family house and a multi-family building.

Uihlein and Eder 2010 examined European (EU27) residential building stocks proposing for each of the countries a model representing the development of the relative building stocks. In more detail, three different building types have been identified, that is: Single-family, Multi-family, and High-rise. These classes have been further divided in historical and new buildings types from 1900 up to 2060.

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Fracastoro and Serraino 2011 examined the energy performance of the residential building stocks of two large Italian regions, Piedmont and Lombardy. The survey was carried out on the basis of the data collected by the Italian census, so that 72 different building geometries were considered, along with 4 different construction age categories, 11 heating system efficiencies and a variable number of degree-days (DD) categories with a chosen step of 100 DD. Ana Brandao de Vasconcelos et al 2015 proposed a methodology meets the needs and the existing lack of information in the definition of reference buildings in Portugal. This methodology was successfully implemented so as to define a reference building (family house) representative of the residential buildings constructed in Lisbon between 1961 and 1990. In this study more importance is given to the parameters related to building function type, building location and construction period, rather than other parameters used by other approaches.
Aline Schaefer and Enedir Ghisi (2016) developed a method for obtaining reference buildings for the low-income housing stock in Florianópolis, Southern Brazil. Field data collection was performed in order to build a database on geometrical features of houses. Two Reference buildings were obtained using cluster analysis: a 76 m$^2$ house, with living room, kitchen and three bedrooms, and a 37 m$^2$ house, with combined living room and kitchen and two bedrooms. Simulations have shown that the reference buildings can represent their cluster properly, since the degree-hour values obtained for them were similar to the housing median sample.

From all the above we can conclude that different criteria have been adopted by the technical/scientific community for defining samples for RB characterization. But the classification criteria for building-stock energy performance which can be resumed as being based on three aspects: the climatic zone, the year of construction and the type and geometrical and thermo-physical features of the buildings.

# 4 ANALYSIS

The current analysis was performed in the framework of WP3 focusing on data collection and statistical analysis concerning the general features for heating, DHW, cooling, construction and geometrical details of residential building stocks in MED countries. Initially, useful data from International, European and regional projects, publications and technical bibliography on this topic was collected, aiming to further define a set of reference buildings. These will be used as prototype buildings in the analysis of the effectiveness of HAPPEN solutions.

## 4.1 Definition of Reference Buildings

According to Annex III of the EPBD recast, RBs are "buildings characterized by and representative of their functionality and geographic location, including indoor and outdoor climate conditions" and therefore, they aim to represent the typical and average building stock in terms of climatic conditions and functionality (e.g. residential buildings, schools, etc.). The accompanying guidelines of the EPBD also state that ''the main purpose of a RB is to represent the typical and average building stock in a certain MS''.

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Therefore, the RBs should be established in order to reflect, as accurately as possible, the current national building stock to ensure that the results are representative.

## 4.2 Characterization of Reference Buildings

The European building stock is very heterogeneous in terms of climatic zones, building styles and usage. In fact, within the same category, building use can vary widely amongst different MSs. Climate conditions have a relevant influence into the construction technologies and the energy needs that characterize the building.

More specifically, the data collected for creating RBs, can be categorised into four main areas of investigation as listed below:

1. **Form**: building type (e.g. office, school, etc.), size and general geometry of the building;
2. **Envelope**: construction technologies and materials used in the building;
3. **System**: heating and cooling systems, mechanical ventilation systems (when applicable), generation systems and production from renewable sources;
4. **Operation**: operational parameters affecting the usage of the building (i.e. lighting schedule, equipment schedule, heating temperature schedule, etc.).

Moreover, collected data is subsequently classified in terms of age, location and type.

According to Corgnati et al 2013, there are three methodologies to classify RBs:

- "Example (Reference) Building". This methodology is used when no statistical data are available, and it thus relies on the basis of experts' assumption and studies. The result is a building that is the most probable of a group of buildings, within a selected location and age.
- "Real (Reference) Building". The RB is the most typical building in a certain category. It is a real existing building, with average characteristics based on statistical analysis.
- "Theoretical (Reference) Building". This method processes statistical data in order to define a RB as a statistical composite of the features found within a category of buildings in the stock. The building is therefore made of the most commonly used materials and systems.

The choice between these options should depend on expert enquiries and statistical data availability. It is possible to use different approaches for different building categories, in order to identify (real or virtual) reference buildings able to represent the characteristics (geometry, envelope, systems, etc.) of each specific building category.

## 4.3 Methodology

Building stocks are characterised by a large diversity of houses and heat supply systems, as well as a very large number and variety of possible classification systems and indicators. The procedure, which is described in the following lines, attempts to keep the problem manageable.

Building typologies have proved to be a useful instrument for an in-depth understanding of the energy performance of certain building types and categories. In the framework of HAPPEN project, residential

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building typologies have been analysed for seven European countries following a common methodological structure. Each national typology consists of a classification scheme grouping buildings according to their size, age and further energy-relevant parameters.

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.

In general, the information needed just for the building stock inventory is less than what it is needed for a realistic view of a reference building.

The methodology proposed in this report is therefore to develop a two-step procedure:

1. Collection and statistical analysis of data from previous EU projects and studies in order to make an evaluation of the existing information;
2. Additional information for a deeper analysis of the building stock. Identification of reference buildings for each country.

According to above mentioned procedure, two types of templates has been provided to the partners. The first one was a simplified version (proposed structured table, presented in Annex A) using only basic information about the buildings, such as building age, construction materials and corresponding thermal properties of the building envelope, HVAC systems and air tightness.

The necessary data for each MED country targeted by the project were sought in existing studies and other EU projects, as well as in partners' knowledge and experience. In cases when relevant data were not found, the use of default data is recommended. In order to be able to distinguish between specific subsets of a building stock, this data is required for the respective clusters to be grouped e.g. by building size (single/multi-family home) and/or specific age bands.

To effectively monitor energy saving processes in building stocks, the identification and definition of appropriate indicators is essential. The indicator scheme must be suitable for the mapping of the state of the building stock at a particular point in time as well as to understand the dynamics of the development over time. Furthermore, the respective data will be collected by means of feasible, reliable methods as e.g. representative surveys.

In order to set up the building stock models with regards to energy balance calculations, basic and structural data are required:

- **Construction period of the building stock**

Classification of the entire building stock on the root of the construction period of buildings, since this time-based classification corresponds to different typology and structural features.
The information needed can only be obtained by means of statistical databases that are developed and up-to-dated by means of recurrent census inquiries.

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- **Geometrical properties such as**

1) Typology and use: Within buildings for residential use we can divide them into multi-family buildings (MFH) and single-family buildings (SFH). Thanks to statistical studies, you can define which buildings are most common in each area and, thanks to descriptive studies, you can specify how these representative buildings are.
2) Footprint shape: This point is the least contemplated by the reviewed reference studies, due to the great variety of forms that existing buildings present.
3) Built area: necessary data for the choice of reference buildings is the identification of the types of buildings that have been built the most in each selected period. Normally the same construction methods are used in each period since same regulations apply.
4) Number of floors: the number of floors of a building is of great importance in order to assess the energy behaviour of the building stock.
5) Envelope area: Among the descriptive data necessary for the characterization of the envelope it is important to know the area of: the external walls, the area of the walls in contact with another building, the area of windows and doors, floor area and roof area. The majority of these areas could be inferred, with a series of calculations and assumptions, from other data that geometrically describe the reference buildings, although quantifying the walls that are in contact with another building, or the percentage of holes in a wall is very difficult or impossible. This data will help model the geometry of the building and can clarify important issues such as compactness or how much surface is in contact with the outside.

- **Thermo-physical properties**

1) Thermal transmission or U-Values (in W / $m^2K$) describing the ability of a construction material of the building envelope to conduct heat.
2) Air tightness of the building, which will describe how well the building is sealed, being able to quantify if the building suffers from air infiltration.

- Heating system and appliances

HVAC Systems are used to describe whether a reference building achieves comfort conditions.
1) DHW Systems or sanitary hot water systems (DHW) will specify the type of equipment most commonly used in the building stock, such as boilers or thermoses of fossil fuels, electric water heaters, etc. The efficiency and condition of this equipment will also be described.
2) Energy sources: It is closely linked to the description of the equipment. In this section the most commonly used types of energy sources will be identified, used for comfort and ACS.

- **Geographical localization of buildings**

The categories are defined according to the building size (single family house or multi flat building) and their construction period.

According to all the above, it was decided to focus in three different construction periods (<1980, 1981-2000, 2001-2010) without taking into consideration buildings after 2010 and EPBD's issuing because they may not need refurbishment. The grouping into the three age categories can be seen as a way to simplify the overview but may mask many specificities. In particular, some of the identified building types show an overlapping of the age groups, meaning that one building type includes buildings from the other groups.

In this respect, the residential building types were reduced in order to minimize the noise created by complex definitions, errors and misunderstandings. More specifically, SFH definition will also include terraced houses and MFH will include apartment blocks.

Thus, the reference building for a building category/subcategory can be defined as a building with representative characteristics for the indicators below:

- Type of building construction (as defined at national level);
- Age (year of construction / commissioning);
- Geometry, including footprint type, total floor area, number of floors;
- Compactness, including wall/window area per orientation;
- Building energy services/uses (e.g. heating, cooling, mechanical ventilation, DHW, artificial lighting);
- Type of heating/cooling system, including fuel type and COP;
- Construction materials and thermal properties.

Therefore, the proposed methodology includes the creation of a virtual building using a mixed approach (not used by the previous methods), based at first on basic statistical data, and later on experts' enquiries and other sources of information.

The added value of this work consists of the analysis of heterogeneous data sources and collecting and comparing the information of the housing stock under a common comparison framework of building typology data between countries, and the contribution in the harmonization of the building typology approach.

## 4.4 Results

Within the collaboration of seven countries, HAPPEN dealt with the development of a harmonized structure for residential building typologies. A set of typical residential buildings, was developed for each participant country and data in terms of construction time and building type was collected. RBs are considered as example and theoretical buildings according to the definition mentioned above.

There is an infinite number of combinations in the existing buildings stock, and no "correct average" exists. Therefore, the creation of a typical, in terms of size, number of floors and use, reference building for each building category (SFH-MFH) is recommended.

Most of this input data can be collected for existing and previous building regulations and norms from the sources listed above for the definition of building geometry. In particular, regarding the definition of thermal properties, several approaches are possible. As the building stock will be divided into groups based on the year 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

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corresponding U-value requirements are specified. For each building category, reference buildings could be defined with U-values for each of these time periods.

The collected data structure for each MED country is depicted in the following table (Table 1), while the filled templates are presented in Annex B.

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| COUNTRY | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA ($m^2$) | No. FLOORS | FLAT ROOF AREA ($m^2$) | AREA OF EXTERNAL WALLS PER ORIENTATION ($m^2$) | AREA OF PARTY-WALLS PER ORIENTATION ($m^2$) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES ($W/m^2 K$) | | DESCRIPTION | AIR TIGHTNESS (n50) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| <1980 | | | | | | | | | ROOF | | | | | |
| | | | | | | | | | SLAB ON GRADE | | | | | |
| | | | | | | | | | WALL | | | | | |
| | | | | | | | | | WINDOW | | | | | |
| 1981-2000 | | | | | | | | | ROOF | | | | | |
| | | | | | | | | | SLAB ON GRADE | | | | | |
| | | | | | | | | | WALL | | | | | |
| | | | | | | | | | WINDOW | | | | | |
| 2000-2010 | | | | | | | | | ROOF | | | | | |
| | | | | | | | | | SLAB ON GRADE | | | | | |
| | | | | | | | | | WALL | | | | | |
| | | | | | | | | | WINDOW | | | | | |

Table 1: Data structure for RBs for each country per construction period

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Due to the objective of implementing improvements in existing buildings in the Mediterranean area, as mentioned before it was necessary to generate a series of Reference Buildings (RB's). The existing real buildings have different constructive natures, so it is necessary to make a classification with the objective of agglomerating the types that are congruent with each other. This methodology called clustering.

Clustering is an unsupervised machine-learning approach that automatically divides data into sub-groups (clusters), and it has been widely used in the building energy research field for different purposes, such as identifying typical occupancy profiles, behaviour patterns, load profiles, key building energy efficiency explanatory factors, and energy performance benchmarking.

Descriptive indicators considered include:

- Geometrical Characteristics which defines the dimensions of the envelope;
- Thermal Characteristics which defines the construction materials and methods;
- Positional Characteristics which defines the position of the building in relation to other buildings.

As highly correlated variables cause problems for clustering analysis results, variable elimination should be done to discount redundant variables before clustering.

In this work, five different variables (U-Values, footprint area, shape, number of floors and party walls) concerning the previous indicators were used. The clusters that were formed for each variable are presented in the following table (the values of each variable's clusters are presented in Annex C).

| Variables | U-Values | Footprint Area | Shape | Number of Floors | Party Walls |
|---|---|---|---|---|---|
| Number of Clusters | 11 | 4 | 4 | 3 | 3 |

Table 2: Clusters per Variable

The combination of these initial clusters leads to the total clusters, which are shown in table 3.
The code TXX means the number of the Thermal Cluster which condensate the thermal properties of walls, slabs on grade, roofs and glazing following the criteria given in the Annex C.
The code CYY means the number of the Construction Cluster which condensate the footprint area, the shape, the number of floors and the number of party walls.

| PERIOD | TYPE | COUNTRY | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | GREECE | SPAIN | ITALY | SLOVENIA | CYPRUS | CROATIA | FRANCE |
| <1980 | SFH | T10C1 | T1C1 | T8C1 | T6C5 | T9C2 | T7C1 | T3C1 |
| | MFH | T10C7 | T10C6 | T8C7 | T6C9 | T9C14 | T3C9 | T10 |
| 1981-2000 | SFH | T11C1 | T2C1 | T2C1 | T6C5 | T9C5 | T7C1 | T4C1 |
| | MFH | T9C7 | T4C7 | T12C15 | T13C7 | T9C14 | T14C15 | T4C1 |
| 2001-2010 | SFH | T12C1 | T2C4 | T2C1 | T5C3 | T2C3 | T7C1 | T5C1 |
| | MFH | T2C7 | T5C10 | T7C12 | T5C8 | T2C9 | T4C7 | T5C11 |

Table 3: Total Clusters

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Based on the concepts of cluster analysis, the formation of clusters was considered adequate at this stage and is an innovative approach applied in this project. The main objectives of the clustering are the next:
1. Quantify the total number of different cases to be optimized in the task 3.3 "Optimal Solutions"
2. Identify between the previous cases the more representatives in order to start to obtain the Packages of Solutions for them and then to verify their performance in the total number of cases.

### 4.4.1 Total Number of Cases

Analysing the table 3, it is possible to identify 16 different typologies for single family houses and 21 different typologies for multi-family houses. The lower figure in the SFH is due to the fact that three typologies are repeated in different countries and periods. This is the case for the typologies T2C1 that is present in Italy in the periods 1981-2000 and >2001 and in Spain in 1981-2000. T6C5 is repeated in Slovenia in <1980 and 1981-2000 periods; and T7C1 is repeated in Croatia in the three periods.

The typologies for a given country will be used to assess the optimal solutions in the reference climates present in this country. The reference climates where identified in the D3.1. The number of combinations of RBs typologies and reference climates have been calculated and leads to a total of 51 different SFH and 63 different MFH -114 different cases- to be optimized.

### 4.4.2 Representative of Cases

Previous number of cases is too high for a direct evaluation of the optimal solutions; therefore, it is proposed to follow an indirect approach by assessing the optimal solutions to a limited number of representative cases. After that, the analysis of these solutions in the total number of cases will lead to an evaluation of them as valid or to a modification of them in order to be applicable to all the possible combinations of building typologies and climates as explained in the previous section.

In order to identify the more representative typologies we have employed the hieratical clustering with Ward's minimum variance method (Ward Jr 1963), which is a method that is not very common but which has been identified in recent studies (Patteeuw et al. 2018) as very interesting and feasible for clustering a building stock towards representative buildings, "hieratical clustering is employed since it leads to a single reproducible result". This hieratical clustering has been carried out by the SPSS © tool, using Euclidean distances and Ward's method for linkage. The number of clusters is the number of representative buildings for the aggregated model. This can be interpreted in the next figure (figure 2) as "cutting the cluster tree" at a certain value of Ward's linkage. The number of representative clusters with a Ward's linkage value lower than 5, and thus really representative of the total population can be 9 or 4.

Next tables summarize the RBs clusters obtained using this methodology. The highlighted cell is the representative building of the cluster.

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| No. CLUSTER | Representative Buildings in each Cluster SFH/MFH No. of building (1-42)_Country Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MFH 18_CY | SFH 15_CR | MFH 14_CR | MFH 2_SP | SFH 3_SP | MFH 15_CR | SFH 6_FR | MFH 12_IT | SFH 9_SL |
| 2 | MFH 5_FR | MFH 3_SP | MFH 6_FR | MFH 9_SL | | | | | |
| 3 | MFH 21_GR | SFH 8_SL | MFH 8_SL | MFH 11_IT | SFH 5_FR | | | | |
| 4 | SFH 2_SP | SFH 21_GR | MFH 4_FR | MFH 17_CY | | | | | |
| 5 | SFH 18_CY | SFH 14_CR | MFH 1_SP | SFH 7_SL | MFH 7_SL | MFH 10_IT | MFH 13_CR | MFH 20_GR | |
| 6 | MFH 19_GR | SFH 4_FR | SFH 12_IT | | | | | | |
| 7 | SFH 13_CR | SFH 10_IT | SFH 11_IT | MFH 16_CY | SFH 1_SP | SFH 17_CY | | | |
| 8 | SFH 16_CY | SFH 20_GR | | | | | | | |
| 9 | SFH 19_GR | | | | | | | | |

Table 4: RBs in each cluster for a 9 clusters scenario

| No. CLUSTER | Representative Buildings in each Cluster SFH/MFH No. of building (1-42)_Country Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MFH 18_CY | SFH 15_CR | MFH 14_CR | MFH 2_SP | SFH 3_SP | MFH 15_CR | SFH 6_FR | MFH 12_IT | SFH 9_SL |
| | MFH 5_FR | MFH 3_SP | MFH 6_FR | MFH 9_SL | | | | | |
| | MFH 21_GR | SFH 8_SL | MFH 8_SL | MFH 11_IT | SFH 5_FR | | | | |
| 2 | SFH 2_SP | SFH 21_GR | MFH 4_FR | MFH 17_CY | | | | | |
| | SFH 18_CY | SFH 14_CR | MFH 1_SP | SFH 7_SL | MFH 7_SL | MFH 10_IT | MFH 13_CR | MFH 20_GR | |
| 3 | MFH 19_GR | SFH 4_FR | SFH 12_IT | | | | | | |
| | SFH 13_CR | SFH 10_IT | SFH 11_IT | MFH 16_CY | SFH 1_SP | SFH 17_CY | | | |
| 4 | SFH 16_CY | SFH 20_GR | | | | | | | |
| | SFH 19_GR | | | | | | | | |

Table 5: RBs in each cluster for a 4 clusters scenario

This is very useful for the correct development of the Task 3.3 "Optimal Solutions" because initially the set of optimal solutions are going to be obtained only in the more representative buildings and then validated, or corrected by analysing their applicability in the total population.

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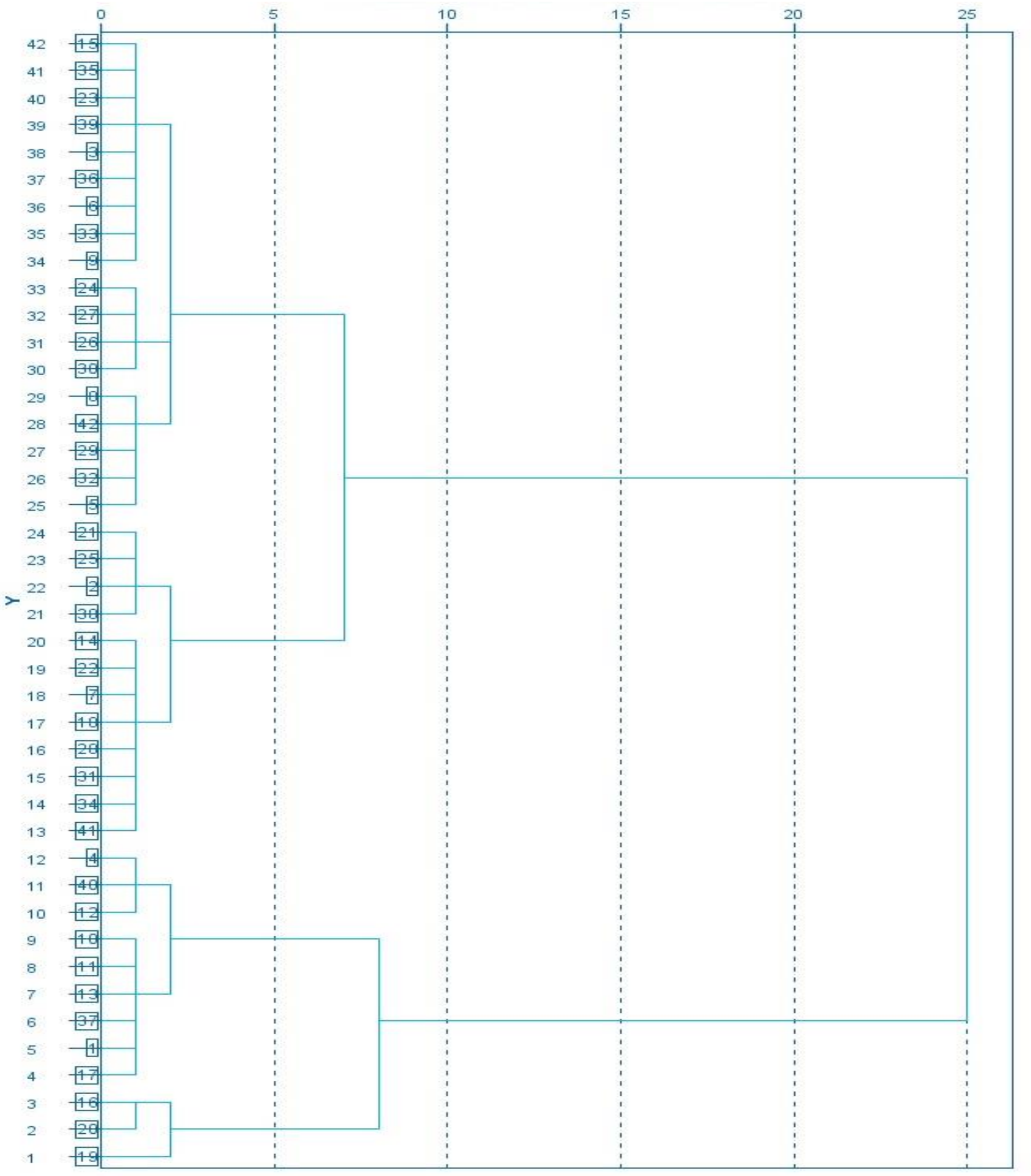


**Fig. 2: Dendrogram of hieratical clustering on ED data for the 6 RBs of the 7 countries (42 different buildings)**

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# 5 CONCLUSIONS AND RECOMMENDATIONS

The main objective of this report was to analyse the existing residential building stock in the countries or regions represented by the HAPPEN project consortium, with the view to assess key data concerning the general features and the residential buildings total energy consumption, in order to permit the definition of representative buildings as a basis for cost benefit analysis.

The starting point of the analysis was the collection of the necessary data from European and regional projects, publications and technical bibliography on the topic, as well as other sources of statistical data or summarised information, with the aim to get a realistic idea of the residential building stock in the selected countries. Among these sources, were the TABULA-EPISCOPE Project, RePublic_ZEB project and the European building stock observatory database.

The collection of information in each country participating in the HAPPEN project was designed starting from a comprehensive template which included detailed data required for the identification of representative buildings. Depending on the information available, a real or theoretical building was selected to provide performance data, which would identify the corresponding category.

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 information to select building categories, 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 (e.g., average conditioned area, compactness ratio, number of floors, EP indicators, age, systems, fuel type etc.).

For the selected reference buildings in each MED country the corresponding necessary geometrical data, building energy use, base heat supply regime (type of the heating system, energy resource/carrier etc.) should be included to the simulation of the energy consumption and the estimation of different major renovation strategies and packages of solutions.

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# ANNEX A

| COUNTRY | | | PERIOD | | |
|---|---|---|---|---|---|
| | | | <1980 | 1981-2000 | 2001-2010 |
| | BUILDING | TYPE | | | |
| | HVAC SYSTEM | HEATING SYSTEM | | | |
| | | VENTILATION | | | |
| | | DHW | | | |
| | CONSTRUCTION DETAILS | ROOF | | | |
| | | FLOOR | | | |
| | | WALL | | | |
| | | WINDOW | | | |
| | | DOOR | | | |
| | U-VALUES | U-ROOF | | | |
| | | U-FLOOR | | | |
| | | U-WALL | | | |
| | | U-WINDOW | | | |
| | | U-DOOR | | | |
| | | AIR TIGHTNESS | | | |

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## ANNEX B

**SPAIN**

| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA ($m^2$) | No. FLOORS | FLAT ROOF AREA ($m^2$) | AREA OF EXTERNAL WALLS PER ORIENTATION ($m^2$) | AREA OF PARTY-WALLS PER ORIENTATION ($m^2$) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/$m^2$ K) | | DESCRIPTION | AIR TIGHTNESS (n50) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| <1980 | SFH | Terraced House | 116 | 2 | 116 | Façade N 84.1 | Façade N 0 | 32 | ROOF | 2.67 | (1) | 12 | Boiler η=0.85 Natural Gas | Boiler η=0.85 Natural Gas |
| | | | | | | Façade E 46.4 | Façade E 0 | 18 | SLAB ON GRADE | 1,07 | (2) | | | |
| | 34 | | | 1 | | Façade S 84.1 | Façade S 0 | 18 | WALL | 1.33 | (3) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 46.4 | Façade W 0 | 18 | WINDOW | 5.70 | (4) | | | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MF H | Multi Family House | 240 | 6 | 240 | Façade N<br>348 | Façade N<br>0 | 20 | ROOF | 2.40 | (5) | 9 | N/A<br>η N/A<br>--- | Boiler<br>η=0.85<br>Natural Gas |
| | | | | | | Façade E<br>69.9 | Façade E<br>208.8 | 0 | SLAB ON GRADE | 1.70 | (6) | | | |
| | 66 | Footprint C-shaped | | 12 | | Façade S<br>348 | Façade S<br>0 | 20 | WALL | 1.17 | (7) | | N/A<br>SEER N/A<br>--- | 0% |
| | | | | | | Façade W<br>69.9 | Façade W<br>208.8 | 0 | WINDOW | 5.70 | (8) | | | |
| 1981-2000 | SFH | Terraced House | 107.2 | 2 | 107.2 | Façade N<br>88.74 | Façade N<br>0 | 30 | ROOF | 0.61 | (9) | 9 | Boiler<br>η=0.85<br>Natural Gas | Boiler<br>η=0.85<br>Natural Gas |
| | | | | | | Façade E<br>40.6 | Façade E<br>0 | 20 | SLAB ON GRADE | 0.85 | (10) | | | |
| | 37 | | | 1 | | Façade S<br>88.74 | Façade S<br>0 | 30 | WALL | 0.60 | (11) | | Air conditioning system<br>SEER 1.6<br>Electricity | 0% |
| | | | | | | Façade W<br>40.6 | Façade W<br>0 | 20 | WINDOW | 3.37 | (12) | | | |
| | MF H | Multi Family House | 200 | 6 | 200 | Façade N<br>330.6 | Façade N<br>0 | 38[5] | ROOF | 0.61 | (9) | 9 | Central Boiler<br>η=0.85<br>Natural Gas | Boiler<br>η=0.85<br>Natural Gas |
| | | | | | | Façade E<br>0 | Façade E<br>183 | 0 | SLAB ON GRADE | 0.85 | (10) | | | |
| | 63 | Footprint I-shaped | | 12 | | Façade S<br>330.6 | Façade S<br>0 | 24 | WALL | 0.60 | (11) | | Individual Air conditioning system<br>SEER 1.6<br>Electricity | 0% |
| | | | | | | Façade W<br>0 | Façade W<br>183 | 0 | WINDOW | 3.37 | (12) | | | |
| 2001-2010 | SFH | Terraced House | 64.5 | 3 | 64.5 | Façade N<br>65.2 | Façade N<br>0 | 15 | ROOF | 0.48 | (13) | 6 | Boiler<br>η=0.95<br>Natural Gas | Boiler<br>η=0.95<br>Natural Gas |
| | | | | | | Façade E<br>0 | Façade E<br>74.8 | 0 | SLAB ON GRADE | 0.71 | (14) | | | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | | | 1 | | Façade S 65.2 | Façade S 0 | 25 | WALL | 0.48 | (15) | | | 30% |
| | | | | | Façade W 0 | Façade W 74.8 | 0 | WINDOW | 3.37 | (12) | | Air conditioning system SEER 1.8 Electricity | |
| MFH | Multi Family House<br><br>Footprint L-shaped | 1009.1 | 7 | 1009.1 | Façade N 447 | Façade N 191.6 | 24 | ROOF | 0.48 | (13) | 6 | Central Boiler η=0.95 Natural Gas | Boiler η=0.95 Natural Gas |
| | | | | | Façade E 447 | Façade E 191.6 | 24 | SLAB ON GRADE | 0.71 | (14) | | | |
| 66 | | | 42 | | Façade S 638.6 | Façade S 0 | 24 | WALL | 0.48 | (15) | | Individual Air conditioning system SEER 1.8 Electricity | 30% |
| | | | | | Façade W 638.6 | Façade W 0 | 24 | WINDOW | 3.37 | (12) | | | |

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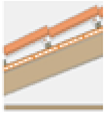
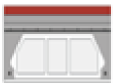
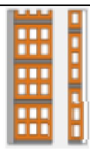
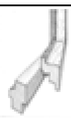
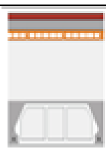
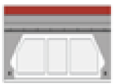
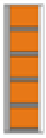
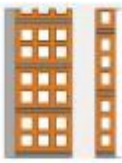
| NUMBER | PICTURE | DESCRIPTION |
|---|---|---|
| (1) |  | Ceramic tile, Ceramic bard board, wooden frame, gypsum plaster, ventilated. |
| (2) |  | Tile of terrazzo, Grip mortar, Forged unidirectional of HA of 200mm of edge |
| (3) |  | Cavity wall, brick, air cavity |
| (4) |  | Metallic carpentry without break of thermal bridge, Folding, Bad adjustment, Without blind |
| (5) |  | Ceramic tile, Grout mortar, Waterproofing, Concrete for slopes, Unidirectional forged from HA, Gypsum plaster |
| (6) |  | Terrazzo tile, grout mortar, unidirectional forged of HA, gypsum plaster |
| (7) |  (1) DEMASIADO  OPTIMISTA!! (2) | (1) 2,94 (W/m2K) Cement plaster, 115mm solid brick, gypsum plaster. (2) 1,33 (W/m2K) Cement Plastering, 115mm Hollow Brick, 30mm Chamber, 40mm Hollow Brick, Gypsum Plaster |
| (8) |  | Metallic carpentry without break of thermal bridge, Folding, Bad adjustment, Without shade |
| (9) |  | Flat roof: unidirectional framework with prestressed joint |

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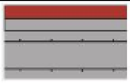
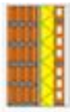
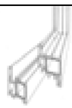
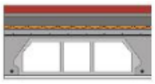
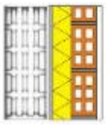
| | | |
|---|---|---|
| (10) |  | Ceramic tile, mortar, SL slab 150 mm edge |
| (11) |  | Cement plastering, Hollow brick of 115 mm, Thermal insulation e = 30 mm, Hollow brick of 40 mm, Gypsum plaster |
| (12) |  | Metallic carpentry with break of thermal bridge, good adjustment, without shade |
| (13) |  | Layer of sand and gravel, Thermal insulation e = 50 mm, Waterproofing, Concrete for slopes, Unidirectional forging of HA of 300mm edge, Gypsum plaster |
| (14) |  | Terrazzo tile, Grout mortar, Reinforced concrete, Mineral wool, Unidirectional forged of 250mm edge, Gypsum plaster |
| (15) |  | White perforated brick of 115mm, Plaster of mortar, Thermal insulation e = 50 mm, Hollow brick of 70mm, Gypsum plaster |

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## Sources

EN UNE 15780/2012 method B

Adaptive Comfort Models Applied to Existing Dwellings in Mediterranean Climate Considering GlobalWarming, Daniel Sánchez-García, Carlos Rubio-Bellido , Jesús A. Pulido-Arcas, Fco. Javier Guevara-García and Jacinto Canivell

IEE Project TABULA (2009 - 2012). "Typology Approach for Building Stock Energy Assessment". Tobias Loga, Nikolaus Diefenbach, Britta Stein, Elena Dascalaki, Constantinos A. Balaras, Marjana Šijanec Zavrl, Andraž Rakušček, Vincenzo Corrado, Ilaria Ballarini, Stefano Corgnati, Hubert Despretz, Michael Hanratty, Charles Roarty, Marlies van Holm, Nele Renders, Malgorzata Popiołek, Maria Amtmann, Zdravko Georgiev, Karin Spets, Tomáš Vimmr, Kim B. Wittchen, Jesper Kragh, Leticia Ortega, Begoña Serrano Lanzarote, Milica Jovanovic Popovic, Dusan Ignjatovic

Use of cadastral data to assess urban scale building energy loss. Application to a deprived quarter in Madrid. Fernando Martín-Consuegra, Fernando de Frutos, Ignacio Oteiza, Hernández Aja Agustín

Instituto Valenciano de la Edificación (IVE). Consejería de Vivienda, Obras Públicas y Vertebración del Territorio. Generalitat Valenciana. http://www.five.es/publicaciones/CataTipoEdifResi/arc/assets/basic-html/index.html#1

Escala de calificación energética para edificios existentes. Instituto para la Diversificación y Ahorro de Energía (IDAE). Ministerio de Industria, Turismo y Comercio, Gobierno de España. Servando Álvarez (Grupo de Termotecnía de AICIA) y José Antonio Tenorio (Unidad de calidad en la Construcción del IETcc) José Manuel Salmerón, Adoración Cerezuela, Rafael Salmerón. http://www.idae.es/uploads/documentos/documentos_11261_EscalaCalifEnerg_EdifExistentes_2011_accesible_c762988d.pdf

(accessed 26/09/2018)

Adaptive Comfort Models Applied to Existing Dwellings in Mediterranean Climate Considering Global Warming. Daniel Sánchez-García, Carlos Rubio-Bellido, Jesús A. Pulido-Arcas, Fco. Javier Guevara-García and Jacinto Canivell

Use of Building Typologies for Energy Performance Assessment of National Building Stock. Valencia Institute of Building. http://episcope.eu/fileadmin/tabula/public/docs/scientific/ES_TABULA_Report_IVE.pdf (accessed 08/10/2018)

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## FRANCE

| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA ($m^2$)/floor | No. FLOORS | FLAT ROOF AREA ($m^2$) | AREA OF OUTDOOR WALLS (m2) | AREA OF PARTY-WALLS ($m^2$) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/$m^2$ K) | | DESCRIPTION | AIR TIGHTNESS (n50[i]) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| <1980 | SFH (1) | Pavillon | 44 | 2 | 12 | Façade N 60 | Façade N 0 | 12,5 | ROOF | 1,35 | (1) | Many leaks | oil heater effort coefficient : 1,81 | Electrical water heater effort coefficient : 4,15 |
| | | | | | | Façade E 44 | Façade E 0 | 0 | SLAB | 2,3 | (2) | | | |
| | 60 | | | 1 | | Façade S 60 | Façade S 0 | 12,5 | WALL | 1,5 or 1,7 | (3) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 44 | Façade W 0 | 0 | WINDOW | 4,8 | (4) | | | |
| | MFH | Multi Family | 198 | 10 | 174 | Façade N 325 | Façade N 0 | 31 | ROOF | 3,2 | (5) | Bad air permab | Gas boiler effort | Gas water heater |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (2) | House | | | | Façade E 325 | Façade E 0 | 31 | SLAB | 2,5 | (6) | ility | coefficient: 1,52 | Effort coefficient :2,27 |
| | 40 | | | 30 | | Façade S 325 | Façade S 0 | 31 | WALL | 3 | (7) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 325 | Façade W 0 | 31 | WINDOW | 2,6 | (8) | | | |
| 1981-2000 | SFH (3) | Pavillon | 97 | 1 | 107 | Façade N 44,24 | Façade N 0 | 17 | ROOF | 0,23 | (9) | Average air permab ility | Wood stove and electrical convectors Effort coefficient :1,92 | Thermodynam ical water heater Effort coefficent: 2,01 |
| | | | | | | Façade E 22,12 | Façade E 0 | 0 | SLAB | 0,42 | (10) | | | |
| | 64 | | | 1 | | Façade S 44,24 | Façade S 0 | 17 | WALL | 0,36 | (11) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 22,12 | Façade W 0 | 0 | WINDOW | 2,6 | (12) | | | |
| | MF H (4) | Multi Family House | 611 | 8 | 654 | Façade N 1093 | Façade N 0 | 33 | ROOF | 0,43 | (13) | Good air permab ility | Gas heater low temperatura Effort coefficent : 1,72 | Instantaneous DHW by individual boiler Effort coefficent : 1,54 |
| | | | | | | Façade E 364 | Façade E | 0 | SLAB | 0,42 | (14) | | | |
| | 36 | | | 69 | | Façade S 1093 | Façade S 0 | 33 | WALL | 0,36 | (15) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 364 | Façade W 0 | 0 | WINDOW | 3,3 | (16) | | | |
| 2000-Presen | SFH (5) | Pavillon | 47,5 | 2 | 57 | Façade N 47 | Façade N 0 | 9 | ROOF | 0,24 | (17) | 1,2 $m^3$ / ($h.m^2$ ) | Heat pump air/water | Heat pump and hot water |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | | | | | | Façade E 47 | Façade E 0 | 9 | SLAB | 0,18 | (18) | | Coefficent effort : 1.1 | tank Effort coefficent : 2,17 |
| | 63 | | | 1 | | Façade S 47 | Façade S 0 | 9 | WALL | 0,34 | (19) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 47 | Façade W 0 | 9 | WINDOW | 1,6 | (20) | | | |
| | MF H (6) | Multi Family House | 777 | 6 | 1301 | Façade N 434 | Façade N 434 | 0 | ROOF | 0,28 | (21) | 0,8 $m^3$ / ($h.m^2$ ) | Gas heater Coefficent effort : 1,55 | Water heater and hot water tank Coefficent effort :2,64 |
| | | | | | | Façade E 868 | Façade E 0 | 46 | SLAB | 0,2 | (22) | | | |
| | 37 | | | 86 | | Façade S 434 | Façade S 434 | 0 | WALL | 0,29 | (23) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 868 | Façade W 0 | 46 | WINDOW | 1,6 | (24) | | | |

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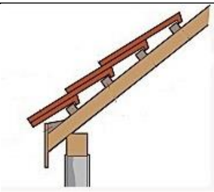
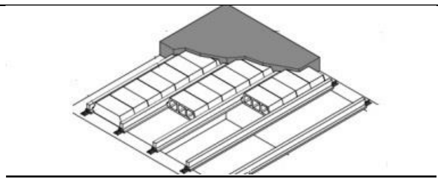
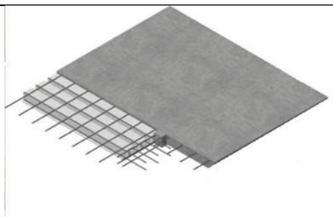
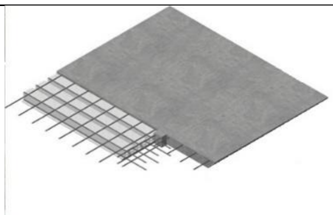
| Number | Picture | Description |
|---|---|---|
| (1) |  | Inclined roof, plaster, 2 cm mineral wool, 2 cm Wood and tiles |
| (2) |  | Steel beams, brick slab |
| (3) |  | Stone and solid bricks |
| (4) |  | Wooden carpentry and single glazing |
| (5) |  | Roof terrace, concrete slab |
| (6) |  | Concrete slab without insulation |

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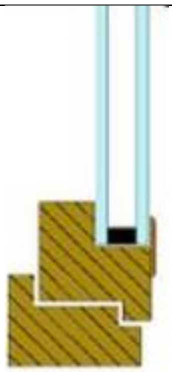
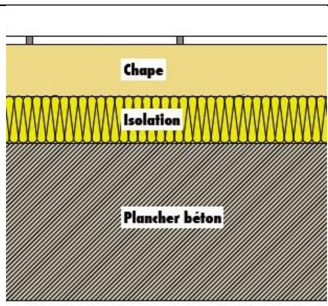
| | | |
|---|---|---|
| (7) |  | Concrete wall |
| (8) |  | Wooden carpentry or PVC with double glazing |
| (9) |  | Wooden floor towards attic, mineral wool 14 cm |
| (10) |  | Concrete slab and 5 cm screed with 7cm of expanded polystyrene (EPS) |
| (11) |  | Concrete with 8 cm of EPS or mineral wool and plaster |

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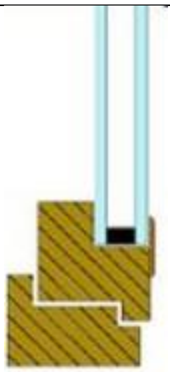
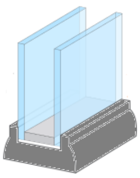
|---|---|---|
| (12) |  | Wooden carpentry or PVC with double glazing |
| (13) |  | 20 cm concrete with 8 cm of EPS or 6 cm of PUR |
| (14) |  | 20 cm concrete with 8cm of insulation ( thermal conductivity of 0,035) |
| (15) |  | Concrete with 8 cm of EPS or mineral wool and plaster |
| (16) |  | Metallic carpentry with double glazing |
| (17) |  | Mineral wool between wood joist 24 cm and plaster |

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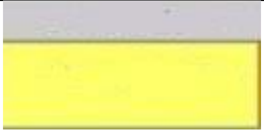
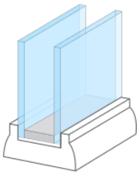
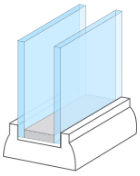
| | | |
|---|---|---|
| (18) |  | Filler insulator and insulation under screed |
| (19) |  | Celular concrete 30 cm |
| (20) |  | Carpentry withdouble glazing, reinforced thermal insulation |
| (21) |  | 20 cm concrete roof terrace with 8 cm of PUR |
| (22) |  | 20 cm concrete slab with 16 cm of mineral wool |
| (23) |  | 18 cm concrete with PSE (12cm) or mineral wool (10cm) |
| (24) |  | Carpentry with double glazing, , reinforced thermal insulation |

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## Sources

Values of a building typology considered representative of the era (representing 9% of the building stock)

Values of a building typology considered representative of the era (representing 4,4% of the building stock)

Values of a building typology considered representative of the era (representing 7,5% of the building stock)

Values of a building typology considered representative of the era (representing 2,8% of the building stock)

Values of a building typology considered representative (representing 5,8% of the building stock)

Values of a building typology considered representative (representing 2,4% of the building stock)

Tabula et Episcope, Bâtiments résidentiels Typologie du parc existant et solutions exemplaires pour la rénovation énergétique en France 2015

Programme d'action pour la qualité de la construction et de la transition énergétique, analyse détaillée du parc résidentiel existant, juillet

Cadre réglementaire de la RT 2005 (thermal regulation standard for buildings between 2005 and 2012.

Notes: All the values are either from an example building or from statistics. The effort coefficient is the ratio between primary energy and the useful energy.

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**SLOVENIA**

| PERIOD | TYPE / % BUILT IN THE PERIOD[iii] | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA (m²) | No. FLOORS / No. Dwellings | FLAT ROOF AREA (m²) | AREA OF OUTDOOR WALLS (m2) | AREA OF PARTY-WALLS (m²) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/m² K) | | DESCRIPTION | AIR TIGHTNESS (n50[ii]) | Heating System. Coefficient of Performance Energy Source / Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | DHW System Coefficient of Performance. Energy Source. / Solar contribution |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <1980 | SFH | Terraced house | 106 | 3 | It is a gable roof 80 | Façade N 51 | 0 | 50 | ROOF | 0,77 | (1) | 6 | Old wood or coal boiler η=0.85 Wood/wooden biomass | Electric heater η=1 Electricity |
| | | | | | | Façade E 0 | 75 | 0 | SLAB | 1,17 | (2) | | | |
| | 94% | | | 1 | | Façade S 51 | 0 | 50 | WALL | 1,5 | (3) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 0 | 75 | 0 | WINDOW | 2,7 | (4) | | | |
| | MFH | Multi Family House | 290 | 4 | 303 | Façade N 333,75 | 0 | 53 | ROOF | 0,77 | (1) | 6 | Gas Boiler η=0.9 Gas | Gas Boiler η=0.9 Gas |
| | | | | | | Façade E 111,25 | 0 | 0 | SLAB | 1,46 | (6) | | | |
| | 6% | Footprint I-shaped | | 7 | | Façade S 333,75 | 0 | 47 | WALL | 1,5 | (5) | | N/A SEER N/A | 0% |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Façade W 111,25 | 0 | 0 | WINDOW | 2,7 | (4) | | --- | |
| 1981-2000 | SFH | Single Unit House | 91 | 2 | It is a gable roof 91,7 | Façade N 44,7 | 0 | 32 | ROOF | 0,3 | (7) | 3 | Central Boiler η=0.95 fuel oil | Central Boiler η=0.95 fuel oil (in combination with heating system) |
| | | | | | | Façade E 29,8 | 0 | 14 | SLAB | 0,75 | (8) | | | |
| | 98% | | | 1 | | Façade S 44,7 | 0 | 39 | WALL | 0,7 | (9) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 29,8 | 0 | 15 | WINDOW | 2,7 | (10) | | | |
| | MFH | Multi Family House Footprint I-shaped | 421 | 6 | 506,5 | Façade N 186,45 | 0 | 5 | ROOF | 1,17 | (11) | 3 | Central Boiler η=0.95 Gas oil | Electric heaters η=1 Electricity |
| | | | | | | Façade E 435 | 0 | 41 | SLAB | 0,75 | (8) | | | |
| | 2% | | | 40 | | Façade S 186,45 | 0 | 12 | WALL | 1,8 | (12) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 435 | 0 | 42 | WINDOW | 2,7 | (10) | | | |
| 2000-Present | SFH | Single Unit House | 142 | 2 | It is a gable roof 69,13 | Façade N 53,08 | 0 | 20 | ROOF | 0,2 | (13) | 2 | Air heat pump η=2.5 Electricity | Air heat pump η=2.5 Electricity |
| | | | | | | Façade E 64,88 | 0 | 21 | SLAB | 0,3 | (14) | | | |
| | 94% | | | 1 | | Façade S 53,08 | 0 | 29 | WALL | 0,38 | (15) | | Individual Air conditioning system EER 3 Electricity | 0% |
| | | | | | | Façade W 64,88 | 0 | 30 | WINDOW | 1,4 | (16) | | | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFH | Multi Family House<br>Footprint I-shaped | 2.249 | 7 | 3483 | Façade N 1821,05 | 0 | 26 | ROOF | 0,2 | (17) | 2 | District heating η=1.0 | District heating η=1.0 |
| | | | | | | Façade E 780,45 | 0 | 17 | SLAB | 0,24 | (18) | | | |
| | 6% | | | 160 | | Façade S 1821,05 | 0 | 30 | WALL | 0,3 | (19) | | Individual Air conditioning system EER 3 Electricity | 0% |
| | | | | | | Façade W 780,45 | 0 | 27 | WINDOW | 1,4 | (16) | | | |

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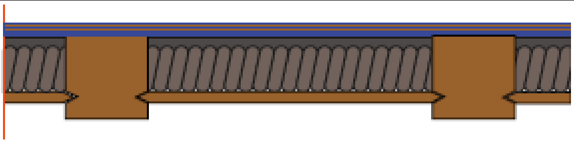
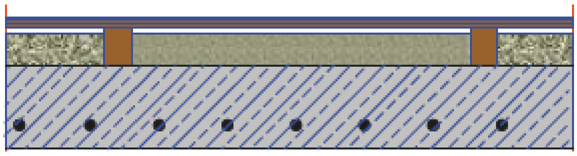
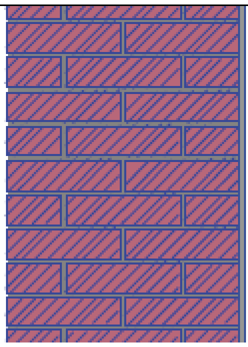
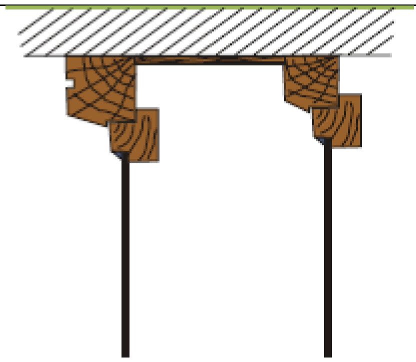
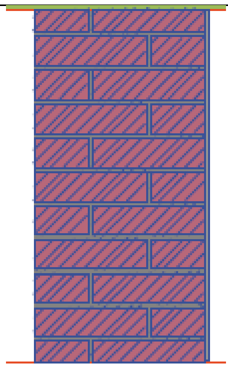
| NUMBER | PICTURE | DESCRIPTION |
|---|---|---|
| (1) |  | Classic wooden roof without insulation |
| (2) |  | Concrete slab on grade with concrete screed, without insulation; wooden finish layer |
| (3) |  | Stone wall without insulation |
| (4) |  | Wooden box window |
| (5) |  | Brick wall with plaster, without insulation |

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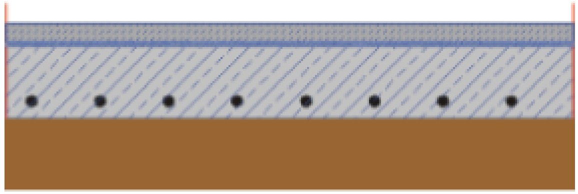
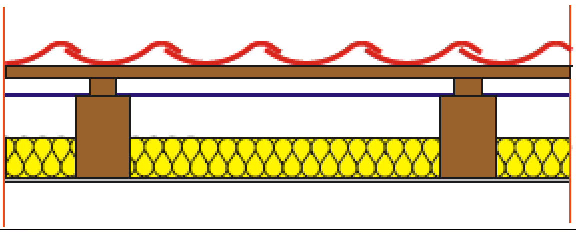
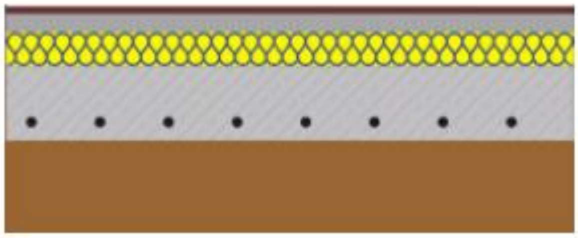
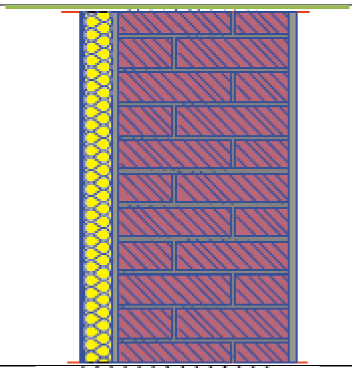
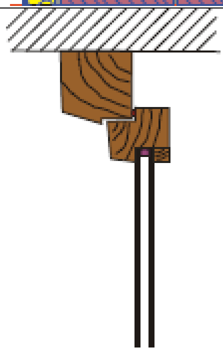
| | | |
|---|---|---|
| (6) |  | Concrete slab 30 cm with concrete screed |
| (7) |  | Wooden structure roof with the thermal insulation between load bearing elements |
| (8) |  | Reinforce concrete slab with 3 cm of thermal insulation |
| (9) |  | Brick wall with 3 cm of thermal insulation |
| (10) |  | Old wooden double glazing windows (air inside the gap) |

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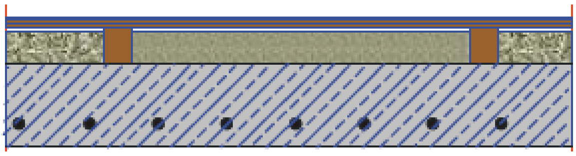
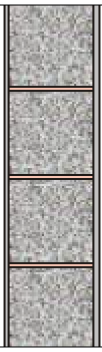
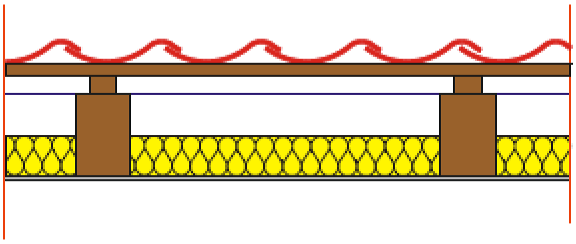
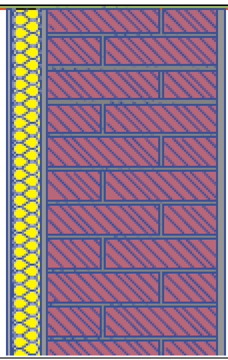
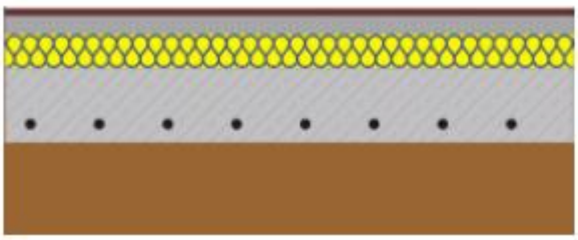
| | | |
|---|---|---|
| (11) |  | Concrete roof with concrete screed, without insulation |
| (12) |  | Concrete blocks with plaster finish, without insulation |
| (13) |  | Wooden roof with 20 cm of thermal insulation between load bearing elements |
| (14) |  | Brick wall with 8 cm of thermal insulation |
| (15) |  | Reinforce concrete slab with 10 cm of thermal insulation |

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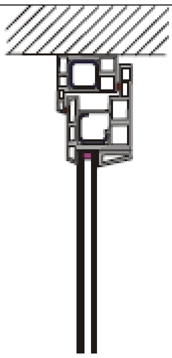
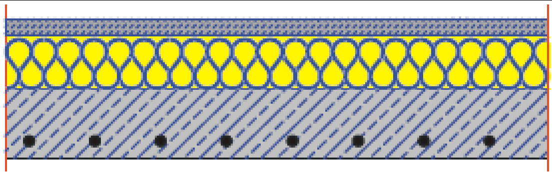
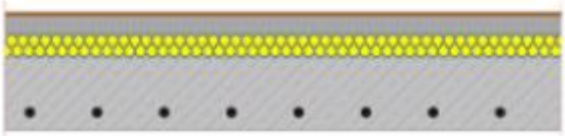
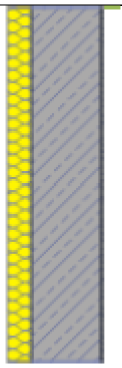
| | | |
|---|---|---|
| (16) |  | PVC double glazing windows |
| (17) |  | Reinforced concrete with 20 cm thermal insulation |
| (18) |  | Reinforced concrete slab with 15 cm thermal insulation |
| (19) |  | Reinforced concrete wall with 12 cm thermal insulation |

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## Sources

IEE Project TABULA (2009 - 2012). "Typology Approach for Building Stock Energy Assessment". Tobias Loga, Nikolaus Diefenbach, Britta Stein, Elena Dascalaki, Constantinos A. Balaras, Marjana Šijanec Zavrl, Andraž Rakuščček, Vincenzo Corrado, Ilaria Ballarini, Stefano Corgnati, Hubert Despretz, Michael Hanratty, Charles Roarty, Marlies van Holm, Nele Renders, Malgorzata Popiołek, Maria Amtmann, Zdravko Georgiev, Karin Spets, Tomáš Vimmr, Kim B. Wittchen, Jesper Kragh, Leticia Ortega, Begoña Serrano Lanzarote, Milica Jovanovic Popovic, Dusan Ignjatovic

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| CROATIA | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA (m²) | No. FLOORS | FLAT ROOF AREA (m²) | AREA OF OUTDOOR WALLS (m2) | AREA OF PARTY-WALLS (m²) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/m² K) | | DESCRIPTION | AIR TIGHTNESS (n50) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| | SFH* | | | 1 | | Façade N 24 | Façade N | 8 | ROOF | 1,12<br>0,29 | 1 | | Electric heaters (3.5 kW) - thermostat control over the reference room | Electric boilers DHW without circulating loop |
| <1970 | | Footprint I | 72,19 | | 72,19 | Façade E 23,98 | Façade E | 12 | SLAB | 1,24 | 2 | 9,66 | | |
| | 50 | | | 1 | | Façade S 24,88 | Façade S | 6 | WALL | 1,96<br>0,45 | 3 | | NA | 0% |
| | | | | | | Façade W 24,52 | Façade W | 7 | WINDOW | 4,65<br>2,38 | 4 | | | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFH** | Terraced house | 1082,20 | 3 | 1082,20 | Façade N 498,96 | Façade N | 23 | ROOF | 1,01 | 5 | | No central heating and cooling system<br><br>Electrical accumulatio n furnaces, el. heaters and inverter split systems (COP 3.27-3.72) | Electric boilers |
| | | | | | | Façade E | Façade E 132,84 | 0 | SLAB | 2,12 | 6 | | | |
| | 50 | | | - | | Façade S 498,96 | Façade S | 31 | WALL | 2,12 | 7 | | inverter split systems (COP 3.27-3.72) Electricity | 0% |
| | | | | | | Façade W | Façade W 132,84 | 0 | WINDOW | 5,20 | 8 | | | |
| *1971-1987 / **1971 -2005 | SFH* | Footprint I | 95,39 | 1 | 95,39 | Façade N 26,56 | Façade N | 9 | ROOF | 1,14 0,36 | 9 | 3,53 | Electric heaters (3.5 kW) - thermostat control over the reference room | Electric boilers DHW without circulating loop |
| | | | | | | Façade E 25,20 | Façade E | 23 | SLAB | 1,24 | 10 | | | |
| | *46 **48 | | | 1 | | Façade S 26,04 | Façade S | 8 | WALL | 2 0,45 | 11 | | NA | 0% |
| | | | | | | Façade W | Façade W | 9 | WINDOW | 2,70 | 12 | | | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 25,67 | | | | 2,38 | | | | |
| | MFH** | Terraced house | 936,00 | 5 | 936,00 | Façade N 296,8 | Façade N | 45 | ROOF | 0,68 | 13 | | No central heating and cooling system<br><br>Electrical accumulation furnaces, el. heaters and inverter split systems (COP 3.27-3.72) | Electric boilers |
| | | | | | | Façade E | Façade E 156,80 | 0 | SLAB | 1,67 | 14 | | | |
| | *54 **52 | | | - | | Façade S 296,80 | Façade S | 35 | WALL | 1,67 | 15 | | inverter split systems (COP 3.27-3.72) Electricity | 0% |
| | | | | | | Façade W | Façade W 156,80 | 0 | WINDOW | 4,28 | 16 | | | |
| *1988-Present/ **2005 - Present | SFH* | - | 95,39 | 1 | 95,39 | Façade N 26,56 | Façade N | 9 | ROOF | 0,88<br>0,33 | 17 | 2,99 | Electric heaters (3kW) - thermostat control over the reference room | Electric boilers DHW without circulating loop |
| | | | | | | Façade E 25,20 | Façade E | 23 | SLAB | 1,24 | 18 | | | |
| | *49 **36 | | | 1 | | Façade S 26,04 | Façade S | 8 | WALL | 1,29<br>0,40 | 19 | | NA | 0% |
| | | | | | | Façade W 25,67 | Façade W | 9 | WINDOW | 2,90 | 20 | | | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 2,38 | | | | |
| | MFH** | Terraced house | 554,04 | 5 | 554,04 | Façade N 174,6 | Façade N | 28 | ROOF | 0,39 | 21 | | Electric heating and cooling, LPG use, low radiant heating systems (floor, wall, ceiling), fan coils, radiators | Electric boilers |
| | | | | | | Façade E | Façade E 109,8 | 0 | SLAB | 0,67 | 22 | | | |
| | *51 **64 | | | - | | Façade S 174,6 | Façade S | 29 | WALL | 0,67 | 23 | | inverter split systems Electricity | 0% |
| | | | | | | Façade W | Façade W 109,8 | 0 | WINDOW | 1,50 | 24 | | | |

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| NUMBER | DESCRIPTION |
|---|---|
| (1) | Ceilings bordering unheated attic are usually made of wood<br>Underneath the attic is a lacquered plank.<br>Beams are coated with plating, plaster<br>At 24,77% the house ceiling construction was subsequently improved with 10cm of mineral wool<br>Roof is wooden; unheated attic is not ventilated |
| (2) | Concrete base on 2cm expanded polystyrene (EPS) on waterproofing and concrete substrate |
| (3) | Stone in an extension mortar, 45 cm external walls, without isolation.<br>At 19,3% of SFH wall was subsequently isolated by 6cm of expanded polystyrene -EPS with thin layer plaster (ETICS facade system) |
| (4) | The original windows of the building period are wooden doors and single glazed windows d = 4 mm in a 6 cm thick wooden coniferous frame.<br>Shutters or roller shades are used for sun protection<br>At 58,61% of the houses wooden windows were replaced with PVC, glazing IZO glass 4+16+4mm in tri chamber window |
| (5) | PRIOR TO 1940<br>Ceilings are mostly wooden or solid, made of brick, stone or concrete elements (ribbed concrete ceiling). ceilings bordering unheated attic are usually made of wood with (plastered board) underside, a layer of rubble and an upper board decking as the attic floor<br>1941-1970<br>For flat roofs: 16 cm concrete slab, 3 cm thermal insulation, cement screed and hydro-insulation |
| (6) | Reinforced concrete<br>Bitumen tape<br>Concrete as base<br>Wood, parquet, tiles |
| (7) | PRIOR TO 1940<br>30 – 60 cm full brick or stone (plastered on both sides)<br>1941-1970<br>20 cm reinforced concrete (1.5 cm plaster layer on the inside) or25 cm reinforced concrete |
| (8) | PRIOR TO 1940<br>Wooden frame, double single-glazed (4 mm) window, two window jambs at a distance of d=30cm, no seal<br>1941-1970<br>Wooden frame, single-glazed (4 mm) window, no seals<br>DOOR – mostly wooden |
| (9) | Ceilings bordering unheated attic – reinforced concrete thickness 12cm on the upper side 2cm EPS<br>At 27,71% of the house ceiling construction was improved by insulation of 10cm mineral wool<br>Wooden roof, unheated ceiling space |
| (10) | Concrete base on 2cm thick polystyrene on waterproofing and concrete substrate |
| (11) | Concrete blocks in the extended mortar<br>25 cm eternal walls without insulation, two-sided plaster<br>25cm internal portable walls, two-sided plaster<br>On 30,42% of houses walls and roofs were subsequently improved by 6cm of thermal insulation (expanded polystyrene -EPS) with layer plaster (ETICS facade systems) |
| (12) | Wooden joinery glazed with double IZO glass 4+6+14mm in a 8cm thick wooden frame<br>Shutters or roller shades are used for sun protection<br>At 62,53% of the houses wooden windows were replaced with PVC, glazing IZO glass 4+16+4mm in tri chamber window |
| (13) | 1971-1980<br>Inclined roof with residential space underneath - Timber joists with 5 cm thermal insulation infill.<br>Flat roof (residential space underneath)- 16 cm concrete slab, 3 cm thermal insulation, cement screed and hydro-insulation |

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| | |
|---|---|
| | 1980-2000<br>Flat roof, waterproofing bitumen tape, concrete slab, gravel |
| (14) | Reinforced concrete<br>Hydro-insulation on the ground floor – bitumen tape<br>Thermal insulation-glass wool, XPS<br>concrete with fibre without reinforcement<br>tiles, parquet |
| (15) | 1971-1980<br>External wall bordering outer space- 25 cm reinforced concrete<br><br>All commercially available materials were used for construction, 25 cm reinforced concrete and full brick dominating,<br>no thermal protection applied |
| (16) | 1971-1980<br>Metal frame with no thermal bridge interruption, double (4/6–8/4) simple glazing, no seal<br>Wood, roller shutters<br>DOOR – mostly wooden |
| (17) | Ceiling structure to unheated attic was made as a FERT ceiling<br>(4 x 16 cm). On the underside it is plastered, with the upper part of the plates expanded polystyrene (EPS) 2 cm.<br>At 40.41%, the house ceiling structure was improved by laying mineral wool (MW) plated with 10 cm thick ceiling glass from the ceiling side of the construction instead of EPS<br>Wooden roof, tile |
| (18) | 2 cm thick polystyrene (EPS) on concrete substrates, waterproofing |
| (19) | Hollow block of brick in the extension mortar<br>External load-bearing walls are 25 thick cm, without insulation, both plastered<br>Inner support walls are also 25 cm, surface processing is a two-sided plaster<br>At 36.30% the houses the walls are later enhanced by thermal insulation (expanded polystyrene - EPS) in thickness of 6 cm thin layer plaster (ETICS façade system). |
| (20) | wooden joinery glazed with double IZO glass 4 + 16 + 4 mm in a wooden frame of ivory 7 cm thick<br>Sun protection is foreseen with grille or roller shutter.<br>At 82,19% houses the windows were replaced by PVC joinery, glazing IZO glass 4 + 16 + 4 mm in tripartite frames |
| (21) | flat roof, insulation: wooden fibres, EPS, XPS |
| (22) | Reinforced concrete<br>Hydro-insulation on the ground floor – bitumen tape<br>Thermal insulation-stone wool, XPS<br>concrete with fibre without reinforcement<br>tiles, parquet |
| (23) | All commercially available materials were used for construction, 25 cm reinforced concrete and full brick dominating<br>2000-2004<br>no thermal protection applied<br>2005-2010<br>thermal protection of<br>buildings (Technical regulation on thermal energy savings and thermal protection in buildings was adopted in 2005. It applies to both new-builds and the reconstruction of existing buildings) |
| (24) | Aluminium, PVC, roller shutters, double glazed frame<br>DOOR - MDF |

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## Sources

Croatia is divided on two climatic zones: continental and coastal. For the purpose of HAPPEN project data concerning reference buildings in coastal Croatia are taken into consideration.

Construction periods have been set according to specific time periods in which the buildings have significantly different properties due to building regulations that were into force at that time. Source: (*)Report according Act 5(2) Directive 2010/31/EU and Act 6 Ordinance (EU) 244/2012 from 16.01.2012.: Minimum Energy Requirements of single family house building for continental and coastal Croatia, for the period up to 1970, 1970 - 1987, after 1987, and almost zero energy buildings and (**)Report according Act 5(2) Directive 2010/31/EU and Act 6 Ordinance (EU) 244/2012 from 16.01.2012.: Minimum Energy Requirements of multifamily house building for continental and coastal Croatia, for the period up to 1970, 1970 - 2005, after 2005, and almost zero energy buildings.

In case of SFH significant number of representative buildings in presented period was renovated, for that reason in column No8 two u- values are indicated: first one represents construction part without insulation, while second value represents construction part with insulation.

Hrvoje Krstić, Željko Koški, Irena Ištoka Otković, Martina Španić: Application of neural networks in predicting airtightness of residential units

National Statistical Report: Census of Population, Households and Dwellings 2011, https://www.dzs.hr/hrv/censuses/census2011/results/censustabsxls.htm . Data calculated according "Nastanjeni stanovi prema godini gradnje, vrsti zgrade I broju kućanstava u stanu, popis 2011."

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| ITALY | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERIOD | TYPE / % BUILT IN THE PERIOD | FOOTPRINT TYPE (O, C, L...) | FOOTPRINT AREA (m²) | No. FLOORS / No. Dwellings | FLAT ROOF AREA (m²) | AREA OF OUTDOOR WALLS (m²) | AREA OF PARTY-WALLS (m²) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/m² K) | | DESCRIPTION | AIR TIGHTNESS (n50) | Heating System. Coefficient of Performance Energy Source / Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | DHW System Coefficient of Performance. Energy Source. / Solar contribution |
| <1980 | SFH | Detached House | 81 (80,9) | 2 | 81 | Façade N 66.8 | Façade N 0 | 0 | ROOF | 2.20 | (1) | 10 | Boiler η=0.82 fuel gas | Boiler η=0.80 fuel gas |
| | | | | | | Façade E 66.8 | Façade E 0 | 8 | SLAB | 2 | (2) | | | |
| | 34 | | | 1 | | Façade S 66.8 | Façade S 0 | 10 | WALL | 1.46[8] | (3) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 66.8 | Façade W 0 | 8 | WINDOW | 4.9 | (4) | | | |
| | MFH | Multi Family House Tower (I) | 540 | 5 | 540 | Façade N 951.3 | Façade N 0 | 0 | ROOF | 1.9 [9] | (1a or 1) | 8 | Central Boiler η=0.71 fuel gas | Boiler η=0.73 fuel gas |
| | | | | | | Façade E 198.4 | Façade E 0 | 40 | SLAB | 1.56 | (5) | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 66 | shaped | | 40 | | Façade S 951.3 | Façade S 0 | 15 | WALL | 1.10 | (6) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 198.4 | Façade W 0 | 40 | WINDOW | 4.9 | (4) | | | |
| 1981-2000 | SFH | Detached House | 106 | 2 | 106 | Façade N 64.8 | Façade N 0 | 0 | ROOF | 0.94 | (7) | 7 | Central Boiler η=0.89 fuel gas | Boiler η=0.80 Fuel gas |
| | | | | | | Façade E 64.8 | Façade E 0 | 11 | SLAB | 0.88 | (8) | | | |
| | 23 | | | 1 | | Façade S 64.8 | Façade S 0 | 14 | WALL | 0.68 | (9) | | N/A | 0% |
| | | | | | | Façade W 64.8 | Façade W 0 | 11 | WINDOW | 2.80 | (10) | | | |
| | MFH | Multi Family House<br><br>Footprint I-shaped | 716 | 6 | 716 | Façade N 1067.3 | Façade N 0 | 0 | ROOF | 1.28 | (11) | 5 | Central Boiler till 1991 and boiler till 2000 η=0.88 fuel gas | Boiler η=0.84 fuel gas |
| | | | | | | Façade E 246.6 | Façade E 0 | 40 | SLAB | 0.88 | (8) | | | |
| | 77 | | | 42 | | Façade S 1067.3 | Façade S 0 | 16 | WALL | 0.68 | (9) | | N/A | 0% |
| | | | | | | Façade W 246.6 | Façade W 0 | 40 | WINDOW | 3.6 | (12) | | | |
| 2000-Present | SFH | Detached House | 96 | 2 | 96 | Façade N 61.7 | Façade N 0 | 0 | ROOF | 0.74 | (13) | 2 | Low temperature Boiler η=0.92 Fuel gas | Low-temperature Boiler η=0.91 Fuel gas |
| | | | | | | Façade E 61.7 | Façade E 0 | 11 | SLAB | 0.33 | (14) | | | |
| | 52 | | | 1 | | Façade S 61.7 | Façade S 0 | 14 | WALL | 0.34 | (15) | | Individual Air | 50% |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Façade W 61.7 | Façade W 0 | 11 | WINDOW | 2.20 | (16) | | conditioning system EER 3.2 Electricity | |
| | MFH 48 | Multi Family House<br><br>Footprint I-shaped | 410 | 2 | 410 | Façade N 482.9 | Façade N 0 | 0 | ROOF | 0.74 | (13) | 2 | Low Temperature Central Boiler η=0.94 Fuel gas | Condensing Boiler η=0.90 Fuel gas |
| | | | | | | Façade E 33.7 | Façade E 0 | 10 | SLAB | 0.33 | (14) | | | |
| | | | | 4 | | Façade S 482.9 | Façade S 0 | 10 | WALL | 0.34 | (15) | | Individual Air conditioning system EER 3.2 Electricity | 50% |
| | | | | | | Façade W 33.7 | Façade W 0 | 10 | WINDOW | 2.20 | (16) | | | |

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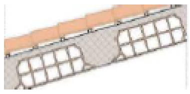
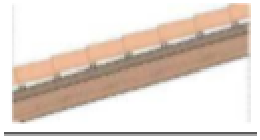
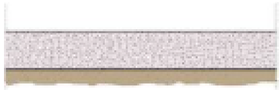
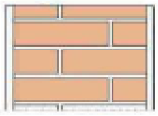
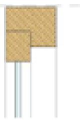
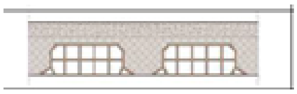
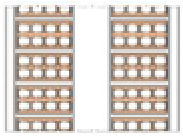
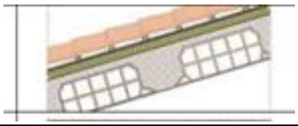
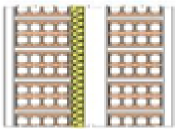
| NUMBER | PICTURE | DESCRIPTION |
|---|---|---|
| (1) |  | Pitched roof with brick - concrete slab |
| (1a) |  | Pitched roof with wood structure and planking |
| (2) |  | concrete floor on soil |
| (3) |  | Solid Brick Masonry |
| (4) |  | single glass, wood frame |
| (5) |  | Floor with reinforced brick- Concrete slab |
| (6) |  | Hollow wall brick masonry |
| (7) |  | Pitched roof with brick- concrete slab low -mid insulation |
| (8) |  | Floor with reinforced brick- Concrete slab with low- mid insulation |
| (9) |  | hollow brick masonry with low-mid insulation |

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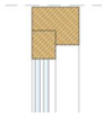
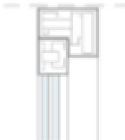
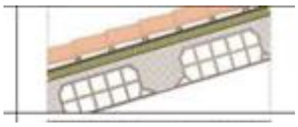
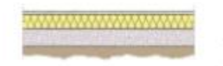
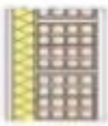
| | | |
|---|---|---|
| (10) |  | Double glass, air filled wood frame |
| (11) |  | Flat roof with reinforced brick - concrete slab with low - mid insulation |
| (12) |  | Double Glass, air filled, metal frame with or without thermal break |
| (13) |  | Pitched roof (roof brick flaps) with concrete slab -mid insulation level |
| (14) |  | Concrete floor on soil, with high insulation |
| (15) |  | Honeycomb brick masonry (High thermal resistance – High Insulation level) |
| (16) |  | Low e –double glass, air gap or other gases filled, wood frame |

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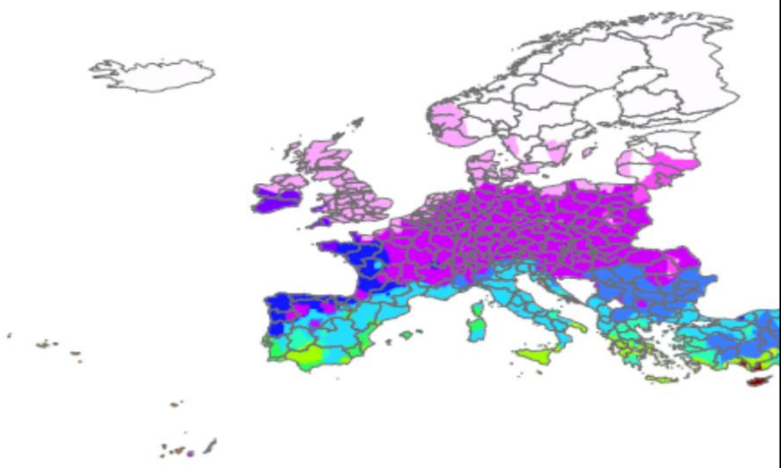
## Motivation of the technical choices

1. On the basis of the reference climate definition carried out by USE (Del. 3.1), the typical data of the W2S2 climatic zone, is taken into account for Italy (Fig.1). In particular, a city which is representative for that climatic zone is Milan and data and results are available for Milan in [1].



| | S0 | S1 | S2 |
|---|---|---|---|
| W0 | W0S0 | W0S1 | W0S2 |
| W1 | W1S0 | W1S1 | Marseille_FR |
| W2 | Nantes_FR | Bilbao_SP | Milano_IT |
| W3 | Cerknica_SL | Maribor_SL | Varazdin_CR |
| W4 | Monte Cimone_IT | W4S1 | W4S2 |

**Figure 1. Reference Climate Definition**

2. As far as the choices of the **Periods** is concerned, three periods are taken into account in order to harmonize the data provided by all the Partners of the Consortium. Differently from other Projects (TABULA), in the HAPPEN Framework the Construction Periods are the same and harmonized for all the MED Countries involved, in order to avoid any lack of data.
3. With regard to the **Type** and to the **Percentage built in the Period** it is important to consider the Fig. 2 and the Fig.3. The data for the number of dwellings in buildings for each construction period were collected in the Tabula Project until 2001. Therefore, the data to characterize the Italian Building Stock in the first two periods (<1980, between 1980 and 2000) are derived from [2], whereas for the third period, the Census (ISTAT) data is considered [3]. There is a remarkable variety among the number of dwellings in the MFH. Therefore, the predominant percentage of the number of dwellings in the buildings is considered. The percentage of the most widespread MFH building construction is reported.
   **Evaluation carried out for:** period 1 (<1980): SFH and MFH (Number of dwellings higher than 16; the reported percentage refers to this kind of MFH);
   Period 2 (between 1981 and 2000): SFH and MFH (Number of dwellings higher than 16, the reported percentage refers to the whole amount of MFH);

Period 3 (>2001): SFH and MFH (Number of dwellings between 3 and 8, the reported percentage refers to the whole amount of MFH). It is not considered the case with 2 dwellings (third column in Fig.3) because *according to our experience*, in almost the cases, buildings with two dwellings belong to the same family cluster.

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## CYPRUS

| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA ($m^2$) | No. FLOORS | FLAT ROOF AREA ($m^2$) | AREA OF EXTERNAL WALLS PER ORIENTATION ($m^2$) | AREA OF PARTY-WALLS PER ORIENTATION ($m^2$) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES ($W/m^2 K$) | | DESCRIPTION | AIR TIGHTNESS (n50) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| <1980 | SFH | Single Semi-detached House | 56 | 2 | 52 | Façade N 51 | Façade N 0 | 17.6 | ROOF | 3.42 | (1) | 12 | Boiler η=0.8 fuel oil | Immersion Heater n=0.85 Electricity[3,6] |
| | | | | | | Façade E 44 | Façade E 0 | 9.7 | SLAB ON GRADE | 1.97 | (2) | | | |
| | 73 | | | 1 | | Façade S 51 | Façade S 0 | 26.5 | WALL | 1.39 | (3) | | N/A SEER N/A | 50% |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Façade W 0 | Façade W 44 | 0 | WINDOW | 6.1 | (4) | | --- | |
| | MF H | Multi Family House<br><br>Footprint U-Shaped[5] | 370 | 3 | 370 | Façade N 365 | Façade N 0 | 16 | ROOF | 3.42 | (2) | 12 | Boiler n=0.9 fuel oil | Immersion Heater n=0.85 Grid Electricity |
| | | | | | | Façade E 275 | Façade E 0 | 24 | SLAB ON GRADE | 1.56 | (5) | | | |
| | 27 | | | 4 | | Façade S 365 | Façade S 0 | 39 | WALL | 1.39 | (3) | | N/A SEER N/A --- | 50% |
| | | | | | | Façade W 275 | Façade W 0 | 26 | WINDOW | 6.1 | (4) | | | |
| 1981-2000 | SFH | Single Detached House | 172 | 2 | 160 | Façade N 83 | Façade N 0 | 32 | ROOF | 3.42 | (1) | 8 | Boiler n=0.8 fuel oil | Boiler n=0.8 fuel oil |
| | | | | | | Façade E 89 | Façade E 0 | 15 | SLAB ON GRADE | 1.97 | (2) | | | |
| | 67 | | | 1 | | Façade S 83 | Façade S 0 | 17 | WALL | 1.39 | (3) | | Reverse Heat Pump SEER 2.6 Grid Electricity | 65% |
| | | | | | | Façade W 89 | Façade W 0 | 22 | WINDOW | 6.1 | (4) | | | |
| | MF H | Multi Family House | 580 | 4 | 490 | Façade N 350 | Façade N 0 | 16 | ROOF | 3.42 | (2) | 8 | Heat Pump 1.9 Grid | Immersion Heater n=0.9 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Footprint U-Shaped | | | | Façade E 580 | Façade E 0 | 24 | SLAB ON GRADE | 1.56 | (5) | | Electricity & Boiler n=0.9 fuel oil | Grid Electricity |
| | 33 | | | 4 | | Façade S 350 | Façade S 0 | 13 | WALL | 1.39 | (3) | | Reverse Heat Pump SEER 3.2 Grid Electricity | 80% |
| | | | | | | Façade W 580 | Façade W 0 | 23 | WINDOW | 6.1 | (4) | | | |
| 2001-2010 | SFH | Single Detached House | 192 | 3 | 136 | Façade N 75 | Façade N 0 | 35 | ROOF | 0.6 | (6) | 6 | Boiler n=0.9 fuel oil | Immersion Heater/ Tankless Heaters n=0.9 Grid Electricity |
| | | | | | | Façade E 97 | Façade E 0 | 18 | SLAB ON GRADE | 0.91 | (5) | | | |
| | 51 | | | 1 | | Façade S 70 | Façade S 0 | 12 | WALL | 0.65 | (7) | | | 90% |
| | | | | | | Façade W 95 | Façade W 0 | 13 | WINDOW | 3.2 | (8) | | Split Unit SEER 3 Electricity | |
| | MF H | Multi Family House Footprint □-Shaped | 740 | 3 | 740 | Façade N 230 | Façade N 0 | 16 | ROOF | 0.6 | (6) | 6 | Central Boiler η=0.9 Fuel oil | Central Boiler η=0.9 Fuel oil |
| | | | | | | Façade E 315 | Façade E 0 | 20 | SLAB ON GRADE | 0.65 | (9) | | | |
| | 49 | | | 9 | | Façade S 230 | Façade S 0 | 26 | WALL | 0.65 | (7) | | Split Units SEER 3.2 Grid Electricity | 90% |
| | | | | | | Façade W 315 | Façade W 0 | 17 | WINDOW | 3.2 | (8) | | | |

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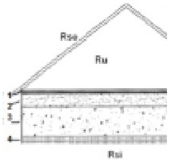
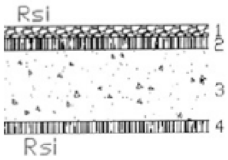
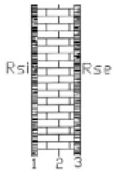
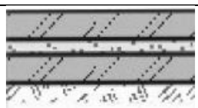
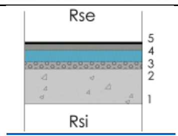
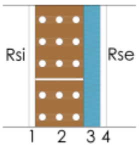
| NUMBER | PICTURE | DESCRIPTION |
| --- | --- | --- |
| (1) |  | Flat roof under non insulated inclined roof |
| (2) |  | Floor of reinforced concrete supernatant closed non-heated basement or semi-basement space |
| (3) |  | External brick wall without insulation |
| (4) |  | Metal door, partially glazed with single pane |
| (5) |  | Floor over unheated space |
| (6) |  | Flat insulated roof |
| (7) |  | Insulated brick wall |
| (8) |  | Double glazed (4mm), air gap (12mm), metal frame |

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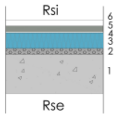
| | | |
|---|---|---|
| (9) |  | Thermally insulated Exposed Floor slab |

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## Sources

*Cyprus Statistical Service, Census 2011*

*Cyprus Land Development Corporation, Statistical data*

http://webtool.building-typology.eu/#bm

Feasibility of NZEB implementation in schools – Split, Croatia

Frederick Unicersity, Υπολογισμός των βέλτιστων από πλευρά κόστους επιπέδων των ελάχιστων απαιτήσεων ενεργειακής απόδοσης κτιρίων σύμφωνα με το άρθρο 5 της Οδηγία 2010/31/ΕΕ για την ενεργειακή απόδοση των κτιρίων

http://episcope.eu/building-typology/country/cy/

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## GREECE

| PERIOD | TYPE | FOOTPRINT TYPE (O, C, L…) | FOOTPRINT AREA (m²) | No. FLOORS | FLAT ROOF AREA (m²) | AREA OF OUTDOOR WALLS (m2) | AREA OF PARTY-WALLS (m²) | AREA OF WINDOWS PER WALL AREA (%) | U-VALUES (W/m² K) | | DESCRIPTION | AIR TIGHTNESS (n50[1]) | Heating System. Coefficient of Performance Energy Source | DHW System Coefficient of Performance. Energy Source. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % BUILT IN THE PERIOD | | | No. Dwellings | | | | | | | | | Cooling System. Seasonal Energy Efficiency Ratio. Energy Source | Solar contribution |
| <1980 | SFH | Single Family House | 130 | 1 | 130 | Façade N 27 | Façade N 0 | 5 | ROOF | 3.05 | (1) | 12 | Boiler η=0.85 fuel oil | Boiler η=0.85 fuel oil |
| | | | | | | Façade E 43.2 | Façade E 0 | 27 | SLAB | 3.1 | (2) | | | |
| | 66 | | | 1 | | Façade S 27 | Façade S 0 | 10 | WALL | 3.05 | (3) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 43.2 | Façade W 0 | 16 | WINDOW | 4.7 | (5) | | | |

1

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MF H | Multi Family House Footprint I-shaped | 322 | 4 | 322 | Façade N 204 | Façade N 204 | 0 | ROOF | 3.05 | (1) | 12 | Central Boiler η=0.85 fuel oil | Boiler η=0.85 fuel oil |
| | | | | | | Façade E 228 | Façade E 0 | 43 | SLAB | 3.1 | (2) | | | |
| | 34 | | | 16 | | Façade S 204 | Façade S 0 | 27 | WALL | 3.4 | (4) | | N/A SEER N/A --- | 0% |
| | | | | | | Façade W 228 | Façade W 228 | 0 | WINDOW | 4.7 | (5) | | | |
| 1981-2000 | SF H | Single Family House | 107.2 | 1 | 107.2 | Façade N 24 | Façade N 0 | 0 | ROOF | 3.05 | (1) | 6 | Boiler η=0.85 fuel oil | Eleectric heaters η=1 Electricity |
| | | | | | | Façade E 40.2 | Façade E 0 | 16 | SLAB | 3.1 | (2) | | | |
| | 60 | | | 1 | | Façade S 24 | Façade S 0 | 14 | WALL | 0.95 | (7) | | Air conditioning system EER 3 Electricity | 30% |
| | | | | | | Façade W 40.2 | Façade W 0 | 12 | WINDOW | 4.1 | (9) | | | |
| | MF H | Multi Family House Footprint I-shaped | 360 | 5 | 360 | Façade N 240 | Façade N 0 | 8 | ROOF | 3.05 | (1) | 6 | Central Boiler η=0.85 fuel oil | Eleectric heaters η=1 Electricity |
| | | | | | | Façade E 337.5 | Façade E 337.5 | 0 | SLAB | 2.75 | (6) | | | |
| | 40 | | | 20 | | Façade S 240 | Façade S 0 | 26 | WALL | 1 | (8) | | Individual Air conditioning system EER 3 Electricity | 30% |
| | | | | | | Façade W 337.5 | Façade W 0 | 35 | WINDOW | 4.1 | (9) | | | |
| 2000-Prese | SF H | Single Family | 80 | 2 | 80 | Façade N 36 | Façade N 0 | 0 | ROOF | 1.05 | (10) | 5 | Boiler η=0.85 | Boiler η=0.85 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nt | | House | | | | Façade E 79.8 | Façade E 0 | 28 | | SLAB | 0.95 | (12) | | Fuel oil | Fuel oil |
| | 55 | | | 1 | | Façade S 36 | Façade S 0 | 11 | | WALL | 0.7 | (13) | | Air conditioning system EER 3 Electricity | 60% |
| | | | | | | Façade W 79.8 | Façade W 0 | 19 | | WINDOW | 2.7 | (14) | | | |
| | MF H | Multi Family House Footprint I-saped | 150 | 4 | 150 | Façade N 108 108 | Façade N 0 0 | 4 4 | | ROOF | 0.95 | (11) | 5 | Central Boiler η=0.85 Fuel oil | Boiler η=0.85 Fuel oil |
| | | | | | | Façade E 200 | Façade E 0 | 27 | | SLAB | 0.8 | (15) | | | |
| | 45 | | | 8 | | Façade S 108 | Façade S 0 | 12 | | WALL | 0.7 | (13) | | Individual Air conditioning system EER 3 Electricity | 60% |
| | | | | | | Façade W 200 | Façade W 0 | 23 | | WINDOW | 2.7 | (14) | | | |

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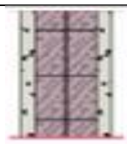
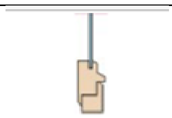
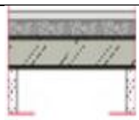
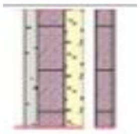
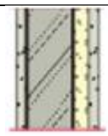
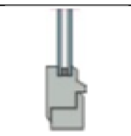
| NUMBER | PICTURE | DESCRIPTION |
|---|---|---|
| (1) |  | conventional flat roof no insulated |
| (2) |  | Slab on grade |
| (3) |  | brickwork 10cm, plastered on both sides |
| (4) |  | load bearing structure, reinforced concrete (thickness<80cm)plastered on both sides |
| (5) |  | single glazed, wooden frame |
| (6) |  | slab over unheated space (pilotis) |
| (7) |  | double brickwork 10cm with slightly ventilated air layer, unplastered on one side, insulation 5 cm |
| (8) |  | load bearing structure, reinforced concrete (thickness<80cm)plastered on both sides, 5cm insulation |
| (9) |  | double glazed (6mm), metal frame |
| (10) |  | tilted reinforced concrete slab with ceramic tiles, 6cm insulation |
| (11) |  | conventional flat roof with 6cm insulated |

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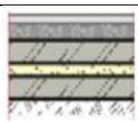
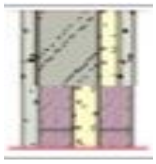
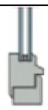
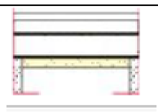
| | | |
|---|---|---|
| (12) |  | slab on grade, 5cm insulation |
| (13) |  | double brickwork 10cm plastered on both sides ,load bearing structure, reinforced concrete (thickness<80cm)plastered on both sides, insulation 5cm or 6cm |
| (14) |  | double glazed (12mm), synthetic frame |
| (15) |  | slab over unheated space with 5cm insulation |

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## ANNEX C

| Thermal Clusters | | | | |
|---|---|---|---|---|
| | ROOFS | SLABS ON GRADE | WALLS | GLAZINGS |
| T1 | F | C | C | J |
| T2 | B | B | B | E |
| T3 | C | E | D | H |
| T4 | A | A | A | D |
| T5 | A | A | A | B |
| T6 | B | C | C | D |
| T7 | A | C | A | C |
| T8 | E | E | C | I |
| T9 | G | D | C | K |
| T10 | G | G | G | H |
| T11 | G | G | B | G |
| T12 | C | B | B | E |
| T13 | C | B | D | D |
| T14 | B | D | D | G |

Where the letters indicate the quality of the thermal properties for the different elements of the building envelope. Next ranges have been used in order to define these letters starting from the U-values provided in the Annex B tables.

| Scale Based on U-values (W/m²K) | | | |
|---|---|---|---|
| ROOFS, SLABS ON GRADE, WALLS | | GLAZINGS | |
| A | 0,01 - 0,49 | A | 0,90 - 1,39 |
| B | 0,50 - 0,99 | B | 1,40 - 1,89 |
| C | 1,00 - 1,49 | C | 1,90 - 2,39 |
| D | 1,50 - 1,99 | D | 2,40 - 2,89 |
| E | 2,00 - 2,49 | E | 2,90 - 3,39 |
| F | 2,50 - 2,99 | F | 3,40 - 3,89 |
| G | 3,00 - 3,49 | G | 3,90 - 4,39 |
| H | 3,50 - 3,99 | H | 4,40 - 4,89 |
| I | 4,00 - 4,49 | I | 4,90 - 5,39 |
| J | 4,50 - 4,99 | J | 5,40 - 5,89 |
| K | 5,00 - 5,49 | K | 5,90 - 6,39 |

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| Construction Clusters | |
|---|---|
| SINGLE FAMILY HOUSES (SFH) | |
| C1 | ≤150 m$^2$ ; ≤2 storey; DETACHED |
| C2 | ≤150 m$^2$; ≤2 storey; SEMIDETACHED |
| C3 | ≤150 m$^2$; 3 TO 6 storey; DETACHED |
| C4 | ≤150 m$^2$; 3 TO 6 storey; SEMIDETACHED |
| C5 | 150-600 ; ≤2 storey; DETACHED |
| MULTI-FAMILY HOUSES (MFH) | |
| C6 | 150-600 m$^2$; C-shaped ; 3 TO 6 storey |
| C7 | 150-600 m$^2$; I-shaped ; 3 TO 6 storey |
| C8 | >1000 m$^2$; l-shaped ; >6 storey |
| C9 | >1000 m$^2$; l-shaped ; 3 TO 6 storey |
| C10 | >1000 m$^2$; L-shaped ; >6 storey |
| C11 | 600-1000 m$^2$; I-shaped ; 3 TO 6 storey |
| C12 | 150-600 m$^2$; I-shaped ; ≤2 storey |
| C13 | ≤150 m$^2$; I-shaped ; 3 TO 6 storey |
| C14 | 150-600 m$^2$; U-shaped ; 3 TO 6 storey |
| C15 | 600-1000 m$^2$; I-shaped ; 3 TO 6 storey |