Typology Approach
for Building Stock
Energy Assessment

TABULA

D6.2

National scientific report on the TABULA activities in Italy

Vincenzo Corrado

Ilaria Ballarini

Stefano Paolo Corgnati

Politecnico di Torino – Dipartimento Energia

Torino, Italy

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1. Introduction

1.1. Objectives of the IEE TABULA Project

The purpose of the IEE TABULA Project comes from the need to assess the energy consumption of national building stocks and, consequently, to predict the impact of energy efficiency measures in order to select effective retrofit strategies on the existing buildings. At the basis of the analysis is the concept of “building typology”.

The “building typology” classification is a concept already used in many European countries at national and/or regional level. However some problems exist, such as lack of a shared definition on building typology, unknown or not updated building typologies, difficulty in understanding the concept of “building typology” that makes this classification not used. Moreover, it is impossible to perform a comparison among the building typologies of the European countries without shared definitions.

The objective of TABULA is the creation of a harmonised structure for European Building Typologies. Each participating country developed on that basis a National Building Typology, that is a set of model buildings (named “building-types”) with characteristic energy related properties. Each building-type represents a certain construction period of the country and a specific building size. The typical buildings have been used in each country as a showcase for demonstrating the energy performance and the energy saving potentials which can be obtained by refurbishing the thermal envelope and the supply system. Two levels of building retrofit have been considered: “standard refurbishment”, applying measures which are commonly used in the country, and “advanced refurbishment”, applying measures which reflect the best available technologies. The demonstration calculations have been performed in each country by using the national EPBD asset rating method and by showing the energy performance before and after the refurbishment. The results have been published by each partner in National “Building Typology Brochures”.

Additional statistical information about the frequencies of construction and system types has made possible the use of the typology as a model for the assessment of the energy performance of the whole national building stock.

The main result of the project is a *webtool* which provides thermal envelope areas, *U*-values, supply system efficiencies and other indicators for typical buildings of each participating country. The published data can be used by experts from all European countries for the assessment of national building stocks, for cross-country comparisons or for scenario calculations (evaluations for energy saving policies, programmes or projects, e.g. in the frame of the Energy Services Directive implementation). Apart from publishing the building data and statistics, the *webtool* serves as a demonstration tool: for each typical building an online-calculation shows the possible energy saving which can be obtained by refurbishment measures of different quality (categories “standard” and “advanced”).

In the long run the national building typologies can be used as data sources for forecasting and evaluating the energy savings and the CO_2 emission reductions for each European country.

1.2. Italian contribution to the IEE TABULA Project

The aim of TABULA Project in Italy has been the improvement of the existing residential building typology and its adaptation to the harmonised approach. The result has been the identification of a methodology that has allowed to define building-types, as reference buildings functional for the assessment of the energy performance of the building stock and the evaluation of the impact of energy conservation scenarios at national or regional or local level.

In particular, the Italian contribution was addressed to:

- the development of the harmonised structure for the Italian typology and the supply of input data on buildings, constructions and systems (heating and DHW), which constitute the main data for the *webtool*;
- the application of the typology concept for the assessment of the energy performance of residential buildings and for the evaluation of the impact of energy conservation measures, through the calculation of the energy performance of the building-types;
- the use of the typology concept to create a model for the estimation of the national energy balance of the residential building stock by the support of national statistical data.

The main outcome of the research at national level is the "Building Typology Brochure", a project deliverable that contains information on the Italian residential building typology, its classification, the definition of building-types, the representation of types of construction elements and systems, the identification of refurbishment measures to be applied to the building envelope and systems. Each building-type is represented through a display sheet showing its construction and system features and the calculated energy performance before and after the application of two levels of refurbishment measures, standard and advanced.

The research can have many impacts at national level. It can be used by consultants for initial energy advice activities to provide house owners a quick overview of the energy performance of a building similar to their own. Moreover the typology can be used as a set of example buildings, e.g. in software comparison studies or for the evaluation of subsidy programmes. The building typology can be an appropriate instrument for housing companies to assess the energy performance of their building portfolio. It offers the possibility to supply a wide range of information for individual reference buildings, to assess their importance by projection to the whole stock or to subsets of the stock, and to quantify the potential of energy savings due to refurbishment actions. In this way it could address energy policy at national or local level.

The research was mostly addressed to the following target groups:

- national and international experts (e.g. scientists, energy managers, energy consultants);
- building designers (architects, building engineers, mechanical engineers);
- constructors;
- public bodies (local and national policy makers);
- local energy agencies;
- real estate holders (public, private).

The key actors of the project have been POLITO researchers and members of the *National Advisory Group* (NAG) which was set up at the beginning of the project. The NAG is a group of national experts in the field of energy and building technology that contributed to the development of the project by means of advices and supply of data. The Italian NAG was identified within the following organizations:

- the Italian Ministry of Economic Development and the Italian Ministry of Environment;
- the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA);
- the local governmental bodies (e.g. Piedmont Region, Province of Torino, City of Torino);
- the main Technical Universities involved in past research projects on energy conservation in buildings;
- the local Orders of Engineers and Architects;
- the local constructors association;
- the local Social Housing Agency;
- the associations of energy auditors;
- the real estate holders.

2. Italian building stock

2.1. Statistical data

The classification of the Italian residential building typology and the identification of building-types have been supported by statistical data about frequency distribution of the residential buildings, number of apartments in buildings by construction period, frequency of building construction and system typologies, most used energy carriers, etc. These information is got from national sources of statistical data, as the National Institute of Statistics (ISTAT, Report 2004 from Census 2001), CRESME (Centre Economical, Social and Market Surveys in the Building Sector, CRESME, Report 2006) and the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA, Energy Report 2008).

The most significant statistical data are reported in graphs considering the following items:

- frequency of buildings (from Figure 1 to Figure 4);
- building construction typologies (Figure 5);
- technical system typologies (Figure 6 and Figure 7);
- refurbishment actions in buildings (Figure 8 and Figure 9);
- energy consumptions and energy carriers (Figure 10).

The statistical data reported in this Section are referred to the national territory, but other data from National Institute of Statistics are available also split by Italian region. At national level the following general information is reported:

- the whole Italian residential building stock consists of 11,226,595 buildings;

- the total amount of apartments is 27,291,993;

- the average floor area of an Italian dwelling is 96 m^2.

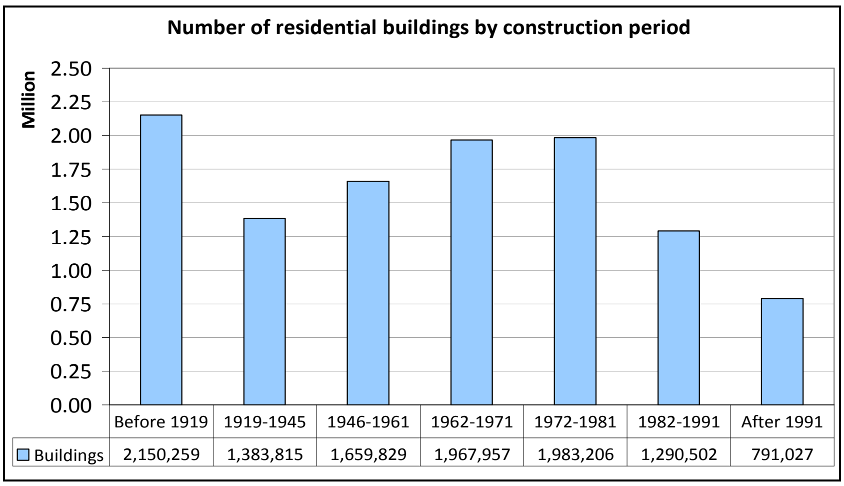


Figure 1. Number of Italian residential buildings by construction period (source: ISTAT, Report 2004).

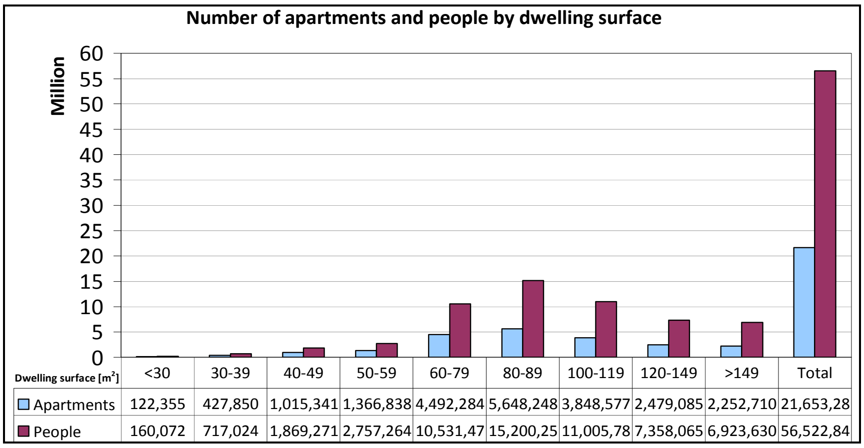


Figure 2. Number of apartments and people in Italy by living surface (source: ISTAT, Report 2004).

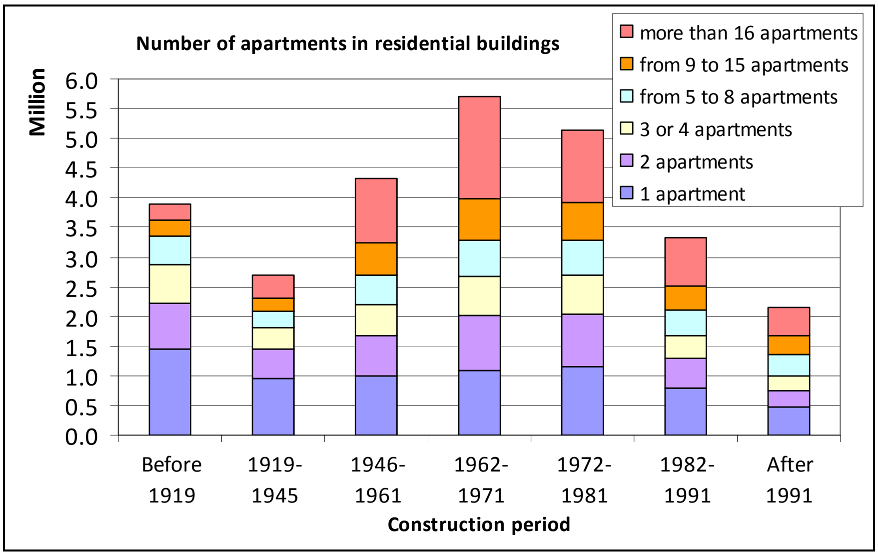


Figure 3. Number of apartments of Italian residential buildings by construction period and number of apartments in the building (source: ISTAT, Report 2004).

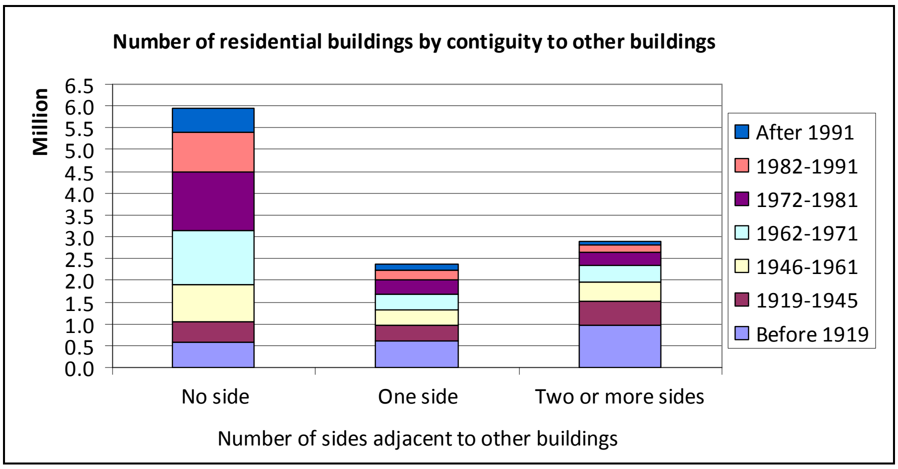


Figure 4. Number of Italian residential buildings by contiguity to other buildings and construction period (source: ISTAT, Report 2004).

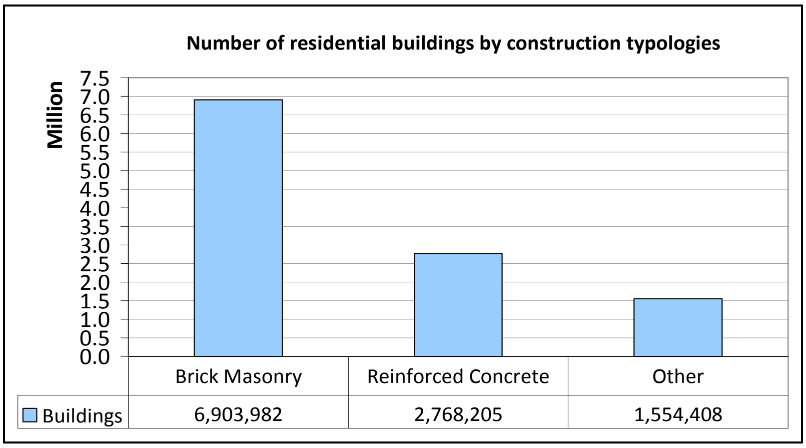


Figure 5. Number of Italian residential buildings by construction typologies (source: ISTAT, Report 2004).

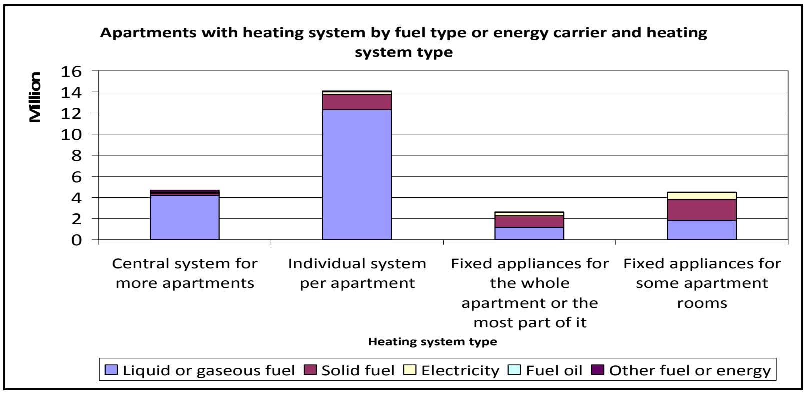


Figure 6. Number of Italian apartments with heating system by fuel type or energy carrier and heating system type (source: ISTAT, Report 2004).

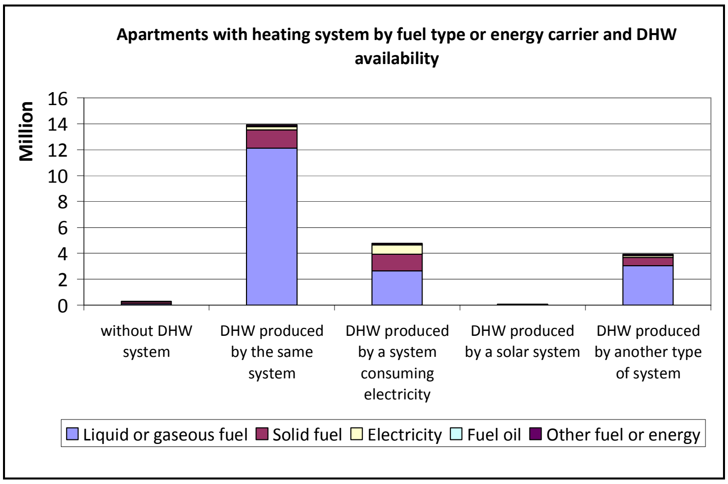


Figure 7. Number of Italian apartments with heating system by fuel type or energy carrier and domestic hot water availability (source: ISTAT, Report 2004).

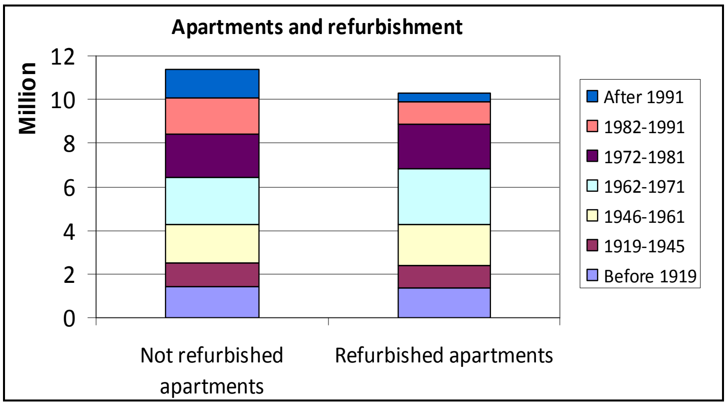


Figure 8. Number of Italian refurbished and not refurbished apartments by construction period (source: ISTAT, Report 2004).

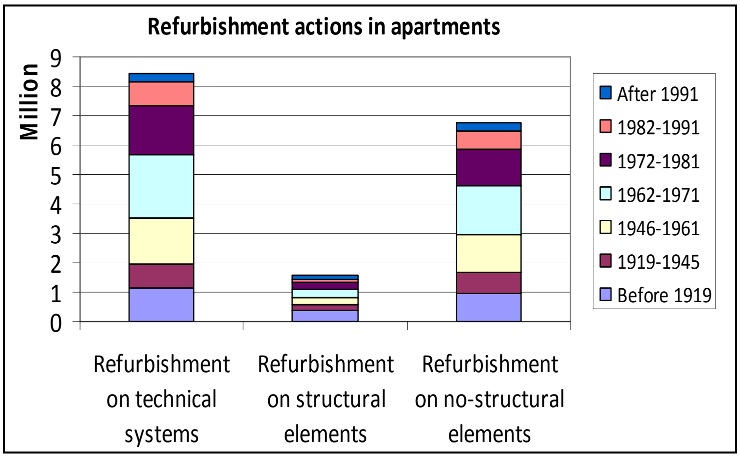


Figure 9. Number of refurbishment actions in Italian apartments by type of refurbishment and construction period (source: ISTAT, Report 2004).

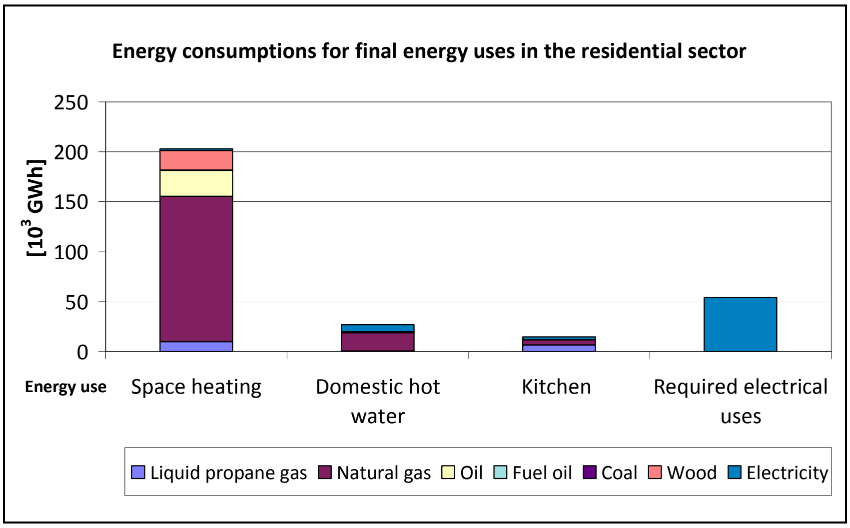


Figure 10. Energy consumptions for final energy uses in the Italian residential sector (source: ENEA, Energy Report 2008).

2.2. Building construction elements

The residential Italian building stock was characterised through the definition of the types of building construction elements and the types of building systems.

The types of Italian building construction elements were identified through the experience (e.g. advices from experts of the sector), with the support of scientific-technical literature, statistical data and technical standards. The building construction elements reported in this Section are the building envelope technologies that are considered typical within a given historical period. The description of each building construction element, the period of its greatest diffusion and its thermo-physical parameter values (i.e. *U*-value for opaque and transparent envelope components, $g_{\mathrm{gl,n}}$-value for transparent envelope components) are shown from Table 1 to Table 6. The following building envelope components were taken into account:

- roofs (Table 1);
- ceilings (Table 2);
- walls (Table 3);
- floors (Table 4);
- doors (Table 5);
- windows (Table 6).

The following specifications are necessary to clarify the criteria of classification of the building construction elements and their thermo-physical parameters:

- the Italian constructions are typically massive structures;
- the traditional materials which constitute the building components are usually bricks (hollow and solid bricks) and concrete;
- the construction period is closely related to the thermal insulation level of the building envelope components. According to the evolution of the national regulations on energy efficiency of buildings, the following assumptions were taken into account:
    - o insulation materials are not used up to 1976. In fact, no regulations on energy savings in buildings are in force before 1976. In this case, the thermal transmittance of the building envelope is only influenced by the component materials and their thickness;
    - o a low insulation level of the building envelope is considered between 1976 and 1991 (e.g. $U_{\mathrm{wall}} \approx 0.8$ W/m^{2}K);
    - o a medium thermal insulation level of the building envelope is considered between 1991 and 2005 (e.g. $U_{\mathrm{wall}} \approx 0.6$ W/m^{2}K), following the enactment of Law no. 10/1991 and its implementing decrees;
    - o the thermal insulation level of the building envelope is determined after 2005 by national regulations (i.e. Legislative Decrees no. 192/2005 and no. 311/2006) and

regional regulations which set maximum values of thermal transmittance (e.g. $U_{wall} \approx 0.34$ W/m^{2}K).

Table 1. Typical roofs in the Italian residential building stock.

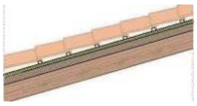
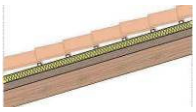
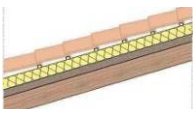
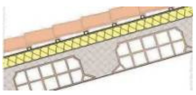
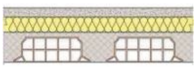
ROOFS				
DESCRIPTION		PERIOD from	PERIOD to	*U* [W/(m^2 K)]
	Pitched roof with wood structure and planking	-	1950	1.80
	Pitched roof with brick-concrete slab	1930	1975	2.20
	Flat roof with reinforced brick-concrete slab	1930	1975	1.85
	Pitched roof with wood structure and planking, low insulation	1976	1990	0.95
	Pitched roof with brick-concrete slab, low insulation	1976	1990	1.14
	Flat roof with reinforced brick-concrete slab, low insulation	1976	1990	1.01
	Pitched roof with wood structure and planking, medium insulation	1991	2005	0.64
	Pitched roof with brick-concrete slab, medium insulation	1991	2005	0.74
	Flat roof with reinforced brick-concrete slab, medium insulation	1991	2005	0.70
	Pitched roof with wood structure and planking, high insulation	2006	-	0.30
	Pitched roof with brick-concrete slab, high insulation	2006	-	0.30
	Flat roof with reinforced brick-concrete slab, high insulation	2006	-	0.30

Table 2. Typical ceilings in the Italian residential building stock.

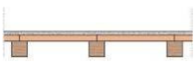
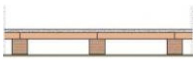
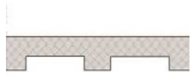
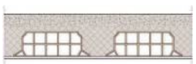
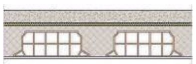
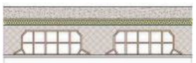
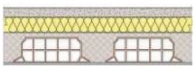
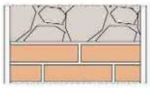
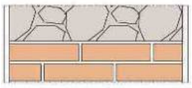
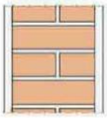
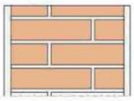
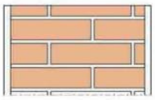
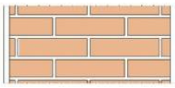
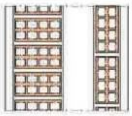
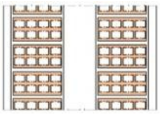
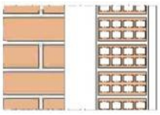
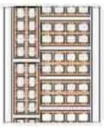
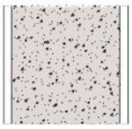
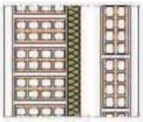
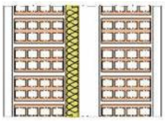
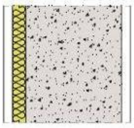
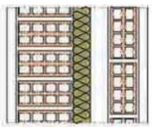
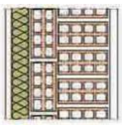
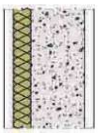
CEILINGS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m^2 K)]
	Vault ceiling with solid bricks	-	1900	2.07
	Ceiling with wood beams and hollow bricks	-	1900	2.86
	Ceiling with wood beams and hollow bricks, bamboo reeds finishing	-	1900	1.96
	Vault ceiling with bricks and steel beams	-	1930	2.60
	Vault ceiling with hollow bricks and steel beams	1910	1940	1.88
	Flat ceiling with hollow bricks and steel beams	1920	1945	2.48
	Ceiling with reinforced concrete	1901	1930	2.66
	Ceiling with reinforced brick-concrete slab	1930	1975	1.65
	Ceiling with reinforced brick-concrete slab, low insulation	1976	1990	0.97
	Ceiling with reinforced brick-concrete slab, medium insulation	1991	2005	0.69
	Ceiling with reinforced brick-concrete slab, high insulation	2006	-	0.30

Table 3. Typical walls in the Italian residential building stock.

WALLS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m^2 K)]
	Stone masonry with plaster on both sides (45 cm)	-	1920	2.40
	Stone masonry with plaster on both sides (60 cm)	-	1920	2.00

WALLS				
DESCRIPTION		PERIOD		U
		from	to	[W/(m^2 K)]
	Masonry with lists of stones and bricks (40 cm)	-	1930	1.61
	Masonry with lists of stones and bricks (60 cm)	-	1930	1.19
	Solid brick masonry (25 cm)	1900	1950	2.01
	Solid brick masonry (38 cm)	1900	1950	1.48
	Solid brick masonry (50 cm)	1900	1950	1.14
	Solid brick masonry (62 cm)	1900	1950	1.02
	Hollow wall brick masonry (30 cm)	1930	1975	1.15
	Hollow wall brick masonry (40 cm)	1930	1975	1.10
	Hollow wall brick masonry with solid and hollow bricks (40 cm)	1930	1975	1.26
	Hollow brick masonry (25 cm)	1950	1975	1.76
	Hollow brick masonry (40 cm)	1950	1975	1.26
	Concrete masonry (18 cm)	1955	1975	3.40

WALLS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m² K)]
	Concrete masonry (30 cm)	1955	1975	2.80
	Hollow wall brick masonry (30 cm), low insulation	1976	1990	0.78
	Hollow wall brick masonry (40 cm), low insulation	1976	1990	0.76
	Hollow brick masonry (25 cm), low insulation	1976	1990	0.80
	Hollow brick masonry (40 cm), low insulation	1976	1990	0.76
	Concrete masonry (also prefabricated, 18 cm), low insulation	1976	1990	0.82
	Concrete masonry (also prefabricated, 30 cm), low insulation	1976	1990	0.79
	Hollow wall brick masonry (30 and more), medium insulation	1991	2005	0.59
	Hollow brick masonry (25 cm), medium insulation	1991	2005	0.61
	Hollow brick masonry (40 cm), medium insulation	1991	2005	0.59
	Concrete masonry (also prefabricated, 18-20 cm), medium insulation	1991	2005	0.62

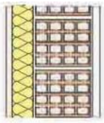
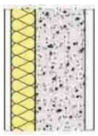
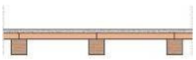
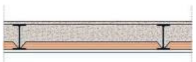
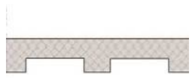
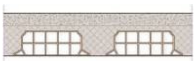
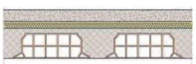
WALLS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m^2 K)]
	Concrete masonry (also prefabricated, 30 cm), medium insulation	1991	2005	0.60
	Honeycomb bricks masonry (high thermal resistance), high insulation	2006	-	0.34
	Concrete masonry (also prefabricated), high insulation	2006	-	0.34

Table 4. Typical floors in the Italian residential building stock.

FLOORS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m^2 K)]
	Vault floor with solid bricks	-	1900	1.58
	Floor with wood beams and hollow bricks	-	1900	2.04
	Vault floor with bricks and steel beams	-	1930	1.87
	Concrete floor on soil	-	1975	2.00
	Vault ceiling with hollow bricks and steel beams	1910	1940	1.47
	Floor with hollow bricks and steel beams	1920	1945	1.81
	Floor with reinforced concrete	1901	1930	1.95
	Floor with reinforced brick-concrete slab	1930	1975	1.30
	Floor with reinforced brick-concrete slab, low insulation	1976	1990	0.98
	Concrete floor on soil, low insulation	1976	1990	1.24
	Floor with reinforced brick-concrete slab, medium insulation	1991	2005	0.77
	Concrete floor on soil, medium insulation	1991	2005	0.93

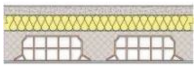
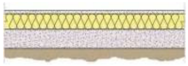
FLOORS				
DESCRIPTION		PERIOD		*U*
		from	to	[W/(m^2 K)]
	Floor with reinforced brick-concrete slab, high insulation	2006	-	0.33
	Concrete floor on soil, high insulation	2006	-	0.33

Table 5. Typical doors in the Italian residential building stock.

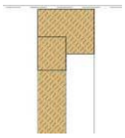
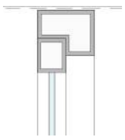
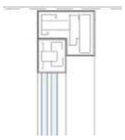
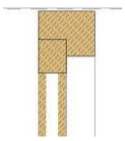
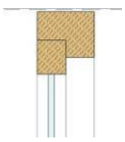
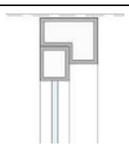
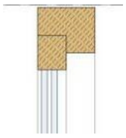
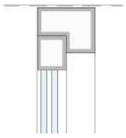
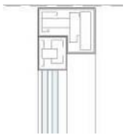
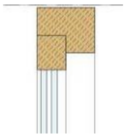
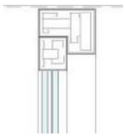
DOORS					
DESCRIPTION		PERIOD		*U*	$g_{gl,n}$
		from	to	[W/(m^2 K)]	[-]
	Wooden door	-	1980	3.0	-
	Glass and metal door	-	1980	5.7	0.85
	Glass and metal door (thermally improved)	1980	2005	3.8	0.75
	Double panel wooden door	1980	-	1.7	-

Table 6. Typical windows in the Italian residential building stock.

WINDOWS					
DESCRIPTION		PERIOD		*U*	$g_{gl,n}$
		from	to	[W/(m^2 K)]	[-]
	Single glass, wood frame	-	1975	4.9	0.85
	Single glass, metal frame without thermal break	-	1975	5.7	0.85

WINDOWS					
DESCRIPTION		PERIOD		*U*	$g_{gl,n}$
		from	to	[W/(m^2 K)]	[-]
	Double glass, air filled, wood frame	1976	2005	2.8	0.75
	Double glass, air filled, metal frame without thermal break	1976	2005	3.7	0.75
	Double glass, air filled, metal frame with thermal break	1991	2005	3.4	0.75
	Low-e double glass, air or other gas filled, wood frame	2000	-	2.2	0.67
	Low-e double glass, air or other gas filled, metal frame with thermal break	2000	-	2.4	0.67

The building construction elements were put in the “Excel Workbook” (see Figure 11). They constitute the datasets for the building-types whose definition is explained later in Section 3. The “Excel Workbook” is the appointed tool to perform the energy performance calculation of the building-types according to the common methodology adopted at European level (see Section 5). The “Excel Workbook” also represents the data source for the *webtool.*

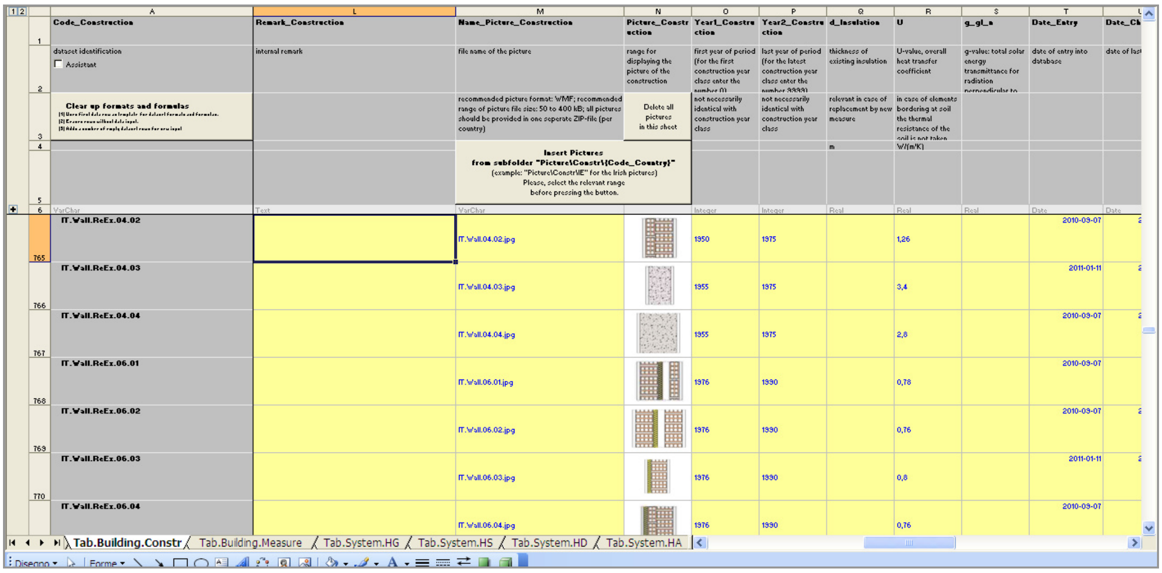


Figure 11. “Excel Workbook” filled with building construction data.

2.3. Building systems

The types of Italian technical systems installed in residential buildings were identified through the experience, with the support of scientific-technical literature, statistical data and technical standards. The analysed building systems include the space heating and domestic hot water systems that are considered typical of a given historical period.

The system typology is defined through the combination of the subsystem types, among which heat generation, heat storage, heat distribution, heat emission and electrical auxiliary subsystems. The description of each subsystem, the period of its greatest diffusion (construction/installation) and the average value of its performance parameter (i.e. efficiency, thermal loss, etc.) are supplied in this Section.

Each subsystem type can be separately referred to a specific size of the building ("SUH" or "MUH") or to all the building sizes ("Gen"). The acronym "SUH" is for "Single-Unit Housing", "MUH" is for "Multi-Unit Housing" and "Gen" is for "Generic".

2.3.1. Space heating system

Space heating system - heat generation subsystem

The types of heat generation subsystem of the space heating system are reported in Table 7. They were classified according to:

- the application field (i.e. building category, as "MUH", "SUH" or "Gen");
- the heating system type (centralised or individual) for the "MUH" building category;
- the heat generator type and its installation period;
- the space in which the heat generator is installed (i.e. in conditioned space, in unconditioned space, in thermal plant);
- the used energy carrier.

The performance indicator of the heat generator types is the *expenditure coefficient*, defined as the delivered energy (based on gross calorific value) divided by the produced heat (annual values). The expenditure coefficient was obtained through the conversion of the efficiency value of the heat generators supplied by national technical standards. The efficiency value was derived from Technical Specification UNI/TS 11300-2 for gas and oil heat generators and from Technical Specification UNI/TS 11300-4 for biomass heat generators. The expenditure coefficient for the district heating substation was calculated considering the heat losses of the substation that were determined according to the calculation procedure reported in UNI/TS 11300-4. The expenditure coefficient for the heat pumps was determined from the standard seasonal value of the coefficient of performance (*COP*).

Table 7. Types of heat generator for space heating in the Italian residential building stock.

SPACE HEATING SYSTEM - HEAT GENERATOR TYPES						
BUILDING SIZE	DESCRIPTION			PERIOD		EXPENDITURE COEFFICIENT (based on gross calorific value)
	Energy carrier	Heat Generator type	Specifications	from	to	
SUH	gas	non-condensing boiler, atmospheric burner	in unconditioned space, chimney < 10 m	-	1995	1.53
				1996	-	1.41
			in conditioned space, chimney < 10 m	-	1995	1.36
				1996	-	1.27
MUH	gas	non-condensing boiler, atmospheric burner	in unconditioned space, chimney > 10 m	-	1995	1.57
				1996	-	1.45
			in conditioned space, chimney > 10 m	-	1995	1.39
				1996	-	1.29
Gen	gas	non-condensing boiler, forced draft burner	in thermal plant	-	1995	1.31
				1996	-	1.25
	oil			-	1995	1.23
				1996	-	1.18
MUH	gas	non-condensing boiler for individual heating systems (per apartment)	in unconditioned space	-	-	1.27
			in conditioned space	-	-	1.21
Gen	wood	stove for solid fuels	-	-	1977	2.50
				1978	1994	2.08
				1995	-	1.79
Gen	pellet	boiler for combustion of wood-pellets	in unconditioned space	-	-	1.44
			in conditioned space	-	-	1.40
Gen	gas	condensing boiler	in thermal plant	1990	-	1.14
MUH	-	district heating transfer station - high efficiency of the substation	-	-	-	1.09
Gen	solar energy	thermal solar plant	-	2005	-	0
Gen	electricity	ground source heat pump (or geothermal heat pump)	-	2005	-	0.33
Gen	electricity	air source heat pump	-	2005	-	0.40

Space heating system - heat storage subsystem

The types of heat storage subsystem of the space heating system are reported in Table 8.

They were classified according to:

- the application field (i.e. building category, as “MUH”, “SUH” or “Gen”);
- the heating system type (centralised or individual) for the “MUH” building category;
- the thermal insulation level of the storage tank (low, medium, high).

The calculation of the heat losses of the heat storage types was performed according to national technical specification UNI/TS 11300-2. It was supposed that they are installed in thermal plant or unconditioned space. For each type of heat storage subsystem, the value of heat losses is a reference average value obtained considering the following input data:

- the storage volume can vary from 60 to 200 litres per dwelling;
- the average temperature difference between the hot water in the storage and in the space in which the storage is installed varies from 40 °C (for low temperature plants) to 70 °C (for high temperature plants);
- the thickness of the thermal insulation material around the tank varies from 2 cm (low insulation level) to 6 cm (high insulation level);
- the thermal conductivity of the insulation material was fixed at 0.04 W/(m K).

As the national standards don’t supply a reference period of the thermal insulation level of the tank, the following classification is supposed according to experience:

- low insulation level, up to 1975;
- medium insulation level, from 1976 to 2005;
- high insulation level, after 2005.

The heat losses of the storage types were normalised on the useful floor area of reference buildings belonging to “SUH” and “MUH” categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 8. Types of heat storage for space heating in the Italian residential building stock.

SPACE HEATING SYSTEM - HEAT STORAGE TYPES					
BUILDING SIZE	DESCRIPTION		PERIOD		TYPICAL HEAT LOSS [kWh/m^{2}y]
	Heat Storage type	Specifications	from	to	
MUH	hot water storage (tank) for central heating system	low insulation	N/A	N/A	4.4
		medium insulation	N/A	N/A	2.2
		high insulation	N/A	N/A	0.8
MUH	hot water storage (tank) for individual heating system (per apartment)	low insulation	N/A	N/A	6.6
		medium insulation	N/A	N/A	3.3
		high insulation	N/A	N/A	1.3

SPACE HEATING SYSTEM - HEAT STORAGE TYPES					
BUILDING SIZE	DESCRIPTION		PERIOD		TYPICAL HEAT LOSS [kWh/m^{2}y]
	Heat Storage type	Specifications	from	to	
SUH	hot water storage (tank)	low insulation	N/A	N/A	7.5
		medium insulation	N/A	N/A	3.8
		high insulation	N/A	N/A	1.4

Space heating system - heat distribution subsystem

The types of heat emission subsystems of the space heating system are not classified in TABULA, therefore the thermal losses of the emission subsystem were included in the thermal losses of the distribution subsystem. Reference emission subsystems were taken into account and their efficiency were derived from the national technical specification UNI/TS 11300-2. The following assumptions were considered:

- traditional radiators installed in no-insulated partially external wall and mean annual thermal load between 4 and 10 W/m^3 (up to 1975);
- traditional radiators installed in insulated partially external wall and mean annual thermal load between 4 and 10 W/m^3 (1976-1990);
- radiant panels and mean annual thermal load between 4 and 10 W/m^3 (1991-2005);
- radiant panels and mean annual thermal load below 4 W/m^3 (after 2005).

The types of heat distribution subsystem are reported in Table 9. The heat losses were calculated considering the efficiency values of the heat distribution subsystem supplied by Italian technical specification UNI/TS 11300-2. The efficiency values are classified in the technical specification considering the following influencing parameters:

- the application field (i.e. building category, as “MUH” or “SUH”);
- the heating system type (centralised or individual) for the “MUH” building category;
- the length of pipes, depending on the average number of floors;
- the position of pipes (in heated rooms or partially in unheated rooms);
- the distribution type (horizontal or vertical with horizontal strings);
- the insulation level of pipes (correlated to the construction period).

The heat losses were normalised on the useful floor area of reference buildings belonging to “SUH” and “MUH” categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 9. Types of heat distribution for space heating in the Italian residential building stock.

SPACE HEATING SYSTEM - HEAT DISTRIBUTION TYPES				
BUILDING SIZE	DESCRIPTION	PERIOD from	PERIOD to	TYPICAL HEAT LOSS (including emission) [kWh/m^{2}y]
MUH	central distribution, horizontal strings in unheated rooms (e.g. cellar or soil)	-	1960	35.1
		1961	1976	29.0
		1977	1993	14.3
		1994	2005	9.9
		2005	-	3.2
MUH	separate pipeline per apartment	-	1960	22.4
		1961	1976	19.0
		1977	1993	8.6
		1994	2005	5.3
		2005	-	1.8
SUH	central distribution, horizontal strings in heated rooms	-	1960	32.1
		1961	1976	30.0
		1977	1993	11.9
		1994	2005	7.0
		2005	-	2.8
SUH	central distribution, horizontal strings in unheated rooms (e.g. cellar or soil)	-	1960	53.1
		1961	1976	46.7
		1977	1993	20.5
		1994	2005	13.7
		2005	-	5.2

Space heating system – auxiliary system

The types of auxiliary system of space heating system are listed in Table 10. They were classified according to:

- the application field (i.e. building category, as “MUH”, “SUH” or “Gen”);
- presence or absence of a circulation pump;
- the type of heat generator that determines the type of the installed auxiliary (electrical power).

The typical auxiliary energy demand (mean annual value) was calculated according to the procedure of UNI/TS 11300-2. The values reported in Table 10 are average reference values determined considering the following assumptions and simplifications:

- the water flow rate in pipes varies from 850 to 1600 l/h for the "SUH" building category and from 5000 to 10000 l/h for the "MUH" building category;
- the prevalence of the pump varies as function of the number of building floors. An average reference value was identified for each of the building categories, "SUH" and "MUH". This value was determined considering the variability of the pressure losses consequent to the use (variability of a reference value of water velocity inside the pipes);
- the electrical power of the auxiliaries of the heat generators was determined as function of the type and the heat power of the generator (linked to the building size category);
- the seasonal mean load of the heat generator was fixed at 0.7.

A reference construction period is not shown in Table 10 for all the considered auxiliary types. This period generally follows that of the relative subsystem type (distribution, generation) to which the auxiliary is referred.

The energy demand was normalised on the useful floor area of the reference buildings belonging to "SUH" and "MUH" categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 10. Types of auxiliary system for space heating in the Italian residential building stock.

SPACE HEATING SYSTEM – AUXILIARY SYSTEM TYPES				
BUILDING SIZE	DESCRIPTION	PERIOD		TYPICAL AUXILIARY ENERGY DEMAND [kWh/m²y]
		from	to	
MUH	pump for central heating - non-condensing boiler with atmospheric burner (auxiliary)	-	-	1.7
MUH	pump for central heating - boiler with forced draft burner (auxiliary)	-	-	2.6
MUH	pump for central heating - condensing boiler (auxiliary)	1990	-	2.6
MUH	pump for central heating	-	-	1.6
MUH	non-condensing boiler (auxiliary) for individual heating system (per apartment)	-	-	1.6
MUH	condensing boiler (auxiliary) for individual heating system (per apartment)	1990	-	4.9
SUH	pump for central heating - non-condensing boiler with atmospheric burner (auxiliary)	-	-	3.7
SUH	pump for central heating - boiler with forced draft burner (auxiliary)	-	-	4.4
SUH	pump for central heating - condensing boiler (auxiliary)	1990	-	4.4
SUH	pump for central heating	-	-	2.7

Space heating system – combination of subsystems

Different typologies of space heating system were identified through the combination of types of subsystem. The typical space heating systems are listed from Table 11 to Table 13 for "MUH" building category and from Table 14 to Table 17 for "SUH" building category (each row of the table represents a heating system).

The following specifications were taken into account for the combination of subsystem types:

- the heat generation subsystem type and the heat distribution subsystem type are associated to each other consistently according to the same reference installation period (e.g. if a heat generator is installed after 1996, the heat distribution subsystem type is that belonging to the reference period after 1994);
- the heat storage is considered, as an exemplification, only for the heating systems with the following heat generators:
    - gas and oil non-condensing boilers with forced draft burner ("MUH");
    - wood-pellets boilers, heat pumps and thermal solar plants ("MUH" and "SUH");
- the auxiliary system type is considered within the heating system according to the relative subsystem types (distribution, generation) to which the auxiliary is referred (see also Table 10);
- if the thermal solar plant is present, the percentage of energy need covered by renewable energy is supposed 20% on average;
- for "SUH" heating systems, if the heat generator is installed in unconditioned space or in thermal plant, the distribution subsystem type is "horizontal strings in unheated rooms (e.g. cellar or soil)", while if the heat generator is installed in conditioned space, the distribution subsystem type is "horizontal strings in heated rooms", with reference to Table 9;
- the terminology "pipes outside" and "pipes inside" from Table 15 to Table 17 means respectively "horizontal strings in unheated rooms (e.g. cellar or soil)" and "horizontal strings in heated rooms", with reference to Table 9.

Since less than 1% of the Italian residential buildings are equipped with mechanical ventilation system, this type of heating system was not taken into account.

Table 11. Types of “MUH” Italian heating system determined by the combination of types of subsystem.

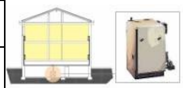
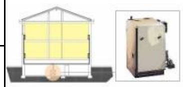
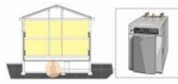
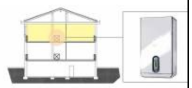
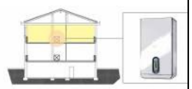
MUH – Heating Systems (1/3)												
Heating System type		***Heat Generator type***					***Heat Distribution type***					***PICTURE***
Central	Decentral (per apartment)	gas non-condensing boiler: atmospheric burner in uncond. Space	gas non-condensing boiler: forced draft burner in thermal plant	gas non-condensing boiler: in uncond. space	gas non-condensing boiler: in cond. space	oil non-condensing boiler: forced draft burner in thermal plant	not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
x		x					x					
x		x						x				
x		x							x			
x		x								x		
x			x				x					
x			x					x				
x			x						x			
x			x							x		
x						x	x					
x						x		x				
x						x			x			
x						x				x		
	x			x			x					
	x			x				x				
	x			x					x			
	x			x						x		
	x				x		x					
	x				x			x				
	x				x				x			
	x				x					x		

Table 12. Types of "MUH" Italian heating system determined by the combination of types of subsystem.

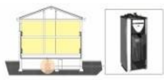
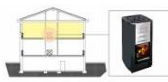
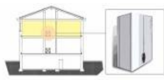
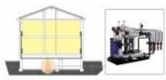
MUH – Heating Systems (2/3)											
Heating System type		***Heat Generator type***				***Heat Distribution type***					***PICTURE***
Central	Decentral (per apartment)	stove for solid fuels	boiler for wood-pellets (uncond. space)	gas condensing boiler	district heating	not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
x			x			x					
x			x				x				
x			x					x			
x			x						x		
	x	x				x					
	x	x					x				
	x	x						x			
	x	x							x		
	x			x						x	
x					x					x	

Table 13. Types of “MUH” Italian heating system determined by the combination of types of subsystem.

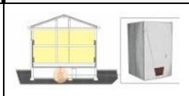
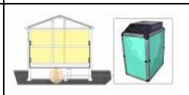
MUH – Heating Systems (3/3)											
Heating System type		***Heat Generator type***				***Heat Distribution type***					***PICTURE***
Central	Decentral (per apartment)	thermal solar plant	ground source heat pump	gas condensing boiler	air source heat pump	not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
x				x						x	
x			x							x	
x					x					x	
x		x		x						x	
x		x	x							x	
x		x			x					x	

Table 14. Types of "SUH" Italian heating system determined by the combination of types of subsystem.

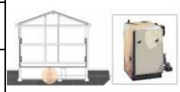
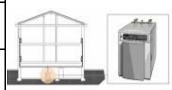
SUH – Heating systems (1/4)									
Heat Generator type				***Heat Distribution type***					***PICTURE***
gas non-condensing boiler			oil non-condensing boiler	not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
atmospheric burner		forced draft burner	forced draft burner						
uncond. space	cond. space	in thermal plant	in thermal plant						
x				x					
x					x				
x						x			
x							x		
	x			x					
	x				x				
	x					x			
	x						x		
		x		x					
		x			x				
		x				x			
		x					x		
			x	x					
			x		x				
			x			x			
			x				x		

Table 15. Types of “SUH” Italian heating system determined by the combination of types of subsystem.

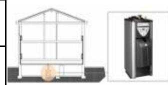
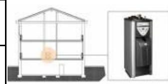
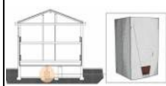
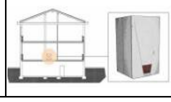
SUH – Heating systems (2/4)										
Heat Generator type					***Heat Distribution type***					***PICTURE***
stove for solid fuels	boiler for wood-pellets		gas condensing boiler		not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
	uncond. space	cond. space	pipes outside	pipes inside						
x					x					
x						x				
x							x			
x								x		
	x				x					
	x					x				
	x						x			
	x							x		
		x			x					
		x				x				
		x					x			
		x						x		
			x						x	
				x					x	

Table 16. Types of “SUH” Italian heating system determined by the combination of types of subsystem.

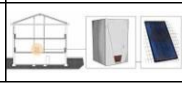
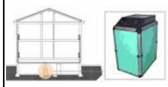
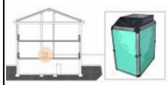
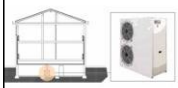
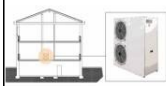
SUH – Heating systems (3/4)								
Heat Generator type			***Heat Distribution type***					***PICTURE***
thermal solar plant	gas condensing boiler		not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
	pipes outside	pipes inside						
x	x						x	
x		x					x	

Table 17. Types of "SUH" Italian heating system determined by the combination of types of subsystem.

SUH – Heating systems (4/4)										
Heat Generator type					***Heat Distribution type***					***PICTURE***
thermal solar plant	ground source heat pump		air source heat pump		not insulated pipes (up to 1960)	not insulated pipes (1961-1976)	insulated pipes (1977-1993)	insulated pipes (1994-2005)	insulated pipes (after 2005)	
	pipes outside	pipes inside	pipes outside	pipes inside						
	x								x	
		x							x	
x	x								x	
x		x							x	
			x						x	
				x					x	
x			x						x	
x				x					x	

Also the heating systems were put in the "Excel Workbook" (see Figure 12).

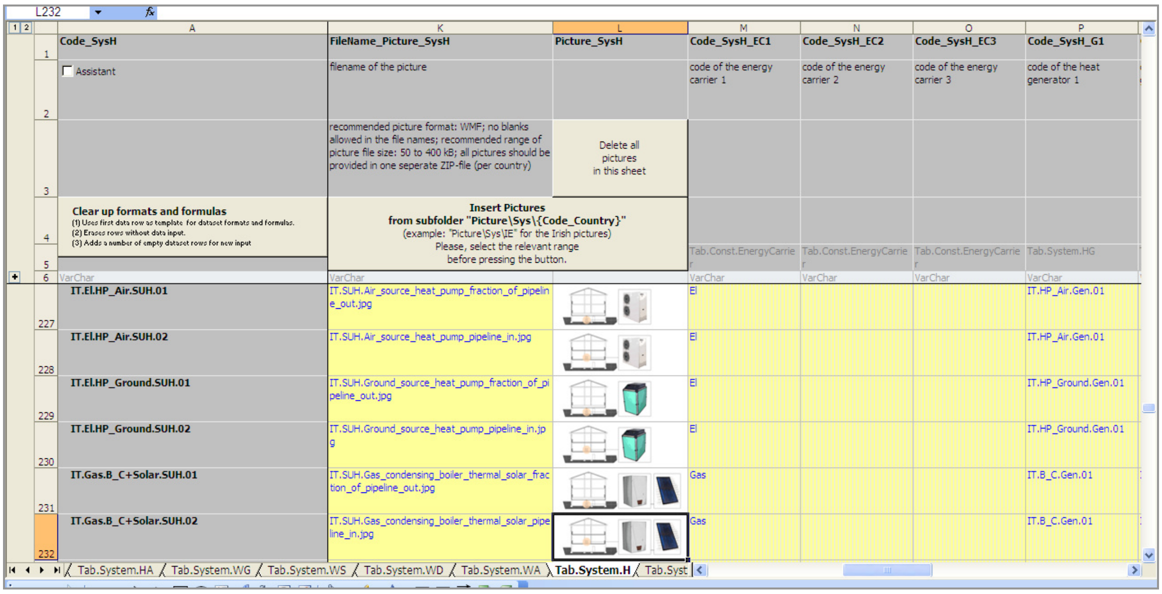


Figure 12. "Excel Workbook" filled with heating system data.

2.3.2. Domestic hot water system

Domestic hot water system – heat generation subsystem

The types of heat generation subsystem of the domestic hot water system are reported in Table 18.

They were classified according to:

- the application field (i.e. building category, as “MUH”, “SUH” or “Gen”);
- the DHW system type:
    - individual, by means of water heaters;
    - individual, combined production of heating and DHW;
    - centralised, DHW production separated from space heating production;
    - centralised, combined production of heating and DHW;
- the heat generator type and the installation period;
- the environment in which the heat generator is installed (i.e. in conditioned space, in unconditioned space, in thermal plant);
- the used energy carrier.

The performance indicator of the heat generator types is the expenditure coefficient, defined as the delivered energy need (based on gross calorific value) divided by the produced heat (annual values). The expenditure coefficient was obtained through the conversion of the efficiency value of the heat generators supplied by national technical standards. The efficiency value was derived from UNI/TS 11300-2 for gas and oil heat generators and for electric heaters. The coefficients of performance (*COP*) of the heat pumps are standard seasonal values.

Table 18. Types of heat generator for domestic hot water in the Italian residential building stock.

DOMESTIC HOT WATER SYSTEM - HEAT GENERATOR TYPES						
BUILDING SIZE	DESCRIPTION			PERIOD		EXPENDITURE COEFFICIENT (based on gross calorific value)
	Energy carrier	Heat Generator type	Specifications	from	to	
Gen	gas	instantaneous water heater, non-condensing	open combustion chamber with standing pilot	-	-	2.47
			open combustion chamber without standing pilot	-	-	1.45
			sealed combustion chamber without standing pilot	-	-	1.39

DOMESTIC HOT WATER SYSTEM - HEAT GENERATOR TYPES						
BUILDING SIZE	DESCRIPTION			PERIOD		EXPENDITURE COEFFICIENT (based on gross calorific value)
	Energy carrier	Heat Generator type	Specifications	from	to	
Gen	gas	instantaneous water heater, condensing	-	1990	-	1.24
Gen	electricity	electric heater	-	-	-	1.33
MUH	gas	non-condensing boiler, atmospheric burner	in unconditioned space, chimney > 10 m	-	1995	1.53
				1996	-	1.41
			in conditioned space, chimney > 10 m	-	1995	1.36
				1996	-	1.27
MUH	gas	non-condensing boiler, forced draft burner	in thermal plant	-	1995	1.29
				1996	-	1.24
	oil			-	1995	1.22
				1996	-	1.17
MUH	gas	non-condensing boiler, for individual DHW systems (combined heating and DHW per apartment)	in unconditioned space	-	-	1.33
			in conditioned space	-	-	1.29
SUH	gas	non-condensing boiler (combined heating and DHW), atmospheric burner	in unconditioned space, chimney < 10 m	-	1995	1.48
				1996	-	1.43
			in conditioned space, chimney < 10 m	-	1995	1.40
				1996	-	1.35
SUH	gas	non-condensing boiler (combined heating and DHW), forced draft burner	in thermal plant	-	1995	1.35
				1996	-	1.32
	oil			-	1995	1.27
				1996	-	1.24
Gen	gas	condensing boiler	in thermal plant	1990	-	1.12
Gen	solar energy	thermal solar plant	-	2005	-	0
Gen	electricity	ground source heat pump (or geothermal heat pump)	-	2005	-	0.33
Gen	electricity	air source heat pump	-	2005	-	0.40

Domestic hot water system – heat storage subsystem

The types of heat storage subsystem of the domestic hot water system are reported in Table 19.

They were classified according to:

- the application field (i.e. building category, as "MUH", "SUH" or "Gen");
- the DHW system type (centralised or individual) for the "MUH" building category;
- the thermal insulation level of the storage tank (low, medium, high);
- the environment in which the storage is installed (in heated space, in unheated space).

The calculation of the heat losses and the recovered heat losses of the heat storage types was performed according to national technical specification UNI/TS 11300-2. For each type of heat storage subsystem, the value of heat losses is a reference average value obtained considering the following input data:

- the storage volume can vary from 60 to 200 litres per dwelling;
- the mean annual temperature difference between the hot water in the storage and the environment in which the storage is installed varies from 50 °C (for tanks installed in unheated rooms) to 40 °C (for tanks installed in heated rooms);
- the thickness of the thermal insulation material around the tank varies from 2 cm (low insulation level) to 6 cm (high insulation level);
- the thermal conductivity of the insulation material was fixed at 0.04 W/(m K).

As the national standards don't supply a reference period of the thermal insulation level of the tank, the following classification is supposed according to experience:

- low insulation level, up to 1975;
- medium insulation level, from 1976 to 2005;
- high insulation level, after 2005.

The heat losses and the recovered heat losses of the storage types were normalised on the useful floor area of reference buildings belonging to "SUH" and "MUH" categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 19. Types of heat storage for domestic hot water in the Italian residential building stock.

DOMESTIC HOT WATER SYSTEM - HEAT STORAGE TYPES						
BUILDING SIZE	DESCRIPTION		PERIOD		TYPICAL HEAT LOSS	TYPICAL RECOVERED HEAT LOSS
	Heat Storage type	Specifications	from	to	[kWh/m^{2}y]	[kWh/m^{2}y]
MUH	hot water storage (tank) for central DHW system, in unconditioned space	low insulation	N/A	N/A	6.2	0
		medium insulation	N/A	N/A	3.1	0
		high insulation	N/A	N/A	2.1	0
	hot water storage (tank) for central DHW system, in conditioned space	low insulation	N/A	N/A	4.9	2.6
		medium insulation	N/A	N/A	2.5	1.3
		high insulation	N/A	N/A	1.6	0.9
SUH	hot water storage (tank), in unconditioned space	low insulation	N/A	N/A	10.7	0
		medium insulation	N/A	N/A	5.4	0
		high insulation	N/A	N/A	3.6	0
	hot water storage (tank), in conditioned space	low insulation	N/A	N/A	8.4	4.5
		medium insulation	N/A	N/A	4.2	2.2
		high insulation	N/A	N/A	2.8	1.5
MUH	hot water storage (tank) per apartment	low insulation	N/A	N/A	7.4	4.0
		medium insulation	N/A	N/A	3.7	2.0
		high insulation	N/A	N/A	2.5	1.3

Domestic hot water system – heat distribution subsystem

The types of heat distribution subsystem are reported in Table 20. They were classified according to:

- the application field (i.e. building category, as “MUH”, “SUH” or “Gen”);
- the DHW system type (centralised or individual);
- the DHW system with or without circulation;
- the position of pipes (pipeline inside of thermal envelope or fraction of pipeline outside);
- the length of pipes for system with circulation (depending on the average number of floors);
- the thermal transmittance of pipes (correlated to the construction period).

The values of the heat losses were calculated according to the Italian technical specification UNI/TS 11300-2, considering also the recovered heat losses.

For DHW systems without circulation, the heat losses and the recovered heat losses of the heat distribution subsystem were determined considering the net energy need for domestic hot water calculated according to UNI/TS 11300-2.

For DHW systems with circulation, the heat losses and the recovered heat losses of the heat distribution subsystem were determined according to Annex A of UNI/TS 11300-2. The following assumptions and simplifications were taken into account:

- the pipeline length was determined as a function of typical number of floors (i.e. average value of the number of floors of the building-types defined later in Section 3.3.);
- the mean annual temperature difference between the hot water in pipes and the environment in which the pipes are installed was considered 40 °C when the pipeline is partially outside the thermal envelope;
- the mean annual temperature difference between the hot water in pipes and the environment in which the pipes are installed was considered 30 °C when the pipeline is inside the thermal envelope;
- the thermal insulation thickness of pipes, which determines the thermal transmittance value, was considered:
    - equal to zero, up to 1975;
    - equal to a third of the value reported in *Italian Presidential Decree* no. 412/1993, from 1976 to 1990;
    - equal to the value reported in *Italian Presidential Decree* no. 412/1993, after 1991.

The heat losses and the recovered heat losses were normalised on the useful floor area of reference buildings belonging to "SUH" and "MUH" categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 20. Types of heat distribution for domestic hot water in the Italian residential building stock.

DOMESTIC HOT WATER SYSTEM - HEAT DISTRIBUTION TYPES						
BUILDING SIZE	DESCRIPTION		PERIOD		TYPICAL HEAT LOSS	TYPICAL RECOVERED HEAT LOSS
	Heat Distribution type	Specifications	from	to	[kWh/m^{2}y]	[kWh/m^{2}y]
MUH	separate DHW distribution per apartment	without circulation	-	1975	1.9	1.0
			1976	-	1.3	0.6
SUH	DHW distribution, pipeline inside of thermal envelope	without circulation	-	1975	1.3	0.6
			1976	-	0.8	0.4
MUH	central DHW distribution with circulation	fraction of pipeline outside of thermal envelope	-	1975	12.4	2.5
			1976	1990	5.7	1.1
			1991	-	2.8	0.6
		pipeline inside of	-	1975	9.1	1.8

DOMESTIC HOT WATER SYSTEM - HEAT DISTRIBUTION TYPES						
BUILDING SIZE	DESCRIPTION		PERIOD		TYPICAL HEAT LOSS	TYPICAL RECOVERED HEAT LOSS
	Heat Distribution type	Specifications	from	to	[kWh/m^{2}y]	[kWh/m^{2}y]
		thermal envelope	1976	1990	4.2	0.8
			1991	-	2.0	0.4
SUH	DHW distribution with circulation	fraction of pipeline outside of thermal envelope	-	1975	13.9	2.8
			1976	1990	5.5	1.1
			1991	-	3.0	0.6
		pipeline inside of thermal envelope	-	1975	10.2	2.0
			1976	1990	4.1	0.8
			1991	-	2.2	0.4

<u>Domestic hot water system – auxiliary system</u>

The types of auxiliary system of domestic hot water system are listed in Table 21. They were classified according to:

- the application field (i.e. building category, as “MUH”, “SUH” or “Gen”);
- presence of absence of a circulation pump;
- the type of heat generator that determines the type of the installed auxiliary (electrical power).

The typical auxiliary energy demand (mean annual value) was calculated according to the procedure of UNI/TS 11300-2. The electricity for the thermal solar plant (circulation pump) was determined according to UNI/TS 11300-4. The values reported in Table 21 are average reference values determined considering the following assumptions and simplifications:

- the water flow rate in pipes can vary from 200 to 400 l/h for the “SUH” building category and from 1600 to 3400 l/h for the “MUH” building category;
- the prevalence of the pump can vary as function of the number of building floors. An average reference value was identified for each of the building categories, “SUH” and “MUH”. This value was determined considering the variability of the pressure losses consequent to the use (variability of a reference value of water velocity inside the pipes);
- the electrical power of the auxiliaries of the heat generators (central DHW system) was determined as function of the type and the heat power of the generator (linked to the building size category);
- the seasonal mean load of the heat generator was fixed at 0.6.

A reference construction period is not shown in Table 21 for all the considered auxiliary types. This period generally follows that of the relative subsystem type (distribution, generation) to which the auxiliary is referred.

The energy demand was normalised on the useful floor area of reference buildings belonging to "SUH" and "MUH" categories. This reference floor area is the average value of the useful floor areas of the building-types defined later in Section 3.3.

Table 21. Types of auxiliary system for domestic hot water in the Italian residential building stock.

DOMESTIC HOT WATER SYSTEM – AUXILIARY SYSTEM TYPES				
BUILDING SIZE	DESCRIPTION	PERIOD		TYPICAL AUXILIARY ENERGY DEMAND
		from	to	[kWh/m^{2}y]
Gen	decentral DHW system	-	-	0.0
MUH	central DHW system with circulation pump - non-condensing boiler with atmospheric burner (auxiliary)	-	-	2.1
MUH	central DHW system with circulation pump - non-condensing boiler with forced draft burner (auxiliary)	-	-	2.8
MUH	central DHW system with circulation pump - condensing boiler (auxiliary)	1990	-	2.8
MUH	central DHW system with circulation pump	-	-	2.0
SUH	central DHW system with circulation pump - non-condensing boiler with atmospheric burner (auxiliary)	-	-	3.9
SUH	central DHW system with circulation pump - non-condensing boiler with forced draft burner (auxiliary)	-	-	4.6
SUH	central DHW system with circulation pump - condensing boiler (auxiliary)	1990	-	4.6
SUH	central DHW system with circulation pump	-	-	3.2
MUH	central DHW system with thermal solar system, with circulation pump	2005	-	2.2
MUH	central DHW system with thermal solar system, with circulation pump, in association with condensing boiler (auxiliary)	2005	-	2.5
SUH	central DHW system with thermal solar system, with circulation pump	2005	-	4.1
SUH	central DHW system with thermal solar system, with circulation pump, in association with condensing boiler (auxiliary)	2005	-	4.9

Domestic hot water system – combination of subsystems

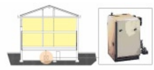
Different typologies of DHW system were identified through the combination of types of subsystem. The typical DHW systems are listed in Table 22 and Table 23 for “MUH” building category and in Table 24 and Table 25 for “SUH” building category (each row of the table represents a DHW system).

The following specifications have to be taken into account for the combination of subsystem types:

- the heat generation subsystem type and the heat distribution subsystem type are associated to each other consistently according to the same reference installation period;
- the heat storage is always considered, except for the instantaneous heat generators. The heat storage type follows the same reference installation period of the heat generator;
- the auxiliary system type is considered within the DHW system according to the relative subsystem types (distribution, generation) to which the auxiliary is referred (see also Table 21);
- if the thermal solar plant is present, the percentage of energy need covered by renewable energy is supposed 60% on average;
- the terminology “pipes outside” and “pipes inside” from Table 22 to Table 25 means respectively “fraction of pipeline outside of thermal envelope” and “pipeline inside of thermal envelope”, with reference to Table 20.

If the heat generator is combined for space heating system and domestic hot water system, it is specified (see column “DHW System type” from Table 22 to Table 25).

Table 22. Types of “MUH” Italian DHW system determined by the combination of types of subsystem.

MUH – Domestic Hot Water Systems (1/2)															
DHW System type			***Heat Generator type***									***Heat Distribution type***			***PICTURE***
			gas non-condensing boiler					oil non-cond. boiler	gas instant. heater (without standing pilot)						
			with circulation, in uncond. space, atmosph. burner		without circulation		forced draft burner (in thermal plant, with circulation and pipes outside)	forced draft burner (in thermal plant, with circulation and pipes outside)							
Central	Combined DHW and heating per apartment	Individual (per apartment)	pipes outside	pipes inside	in uncond. space	in cond. space			open combustion chamber	sealed combustion chamber	electric heater	up to 1975	1976-1990	after 1991	
x			x									x			
x			x										x		
x			x											x	
x				x								x			
x				x									x		
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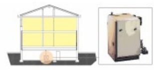
x							x					x			
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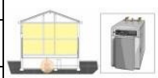
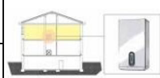
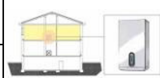
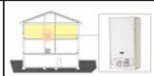
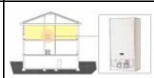
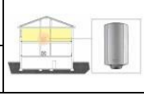
x								x				x			
x								x					x		
x								x						x	
	x				x							x			
	x				x								x	x	
	x					x						x			
	x					x							x	x	
		x							x			x			
		x								x			x	x	
		x									x	x			
		x									x		x	x	

Table 23. Types of "MUH" Italian DHW system determined by the combination of types of subsystem.

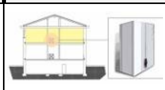
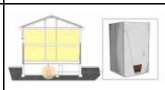
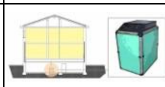
MUH – Domestic Hot Water Systems (2/2)													
DHW System type			***Heat Generator type***							***Heat Distribution type***			***PICTURE***
						gas condensing boiler (with circulation)							
Central	Combined DHW and heating per apartment	Individual (per apartment)	thermal solar plant	ground source heat pump (with circulation, pipes outside)	air source heat pump (with circulation, pipes outside)	pipes outside	pipes inside	gas instantaneous heater - condensing	electric heater (per apartment)	up to 1975	1976-1990	after 1991	
		x						x				x	
x						x						x	
x		x	x						x			x	
x				x								x	
x					x							x	
x			x			x						x	
x			x				x					x	
x			x	x								x	

Table 24. Types of "SUH" Italian DHW system determined by the combination of types of subsystem.

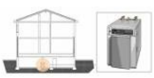
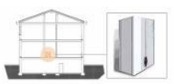
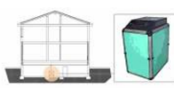
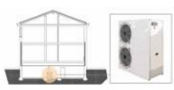
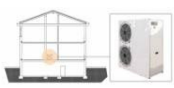
SUH – Domestic Hot Water Systems (1/2)												
DHW System type		***Heat Generator type***							***Heat Distribution type***			***PICTURE***
Combined DHW and heating	Separate DHW	gas non-condensing boiler			oil non-cond. boiler	gas instant. heater (without standing pilot, without circulation)		electric heater (without circulation)	up to 1975	1976-1990	after 1991	
		atmospheric burner (with circulation)		forced draft burner (in thermal plant, with circulation and pipes outside)	forced draft burner (in thermal plant, with circulation and pipes outside)	open combustion chamber	sealed combustion chamber					
		uncond. space, pipes outside	cond. space, pipes inside									
	x					x			x			
	x						x			x	x	
	x							x	x			
	x							x		x	x	
x		x							x			
x		x								x		
x		x									x	
x			x						x			
x			x							x		
x			x								x	
x				x					x			
x				x						x		
x				x							x	
x					x				x			
x					x					x		
x					x						x	

Table 25. Types of “SUH” Italian DHW system determined by the combination of types of subsystem.

SUH – Domestic Hot Water Systems (2/2)													
DHW System type		***Heat Generator type***								***Heat Distribution type***			***PICTURE***
Combined DHW and heating	Separate DHW	thermal solar plant	ground source heat pump (with circulation)		air source heat pump (with circulation)		gas condensing boiler (with circulation)		gas instantan. heater – condensing (without circulation)	up to 1975	1976-1990	after 1991	
			pipes outside	pipes inside	pipes outside	pipes inside	pipes outside	pipes inside					
	x								x			x	
x			x									x	
x				x								x	
x					x							x	
x						x						x	
x							x					x	
x								x				x	
x		x	x									x	
x		x		x								x	
x	x	x					x					x	
x	x	x						x				x	

Also the DHW systems were put in the "Excel Workbook" (see Figure 13).

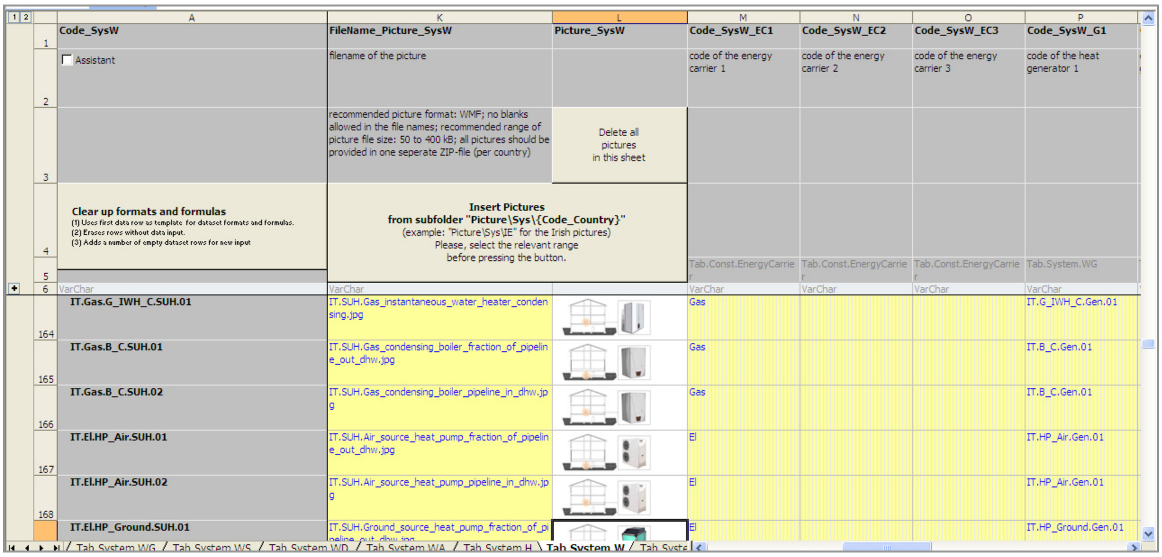


Figure 13. "Excel Workbook" filled with DHW system data.

3. Italian building typology

This Section presents the Italian building typology developed in TABULA Project. In particular the following items are illustrated:

- classification of the Italian building typology according to the common TABULA structure;
- definition of the "building-types";
- creation of the so-called "Building Typology Matrix";
- identification of the construction elements of the building-types;
- association of heating and DHW system types to the building-types;
- definition of refurbishment measures on constructions (i.e. building envelope) and systems.

3.1. Building typology classification

As TABULA Project is strictly aimed at assessing and improving the energy performance of the existing buildings, the typological concept focuses on building parameters related to energy consumption. The national "building typology" has been classified according to the following criteria:

- region/climatic area;
- building age;
- building size.

Italy is characterised by six different climatic zones according to Presidential Decree no. 412/1993, from "A zone" to "F zone" according to the number of heating degree-days (see Figure 14). Three climatic zone were considered to classify the National building typology in TABULA; they originate by grouping some climatic zones:

- *Middle climatic Zone*, coincident with "E zone";
- *Alpine Zone*, coincident with "F zone";
- *Mediterranean Zone*, coincident with "A zone", "B zone", "C zone" and "D zone".

Eight construction age classes were identified for each climatic zone. Each construction age class defines a precise historical period that mirrors significant geometrical and construction typologies from the energy point of view. The construction age classes are the followings:

- *class I*, up to 1900 – the Nineteenth Century;
- *class II*, from 1901 to 1920 – the beginning of the Twentieth Century;
- *class III*, from 1921 to 1945 – the period between the two World Wars;
- *class IV*, from 1946 to 1960 – the Postwar period and the Reconstruction;
- *class V*, from 1961 to 1975 – towards the oil crisis;
- *class VI*, from 1976 to 1990 – first Italian regulations on energy efficiency;

- *class VII*, from 1991 to 2005 – recent regulations on the energy performance of buildings in Italy (from Law no. 10/1991 to the Legislative Decree no. 192/2005);
- *class VIII*, after 2005 – more restrictive energy performance requirements (implementation decrees of Legislative Decree no. 192/2005 and regional laws).

Each construction age class is represented by building size classes. They refer to specific dimensional typologies, i.e. buildings characterised by a certain size and geometry. The following classes have been identified:

- *single-family house*, one or two floors single flat, detached o semi-detached house;
- *terraced house*, one or two floors single flat, terraced;
- *multi-family house*, small building characterised by a limited number of apartments (e.g. from 2 to 5 floors and up to 20 apartments);
- *apartment block*, big building characterised by a high number of apartments (e.g. more than 4 floors and more than 15 apartments).

The elements that allow to classify the building typology compose the axes of the so-called “Building Typology Matrix”. Each climate zone is characterized by a matrix and each matrix consists of rows, representing the building age classes, and columns, representing the building size classes. Each cell in the matrix is filled with a “building-type”, i.e. a building that is considered representative of that specific condition (climatic zone / construction age / building size).

The Italian “Building Typology Matrix” has been developed for the E zone (*Middle climatic Zone*) that represents 4250 Italian municipalities on a total number of 8100.

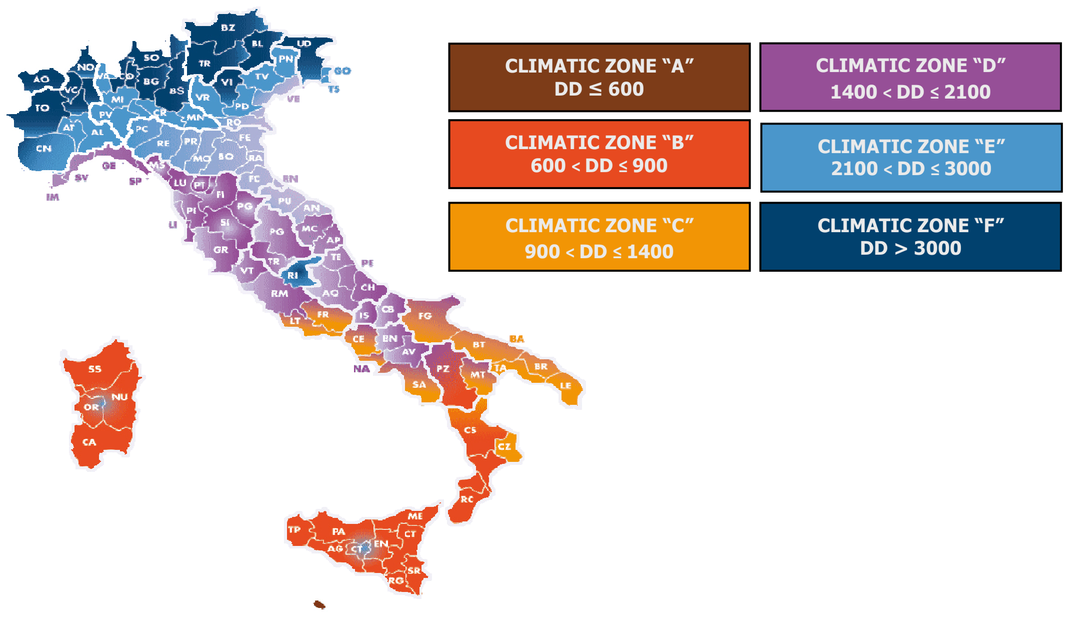


Figure 14. Indication of climatic zones within the national territory. The colour used for each province refers to the climatic zone of the majority of the municipalities in that province.

3.2. Building-type definition

The “building-type” definition followed three different methodological approaches:

- according to the *first approach*, the definition of the representative building, named “Real Example Building” (*ReEx*), is based on a choice made according to the experience. The “building-type” is selected within a climatic context as the most representative of specific size and construction age. This approach is applied when statistical data are not available;
- according to the *second approach*, the “building-type” is identified through the so-called “Real Average Building” (*ReAv*), by a statistical analysis on a large building sample. The analysis is performed to find out a real building showing characteristics similar to the mean geometrical and construction features of the statistical sample;
- according to the *third approach*, the “building-type” is identified through the so-called “Theoretical Building” (*SyAv*), that is an “archetype” based on statistical analysis on a large building sample. The “archetype” is defined as follows: “a statistical composite of the features found within a category of buildings in the stock” (IEA-ECBCS, 2004). The archetype is not a real building, but a “virtual” building characterised by a set of properties detected statistically in a building category.

Table 26. Different approaches for defining the building-types considering geometrical, construction and system features.

		BUILDING-TYPES (GEOMETRICAL FEATURES)		
		Real building (chosen according to experience)	Real building (chosen according to statistical analysis)	Theoretical building (chosen according to statistical analysis)
CONSTRUCTION AND THERMAL SYSTEM TYPOLOGIES	Real technology in the real building chosen	*ReEx*	*ReAv*	
	Technology chosen according to experience	*ReEx* *ReEx*	*ReAv* *ReEx*	*SyAv* *ReEx*
	Technology defined from statistical analysis	*ReEx* *SyAv*	*ReAv* *SyAv*	*SyAv* *SyAv*

According to the availability of data, each of these approaches could be applied to define the building-type according to its geometrical features (heated volume, floor area, compactness factor, number of floors, number of apartments) on the one hand, and its constructive and thermal system characteristics, on the other hand. The possible combination between the way of defining the building-type in its geometric characteristics (first acronym in the cell) and the approach used to define its constructive and thermal system properties (second acronym in the cell) is shown in Table 26. The various combinations to define a building-type are listed below:

- real building chosen according to experience as regards its geometrical features and characterised by its real constructive and thermal system technology (*ReEx*);
- real building chosen according to statistical analysis. It represents the average of a statistical sample as regards the geometrical features and it is characterised by its real constructive and thermal system technology (*ReAv*);
- real building chosen according to experience as regards its geometrical features. It is not characterised by its real constructive and thermal system technology, but by a technology that is defined typical according to experience (*ReEx – ReEx*);
- real building chosen according to statistical analysis. It represents the average of a statistical sample as regards the geometrical features and it is not characterised by its real constructive and thermal system technology, but by a technology that is defined typical according to experience (*ReAv – ReEx*);
- archetype building. It is not a real building but it represents the average of a statistical sample as regards the geometrical features and it is characterised by a constructive and thermal system technology that is defined typical according to experience (*SyAv – ReEx*);
- real building chosen according to experience as regards its geometrical features. It is not characterised by its real constructive and thermal system technology, but by a technology that is defined typical according to statistical analysis (*ReEx – SyAv*);
- real building chosen according to statistical analysis. It represents the average of a statistical sample as regards the geometrical features and it is not characterised by its real constructive and thermal system technology, but by a technology that is defined typical according to statistical analysis (*ReAv – SyAv*);
- archetype building. It is not a real building but it represents the average of a statistical sample as regards the geometrical features and it is characterised by a constructive and thermal system technology that is defined typical according to statistical analysis (*SyAv – SyAv*).

Table 27 shows the approaches adopted at national level to define the building-types in the Italian *Middle climatic Zone* as regards their geometrical features and their associated construction and thermal system typologies.

All the technological features of the Italian building-types were defined in TABULA according to the experience (*ReEx*). The criterion of association of a technology to a building-type was based both on the building size class, if a given technology is related to dimensional aspect, and on the building age class, considering the period of greatest diffusion of a given technology in the country. The identification of Italian construction and thermal system typologies of the national residential building stock is described, respectively, in Sections 2.2 and 2.3. The association of the building construction elements and system types to each building-type is described in Section 3.4.

As regards the building-types definition from the geometry point of view (heated volume, floor area, compactness factor, etc.), it was performed according to both statistical analysis (identifying archetypes, *SyAv*)) for some building classes and by experience (*ReEx*) for the others. The choice to take into account the experience was due to the lack of consistent statistical data in some cases.

Table 27. Approaches used for defining Italian building-types belonging to the *Middle climatic Zone.*

		BUILDING-TYPES (GEOMETRICAL FEATURES)		
		Real building (chosen according to experience)	Real building (chosen according to statistical analysis)	Theoretical building (chosen according to statistical analysis)
CONSTRUCTION AND THERMAL SYSTEM TYPOLOGIES	Real technology in the real building chosen			
	Technology chosen according to experience	*Multi-family houses and Apartment blocks (classes from 1 to 7)*		*Single-family houses and Terraced houses (classes from 1 to 8)* *Multi-family houses and Apartment blocks (class 8)*
	Technology defined from statistical analysis			

3.3. Italian "Building Typology Matrix"

The identified building-types constitute the so-called "Building Typology Matrix", which was developed for the Italian E zone and it is represented in Figure 15. The building-types belonging to the building size classes of *multi-family houses* and *apartment blocks*, and to the building age classes from *I* (up to 1900) to *VII* (1991-2005), are considered "Example Buildings" (*ReEx*) by the geometrical point of view. Their geometrical data (gross heated volume, compactness factor, gross floor area, number of floors, number of apartments) are real data (see Table 28).

On the contrary, the building-types belonging to the classes of *multi-family houses* and *apartment blocks* for the *VIII* age class (after 2005), and of *single-family houses* and *terraced houses* of all the building age classes are "archetypes" or "Theoretical Buildings" (*SyAv*) as regards their geometrical features. So the "archetypes" are characterised by average dimensional properties (gross heated volume, compactness factor, net floor area, number of floors, number of apartments, see Table 28) of a representative building sample according to statistical analysis. With reference to the *Middle climatic Zone*, the analysis was based on the energy performance certificates database of Piedmont region, that is considered one of the most representative regions of the E zone. The process performed for the identification of the "archetypes" in the database is explained in Section 4.

The "Example Buildings" are real buildings, so they are shown in the "Building Typology Matrix" by means of their photographs (see Figure 15). The "archetypes" are not real buildings, so they are shown in the "Building Typology Matrix" through photographs of similar real buildings from the geometry point of view (see Figure 15). It is necessary to specify, however, that a geometrical correspondence between the "archetype" and the corresponding picture of a real building is manifested only with regard to general dimensional data (i.e. gross heated volume, compactness factor, gross floor area, number of floors, number of apartments) and not detailed dimensional data (in fact, envelope surface per orientation, percentage of transparent envelope surface per orientation, boundaries of unconditioned spaces, etc. are not provided), because of the level of detail of the database used for identifying the "archetype". This aspect causes the building-type identified with the statistical analysis to be a "Theoretical Building" (or "archetype") and not a "Real Building" (*ReAv*).

Building Type Matrix

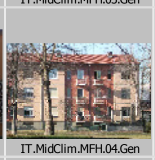
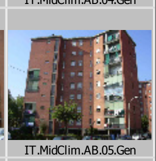
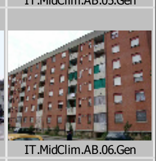
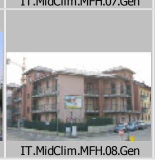
				Italy			
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	Middle Climatic Zone (Zona climatica media - ZONA E)	… 1900	generic	 IT.MidClim.SFH.01.Gen	 IT.MidClim.TH.01.Gen	 IT.MidClim.MFH.01.Gen	 IT.MidClim.AB.01.Gen
2	Middle Climatic Zone (Zona climatica media - ZONA E)	1901 … 1920	generic	 IT.MidClim.SFH.02.Gen	 IT.MidClim.TH.02.Gen	 IT.MidClim.MFH.02.Gen	 IT.MidClim.AB.02.Gen
3	Middle Climatic Zone (Zona climatica media - ZONA E)	1921 … 1945	generic	 IT.MidClim.SFH.03.Gen	 IT.MidClim.TH.03.Gen	 IT.MidClim.MFH.03.Gen	 IT.MidClim.AB.03.Gen
4	Middle Climatic Zone (Zona climatica media - ZONA E)	1946 … 1960	generic	 IT.MidClim.SFH.04.Gen	 IT.MidClim.TH.04.Gen	 IT.MidClim.MFH.04.Gen	 IT.MidClim.AB.04.Gen
5	Middle Climatic Zone (Zona climatica media - ZONA E)	1961 … 1975	generic	 IT.MidClim.SFH.05.Gen	 IT.MidClim.TH.05.Gen	 IT.MidClim.MFH.05.Gen	 IT.MidClim.AB.05.Gen
6	Middle Climatic Zone (Zona climatica media - ZONA E)	1976 … 1990	generic	 IT.MidClim.SFH.06.Gen	 IT.MidClim.TH.06.Gen	 IT.MidClim.MFH.06.Gen	 IT.MidClim.AB.06.Gen
7	Middle Climatic Zone (Zona climatica media - ZONA E)	1991 … 2005	generic	 IT.MidClim.SFH.07.Gen	 IT.MidClim.TH.07.Gen	 IT.MidClim.MFH.07.Gen	 IT.MidClim.AB.07.Gen
8	Middle Climatic Zone (Zona climatica media - ZONA E)	2006 …	generic	 IT.MidClim.SFH.08.Gen	 IT.MidClim.TH.08.Gen	 IT.MidClim.MFH.08.Gen	 IT.MidClim.AB.08.Gen

Figure 15. "Building Typology Matrix" for the Italian *Middle climatic Zone.*

In order to perform the energy performance calculation of the building-type (see Section 5), the detailed dimensional data of the "archetypes" were obtained starting from general geometrical data and then fixing the following assumptions:

- the transparent envelope surface is supposed to be an eighth of the floor area. In this way the opaque and the transparent parts of the building envelope are obtained from the global amount of the envelope surface;
- the transparent envelope surface per orientation is supposed:
    - o 0% at North, 40% at South, 30% at East and 30% at West, for buildings with no attached buildings;
    - o 40% at North, 60% at South, for buildings with attached buildings (assuming that the attached buildings are at East and West).

  In this way, the opaque and the transparent heat transfer surfaces per orientation are obtained;
- the staircases have been considered as conditioned spaces.

From this operation, some "model buildings" were drawn and reported in the Italian "Building Typology Brochure" as another example of "archetypes" representation for the "Building Typology Matrix" (see Figure 16).

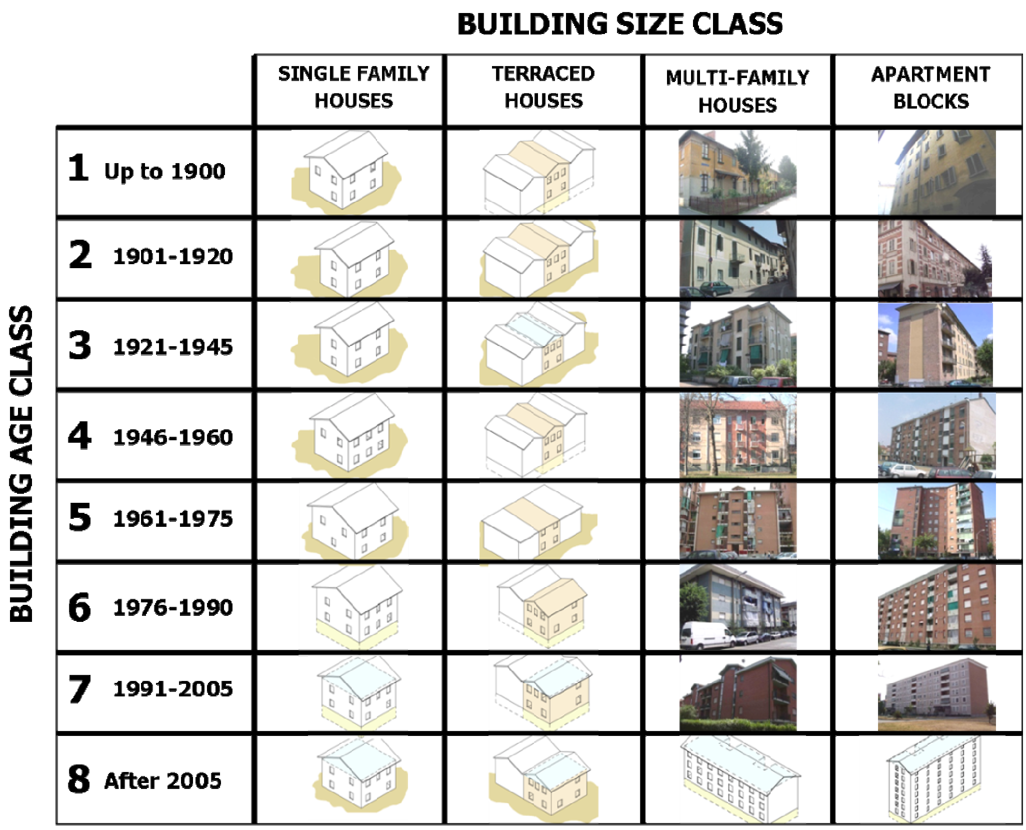


Figure 16. "Building Typology Matrix" for the Italian *Middle climatic Zone*, according to a different representation of "archetypes" proposed in the national "Building Typology Brochure".

The main geometrical features of the building-types are reported in Table 28. They were put in the "Excel Workbook" (see Figure 17) that is the appointed tool to collect building-types datasets and to perform the energy performance calculation of the building-types according to the common methodology adopted at European level (see Section 5). Moreover, the "Excel Workbook" represents the data source for the *webtool.*

Table 28. Main geometrical data of the building-types belonging to the Italian *Middle climatic Zone*.

Building size class	Building age class	Gross heated volume [m^3]	Net floor area [m^2]	Gross floor area [m^2]	Compactness factor [m^{-1}]	Number of floors	Number of apartments
Single-family houses	*I*	533	139	-	0.77	2	1
	II	448	115	-	0.82	2	1
	III	455	116	-	0.81	2	1
	IV	583	162	-	0.75	2	1
	V	679	156	-	0.73	2	1
	VI	725	199	-	0.72	2	1
	VII	605	172	-	0.73	2	1
	VIII	607	174	-	0.72	2	1
Terraced houses	*I*	500	123	-	0.51	2	1
	II	478	112	-	0.51	2	1
	III	428	113	-	0.49	2	1
	IV	400	111	-	0.51	2	1
	V	374	89	-	0.52	2	1
	VI	434	125	-	0.69	2	1
	VII	426	111	-	0.67	2	1
	VIII	519	127	-	0.64	2	1
Multi-family houses	*I*	2684	-	647	0.55	2	5
	II	4113	-	1306	0.54	2	16
	III	4388	-	1164	0.51	4	20
	IV	3076	-	961	0.51	3	12
	V	3074	-	934	0.54	5	10
	VI	4136	-	1209	0.48	3	12
	VII	3526	-	1120	0.54	3	15
	VIII	2959	829	-	0.54	3	13
Apartment blocks	*I*	3745	-	1058	0.35	5	16
	II	11029	-	2880	0.47	4	40
	III	7197	-	2249	0.46	5	30
	IV	5949	-	1763	0.46	4	24
	V	9438	-	2869	0.46	8	40
	VI	12685	-	4125	0.37	6	48
	VII	9912	-	3271	0.43	6	36
	VIII	8199	2124	-	0.40	7	31

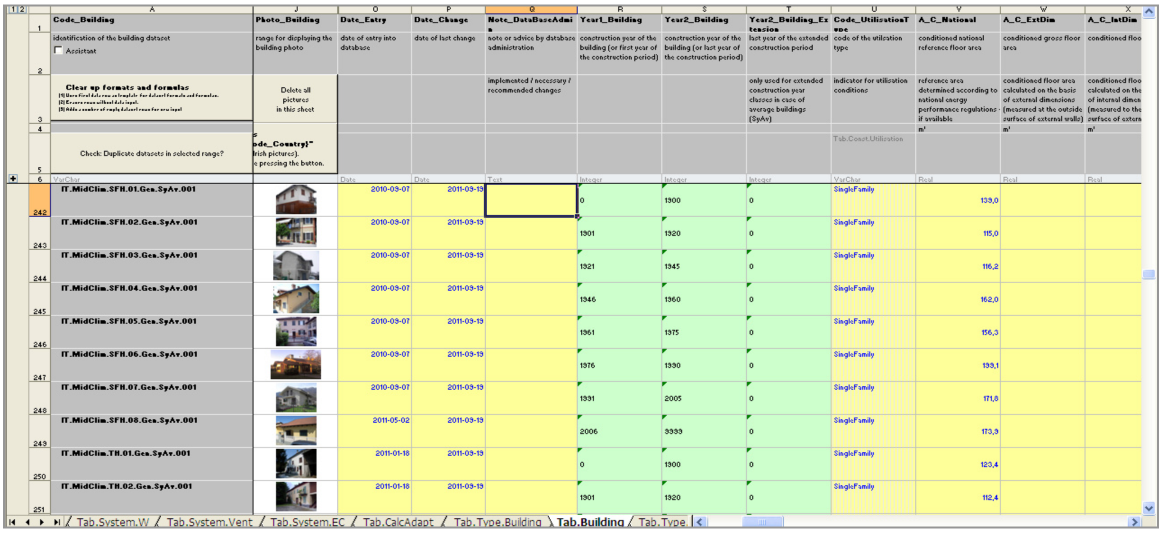


Figure 17. “Excel Workbook” filled with geometrical data of the Italian building-types.

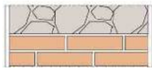
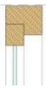
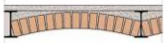
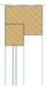
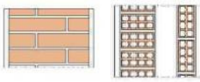
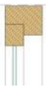
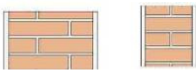
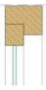
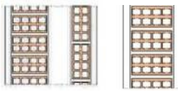
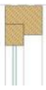
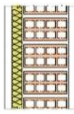
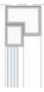
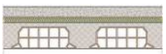
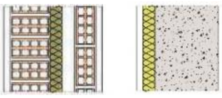
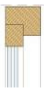
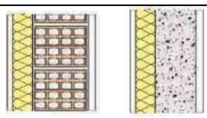
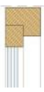
3.4. Construction elements and systems of the building-types

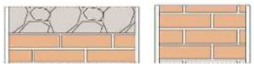
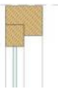
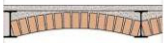
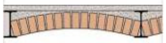
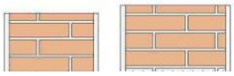
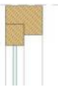
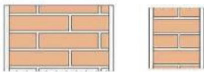
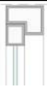
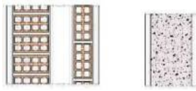
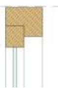
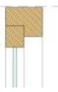
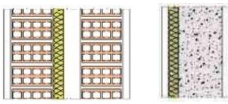
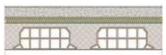
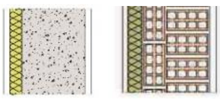
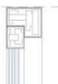
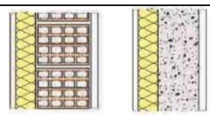
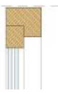
Each building-type of the “Building Typology Matrix” is characterised by envelope construction elements that are typical of the Italian building stock. A specific technology reported in Section 2.2 was associated to each building-type according to the experience, as described previously in Section 3.2. The constructive features of the building-types are reported in Table 29.

Table 29. Construction elements of the building-types.

Building-type	ROOFS/CEILINGS[1]	FLOORS	WALLS	WINDOWS	DOORS
SINGLE-FAMILY HOUSE  up to 1900	Pitched roof with wood structure and planking	Concrete floor on soil	Masonry with lists of stones and bricks (40 cm)	Single glass, metal frame without thermal break	Wooden door
SINGLE-FAMILY HOUSE  1901-1920	Pitched roof with wood structure and planking	Concrete floor on soil	Masonry with lists of stones and bricks (40 cm)	Single glass, metal frame without thermal break	Wooden door
SINGLE-FAMILY HOUSE  1921-1945	Pitched roof with wood structure and planking	Concrete floor on soil	Solid brick masonry (38 cm)	Single glass, wood frame	Wooden door
SINGLE-FAMILY HOUSE  1946-1960	Pitched roof with brick-concrete slab	Concrete floor on soil	Solid brick masonry (38 cm)	Single glass, wood frame	Wooden door
SINGLE-FAMILY HOUSE  1961-1975	Pitched roof with brick-concrete slab	Concrete floor on soil	Hollow brick masonry (40 cm)	Single glass, wood frame	Wooden door
SINGLE-FAMILY HOUSE  1976-1990	Pitched roof with brick-concrete slab, low insulation	Floor with reinforced brick-concrete slab, low insulation	Hollow wall brick masonry (40 cm), low insulation	Double glass, air filled, wood frame	Double panel wooden door
SINGLE-FAMILY HOUSE  1991-2005	Ceiling with reinforced brick-concrete slab, medium insulation	Floor with reinforced brick-concrete slab, medium insulation	Hollow brick masonry (40 cm), medium insulation	Double glass, air filled, wood frame	Double panel wooden door

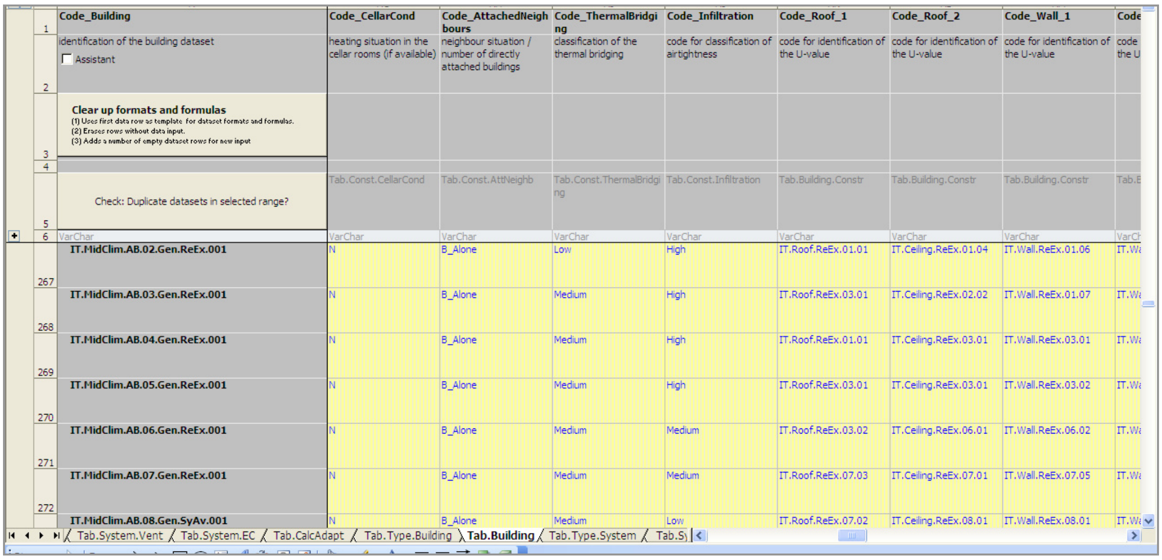
Building-type	ROOFS/CEILINGS[1]	FLOORS	WALLS	WINDOWS	DOORS
SINGLE-FAMILY HOUSE  After 2005	Ceiling with reinforced brick-concrete slab, high insulation	Concrete floor on soil, high insulation	Honeycomb bricks masonry (high thermal resistance), high insulation	Low-e double glass, air or other gas filled, wood frame	Double panel wooden door
TERRACED HOUSE  Up to 1900	Pitched roof with wood structure and planking	Vault floor with solid bricks	Masonry with lists of stones and bricks (40 cm)	Single glass, wood frame	Wooden door
TERRACED HOUSE  1901-1920	Pitched roof with wood structure and planking	Concrete floor on soil	Masonry with lists of stones and bricks (40 cm)	Single glass, wood frame	Wooden door
TERRACED HOUSE  1921-1945	Flat ceiling with hollow bricks and steel beams	Concrete floor on soil	Solid brick masonry (25 cm)	Single glass, wood frame	Wooden door
TERRACED HOUSE  1946-1960	Pitched roof with brick-concrete slab	Floor with reinforced brick-concrete slab	Hollow wall brick masonry (30 cm)	Single glass, wood frame	Wooden door
TERRACED HOUSE  1961-1975	Flat roof with reinforced brick-concrete slab	Concrete floor on soil	Hollow brick masonry (40 cm)	Single glass, wood frame	Wooden door
TERRACED HOUSE  1976-1990	Pitched roof with wood structure and planking, low insulation	Floor with reinforced brick-concrete slab, low insulation	Hollow wall brick masonry (40 cm), low insulation	Double glass, air filled, wood frame	Double panel wooden door
TERRACED HOUSE  1991-2005	Ceiling with reinforced brick-concrete slab, medium insulation	Floor with reinforced brick-concrete slab, medium insulation	Hollow brick masonry (40 cm), medium insulation	Double glass, air filled, wood frame	Double panel wooden door
TERRACED HOUSE  After 2005	Ceiling with reinforced brick-concrete slab, high insulation	Concrete floor on soil, high insulation	Honeycomb bricks masonry (high thermal resistance), high insulation	Low-e double glass, air or other gas filled, wood frame	Double panel wooden door

Building-type	ROOFS/CEILINGS[1]	FLOORS	WALLS	WINDOWS	DOORS
MULTI-FAMILY HOUSE  Up to 1900	 Vault ceiling with solid bricks	 Vault floor with solid bricks	 Masonry with lists of stones and bricks (60 cm)	 Single glass, wood frame	Wooden door
MULTI-FAMILY HOUSE  1901-1920	 Ceiling with wood beams and hollow bricks	 Vault floor with bricks and steel beams	 Masonry with lists of stones and bricks (60 cm). Solid brick masonry (38 cm)	 Single glass, wood frame	-
MULTI-FAMILY HOUSE  1921-1945	 Ceiling with reinforced concrete	 Floor with reinforced concrete	 Solid brick masonry (38 cm). Hollow wall brick masonry (30 cm)	 Single glass, wood frame	-
MULTI-FAMILY HOUSE  1946-1960	 Ceiling with reinforced brick-concrete slab	 Floor with reinforced brick-concrete slab	 Solid brick masonry (38 cm). Solid brick masonry (25 cm)	 Single glass, wood frame	-
MULTI-FAMILY HOUSE  1961-1975	 Ceiling with reinforced brick-concrete slab	 Floor with reinforced brick-concrete slab	 Hollow wall brick masonry (30 cm). Hollow brick masonry (25 cm)	 Single glass, wood frame	-
MULTI-FAMILY HOUSE  1976-1990	 Ceiling with reinforced brick-concrete slab, low insulation	 Floor with reinforced brick-concrete slab, low insulation	 Hollow brick masonry (25 cm), low insulation	 Double glass, air filled, metal frame without thermal break	-
MULTI-FAMILY HOUSE  1991-2005	 Ceiling with reinforced brick-concrete slab, medium insulation	 Floor with reinforced brick-concrete slab, medium insulation	 Hollow wall brick masonry (30 and more), medium insulation. Concrete masonry (also prefabricated, 30 cm), medium insulation	 Low-e double glass, air or other gas filled, wood frame	-
MULTI-FAMILY HOUSE  After 2005	 Ceiling with reinforced brick-concrete slab, high insulation	 Floor with reinforced brick-concrete slab, high insulation	 Honeycomb bricks masonry (high thermal resistance), high insulation. Concrete masonry (also prefabricated), high insulation	 Low-e double glass, air or other gas filled, wood frame	-

Building-type	ROOFS/CEILINGS[1]	FLOORS	WALLS	WINDOWS	DOORS
APARTMENT BLOCK  Up to 1900	 Ceiling with wood beams and hollow bricks	 Vault floor with solid bricks	 Masonry with lists of stones and bricks (60 cm). Solid brick masonry (50 cm)	 Single glass, wood frame	-
APARTMENT BLOCK  1901-1920	 Vault ceiling with bricks and steel beams	 Vault floor with bricks and steel beams	 Solid brick masonry (38 cm). Solid brick masonry (50 cm)	 Single glass, wood frame	-
APARTMENT BLOCK  1921-1945	 Flat ceiling with hollow bricks and steel beams	 Floor with hollow bricks and steel beams	 Solid brick masonry (50 cm). Solid brick masonry (25 cm)	 Single glass, metal frame without thermal break	-
APARTMENT BLOCK  1946-1960	 Ceiling with reinforced brick-concrete slab	 Floor with reinforced brick-concrete slab	 Hollow wall brick masonry (30 cm). Concrete masonry (18 cm)	 Single glass, wood frame	-
APARTMENT BLOCK  1961-1975	 Ceiling with reinforced brick-concrete slab	 Floor with reinforced brick-concrete slab	 Hollow wall brick masonry (40 cm). Hollow brick masonry (40 cm)	 Single glass, wood frame	-
APARTMENT BLOCK  1976-1990	 Ceiling with reinforced brick-concrete slab, low insulation	 Floor with reinforced brick-concrete slab, low insulation	 Hollow wall brick masonry (40 cm), low insulation. Concrete masonry (also prefabricated, 18 cm), low insulation	 Double glass, air filled, metal frame without thermal break	-
APARTMENT BLOCK  1991-2005	 Ceiling with reinforced brick-concrete slab, medium insulation	 Floor with reinforced brick-concrete slab, medium insulation	 Concrete masonry (also prefabricated, 30 cm), medium insulation. Hollow brick masonry (40 cm), medium insulation	 Double glass, air filled, metal frame with thermal break	-
APARTMENT BLOCK  After 2005	 Ceiling with reinforced brick-concrete slab, high insulation	 Floor with reinforced brick-concrete slab, high insulation	 Honeycomb bricks masonry (high thermal resistance), high insulation. Concrete masonry (also prefabricated), high insulation	 Low-e double glass, air or other gas filled, wood frame	-

Notes:
[1] The ceiling is considered instead of the roof when the boundary of the upper floor (attic space) is a unconditioned space.

The construction elements data were associated to the building-types also in the “Excel Workbook” (see Figure 18) to perform the energy performance calculation.



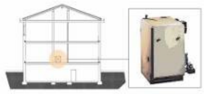
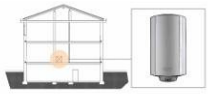
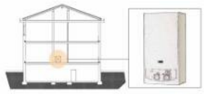
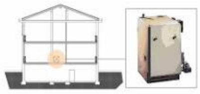
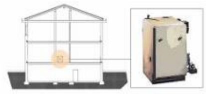
	Code_Building	Code_CellarCond	Code_AttachedNeighbours	Code_ThermalBridging	Code_Infiltration	Code_Roof_1	Code_Roof_2	Code_Wall_1	Code
2	identification of the building dataset Assistant	heating situation in the cellar rooms (if available)	neighbour situation / number of directly attached buildings	classification of the thermal bridging	code for classification of airtightness	code for identification of the U-value	code for identification of the U-value	code for identification of the U-value	code the U
3	**Clear up formats and formulas** (1) Uses first data row as template for dataset formats and formulas. (2) Erases rows without data input. (3) Adds a number of empty dataset rows for new input								
4									
5	Check: Duplicate datasets in selected range?	Tab.Const.CellarCond	Tab.Const.AttNeighb	Tab.Const.ThermalBridging	Tab.Const.Infiltration	Tab.Building.Constr	Tab.Building.Constr	Tab.Building.Constr	Tab.E
6	VarChar	VarChar	VarChar	VarChar	VarChar	VarChar	VarChar	VarChar	VarCh
267	IT.MidClim.AB.02.Gen.ReEx.001	N	B_Alone	Low	High	IT.Roof.ReEx.01.01	IT.Ceiling.ReEx.01.04	IT.Wall.ReEx.01.06	IT.Wa
268	IT.MidClim.AB.03.Gen.ReEx.001	N	B_Alone	Medium	High	IT.Roof.ReEx.03.01	IT.Ceiling.ReEx.02.02	IT.Wall.ReEx.01.07	IT.Wa
269	IT.MidClim.AB.04.Gen.ReEx.001	N	B_Alone	Medium	High	IT.Roof.ReEx.01.01	IT.Ceiling.ReEx.03.01	IT.Wall.ReEx.03.01	IT.Wa
270	IT.MidClim.AB.05.Gen.ReEx.001	N	B_Alone	Medium	High	IT.Roof.ReEx.03.01	IT.Ceiling.ReEx.03.01	IT.Wall.ReEx.03.02	IT.Wa
271	IT.MidClim.AB.06.Gen.ReEx.001	N	B_Alone	Medium	Medium	IT.Roof.ReEx.03.02	IT.Ceiling.ReEx.06.01	IT.Wall.ReEx.06.02	IT.Wa
272	IT.MidClim.AB.07.Gen.ReEx.001	N	B_Alone	Medium	Medium	IT.Roof.ReEx.07.03	IT.Ceiling.ReEx.07.01	IT.Wall.ReEx.07.05	IT.Wa
	IT.MidClim.AB.08.Gen.SyAv.001	N	B_Alone	Medium	Low	IT.Roof.ReEx.07.02	IT.Ceiling.ReEx.08.01	IT.Wall.ReEx.08.01	IT.Wa

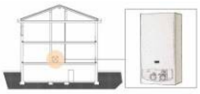
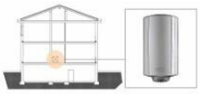
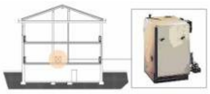
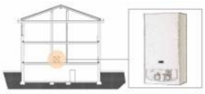
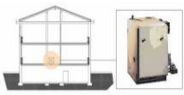
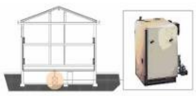
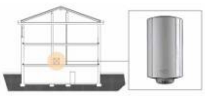
Figure 18. “Excel Workbook” filled with construction elements data of the Italian building-types.

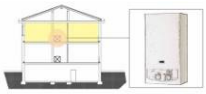
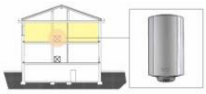
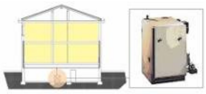
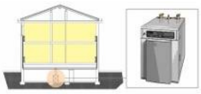
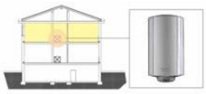
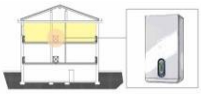
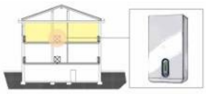
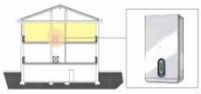
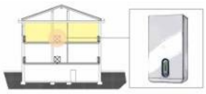
Each building-type of the "Building Typology Matrix" could be characterised by different types of heating and DHW systems, which have been previously analysed in Section 2.3. All the "SUH" category of systems could be applied to "single-family houses" and to "terraced houses", and all the "MUH" category of systems could be applied to "multi-family houses" and to "apartment blocks".

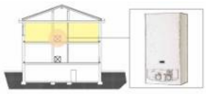
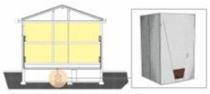
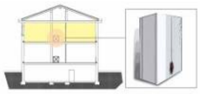
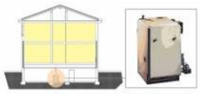
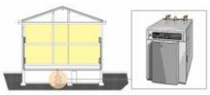
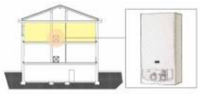
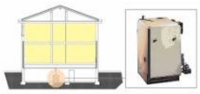
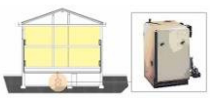
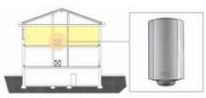
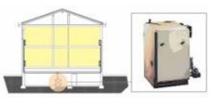
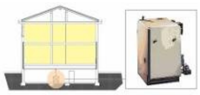
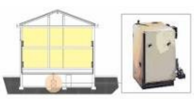
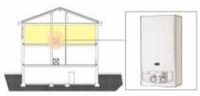
The "Excel Workbook", as the data source for the *webtool*, allows to associate different systems to each building-type. As an exemplification and in order to calculate the energy performance, one heating system and one DHW system for each building-type are proposed. The building-systems associations are those reported in the "Building Typology Brochure". They are shown in Table 30.

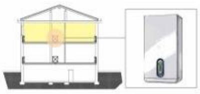
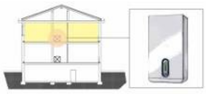
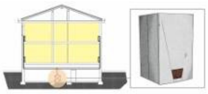
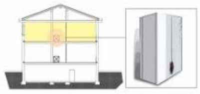
Table 30. Heating and DHW systems of the building-types.

Building-type	HEATING SYSTEM	DHW SYSTEM
SINGLE-FAMILY HOUSE  up to 1900	 gas central heating, non-condensing boiler (atmospheric burner) in conditioned space (before 1996), not insulated pipes (up to 1960, horizontal strings in heated rooms)	 combined heating and DHW - gas non-condensing boiler (atmospheric burner) in conditioned space (before 1996) - dhw distribution with circulation, pipeline inside of thermal envelope (up to 1975)
SINGLE-FAMILY HOUSE  1901-1920	 gas central heating, non-condensing boiler (atmospheric burner) in conditioned space (before 1996), not insulated pipes (up to 1960, horizontal strings in heated rooms)	 electric heater - dhw distribution without circulation (up to 1975)
SINGLE-FAMILY HOUSE  1921-1945	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater (open combustion chamber without standing pilot) - dhw distribution without circulation (up to 1975)
SINGLE-FAMILY HOUSE  1946-1960	 oil central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960, horizontal strings in unheated rooms)	 combined heating and DHW - oil non-condensing boiler (forced draft burner) in thermal plant (before 1996) - dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
SINGLE-FAMILY HOUSE  1961-1975	 gas central heating, non-condensing boiler (atmospheric burner) in conditioned space (before 1996), not insulated pipes (1961-1976, horizontal strings in heated rooms)	 combined heating and DHW - gas non-condensing boiler (atmospheric burner) in conditioned space (before 1996) - dhw distribution with circulation, pipeline inside of thermal envelope (up to 1975)
SINGLE-FAMILY HOUSE  1976-1990	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), insulated pipes (1977-1993, horizontal strings in unheated rooms)	 combined heating and DHW - gas non-condensing boiler (atmospheric burner) in unconditioned space (before 1996) - dhw distribution with circulation, fraction of pipeline outside of thermal envelope (1976-1990)

Building-type	HEATING SYSTEM	DHW SYSTEM
SINGLE-FAMILY HOUSE  1991-2005	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (after 1996), insulated pipes (1994-2005, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater (sealed combustion chamber without standing pilot) - dhw distribution without circulation (after 1975)
SINGLE-FAMILY HOUSE  After 2005	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
TERRACED HOUSE  Up to 1900	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (up to 1960, horizontal strings in unheated rooms)	 electric heater - dhw distribution without circulation (up to 1975)
TERRACED HOUSE  1901-1920	 oil central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960, horizontal strings in unheated rooms)	 combined heating and DHW - oil non-condensing boiler (forced draft burner) in thermal plant (before 1996) - dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
TERRACED HOUSE  1921-1945	 gas central heating, non-condensing boiler (atmospheric burner) in conditioned space (before 1996), not insulated pipes (up to 1960, horizontal strings in heated rooms)	 gas-fired instantaneous water heater (open combustion chamber without standing pilot) - dhw distribution without circulation (up to 1975)
TERRACED HOUSE  1946-1960	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960, horizontal strings in unheated rooms)	 combined heating and DHW - gas non-condensing boiler (forced draft burner) in thermal plant (before 1996) - dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
TERRACED HOUSE  1961-1975	 gas central heating, non-condensing boiler (atmospheric burner) in conditioned space (before 1996), not insulated pipes (1961-1976, horizontal strings in heated rooms)	 combined heating and DHW - gas non-condensing boiler (atmospheric burner) in conditioned space (before 1996) - dhw distribution with circulation, pipeline inside of thermal envelope (up to 1975)
TERRACED HOUSE  1976-1990	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), insulated pipes (1977-1993, horizontal strings in unheated rooms)	 electric heater - dhw distribution without circulation (after 1975)

Building-type	HEATING SYSTEM	DHW SYSTEM
TERRACED HOUSE  1991-2005	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (after 1996), insulated pipes (1994-2005, horizontal strings in unheated rooms)	 combined heating and DHW - gas non-condensing boiler (atmospheric burner) in unconditioned space (after 1996) - dhw distribution with circulation, fraction of pipeline outside of thermal envelope (after 1991)
TERRACED HOUSE  After 2005	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  Up to 1900	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (up to 1960)	 individual dhw system (per apartment) - gas-fired instantaneous water heater (open combustion chamber without standing pilot) - separate dhw distribution without circulation (up to 1975)
MULTI-FAMILY HOUSE  1901-1920	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (up to 1960)	 individual dhw system (per apartment) - electric heater - separate dhw distribution without circulation (up to 1975)
MULTI-FAMILY HOUSE  1921-1945	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960)	 gas central dhw system - non-condensing boiler (forced draft burner) in thermal plant (before 1996) - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
MULTI-FAMILY HOUSE  1946-1960	 oil central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960)	 individual dhw system (per apartment) - electric heater - separate dhw distribution without circulation (up to 1975)
MULTI-FAMILY HOUSE  1961-1975	 gas decentral heating (per apartment), non-condensing boiler in unconditioned space, not insulated pipes (1961-1976)	 individual dhw systems (combined heating and dhw per apartment) - non-condensing boiler in unconditioned space - separate dhw distribution without circulation (up to 1975)
MULTI-FAMILY HOUSE  1976-1990	 gas decentral heating (per apartment), non-condensing boiler in unconditioned space, insulated pipes (1977-1993)	 individual dhw systems (combined heating and dhw per apartment) - non-condensing boiler in unconditioned space - separate dhw distribution without circulation (after 1975)

Building-type	HEATING SYSTEM	DHW SYSTEM
MULTI-FAMILY HOUSE  1991-2005	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (after 1996), insulated pipes (1994-2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater (sealed combustion chamber without standing pilot) - separate dhw distribution without circulation (after 1975)
MULTI-FAMILY HOUSE  After 2005	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation
APARTMENT BLOCK  Up to 1900	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (up to 1960)	 gas central dhw system - non-condensing boiler (atmospheric burner) in unconditioned space (before 1996) - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
APARTMENT BLOCK  1901-1920	 oil central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960)	 individual dhw system (per apartment) - gas-fired instantaneous water heater (open combustion chamber without standing pilot) - separate dhw distribution without circulation (up to 1975)
APARTMENT BLOCK  1921-1945	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (up to 1960)	 gas central dhw system - non-condensing boiler (atmospheric burner) in unconditioned space (before 1996) - central dhw distribution with circulation, pipeline inside of thermal envelope (up to 1975)
APARTMENT BLOCK  1946-1960	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), not insulated pipes (up to 1960)	 individual dhw system (per apartment) - electric heater - separate dhw distribution without circulation (up to 1975)
APARTMENT BLOCK  1961-1975	 gas central heating, non-condensing boiler (atmospheric burner) in unconditioned space (before 1996), not insulated pipes (1961-1976)	 gas central dhw system - non-condensing boiler (atmospheric burner) in unconditioned space (before 1996) - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope (up to 1975)
APARTMENT BLOCK  1976-1990	 gas central heating, non-condensing boiler (forced draft burner) in thermal plant (before 1996), insulated pipes (1977-1993)	 individual dhw system (per apartment) - gas-fired instantaneous water heater (sealed combustion chamber without standing pilot) - separate dhw distribution without circulation (after 1975)

Building-type	HEATING SYSTEM	DHW SYSTEM
APARTMENT BLOCK  1991-2005	 gas decentral heating (per apartment), non-condensing boiler in unconditioned space, insulated pipes (1994-2005)	 individual dhw systems (combined heating and dhw per apartment) - non-condensing boiler in unconditioned space - separate dhw distribution without circulation (after 1975)
APARTMENT BLOCK  After 2005	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation

3.5. Definition of refurbishment measures

Some refurbishment measures were considered for the building-types, except those belonging to the eighth building age class (after 2005). The retrofit actions on the building envelope and the retrofit actions on the systems (heating and domestic hot water) were considered separately. The energy improvement measures were evaluated on two levels:

- "standard" refurbishment, considering the application of measures commonly used in the country;
- "advanced" refurbishment, considering the realisation of measures that reflect the best available technology.

The following "standard" refurbishment measures were applied to the building envelope:

- application of insulation material on walls to reach an *U*-value of 0.33 W/(m^{2}K);
- application of insulation material on floors and roofs (or ceilings) to reach an *U*-value of 0.30 W/(m^2 K);
- replacement of windows and doors to reach an *U*-value of 2.00 W/(m^{2}K).

The following "advanced" refurbishment measures were applied to the building envelope:

- application of insulation material on walls to reach an *U*-value of 0.25 W/(m^{2}K);
- application of insulation material on floors and roofs (or ceilings) to reach an *U*-value of 0.23 W/(m^{2}K);
- replacement of windows and doors to reach an *U*-value of 1.70 W/(m^{2}K).

The considered *U*-values correspond to the requirements established by the new regulations on energy performance of buildings in Piedmont region (D.G.R. no. 46-11968). These *U*-values are more restrictive in comparison to those established by the National legislation (Legislative Decrees no. 192/2005 and no. 311/2006). The *U*-values applied for the "standard" refurbishment are compulsory in the Piedmont Region regulation, while the *U*-values applied for the "advanced" refurbishment are optional in the Piedmont Region regulation.

In order to achieve these performance levels, the following thicknesses of thermal insulation material have to be applied to typical building construction elements, considering thermal conductivity of insulation equal to 0.04 W/(m K):

- from 6 to 11 cm for walls, considering a "standard" refurbishment;
- from 7 to 12 cm for roof/ceilings and floors, considering a "standard" refurbishment;
- from 10 to 15 cm for walls, considering an "advanced" refurbishment;
- from 11 to 16 cm for roof/ceilings and floors, considering an "advanced" refurbishment.

The refurbishment measures on opaque building components that separate unconditioned spaces from the external environment (e.g. roof of an unconditioned attic space) are designed to meet a thermal transmittance value of 0.8 W/(m^{2}K).

As regards the refurbishment of the heating system, the following measures were considered both for the "standard" and for the "advanced" level:

- replacement of radiators with radiant heating panels;
- insulation of the distribution subsystem;
- replacement or new installation of a heat storage (high insulation level);
- replacement of individual heating systems (per apartment) with a central heating system.

As regards the "standard" refurbishment of the heating generator subsystem, the following heat generators have been considered:

- condensing boiler;
- district heating;
- air-to-water heat pump.

As regards the "advanced" refurbishment of the heating generator subsystem, the following heat generators have been considered:

- geothermal heat pump;
- geothermal heat pump coupled with thermal solar plant;
- condensing boiler coupled with thermal solar plant;
- air-to-water heat pump coupled with thermal solar plant.

The performance parameters of the new heating systems are reported in Section 2.3. (with reference to the period after 2005).

The refurbishment of the DHW system has been hypothesized considering the following measures for both the "standard" and the "advanced" level:

- insulation of the distribution subsystem;
- replacement or new installation of a heat storage (high insulation level);
- in some case, replacement of individual DHW systems (per apartment) with a central DHW system.

Moreover, as regards the "standard" refurbishment of the DHW generator subsystem, the following heat generators have been considered:

- condensing boiler and individual DHW production, per apartment;
- condensing boiler and central DHW production;
- thermal solar plant and individual electric water heaters;
- air-to-water heat pump.

As regards the "advanced" refurbishment of the DHW generator subsystem, the following heat generators have been considered:

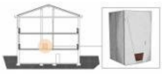
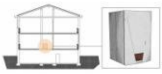
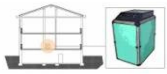
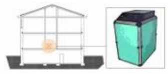
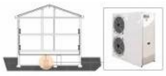
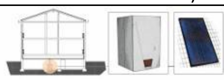
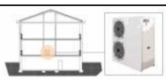
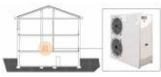
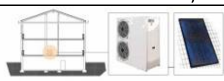
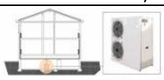
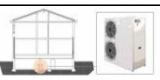
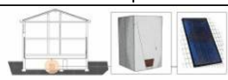
- geothermal heat pump;

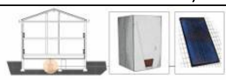
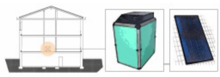
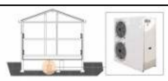
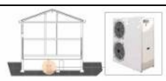
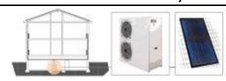
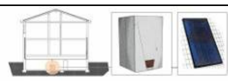
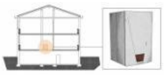
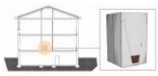
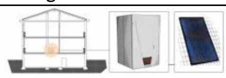
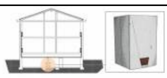
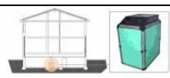
- geothermal heat pump coupled with thermal solar plant;
- condensing boiler coupled with thermal solar plant.

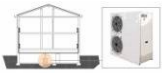
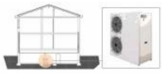
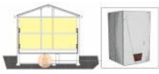
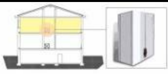
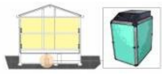
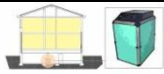
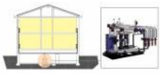
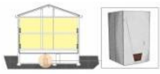
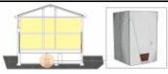
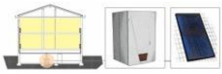
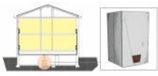
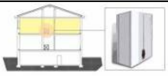
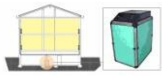
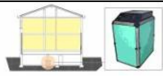
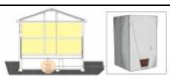
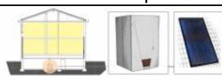
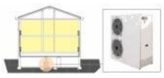
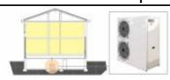
The performance parameters of the new DHW systems are reported in Section 2.3. (with reference to the period after 2005).

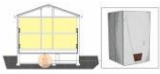
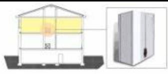
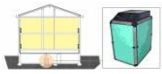
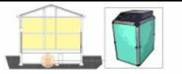
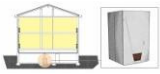
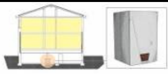
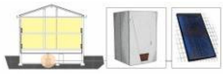
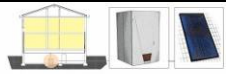
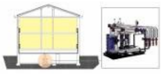
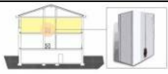
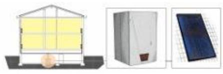
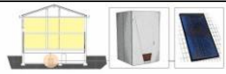
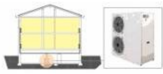
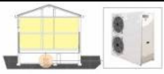
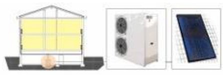
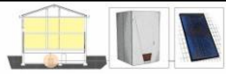
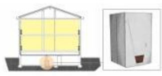
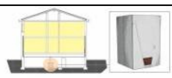
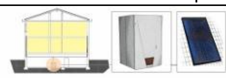
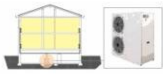
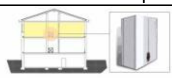
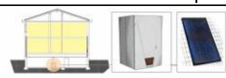
The typical heating and DHW systems of the building-types listed in Table 30 were replaced by those reported in Table 31.

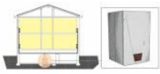
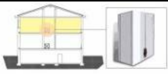
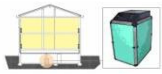
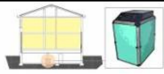
Table 31. Heating and DHW systems of the building-types considering "standard" and "advanced" refurbishment.

Building-type	***"Standard" refurbishment***		***"Advanced" refurbishment***	
	HEATING SYSTEM	**DHW SYSTEM**	**HEATING SYSTEM**	**DHW SYSTEM**
SINGLE-FAMILY HOUSE  up to 1900	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in heated rooms)	 gas condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope
SINGLE-FAMILY HOUSE  1901-1920	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in heated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005, horizontal strings in heated rooms)	 ground source heat pump - dhw distribution with circulation, pipeline inside of thermal envelope
SINGLE-FAMILY HOUSE  1921-1945	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + ground source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
SINGLE-FAMILY HOUSE  1946-1960	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
SINGLE-FAMILY HOUSE  1961-1975	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in heated rooms)	 air source heat pump - dhw distribution with circulation, pipeline inside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope
SINGLE-FAMILY HOUSE  1976-1990	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 air source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope

Building-type	*"Standard" refurbishment*		*"Advanced" refurbishment*	
	HEATING SYSTEM	**DHW SYSTEM**	**HEATING SYSTEM**	**DHW SYSTEM**
SINGLE-FAMILY HOUSE  1991-2005	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 ground source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
TERRACED HOUSE  Up to 1900	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + ground source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
TERRACED HOUSE  1901-1920	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
TERRACED HOUSE  1921-1945	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in heated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms)	 thermal solar plant + ground source heat pump - dhw distribution with circulation, pipeline inside of thermal envelope
TERRACED HOUSE  1946-1960	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 air source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
TERRACED HOUSE  1961-1975	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in heated rooms)	 gas condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope
TERRACED HOUSE  1976-1990	 gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms)	 gas-fired instantaneous water heater, condensing - dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 ground source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope

Building-type	*"Standard" refurbishment*		*"Advanced" refurbishment*	
	HEATING SYSTEM	**DHW SYSTEM**	**HEATING SYSTEM**	**DHW SYSTEM**
TERRACED HOUSE  1991-2005	 central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms)	 air source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms)	 thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  Up to 1900	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005)	 central dhw system - ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  1901-1920	 district heating, insulated pipes (after 2005)	 central dhw system, thermal solar plant + individual electrical water heater	 central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  1921-1945	 gas central heating, condensing boiler, insulated pipes (after 2005)	 central dhw system - condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  1946-1960	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005)	 central dhw system - ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  1961-1975	 gas central heating, condensing boiler, insulated pipes (after 2005)	 central dhw system - condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
MULTI-FAMILY HOUSE  1976-1990	 central heating, air source heat pump, insulated pipes (after 2005)	 central dhw system - air source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope

Building-type	***"Standard" refurbishment***		***"Advanced" refurbishment***	
	HEATING SYSTEM	**DHW SYSTEM**	**HEATING SYSTEM**	**DHW SYSTEM**
MULTI-FAMILY HOUSE  1991-2005	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005)	 central dhw system - ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  Up to 1900	 gas central heating, condensing boiler, insulated pipes (after 2005)	 central dhw system - condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  1901-1920	 district heating, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  1921-1945	 central heating, air source heat pump, insulated pipes (after 2005)	 central dhw system - air source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  1946-1960	 district heating, insulated pipes (after 2005)	 central dhw system, thermal solar plant + individual electrical water heater	 central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  1961-1975	 gas central heating, condensing boiler, insulated pipes (after 2005)	 central dhw system - condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope	 central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope
APARTMENT BLOCK  1976-1990	 central heating, air source heat pump, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005)	 central dhw system, thermal solar plant + condensing boiler - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope

Building-type	***"Standard" refurbishment***		***"Advanced" refurbishment***	
	HEATING SYSTEM	**DHW SYSTEM**	**HEATING SYSTEM**	**DHW SYSTEM**
APARTMENT BLOCK  1991-2005	 gas central heating, condensing boiler, insulated pipes (after 2005)	 individual dhw system (per apartment) - gas-fired instantaneous water heater, condensing - separate dhw distribution without circulation	 central heating, ground source heat pump, insulated pipes (after 2005)	 central dhw system - ground source heat pump - central dhw distribution with circulation, fraction of pipeline outside of thermal envelope

4. Use of energy certificate databases for Italian building typology

As described in Section 3.3., the building-types belonging to the classes of *multi-family houses* and *apartment blocks* for the *VIII* age class (after 2005), and of *single-family houses* and *terraced houses* of all the building age classes are “archetypes” or “Theoretical Buildings” (*SyAv*) as regards their geometrical features. The “archetypes” are characterised by average dimensional properties (gross heated volume, compactness factor, net floor area, number of floors, number of apartments) of a representative building sample according to statistical analysis. With reference to the *Middle climatic Zone*, the analysis was performed on the energy performance certificates database of Piedmont region, that is considered one of the most representative regions of the E zone.

The energy performance certificates database of Piedmont region contains records for more than 66,000 houses rated across Piedmont. The 66,000 house records represent the result of the information collected by EP certificates of Piedmont Region (see Figure 19).

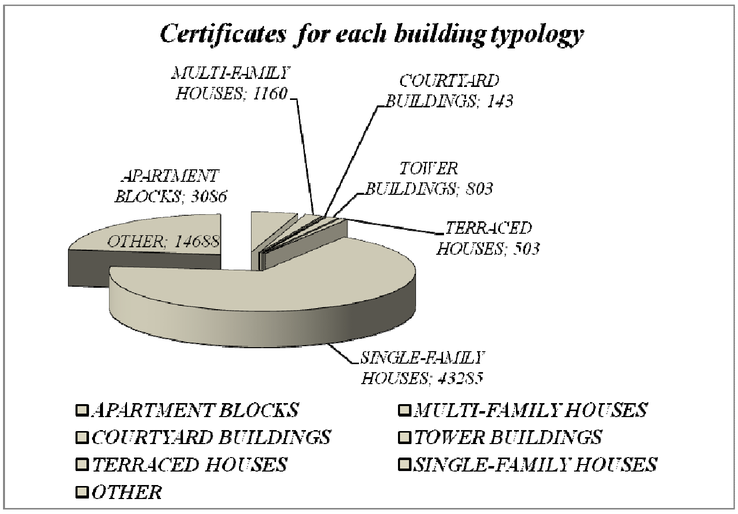


Figure 19. Split of Energy Performance Certificates for each typology of building (66063 certificates).

The database contains information on physical characteristics and energy use of each house. Each submission includes more than 40 information fields among which the following ones are included:

- location;
- construction period;
- compactness factor;
- gross heated volume;
- net floor area;
- average thermal transmittance of windows;
- results of the energy performance calculations.

The purpose of the EPCs database is also to gather the individual energy analyses data. Once an energy advisor successfully completes the energy assessment of a house, the resulting energy analysis data is collected and stored into the regional database.

The energy performance index (the energy performance of the building is defined as the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building) is evaluated by means of software tools based on the EPBD CEN Standard and Italian technical specifications UNI/TS 11300.

In order to keep the quality of the data high, the global amount of data was restricted to only 7,104 certificates. Moreover, to harmonize the analysis, the EPCs were grouped in apartment blocks, multi-family houses, terraced houses and single-family houses (see Figure 20).

In particular, three approaches have been investigated to define reference buildings:

- the first approach identifies the real building with geometrical and thermo-physical characteristics similar to the average of the building sample;
- the second method provides a building having the most probable features;
- the third approach makes groups containing buildings having similar profiles.

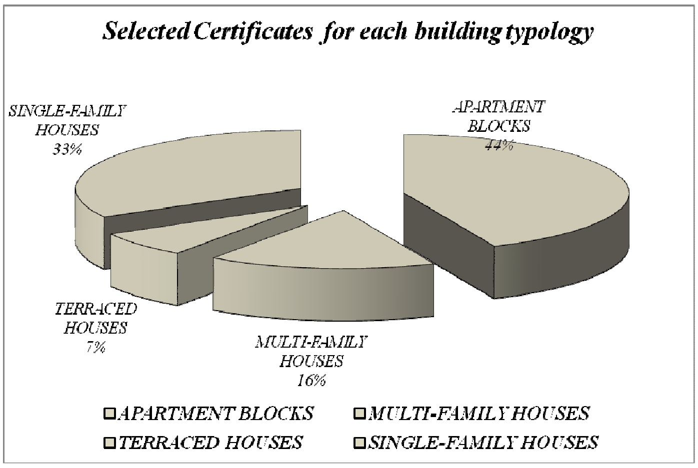


Figure 20. Split of the selected Energy Performance Certificates for each typology of building (7,104 certificates)

Method 1

According to the first approach, based on the available data, representative parameters of geometric and thermal features have been selected. These parameters are:

- volume;
- net floor area;
- envelope area to volume ratio (compactness factor);
- number of floors;
- number of apartments;

- opaque envelope average thermal transmittance;
- window average thermal transmittance.

For each parameter, statistical functions were calculated such as mean, median, 25th percentile, 75th percentile. Moreover, interquartile ranges (IQRs) were evaluated for all the parameters. The intersection of all IQRs has permitted to select the single real building whose parameters are the closest to the median values.

If this procedure had given more than one or no real building, IQRs should be tuned by means of suitable criteria in order to pick out only one real building.

Method 2

The second method begins with the identification of primary independent variables (X_i) for describing the parameters (P_j) of a specific house (B_k) in the stock. The following parameters (P_j) that characterize the building can be considered: building external shape, internal layout, window to wall ratio, thermal insulation…

On the other hand, among the independent variables (X_i) it is possible to consider: floor area, construction year, location, main heating source…

The determination of the trend of each parameter based on independent variables by means of several engineering hypotheses, analysis or rule of thumb permits to figure out the most significant independent variables X_i for each parameter.

Finally, the analytical relation between the *j*-th parameter and its significant independent variables using statistical analysis is determined.

This approach was applied for the window average thermal transmittance (WTT).

This specific parameter presents a significant relation with the floor area. A sampling of 339 buildings was selected from the Piedmont Regional Database of Energy Performance Certificates. The WTT values associated with the 1st quartile, mean, median and 3rd quartile were evaluated for each of the 10 groups defined by the deciles of the population in terms of floor area. The regression curves for the four dispersion values were calculated.

Method 3

The third method performed cluster analysis on each building age class of terraced houses. The following variables were used:

- energy need for space heating ($Q_{H,nd}$);
- primary energy for space heating ($Q_{H,p}$);
- net floor area (A);
- opaque envelope average thermal transmittance (U_{op});
- window average thermal transmittance (U_w).

The values in the data set were normalized before calculating the distance information because variables were measured against different scales.

Such analysis is based on the calculation of the distance between every pair of objects in the data set. There exist five metrics to calculate the distance. The result of this computation is commonly known as a similarity matrix (or dissimilarity matrix).

Once the proximity between objects in the data set has been computed, the objects in the data set have been separated into clusters.

Using several algorithms, pairs of objects that are close are linked together into binary clusters (clusters made up of two objects) then these newly formed clusters are linked to other objects to create bigger clusters until all the objects in the original data set are linked together in a hierarchical tree.

This procedure allowed to identify the cluster containing the representative house for the entire building age class. The reference building of the class was chosen as median value with regard the $Q_{H,nd}$.

5. Energy performance calculation

5.1. Calculation methods

The energy performance of the building-types, both in the original state and after the application of standard and advanced refurbishment measures, has been determined applying two different calculation methodologies, the common calculation procedure and the national calculation procedure (according to national EPBD implementation). Both the methodologies allow to calculate the net energy need for space heating, the primary energy for space heating, the primary energy for domestic hot water, the CO_2 emissions, according to the scope of the project. The common calculation methodology is implemented in the "Excel Workbook" and in the *webtool* as well. Instead, the national calculation procedure was applied for writing up the "Building Typology Brochure".

The common calculation of the energy use and the delivered energy by energy carriers is supposed to be a very simple procedure in order to ensure transparency of the calculation (understandable in each country/comprehensible online calculation) and easy handling (Excel calculation for a large number of buildings). The calculation procedure has been as far as possible defined in accordance with the relevant CEN standards and takes into account standard values for climates and utilisation, fixed on a national level. In general already existing harmonised definitions (CEN, DATAMINE, …) have been taken into account.

According to the common calculation procedure, the energy need for space heating is calculated by applying the seasonal method of EN ISO 13790 on the basis of a one-zone model. The external boundary conditions (air temperature, solar radiation) have been defined by each country. Standard values have been used for the utilisation conditions (room temperature, air exchange rate, internal heat sources) and for the solar radiation reduction factors (shading).

The external dimensions of the building are the basis of the envelope area calculation; a reference floor area has been defined which is used for the purpose of cross-country comparison and has been derived from the available reference quantities by each country. Thermal bridging has been considered by applying three categories (low/medium/high) depending on the effect of constructional thermal bridging. The assessment takes into account the amount of penetration of the thermal envelope by punctual or linear construction elements with significantly higher thermal conductivity not considered in the *U*-values. The respective additional losses are incorporated in the common calculation procedure in the form of an addition to the heat transfer coefficient by transmission.

The energy performance of the supply systems is calculated in the common procedure on basis of tabled values of subsystems (EN 15316 level B). In the case of heat generators energy expenditure coefficients are used which are defined as the ratio of delivered energy need to produced heat. Values for the delivered energy are based on the gross calorific value.

The national calculation procedure is supplied by the Technical Specification UNI/TS 11300 - National Annex to CEN Standards; it is made up of four parts, among which the first and the second supply the methodology for calculating the net energy need for space heating and cooling

(UNI/TS 11300-1), and the net energy need for domestic hot water, the primary energy for heating and for domestic hot water (UNI/TS 11300-2).

The following simplifications and assumptions have been adopted for the calculations:

- climatic data of the city of Turin (for *Middle climatic Zone*) from a national technical standard (UNI 10349);
- natural ventilation rate fixed according to the use (residential, in this case);
- simplified calculation of internal heat gains;
- simplified calculation of building internal heat capacity;
- simplified calculation of thermal bridges;
- simplified calculation of indoor air temperature of unconditioned spaces;
- neither shading devices nor shutters installed on windows;
- fixed value of the reduction factor for shading by permanent obstructions;
- fixed value of the reduction factor for window frame (frame factor).

The energy performance of the supply systems is calculated in the national procedure on basis of tabled values of subsystems (UNI/TS 11300-2). The efficiency values/heat losses of heating and DHW subsystems have been taken from the tables in Section 2.3. that have been filled in according to the requirements of the common procedure ("Excel Workbook"). However, in order to perform the calculation according to the national procedure, some of these data have been re-elaborated. In fact, the energy efficiency values of the heat generators have been used in place of the expenditure coefficients. The efficiency values are defined as the ratio of produced heat to delivered energy need, which is based on the net calorific value. Moreover, the efficiency values of the heat distribution subsystem of the heating system have been considered instead of the heat losses, according to the national procedure (UNI/TS 11300-2).

5.2. Results

The results of the calculation are reported from Figure 21 to Figure 40, underlining the comparison between the common procedure ("CP") and the national procedure ("NP"). The energy performance of the building-types (original state, standard refurbishment, advanced refurbishment), grouped according to the building size class, is shown considering the following quantities:

- annual net energy need for space heating;
- annual delivered energy for space heating and DHW, from fossil fuels ("FF") and electricity ("EL");
- annual primary energy for space heating and domestic hot water.

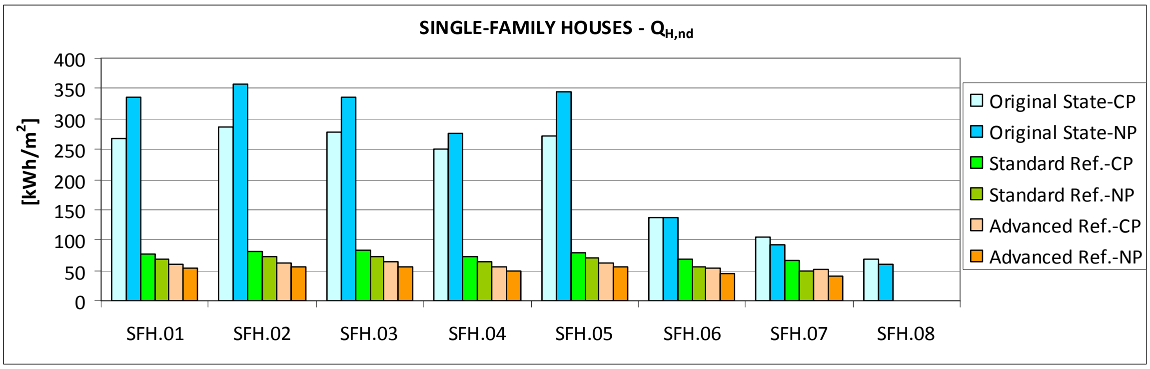


Figure 21. Annual net energy need. Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *single-family houses*.

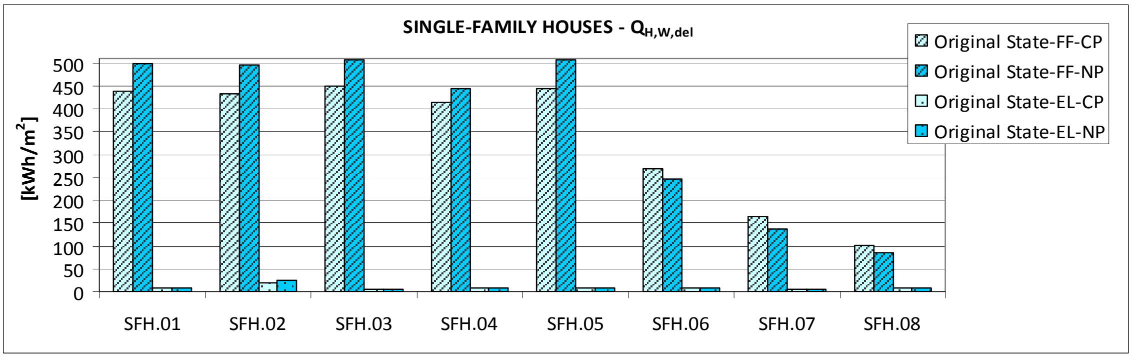


Figure 22. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *single-family houses* (Original State).

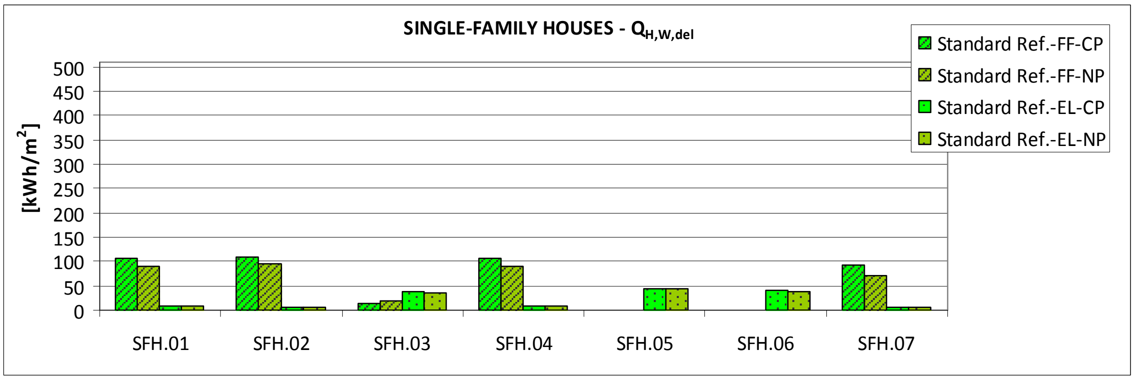


Figure 23. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *single-family houses* (Standard Refurbishment).

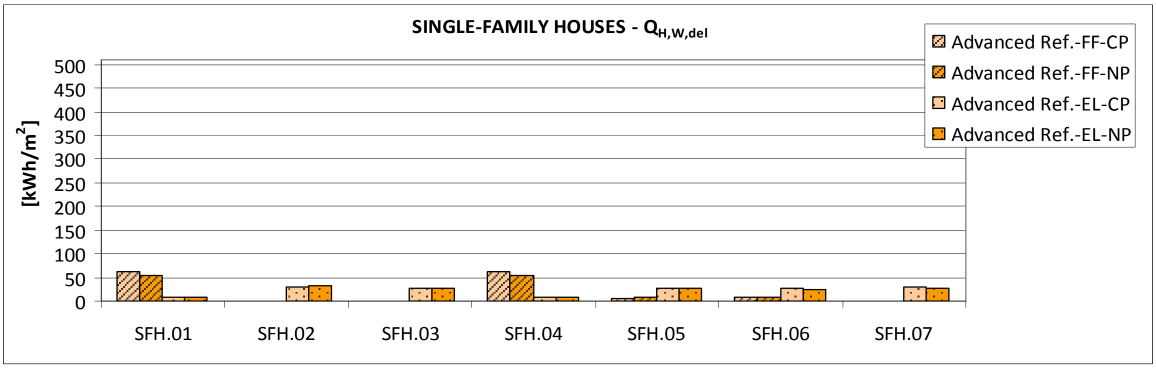


Figure 24. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *single-family houses* (Advanced Refurbishment).

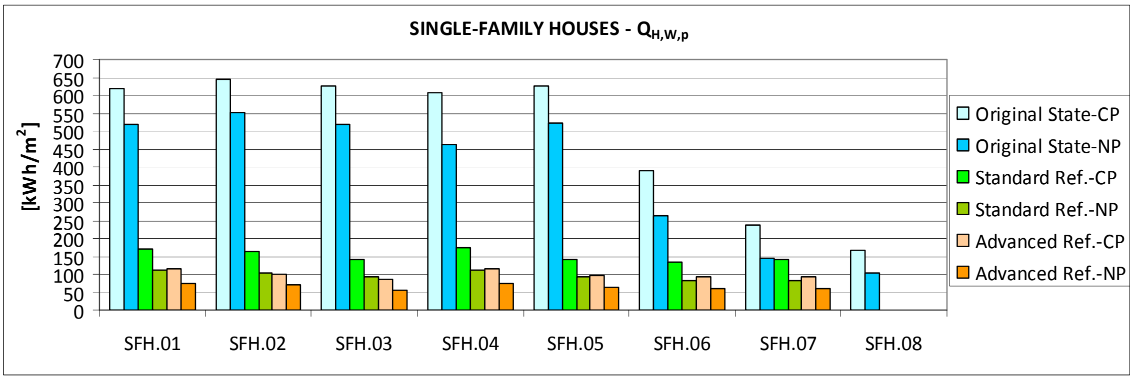


Figure 25. Annual primary energy. Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *single-family houses*.

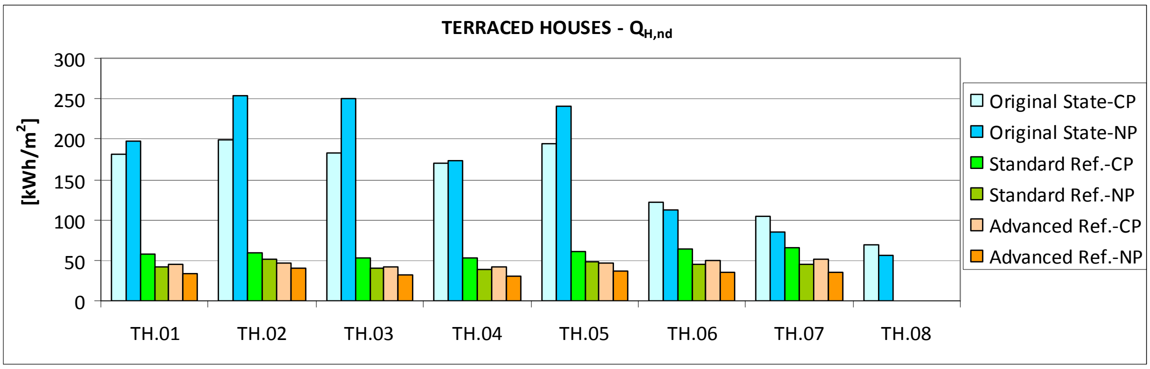


Figure 26. Annual net energy need. Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *terraced houses*.

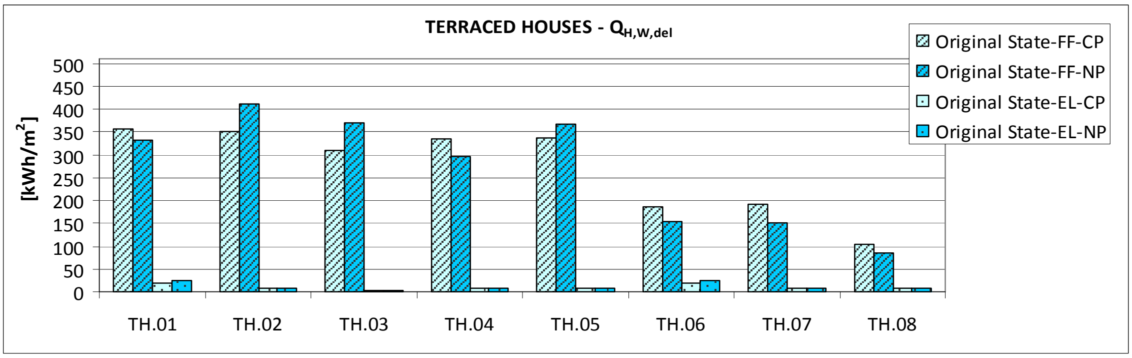


Figure 27. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *terraced houses* (Original State).

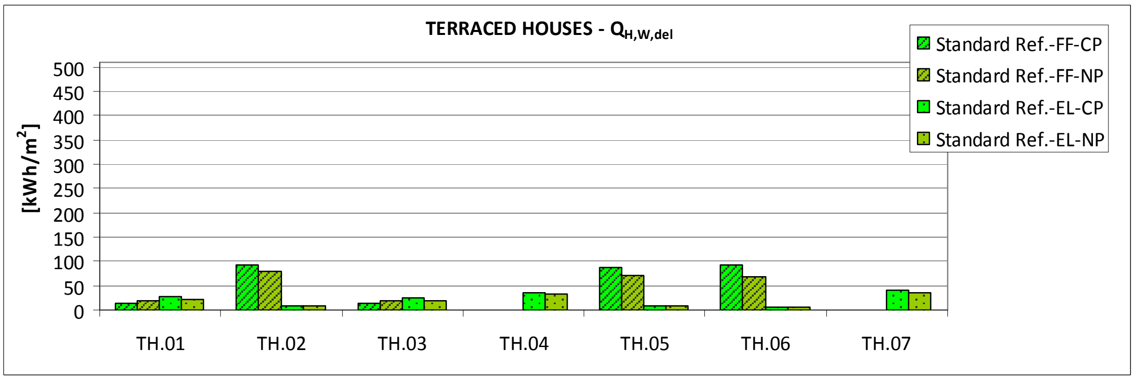


Figure 28. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *terraced houses* (Standard Refurbishment).

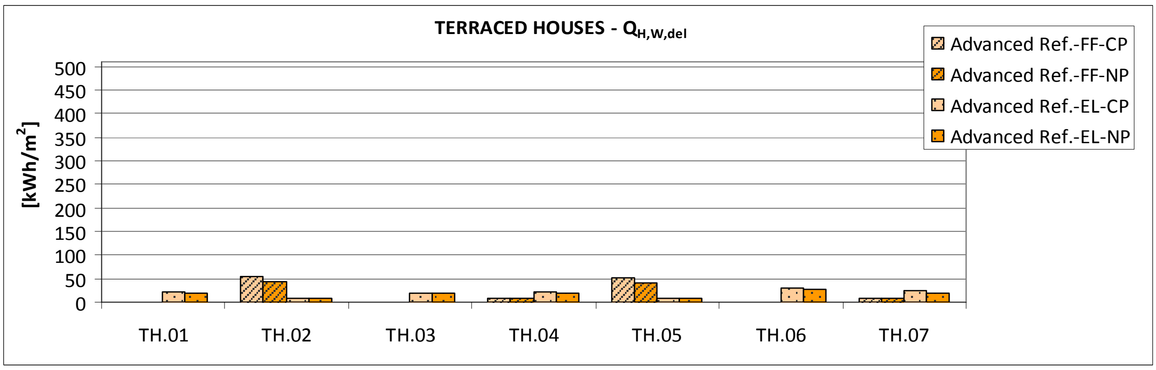


Figure 29. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *terraced houses* (Advanced Refurbishment).

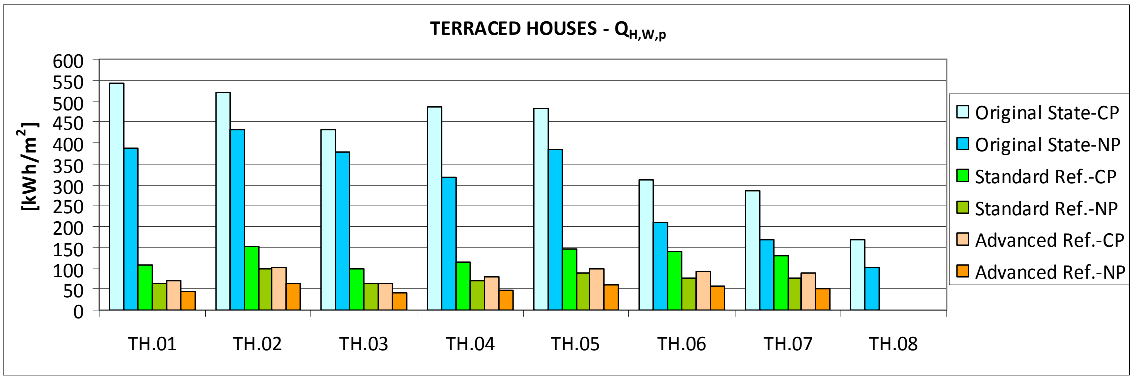


Figure 30. Annual primary energy. Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *terraced houses*.

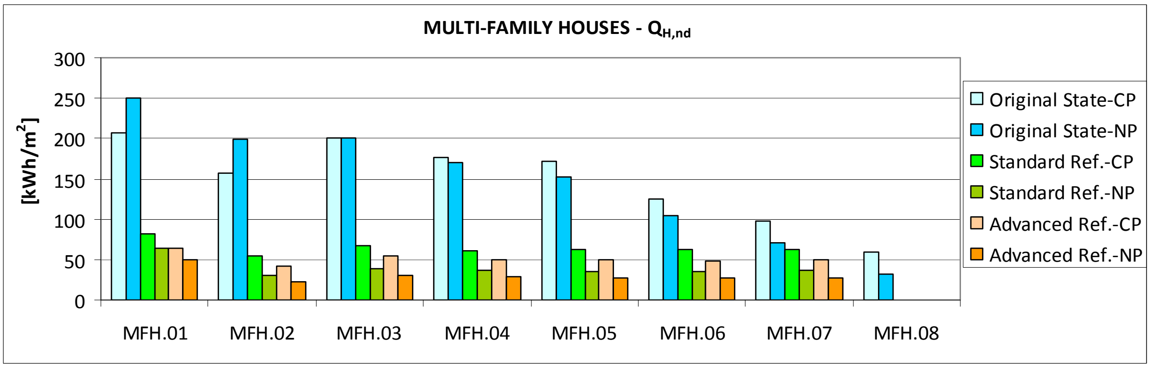


Figure 31. Annual net energy need. Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *multi-family houses*.

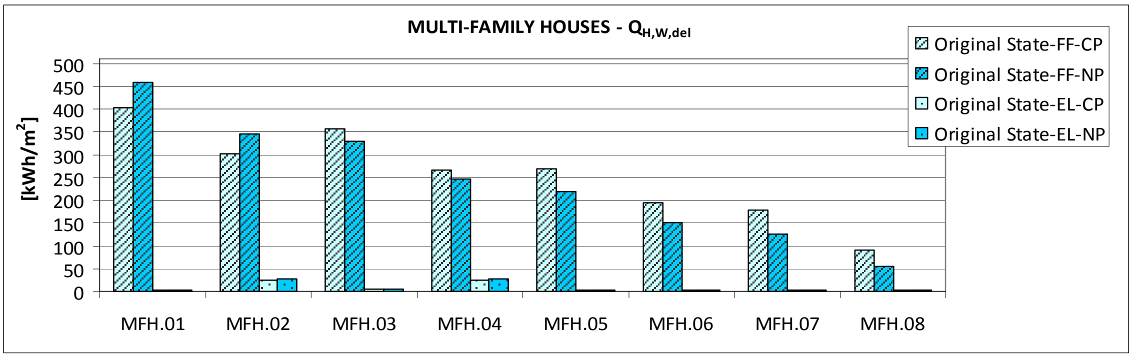


Figure 32. Annual delivered energy need from fossil fuels (“FF”) and electricity (“EL”). Comparison between the two calculation methodologies (common procedure “CP” and national procedure “NP”) for the *multi-family houses* (Original State).

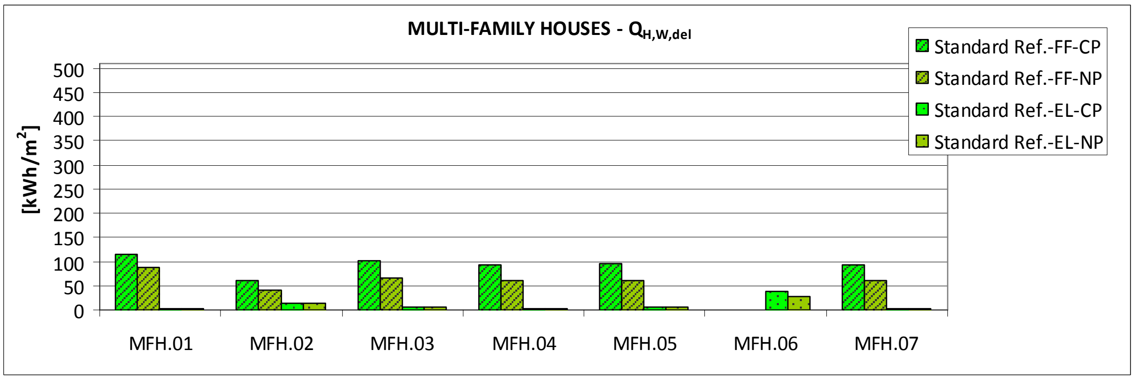


Figure 33. Annual delivered energy need from fossil fuels ("FF") and electricity ("EL"). Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *multi-family houses* (Standard Refurbishment).

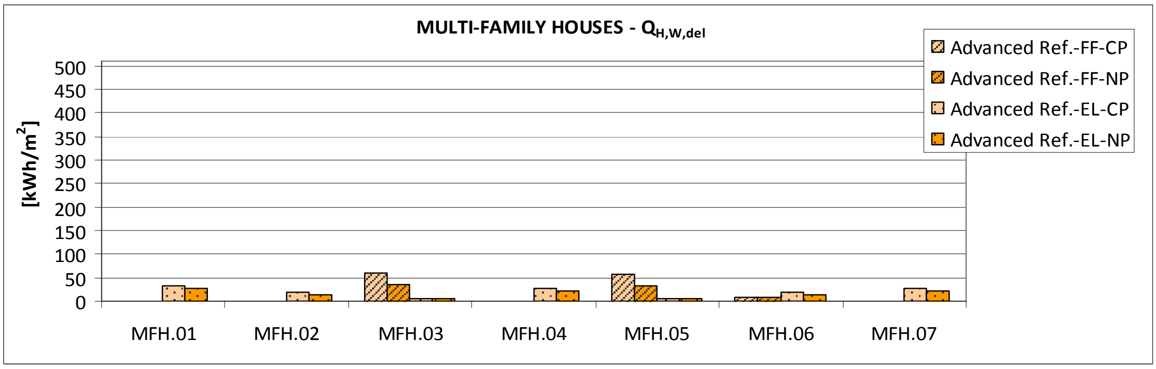


Figure 34. Annual delivered energy need from fossil fuels ("FF") and electricity ("EL"). Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *multi-family houses* (Advanced Refurbishment).

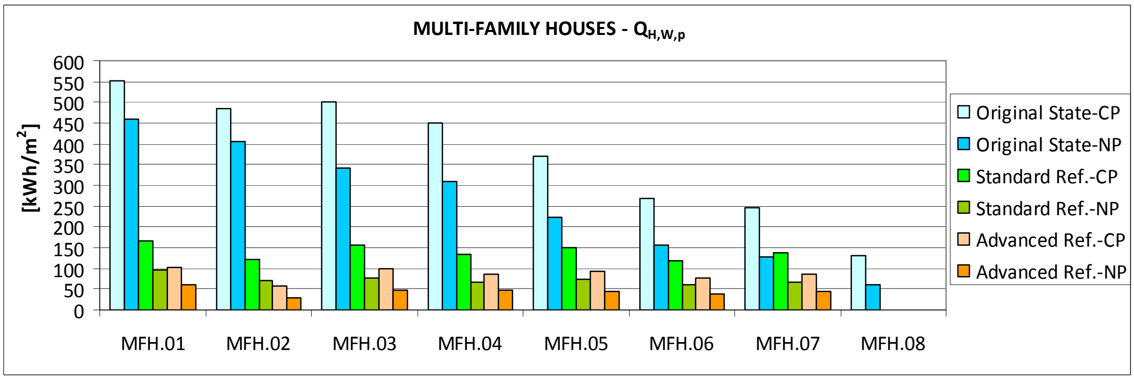


Figure 35. Annual primary energy. Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *multi-family houses*.

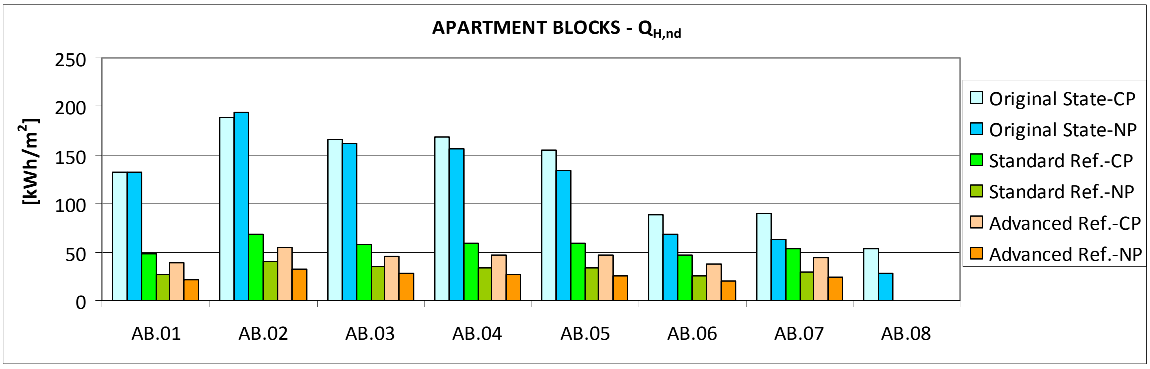


Figure 36. Annual net energy need. Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *apartment blocks*.

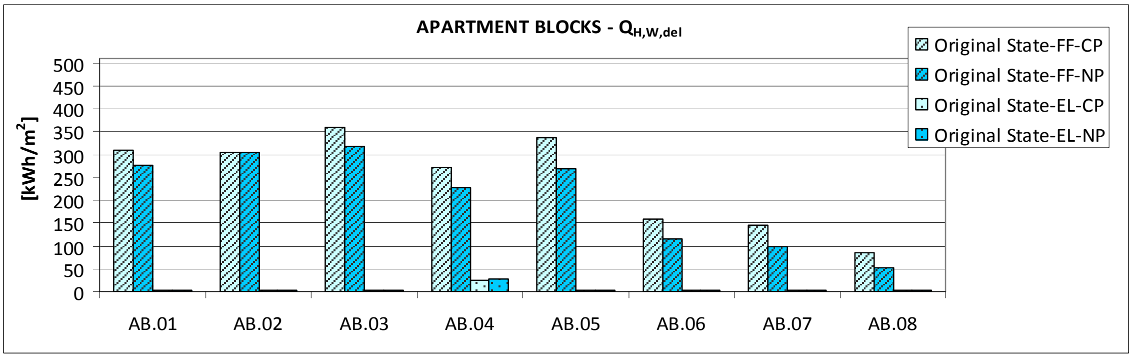


Figure 37. Annual delivered energy need from fossil fuels ("FF") and electricity ("EL"). Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *apartment blocks* (Original State).

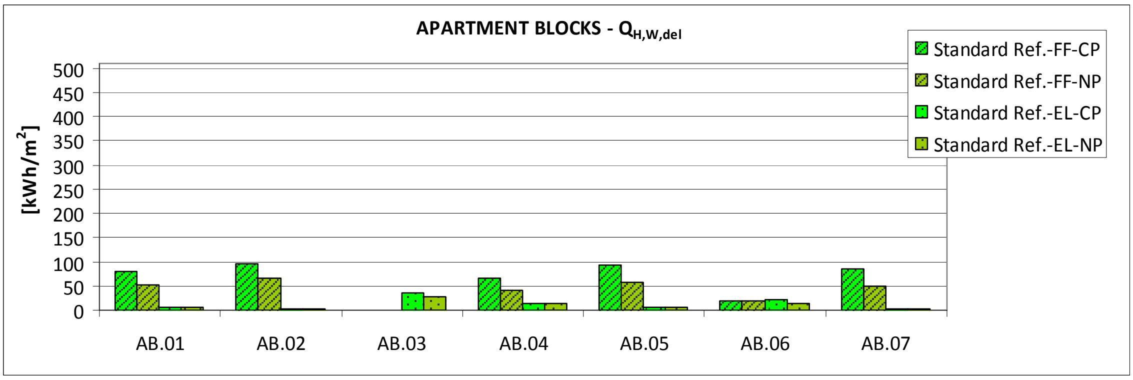


Figure 38. Annual delivered energy need from fossil fuels ("FF") and electricity ("EL"). Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *apartment blocks* (Standard Refurbishment).

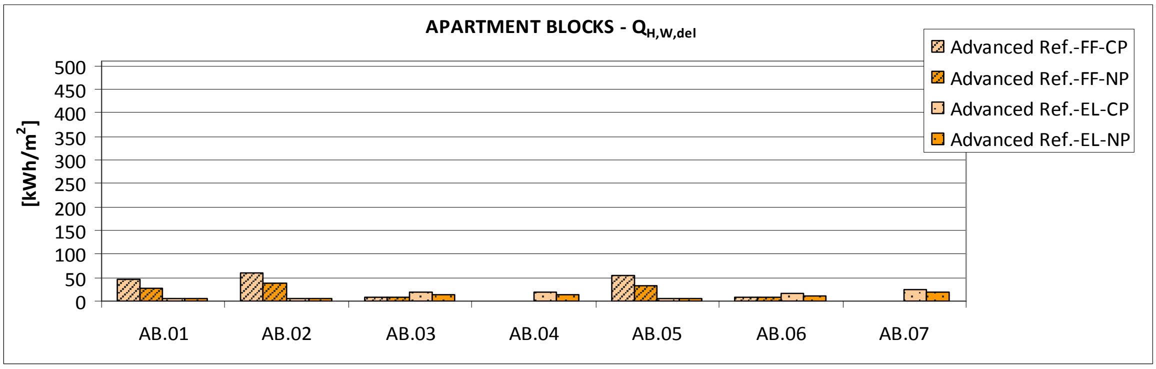


Figure 39. Annual delivered energy need from fossil fuels ("FF") and electricity ("EL"). Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *apartment blocks* (Advanced Refurbishment).

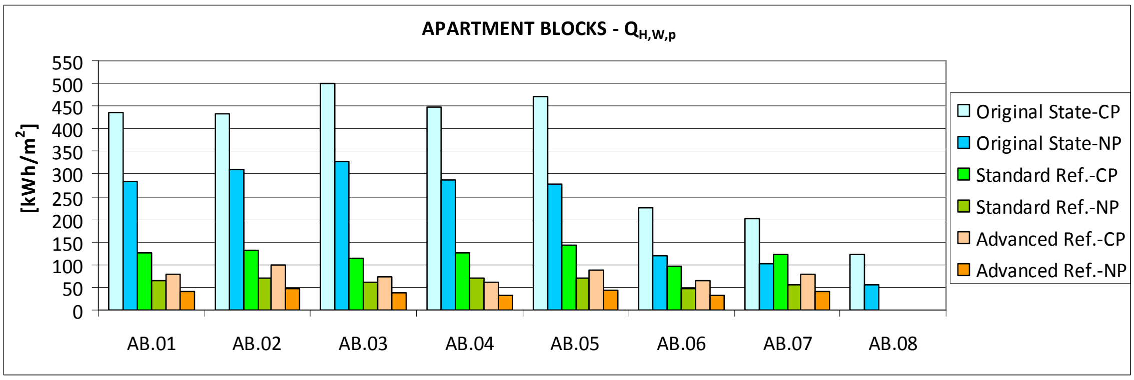


Figure 40. Annual primary energy. Comparison between the two calculation methodologies (common procedure "CP" and national procedure "NP") for the *apartment blocks*.

The deviation of the results between the two calculation procedures is due to different input data and modelling. The basic differences between them are underlined in Table 32.

Table 32. Comparison of input data between the common calculation procedure and the national calculation procedure.

	COMMON CALCULATION PROCEDURE	NATIONAL CALCULATION PROCEDURE
Thermal zones	The building-type is modelled considering a single thermal zone	The building-type is modelled considering a single thermal zone
Net floor area	A reference floor area is automatically calculated from available national values	The useful floor area is considered. If the gross floor area is available, the useful floor area is calculated from the gross value applying a correction factor according to UNI/TS 11300-1
Climatic data (outdoor air temperature and solar irradiance)	Country values. The reference climatic data of Turin are considered for Italian *Middle climatic Zone* (source: UNI 10349)	The reference climatic data of Turin are considered for *Middle climatic Zone* (source: UNI 10349)
Heating set-point temperature	The heating set-point temperature is fixed at 20 °C	The heating set-point temperature is fixed at 20 °C (UNI/TS 11300-1)
Heating system operational time	Continuous operational time without intermittence	Continuous operational time without intermittence (UNI/TS 11300-1)

	COMMON CALCULATION PROCEDURE	NATIONAL CALCULATION PROCEDURE
Length of the heating season	Automatically determined (174 days) according to reference outdoor air temperature	Fixed according to national regulation (183 days for E Climatic Zone) (UNI/TS 11300-1)
Thermal bridges	Additional heat losses through the envelope according to three different categories of thermal bridging (low/medium/high)	Simplified calculation by means of a percentage increase of the thermal transmittance in function of the type of external wall (according to UNI/TS 11300-1)
Correction factor for heat transfer through unconditioned spaces	Pre-determined value considering the type of unconditioned space	Pre-determined value considering the type of unconditioned space according to UNI/TS 11300-1
Natural ventilation	Air exchange rate: 0.4 h^{-1}	Air exchange rate: 0.3 h^{-1} (UNI/TS 11300-1)
Internal heat gains	Fixed value: 3 W/m^2	Variable value according to the useful floor area (UNI/TS 11300-1)
Reduction factor for permanent shading	Fixed value: 0.8	Fixed value: 0.8 (simplification)
Reduction factor for window frame (frame factor)	Fixed value: 0.7	Fixed value: 0.8 (UNI/TS 11300-1)
Internal heat capacity	Fixed value (normalised on floor area): 45 $Wh/(m^2 K)$	Pre-determined value considering the type of building construction according to UNI/TS 11300-1
Correction factor considering solar radiation non perpendicular to the glazing	Fixed value: 0.9	Fixed value: 0.9 (UNI/TS 11300-1)
Net energy need for DHW	Fixed values: 10 kWh/m^2 for SUH; 15 kWh/m^2 for MUH	Calculated according to UNI/TS 11300-2 as function of the useful floor area
Primary energy factors	Fixed as function of the energy carriers (CEN standards)	Fixed as function of the energy carriers (UNI/TS 11300-2)

6. Energy balance of the Italian building stock

Six reference building-types were used for the energy balance analysis of the residential building stock. They have been chosen within the "Building Typology Matrix" which has been defined for the *Middle climatic Zone* as the most representative of the Italian climate (about 4250 municipalities on a total number of 8100). The analysed building-types are the followings (see also Figure 15):

- single-family house up to 1900 ("SFH.01");
- single-family house from 1921 to 1945 ("SFH.03");
- multi-family house from 1946 to 1960 ("MFH.04");
- apartment block from 1961 to 1975 ("AB.05");
- apartment block from 1976 to 1990 ("AB.06");
- apartment block from 1991 to 2005 ("AB.07").

These reference buildings have been chosen according to statistical analysis: they are representative of a large portion of the national residential building stock as regards the *Middle climatic Zone* (for age of construction and building size).

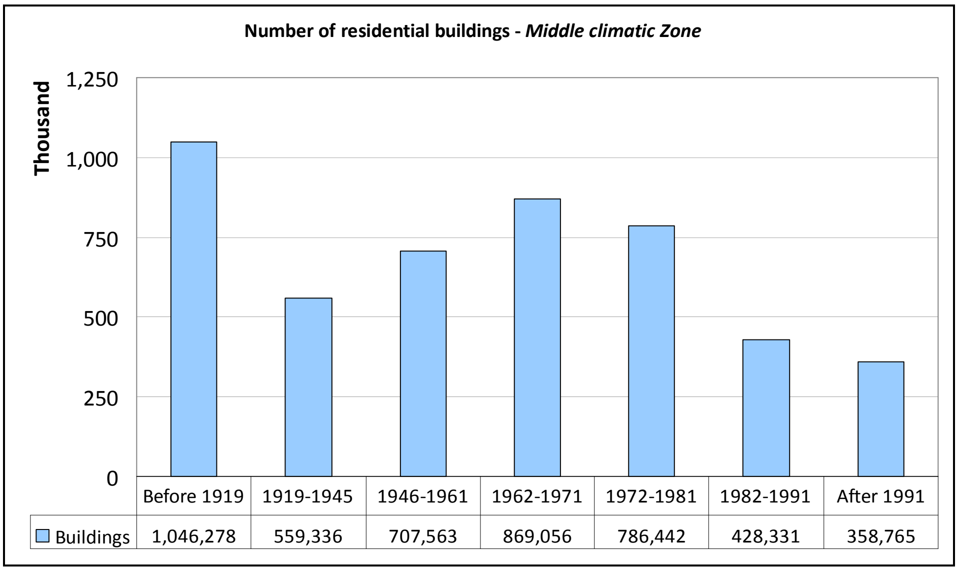


Figure 41. Number of residential buildings in the *Middle climatic Zone* by construction period (source: ISTAT, Report 2004).

In order to choose the six reference buildings, statistical data were analysed for the *Middle climatic Zone* which groups all those regions characterised by prevalent classification of the municipalities in the E Zone (from 2100 to 3000 heating degree-days). In those regions (see also Appendix I), the number of the municipalities falling in E Zone ranges from 58% (Marche region) to 87% (Lombardia region). In particular, Piedmont region is comprised within this group of regions with a percentage of 74% municipalities in E Zone.

Figure 41 and Figure 42 show some statistical data referred to the *Middle climatic Zone*.

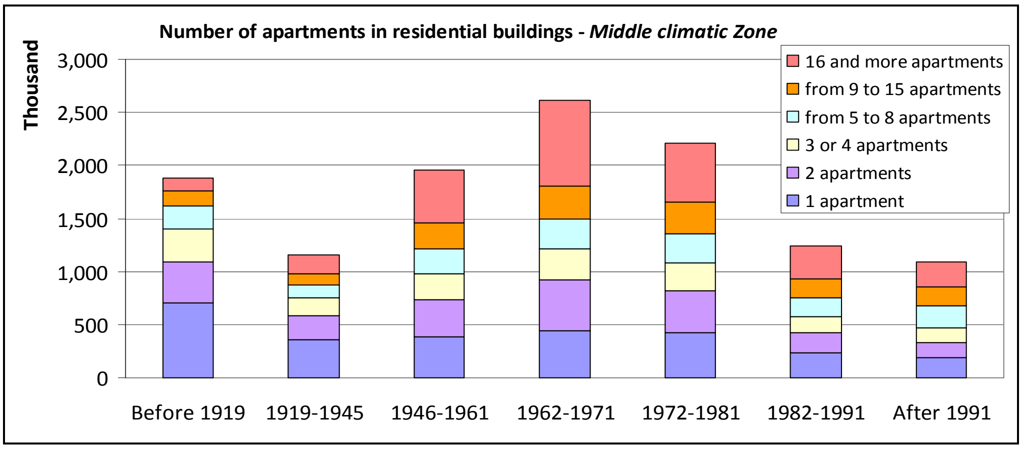


Figure 42. Number of apartments of the *Middle climatic Zone* residential buildings by construction period and number of apartments in the building (source: ISTAT, Report 2004).

The procedure applied for *Energy Balance Method* is shown in Figure 43. Starting from global statistics at national and regional level and from the corresponding available residential building sample for the *Middle climatic Zone* divided in "classes" (in terms of age and size), six reference buildings have been selected in order to obtain a relevant characterization of the analysed buildings.

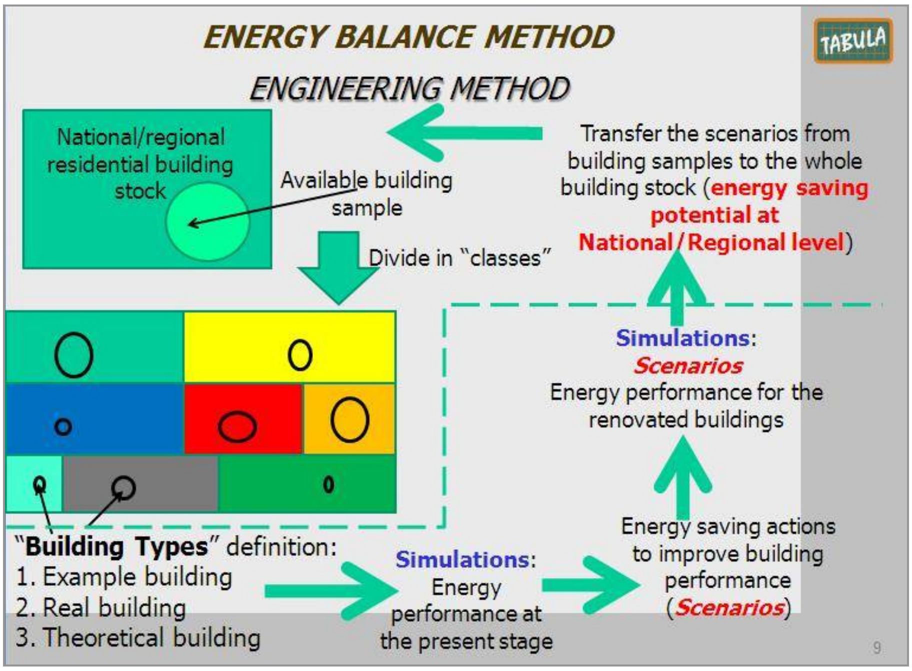


Figure 43. Procedure for *Energy Balance Method*.

The official national calculation method (Technical Specification UNI/TS 11300 - National Annex to CEN Standards) has been applied for the evaluation of the energy demand of the selected reference buildings and to assess the energy saving potential due to energy retrofit actions according to two different scenarios (standard and advanced retrofit actions), as shown in Section

5.

The retrofit scenarios have been firstly applied to the six selected reference buildings; then the obtained results have been statistically enlarged to the whole building stock of the *Middle climatic Zone*: each reference building is in fact considered as representative of a suitable portion of the building stock. As a consequence, energy saving potentials have been assessed.

The results of the energy performance of the six selected reference building-types ("RBT") are shown in Table 33.

The following different quantities of energy balance are concerned:

- net energy need for space heating ($Q_{H,nd,RBT}$);
- net energy need for domestic hot water ($Q_{W,nd,RBT}$);
- primary energy demand for space heating ($Q_{H,p,RBT}$);
- primary energy demand for domestic hot water ($Q_{W,p,RBT}$);
- primary energy demand for space heating and domestic hot water ($Q_{H,W,p,RBT}$);
- CO_2 emissions (referred to both heating and DHW; $t_{CO2,RBT}$).

Table 33. Results of the calculations for different quantities of energy balance referred to the six reference building-types.

		ORIGINAL STATE - Reference building-type (RBT)					
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	$Q_{H,nd,RBT}$ [kWh/m²]	$Q_{W,nd,RBT}$ [kWh/m²]	$Q_{H,p,RBT}$ [kWh/m²]	$Q_{W,p,RBT}$ [kWh/m²]	$Q_{H,W,p,RBT}$ [kWh/m²]	$t_{CO2,RBT}$ [kg/m²]
SFH.01	139	335	15.0	474	42.3	516	105
SFH.03	116	335	15.6	496	21.6	518	105
MFH.04	827	170	17.7	253	54.3	308	63
AB.05	2,450	134	18.2	224	52.6	277	56
AB.06	3,506	67.6	17.4	97.5	22.7	120	24
AB.07	2,879	62.9	17.1	79.0	23.2	102	21

The energy performance of each reference building-type has been projected to the whole residential building stock of Middle climatic Zone according to the available frequency data on dwellings (see Figure 41) split by construction age. Each reference building is defined as the most frequent building-type in the age of construction that it represents (see also Figure 42). The results of the projection from the reference buildings ("RBT") to the residential building stock ("RBS") are shown in Table 34, in which the same energy quantities of Table 33 are considered.

Table 34. Projection of the energy performance of the six reference building-types ("RBT") to the residential building stock ("RBS") according to the *Middle climatic Zone* statistical data on the frequency of buildings.

		ORIGINAL STATE - Projection to the residential building stock (RBS)					
REFERENCE BUILDING-TYPE	**FREQUENCY (number of buildings)**	$Q_{H,nd,RBS}$ [10^3 GWh]	$Q_{W,nd,RBS}$ [10^3 GWh]	$Q_{H,p,RBS}$ [10^3 GWh]	$Q_{W,p,RBS}$ [10^3 GWh]	$Q_{H,W,p,RBS}$ [10^3 GWh]	$t_{CO2,RBS}$ [10^6 t]
SFH.01	1,046,278	48.7	2.2	68.9	6.2	75.1	15.2
SFH.03	559,336	21.7	1.0	32.2	1.4	33.6	6.8
MFH.04	707,563	99.5	10.4	148.0	31.8	179.8	36.5
AB.05	869,056	285.3	38.8	476.9	112.0	588.9	119.6
AB.06	1,214,773	287.9	74.1	415.3	96.7	511.9	103.9
AB.07	358,765	65.0	17.7	81.6	24.0	105.6	21.4
	4,755,771	**808.1**	**144.1**	**1,222.9**	**272.0**	**1,494.9**	**303.5**

Each energy quantity expressed in kWh/m^2 (for "RBT") in Table 33 was transformed in 10^3 GWh (for "RBS") in Table 34 by multiplying it for the useful floor area of the reference building and the frequency (i.e. the number of buildings) in the building stock. The conversion from the energy quantity to the CO_2 emission was made considering a reference emission factor of the natural gas (230 g/kWh) as the most used fuel in Italy by statistics.

The calculated energy consumption ("RBS,CALC") can be compared with the available statistical data ("RBS,STAT") of the residential building stock only as regards the primary energy for space heating because of the lack of consistent statistical values for the other energy quantities (net energy need for space heating and DHW, etc.). However an important reference statistical value is available (source: ENEA): it represents the annual value of primary energy need for heating normalised to the unitary useful floor area ($Q_{H,p,RBS,STAT}$), as shown in Table 35.

Table 35. Comparison between the calculated value and the statistical data of primary energy for space heating with reference to the residential building stock of the *Middle climatic Zone*.

		ORIGINAL STATE - Comparison with statistical data of energy consumption			
		Building stock - Calculated results (RBS,CALC)		*Building stock - Corrected results to consider real operation (RBS,CORR)*	*Building stock - Statistical data (RBS,STAT)*
FREQUENCY (number of buildings)	$A_{f,n,mean}$ [m^2]	$Q_{H,p,RBS,CALC}$ [10^3 GWh]	$Q_{H,p,RBS,CALC}$ [kWh/m^2]	$Q_{H,p,RBS,CORR}$ [kWh/m^2]	$Q_{H,p,RBS,STAT}$ [kWh/m^2]
4,755,771	**1,728**	**1,223**	**149**	**96**	**111**

So the comparison has been carried out between $Q_{H,p,RBS,CALC}$ (kWh/m^2) and $Q_{H,p,RBS,STAT}$ (kWh/m^2); the former is obtained dividing the primary energy consumption of the building stock in 10^3 GWh (see also Table 34) by the total number of buildings and the useful floor area of a mean dwelling in the building stock.

The values of $Q_{H,p,RBS,CALC}$ and $Q_{H,p,RBS,STAT}$ are quite different; this is mainly due to a difference in the system operation time. In fact the calculation of the energy need for heating (according to national technical standards) has been performed considering a continuous system operation (24 hours every day), while in reality it occurs a system intermittency. In order to compare the calculated value of energy consumption and the measured one (statistical value), the calculated value was corrected applying a reduction factor according to EN ISO 13790. This factor (called $a_{H,red}$ in the technical standard) considers both the real hours of heating operation (14 hours a day for E Zone) and the seasonal heat gains to heat losses ratio and the building thermal inertia. The thermal inertia is expressed through the time constant of the building. The values of these parameters were determined considering each reference building-type. The corrected calculated value ($Q_{H,p,RBS,CORR}$) is reported in Table 35. The difference between the corrected calculated value and the statistical value can be explained considering the internal set-point temperature: the value used in the calculation is 20 °C, while the real set-point temperature is often 1.5-2 °C higher, due to thermal comfort reasons.

For each reference building-type two refurbishment measures have been considered, a standard and an advanced one, for both the building envelope and the technical systems (space heating and DHW), as described in Section 3.5.

Table 36. Calculated energy saving and CO_2 emission reduction potentials by standard refurbishment (both for the reference building-types and the residential building stock of the *Middle climatic Zone*).

			STANDARD REFURBISHMENT									
			Reference building-type (RBT)			Projection to the residential building stock (RBS)				Corrected results to consider real operation (RBS,CORR)		
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	FREQUENCY (number of buildings)	$\Delta Q_{H,p,RBT}$ [kWh/m²]	$\Delta Q_{W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,p,RBS}$ [10³ GWh]	$\Delta Q_{W,p,RBS}$ [10³ GWh]	$\Delta Q_{H,W,p,RBS}$ [10³ GWh]	$\Delta t_{CO2,RBS}$ [10⁶ t]	$\Delta Q_{H,W,p,RBS,CORR}$ [10³ GWh]	$\Delta t_{CO2,RBS,CORR}$ [10⁶ t]	Δ% savings
SFH.01	139	1,046,278	392	14.1	406	57.0	2.1	59.0	12.0	38.8	7.9	-76.7%
SFH.03	116	559,336	421	3.5	425	27.3	0.2	27.6	5.6	17.8	3.6	-80.6%
MFH.04	827	707,563	208	33.8	242	121.7	19.8	141.4	28.7	98.2	19.9	-77.2%
AB.05	2,450	869,056	183	23.6	207	389.4	50.2	439.7	89.3	301.2	61.2	-71.8%
AB.06	3,506	1,214,773	71	2.5	73	300.7	10.6	311.3	63.2	204.4	41.5	-56.1%
AB.07	2,879	358,765	43	3.5	46	44.0	3.6	47.6	9.7	32.0	6.5	-41.8%
		4,755,771				940.1	86.6	1,026.7	208.4	692.5	140.6	-65.3%

Table 37. Calculated energy saving and CO_2 emission reduction potentials by advanced refurbishment (both for the reference building-types and the residential building stock of the *Middle climatic Zone*).

			ADVANCED REFURBISHMENT									
			Reference building-type (RBT)			Projection to the residential building stock (RBS)				Corrected results to consider real operation (RBS,CORR)		
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	FREQUENCY (number of buildings)	$\Delta Q_{H,p,RBT}$ [kWh/m²]	$\Delta Q_{W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,p,RBS}$ [10³ GWh]	$\Delta Q_{W,p,RBS}$ [10³ GWh]	$\Delta Q_{H,W,p,RBS}$ [10³ GWh]	$\Delta t_{CO2,RBS}$ [10⁶ t]	$\Delta Q_{H,W,p,RBS,CORR}$ [10³ GWh]	$\Delta t_{CO2,RBS,CORR}$ [10⁶ t]	Δ% savings
SFH.01	139	1,046,278	419	24.4	443	60.9	3.5	64.4	13.1	42.8	8.7	-84.6%
SFH.03	116	559,336	455	6.4	461	29.5	0.4	29.9	6.1	19.4	3.9	-87.8%
MFH.04	827	707,563	227	34.3	261	132.6	20.1	152.7	31.0	105.5	21.4	-83.0%
AB.05	2,450	869,056	196	38.0	234	417.3	80.9	498.2	101.1	349.9	71.0	-83.4%
AB.06	3,506	1,214,773	79	8.8	88	338.2	37.5	375.6	76.3	255.4	51.9	-70.1%
AB.07	2,879	358,765	57	4.0	61	59.3	4.1	63.4	12.9	42.3	8.6	-55.3%
		4,755,771				1,037.8	146.6	1,184.3	240.4	815.4	165.5	-76.9%

The calculated energy saving potentials (primary energy) for the six refurbished reference buildings ("RBT") and for the building stock ("RBS") are shown in Table 36 and in Table 37, respectively for the standard and the advanced level of refurbishment. The CO_2 emission reducing potentials are indicated too. In order to obtain realistic values of the saving potentials (primary energy and CO_2 emissions reduction) due to the refurbishment of the residential building stock, the calculated value has been calibrated according to the real operation of the heating system ("RBS,CORR") as done for the comparison with statistical data.

The performed study has shown the high potentiality in terms of energy saving related to retrofit actions on existing buildings for the Italian *Middle climatic Zone*, grouping the highest portion of the Italian residential building stock.

In Italy in general, and in the Italian *Middle climatic Zone* in particular, the statistical distribution of the number of buildings as a function of the construction age shows a high amount of buildings dated before the emanation of energy laws: as a consequence they are characterized by low energy performance and also the application of basic energy renovations may provide significant increases of the energy performance and consequent reductions of CO_2 emissions. In fact the standard refurbishment level already shows the high potentiality of energy savings up to 80%.

The proposed methodology is an useful tool to define a clear picture for the most representative climatic zone in Italy. A possible increase of the accuracy of the results can be obtained enlarging the building-types used as a reference for the National Energy Balance: to this aim statistics at national level are required for a more detailed division of the number of buildings according to the building typology. Moreover the same methodology could be applied also to the other two Italian climatic zones (*Alpine* and *Mediterranean*).

The same approach can be also performed for a deeper analysis at Piedmont regional level where more detailed data are available for a better description of the building-type used for "Regional Energy Balance".

In general the performed study has allowed to define a clear methodology fit for National Energy Balance. The assessed energy consumptions and savings are sufficiently accurate when compared with actual energy consumptions based on National-Regional statistics.

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Nomenclature

Symbol	Quantity	Unit
A	area	[m^2]
g	total solar energy transmittance	[-]
Q	energy	[J], [Wh]
U	thermal transmittance	[W(m^2 K)]

Subscripts

del	delivered (energy)
f	floor
gl	glass
H	heating
n	net, normal (incidence)
nd	need (energy)
op	opaque (envelope)
p	primary (energy)
W	water
w	window

APPENDICES

APPENDIX I – Statistical Tables

Statistical Table	Item	Available	Remarks
S-1.1	Frequency of building types of the national building stock	yes	[1]
S-1.2.1	Percentage of thermally refurbished envelope areas	yes	[1], [2]
S-1.2.2	Information on insulation level and window types	no	
S-2.1	Centralisation of the heat supply (for space heating)	yes	[1]
S-2.2	Heat distribution and storage of space heating systems	no	
S-2.3	Heat generation of space heating systems	yes	[1]
S.2-4	Heat distribution and storage of domestic hot water systems	no	
S-2.5	Heat generation of domestic hot water systems	yes	[1]
S-2.6	Solar thermal systems	yes	[1], [3]
S-2.7	Ventilation systems	yes	[4]
S-2.8	Air-conditioning systems	no	
S-2.9	Control of central heating systems	no	

[1] Source: National Institute of Statistics (ISTAT, Report 2004).
The available statistical data are split by region in the reference source. In the statistical tables the regional data are merged considering three different groups of regions, each characterised by a range of heating degree-days (see the table below). The following criterion has been taken into account for the grouping: a region is assigned to a specific zone if it presents the highest number of municipalities having a number of heating degree-days falling in that climatic zone.

CLIMATIC ZONE	HEATING DEGREE-DAYS	ITALIAN REGIONS
Mediterranean	Up to 2100	Abruzzo, Basilicata, Calabria, Campania, Lazio, Liguria, Puglia, Sardegna, Sicilia, Toscana
Middle	From 2100 to 3000	Emilia Romagna, Friuli Venezia Giulia, Lombardia, Marche, Molise, Piemonte, Umbria, Veneto
Alpine	More than 3000	Trentino Alto Adige, Valle d'Aosta

[2] No available data on thermally refurbished envelope areas but on type of intervention for age of construction.
[3] Only for DHW, no information on heating.
[4] Source: National Energy Agency Report (ENEA, Report 2008).

Statistics S-1.1: Frequency of building types of the national building stock

MIDDLE CLIMATIC REGIONS				
Construction age	SFH 1 apartment		MFH ≥ 2 apartments	
	number of buildings	number of apartments	number of buildings	number of apartments
Before 1919	704,710	704,710	341,568	1,177,434
1919 - 1945	359,911	359,911	199,425	799,075
1946 - 1961	382,397	382,397	325,166	1,575,103
1962 - 1971	443,492	443,492	425,564	2,168,161
1972 - 1981	419,096	419,096	367,346	1,790,010
1982 - 1991	233,296	233,296	195,035	1,008,875
After 1991	191,184	191,184	167,581	902,337
TOTAL	2,734,086	2,734,086	2,021,685	9,420,995
ALPINE REGIONS				
Construction age	SFH 1 apartment		MFH ≥ 2 apartments	
	number of buildings	number of apartments	number of buildings	number of apartments
Before 1919	33,284	33,284	31,141	93,486
1919 - 1945	10,384	10,384	10,568	36,202
1946 - 1961	10,335	10,335	15,349	60,811
1962 - 1971	14,170	14,170	21,052	91,316
1972 - 1981	14,630	14,630	18,667	96,771
1982 - 1991	11,693	11,693	11,218	54,421
After 1991	11,884	11,884	10,646	49,932
TOTAL	106,380	106,380	118,641	482,939
MEDITERRANEAN REGIONS				
Construction age	SFH 1 apartment		MFH ≥ 2 apartments	
	number of buildings	number of apartments	number of buildings	number of apartments
Before 1919	710,695	710,695	328,861	1,173,958
1919 - 1945	573,539	573,539	229,988	925,858
1946 - 1961	599,961	599,961	326,621	1,705,275
1962 - 1971	632,562	632,562	431,117	2,357,682
1972 - 1981	720,282	720,282	443,185	2,102,151
1982 - 1991	551,207	551,207	288,053	1,465,302
After 1991	273,376	273,376	136,356	732,632
TOTAL	4,061,622	4,061,622	2,184,181	10,462,858

Statistics S-1.2.1: ***Percentage of thermally refurbished envelope areas***

→ Percentage of refurbished apartments

MIDDLE CLIMATIC REGIONS		
Construction age	Not refurbished apartments	Refurbished apartments
Before 1919	46.6%	53.4%
1919 - 1945	44.9%	55.1%
1946 - 1961	41.8%	58.2%
1962 - 1971	40.6%	59.4%
1972 - 1981	43.1%	56.9%
1982 - 1991	57.0%	43.0%
After 1991	77.1%	22.9%
On the whole	***47.5%***	***52.5%***
ALPINE REGIONS		
Construction age	Not refurbished apartments	Refurbished apartments
Before 1919	49.2%	50.8%
1919 - 1945	45.7%	54.3%
1946 - 1961	41.0%	59.0%
1962 - 1971	39.7%	60.3%
1972 - 1981	44.0%	56.0%
1982 - 1991	59.4%	40.6%
After 1991	69.9%	30.1%
On the whole	***48.6%***	***51.4%***
MEDITERRANEAN REGIONS		
Construction age	Not refurbished apartments	Refurbished apartments
Before 1919	56.1%	43.9%
1919 - 1945	56.9%	43.1%
1946 - 1961	53.7%	46.3%
1962 - 1971	52.1%	47.9%
1972 - 1981	55.3%	44.7%
1982 - 1991	64.4%	35.6%
After 1991	76.3%	23.7%
On the whole	***57.2%***	***42.8%***

→ Percentage of refurbishment types

MIDDLE CLIMATIC REGIONS			
Construction age	Refurbishment on technical systems	Refurbishment on structural elements	Refurbishment on no-structural elements
Before 1919	47.2%	15.3%	37.5%
1919 - 1945	49.1%	12.4%	38.5%
1946 - 1961	52.0%	8.8%	39.2%
1962 - 1971	53.1%	7.6%	39.3%
1972 - 1981	54.8%	7.0%	38.2%
1982 - 1991	54.3%	7.8%	37.9%
After 1991	42.2%	18.5%	39.3%
On the whole	***51.5%***	***9.9%***	***38.6%***
ALPINE REGIONS			
Construction age	Refurbishment on technical systems	Refurbishment on structural elements	Refurbishment on no-structural elements
Before 1919	43.2%	17.6%	39.2%
1919 - 1945	45.2%	13.9%	40.9%
1946 - 1961	47.1%	10.3%	42.6%
1962 - 1971	47.6%	9.1%	43.3%
1972 - 1981	48.2%	8.5%	43.3%
1982 - 1991	47.3%	9.7%	43.0%
After 1991	38.4%	24.1%	37.5%
On the whole	***45.7%***	***12.7%***	***41.6%***
MEDITERRANEAN REGIONS			
Construction age	Refurbishment on technical systems	Refurbishment on structural elements	Refurbishment on no-structural elements
Before 1919	45.4%	13.9%	40.7%
1919 - 1945	46.8%	10.9%	42.3%
1946 - 1961	49.1%	7.5%	43.4%
1962 - 1971	50.8%	6.4%	42.8%
1972 - 1981	51.2%	6.6%	42.2%
1982 - 1991	49.8%	7.6%	42.6%
After 1991	43.2%	15.7%	41.1%
On the whole	***49.0%***	***8.6%***	***42.4%***

Statistics S-2.1: Centralisation of the heat supply (for space heating)

	MIDDLE CLIMATIC REGIONS	***ALPINE REGIONS***	***MEDITERRANEAN REGIONS***
Central heating system for several dwellings	24.2 %	37.3 %	14.0 %
Individual heating system for a single dwelling	59.8 %	36.0 %	54.1 %
Single heating devices for dwelling as a whole	6.4 %	10.2 %	11.8 %
Single heating devices for part of dwelling	9.6 %	16.5 %	20.1 %

Statistics S-2.3: Heat generation of space heating systems

MIDDLE CLIMATIC REGIONS	**Liquid or gaseous fuel**	**Solid fuel**	**Electricity**	**Fuel oil**	**Other fuel or energy**
Central heating system for several dwellings	89.3 %	3.14 %	0.80 %	1.35 %	5.41 %
Individual heating system for a single dwelling	88.0 %	10.6 %	0.99 %	0.06 %	0.35 %
Single heating devices for dwelling as a whole	54.1 %	40.5 %	4.00 %	0.20 %	1.20 %
Single heating devices for part of dwelling	50.8 %	44.8 %	3.20 %	0.20 %	1.00 %
On the whole	***81.0 %***	***15.5 %***	***1.46 %***	***0.40 %***	***1.64 %***

ALPINE REGIONS	**Liquid or gaseous fuel**	**Solid fuel**	**Electricity**	**Fuel oil**	**Other fuel or energy**
Central heating system for several dwellings	76.7 %	15.8 %	0.80 %	2.20 %	4.50 %
Individual heating system for a single dwelling	72.9 %	23.6 %	1.00 %	0.45 %	2.05 %
Single heating devices for dwelling as a whole	36.8 %	52.5 %	4.50 %	1.20 %	5.00 %
Single heating devices for part of dwelling	39.9 %	51.80 %	3.50 %	0.90 %	3.90 %
On the whole	***63.5 %***	***29.9 %***	***1.81 %***	***1.20 %***	***3.59 %***

MEDITERRANEAN REGIONS	Liquid or gaseous fuel	Solid fuel	Electricity	Fuel oil	Other fuel or energy
Central heating system for several dwellings	92.8 %	3.75 %	1.70 %	0.70 %	1.05 %
Individual heating system for a single dwelling	86.9 %	9.76 %	2.64 %	0.08 %	0.62 %
Single heating devices for dwelling as a whole	38.5 %	42.5 %	17.5 %	0.20 %	1.30 %
Single heating devices for part of dwelling	34.4 %	43.7 %	20.7 %	0.14 %	1.06 %
On the whole	***69.7 %***	***20.8 %***	***8.44 %***	***0.20 %***	***0.86 %***

Statistics S-2.5: Heat generation of domestic hot water systems

	MIDDLE CLIMATIC REGIONS	*ALPINE REGIONS*	*MEDITERRANEAN REGIONS*
Dwellings without hot water system	1.10 %	3.00 %	1.60 %
Dwellings with hot water system - heating and hot water generated by the same system	67.9 %	73.6 %	54.2 %
Dwellings with hot water system - hot water generated by system different from heating system	31.0 %	23.4 %	44.2 %

Statistics S-2.6: Solar thermal systems

		MIDDLE CLIMATIC REGIONS	*ALPINE REGIONS*	*MEDITERRANEAN REGIONS*
Dwellings with hot water system - hot water generated by system different from heating system	Electricity system	30.6 %	52.3 %	72.0 %
	Solar thermal system	0.40 %	4.70 %	0.50 %
	Other system type	69.0 %	43.0 %	27.5 %

Statistics S-2.7: Ventilation systems

Less than 1% of the buildings are equipped with mechanical ventilation system.

APPENDIX II – Sample Brochure

Example of display sheets for a building-type in the Italian "Building Typology Brochure".

Regione/Zona climatica: Area climatica media

Classe di epoca di costruzione: 1 (fino al 1900)

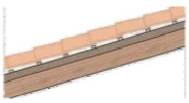
Classe di dimensione edilizia: Edificio multifamiliare

V [m³]	*S/V* [m⁻¹]	$A_{f,l}$ [m²]	Numero di appartamenti	Numero di piani climatizzati
2684	0,55	647	5	2

STATO ORIGINARIO

TIPOLOGIA COSTRUTTIVA

COPERTURA



Tetto a falde con struttura e tavolato in legno [sottotetto non climatizzato]

PARETE

Muratura di pietra listata con mattoni (60 cm)

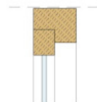
SOLAIO (superiore, verso ambiente non riscaldato)

Solaio a volte in laterizio

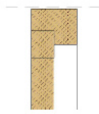
SOLAIO (inferiore, su ambiente non riscaldato)

Solaio a volte in laterizio

SERRAMENTI



1. Vetro singolo, telaio in legno



2. Porta in legno

COPERTURA	PARETE	SOLAIO (superiore)	SOLAIO (inferiore)	SERRAMENTI			
U [W/(m²K)]	*U* [W/(m²K)]	*U* [W/(m²K)]	*U* [W/(m²K)]	U_1 [W/(m²K)]	$g_{gl,n1}$ [-]	U_2 [W/(m²K)]	$g_{gl,n2}$ [-]
1,80	1,19	2,07	1,58	4,90	0,85	3,00	-

TIPOLOGIA IMPIANTISTICA

IMPIANTO DI RISCALDAMENTO

GENERAZIONE	$\eta_{H,gn}$ = 0,71	*ACCUMULO*	$Q_{ls,H,s}$ = 0 kWh/m²	*DISTRIBUZIONE*	$\eta_{H,d}$ = 0,81	*AUSILIARIO*	$Q_{aux,H}$ = 1,7 kWh/m²
caldaia standard (gas), bruciatore atmosferico, installata in ambiente non climatizzato, camino > 10 m, antecedente al 1996		-		distribuzione centralizzata a colonne montanti verticali, collegamenti orizzontali in ambienti non riscaldati (es. cantina o terreno) / fino al 1960		pompa di circolazione per impianto centralizzato - ausiliario elettrico per caldaia standard con bruciatore atmosferico	

IMPIANTO DI PRODUZIONE DI ACQUA CALDA SANITARIA

GENERAZIONE	$\eta_{W,gn}$ = 0,77	*ACCUMULO*	$Q_{ls,W,s}$ = 0 kWh/m²	*DISTRIBUZIONE*	$Q_{ls,W,d}$ = 1,02 kWh/m²	*AUSILIARIO*	$Q_{aux,W}$ = 0 kWh/m²
caldaia standard a gas per per la produzione istantanea di acqua calda sanitaria, a camera aperta senza pilota permanente		-		distribuzione di acqua calda sanitaria separata per appartamento, senza ricircolo - fino al 1975		produzione di ACS per appartamento o separata/individuale	

RIQUALIFICAZIONE STANDARD

INTERVENTI SULL'INVOLUCRO

ELEMENTO	U_{ex} W/(m^{2}K)	U_{new} W/(m^{2}K)	TIPO DI INTERVENTO
COPERTURA	1,80	0,80	Inserimento isolante (3 cm)
PARETE	1,19	0,33	Inserimento isolante (9 cm)
SOLAIO (superiore)	2,07	0,30	Inserimento isolante (11 cm)
SOLAIO (inferiore)	1,58	0,30	Inserimento isolante (11 cm)
SERRAMENTI	4,90 ($g_{gl,n}$ 0,85) 3,00	2,00 ($g_{gl,n}$ 0,67) 2,00	Sostituzione

INTERVENTI SUGLI IMPIANTI

RISCALDAMENTO

GENERAZIONE $\eta_{H,gn}$ = 0,98	*ACCUMULO* $Q_{ls,H,s}$ = 0 kWh/m^2	*DISTRIBUZIONE* $\eta_{H,d}$ = 0,93	*AUSILIARIO* $Q_{aux,H}$ = 2,6 kWh/m^2
caldaia a condensazione, installata in centrale termica	-	distribuzione centralizzata a colonne montanti verticali, collegamenti orizzontali in ambienti non riscaldati (es. cantina o terreno) / livello di isolamento elevato	pompa di circolazione per impianto centralizzato - ausiliario elettrico per caldaia a condensazione

ACQUA CALDA SANITARIA

GENERAZIONE $\eta_{W,gn}$ = 0,90	*ACCUMULO* $Q_{ls,W,s}$ = 0 kWh/m^2	*DISTRIBUZIONE* $Q_{ls,W,d}$ = 0,68 kWh/m^2	*AUSILIARIO* $Q_{aux,W}$ = 0 kWh/m^2
caldaia a condensazione a gas per la produzione di acqua calda sanitaria	-	distribuzione di acqua calda sanitaria separata per appartamento, senza ricircolo - dopo il 1975	produzione di ACS per appartamento o separata/individuale

RIQUALIFICAZIONE AVANZATA

INTERVENTI SULL'INVOLUCRO

ELEMENTO	U_{ex} W/(m^{2}K)	U_{new} W/(m^{2}K)	TIPO DI INTERVENTO
COPERTURA	1,80	0,80	Inserimento isolante (3 cm)
PARETE	1,19	0,25	Inserimento isolante (13 cm)
SOLAIO (superiore)	2,07	0,23	Inserimento isolante (15 cm)
SOLAIO (inferiore)	1,58	0,23	Inserimento isolante (15 cm)
SERRAMENTI	4,90 ($g_{gl,n}$ 0,85) 3,00	1,70 ($g_{gl,n}$ 0,50) 1,70	Sostituzione

INTERVENTI SUGLI IMPIANTI

RISCALDAMENTO

GENERAZIONE *COP* = 3	*ACCUMULO* $Q_{ls,H,s}$ = 0,8 kWh/m^2	*DISTRIBUZIONE* $\eta_{H,d}$ = 0,94	*AUSILIARIO* $Q_{aux,H}$ = 1,6 kWh/m^2
pompa di calore geotermica	serbatoio di accumulo di acqua calda per riscaldamento centralizzato - alto livello di isolamento	distribuzione centralizzata a colonne montanti verticali, collegamenti orizzontali in ambienti non riscaldati (es. cantina o terreno) / livello di isolamento elevato	pompa di circolazione per impianto centralizzato

ACQUA CALDA SANITARIA

GENERAZIONE *COP* = 3	*ACCUMULO* $Q_{ls,W,s}$ = 2,1 kWh/m^2	*DISTRIBUZIONE* $Q_{ls,W,d}$ = 2,39 kWh/m^2	*AUSILIARIO* $Q_{aux,W}$ = 2 kWh/m^2
pompa di calore geotermica	serbatoio di accumulo per produzione centralizzata di ACS, in ambiente non climatizzato - alto livello di isolamento	distribuzione di ACS centralizzata con ricircolo, porzione di rete affacciata all'esterno, dopo il 1991	produzione di ACS centralizzata con pompa di circolazione

PRESTAZIONE ENERGETICA

	Stato originario (SO)	Riqualificazione standard (RS)	Riqualificazione avanzata (RA)
$Q_{H,nd}$ [kWh/m^2]	250	64,1	49,0
$Q_{W,nd}$ [kWh/m^2]	16,1	16,1	16,1
$Q_{H,p}$ [kWh/m^2]	438	76,1	41,9
$Q_{W,p}$ [kWh/m^2]	22,2	18,6	19,2
$Q_{H,W,p}$ [kWh/m^2]	460	94,7	61,1