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STIMULATE ENERGY RENOVATION OF THE BUILDING STOCK: POLICIES AND TOOLS AT MUNICIPAL SCALE

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LIST OF ABBREVIATIONS

AEEG	Autorità per l'energia elettrica il gas ed il sistema idrico	Italian Regulatory Authority for Electricity Gas and Water
AIRU	Associazione Italiana Riscaldamento Urbano	National Association Urban Heating
ANCE	Associazione Nazionale Costruttori Edili	
ANCI	Associazione Nazionale Comuni Italiani	national association of municipalities
ARPA	Agenzia Regionale per la Protezione dell'Ambiente	
BEN	Bilancio Energetico Nazionale	National Energy Balance
BPIE	Buildings Performance Institute Europe	
CAT	National Building & Land Cadaster	
CEER	Catasto Energetico Edifici Regionale	Regional Register fo EPC (Lombardy)
CoM	European Covenant of Mayors	
CTI	Comitato Termotecnico Italiano	Italian Thermotechnical Committee
CURIT	Catasto Unico Regionale degli Impianti Termici	Regional Heating Systems Register (Lombardy)
DBTR	DataBase Topografico Regionale	Regional Topographic database
EED	Energy Efficiency Directive	
ENEA	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
EPBD	Energy Performance of Buildings Directive	
EPC	Energy Performance Certificate	
Ep_h	Primary Energy for Heating	
ESCo	Energy Saving Company	
EU	European Union	
FIRE	Federazione Italiana per l'uso Razionale dell'Energia	Italian federation for energy efficiency
GHG	GreenHouse Gases	
GIS	Geographical Information System	
GSE	Gestore Servizi Energetici	Energy Services Operator
HDD	Heating Degree Days	
INEMAR	INventario EMissioni ARia	Inventory of atmospheric emissions
INSPIRE	Infrastructure for Spatial Information in the European Community	
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale	Institute for Environmental Protection and Research
ISTAT	Istituto nazionale di statistica	National Institute of Statistics
JRC	Joint Research Centre	

LEP	Local Energy Plan	
LOD	Level Of Detail	
MATTM	Ministero dell'Ambiente e della Tutela del Territorio e del Mare	Ministry of the Environment
MEM	Municipal Energy Model	
MiSE	Ministero Sviluppo Economico	Ministry of Economic Development
nZEB	nearly Zero Energy Building	
OMI	Osservatorio del Mercato Immobiliare	observatory of the real estate market
PA	Public Administration	
PAEE	Piano d'Azione italiano per l'Efficienza Energetica	National Actiona Plan
PANZEB	Piano d'azione nazionale per l'incremento degli edifici a energia quasi zero	National action plan for the increase of nearly zero energy buildings
RES	Renewable Energy Sources	
RNDT	Repertorio Nazionale dei Dati Territoriali	National Registry of Spatial Data
RSE	Ricerca sul Sistema Energetico	Research on Energy System
RSG	Registro regionale delle Sonde Geotermiche	Regional Register of Geothermal heat pump
SEAP	Sustainable Energy Action Plan for CoM	
SEN	Strategia Energetica Nazionale	National Energy Strategy
SIAPE	Sistema Informativo sugli Attestati di Prestazione Energetica	Information system for EPCs
SIRENA	Sistema Informativo Regionale ENergia e Ambiente	Regional Informative System for Environment and Energy
Sistan	Sistema statistico nazionale	National Statistical System
STREPIN	Strategia per la riqualificazione energetica del parco immobiliare nazionale	Strategy for energy refurbishment of the national building stock
TOE	Tonne of Oil Equivalent	

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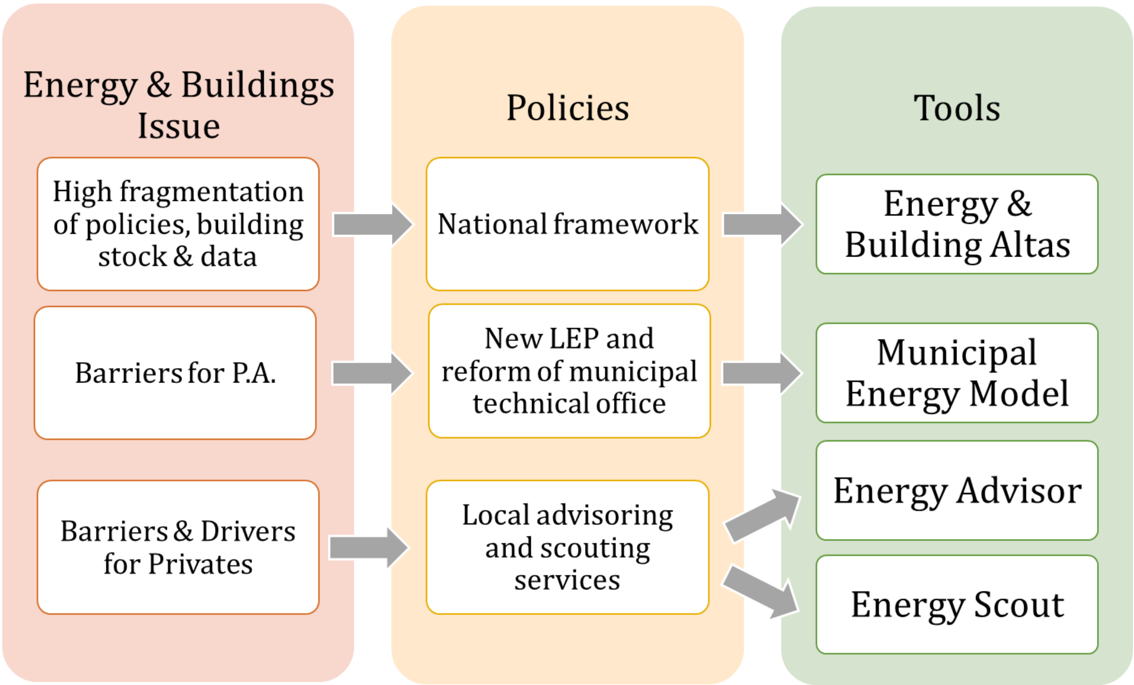
ABSTRACT

The climate change and the linked energy issue must be tackled both at the global and local scale. In Europe and Italy, one of the major sink for potential energy savings is in buildings, but this sink is far from being fully exploited. A widespread retrofit strategy is needed to drastically decrease the energy demand in the existing buildings and improve energy systems towards more sustainable paradigms. To that end, a proactive role of the local authorities and effective municipal energy plans are necessary.

Scheme of the energy & buildings issue and proposals



The research has identified three main points to be addressed: the high fragmentation regarding the energy & buildings issue in terms of policies, building stock & data; the presence of barriers for the public administration (PA) to develop an effective local energy plan (LEP); the presence of barriers and drivers that influence the decisions of private building's owners.

In order to stimulate the energy renovation of the building stock the proposal consist of three main policies, supported by dedicated tools.

At national level, it is necessary to develop a structured framework, including a national data collection that gather and organize the information about the energy & buildings issue. An example of georeferenced database of information with a level of detail of the single municipality is the Energy & Buildings Atlas, developed within the Atlas of Post-Metropolitan Territories project.

To overcome the barriers for the local PA it is important to enhance its energy competencies and develop for each municipality a new model of LEP, with the support of a Municipal Energy Model (MEM) that gather energy information for each building in the municipality.

At local level, it is necessary to engage building owners, building managers, companies in the energy-building sector and investors. The new energy office could provide innovative services to these actors, supported by two tools based on data contained in MEM:

- Energy Advisor, a tool designed to advise building owners and managers;
- Energy Scout, designed to help companies in the energy and building sector and investors to find work opportunities.

In addition to geometric and energy features of the building stock, the Energy Scout shows indicators for non-technological barriers and drivers to the implementation of energy measures on private buildings. It is thus possible to localize buildings that seem most promising for an actual realization of energy measures.

The proposed methodology was tested on an Italian medium-sized municipality, using maps and databases that are or will be available for each Italian municipality.

To pursue these objectives, this dissertation is structured as follows. Chapter 1 analyses the Energy and Buildings issue, with a focus on the Italian context. Chapter 0 analyses the actual strategies, approaches and tools to the energy renovation of the building stock. Chapter 3 presents a data collection framework and an analysis of Italian data sources for the energy and buildings issue. Chapter 4 presents an analysis of the barriers to local energy planning for the public administrations and the analysis of the barriers and drivers for the private actors in the Italian context. Chapter 5 proposes policies and tools to foster more effective local energy plan and stimulate the adoption of energy measures on the building stock. Chapter 6 explains the application of the proposed tools to an Italian municipality and the methods adopted to elaborate data and overcome flaws. Finally, Chapter 7 draws up the conclusions of this work and suggestion for future research.

1 ENERGY AND BUILDINGS ISSUE

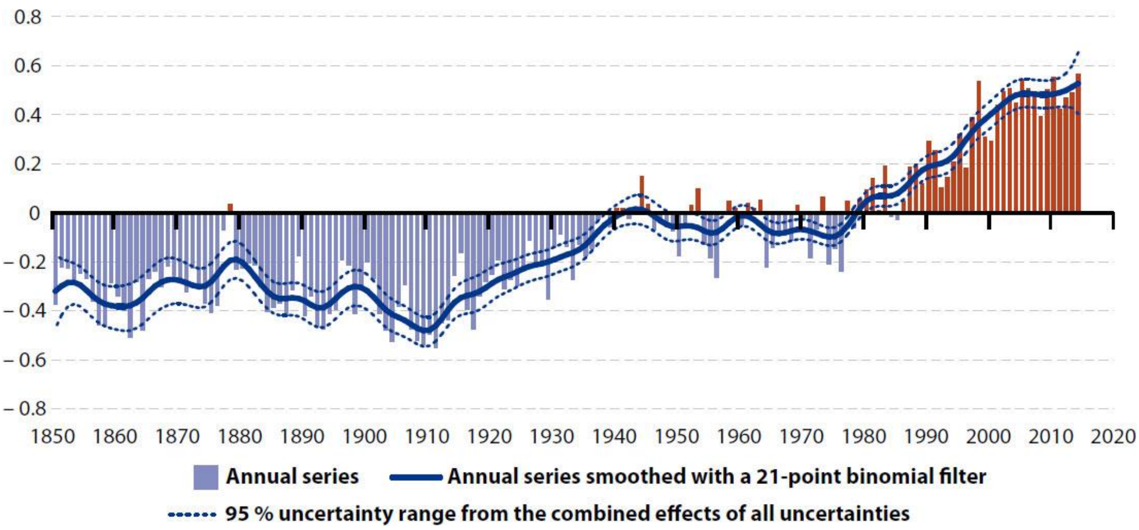
This Chapter introduces the energy issue and the important role of buildings. Since the research focuses on Italy, key data about municipalities and the building stock are reported here. Finally, the Chapter provides a brief reminder and analysis of the energy potential of the building stock.

1.1 ENERGY ISSUE AND THE ROLE OF BUILDINGS

The climate change is not only an environmental concern, because its effects impact on the economic system and, especially in the already vulnerable region, could lead to scarce food supplies, fresh water shortage and extreme natural disaster.

The global annual mean temperature is rising (see Figure 1.1) and in 2015 we will reach 1°C above pre-industrial for the first time[1]: an alerting sign because global warming should be kept below 2°C to avoid dangerous effects of climate change. An historical agreement has been reached in December 2015: the United Nations Framework Convention on Climate Change (COP21)[2] adopted the Paris climate agreement to aim at keeping the global warming under 1.5 °C increase. Actions should follow this agreement: 186 out of 195 countries had already set out a roadmap to limit the effects of global warming, but these plans have to be checked and put in practice.

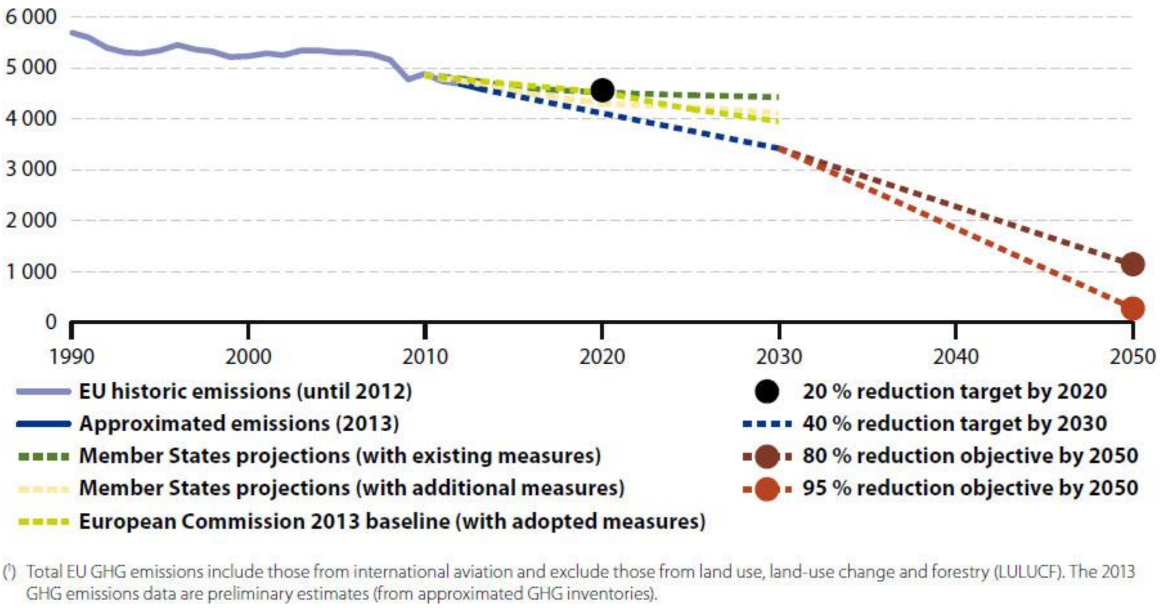
Figure 1.1 Global annual mean temperature deviations, 1850–2014 (temperature deviation in °C, compared with 1961–1990 average) - Source: Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia, HadCRUT4



[1] November 2015, HadCRUT4 dataset by the Met Office and the Climatic Research Unit at the University of East Anglia

[2] http://www.cop21.gouv.fr/en/

Figure 1.2 Greenhouse gas emissions and projections, 1990–2050 (million tonnes of CO2 equivalents) - Source European Environment Agency



Even if the greenhouse gas (GHG) emissions are decreasing (see Figure 1.2), the adopted measures are not enough and the European Union (EU) decided to achieve tighter targets in 2030 and 2050. The EU has approved the "Roadmap for moving to a competitive low carbon economy in 2050" (EU COM 112/2011) with the objective to reduce greenhouse gas emissions by 80-95% by 2050 in comparison to those of 1990. The two most important sources of emissions are the transport and the energy sector (Figure 1.3).

The energy issue could be tackled with a threefold strategy:

- Reduction of energy demand (energy efficiency);
- Optimization of energy generation and management;
- Use of low carbon energy source (renewables).

The energy supply and consumption affect also the national security and the competiveness of the economy. In Europe the energy dependency rate[3] is quite high (53.2% in 2013) and in Italy is even higher (76.9% in 2013). Also because of this dependence, the energy price are relatively high in Europe, however, since there are an historical condition, the EU industry has so far also responded to the persistently higher energy prices through the realisation of significant improvements in the use of energy as reflected in a secular decline in its energy intensity (EU Commission 2014). In fact, the average European energy intensity of the economy is quite low, with Ireland, Denmark, United Kingdom and Italy having the best economy's energy efficiency in 2013 (see Figure 1.4).

Looking at the energy consumption per sector in Europe (Figure 1.5), private households, commerce, public administration and services consume 41% of the final energy consumption. Then follows the transport sector, with 32% of energy consumption and the industry sector – with the exclusion of the energy sector – with 25%. In Italy (Figure 1.6) the figures are similar and it should be noted that the energy consumed by the buildings is

[3] Source: Eurostat (Dataset: tsdcc310)

constantly increasing, while it is the industry that really decrease its energy consumption with a peak in 2009 due to the economic crisis.

Figure 1.3 Greenhouse gas emissions, by source sector, EU-28, 1990 and 2012 (percentage of total) Source: Eurostat (dataset: env_air_gge), European Energy Agency, European Topic Centre on Air and Climate

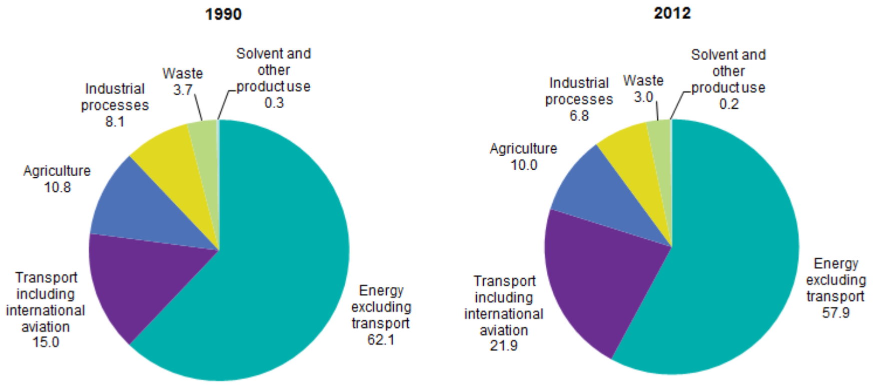


Figure 1.4 Energy intensity of the economy, 2003 and 2013 (kg of oil equivalent per thousand EUR of GDP) Source: Eurostat (dataset: tsdec360)

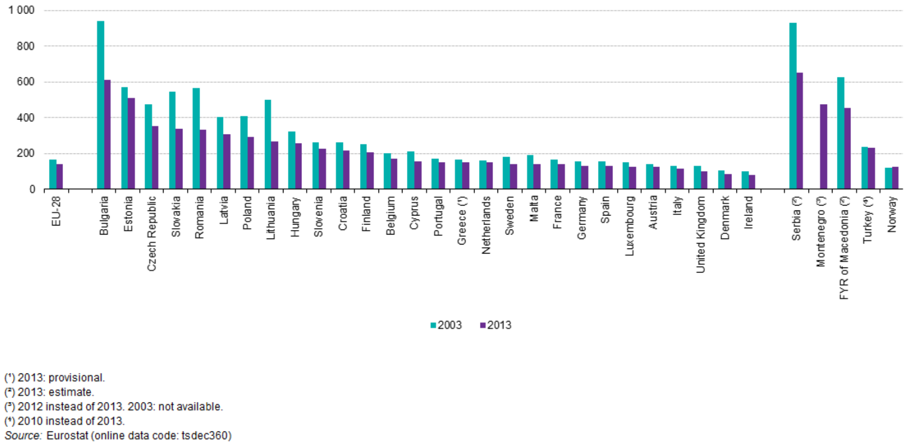
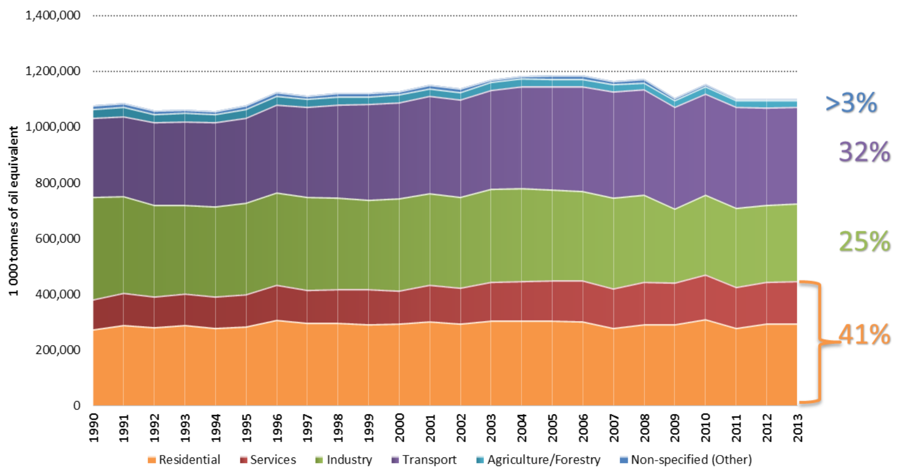


Figure 1.5 Final energy consumption by sector in EU (28 countries). Own elaboration, data source Eurostat (dataset: tsdpc320)



As assessed by Buildings Performance Institute Europe - BPIE (see Figure 1.7), the energy consumption in the residential sector is strongly correlated with the Actual Heating Degree Days (HDD): mild winters lead to minor energy consumption. In contrast, the electricity consumption is constantly rising over time; this is ever higher in non-residential buildings where electricity consumption has increased by a remarkable 74% over the last 20 years (BPIE 2011).

The energy mix in households (Figure 1.8) shows that the Italian housing sector is highly dependent on gas, compared with the average European value. However, it has a high share of RES, which increased significantly in recent years (Figure 1.9). In the residential sector more than two third of the energy consumption is for heating and the remaining third is split among electrical appliance (13.5%), cooking and domestic hot water (16.5%) (Odyssee, 2012).

Figure 1.6 Final energy consumption by sector in Italy. Own elaboration, data source Eurostat (dataset : tsdpc320)

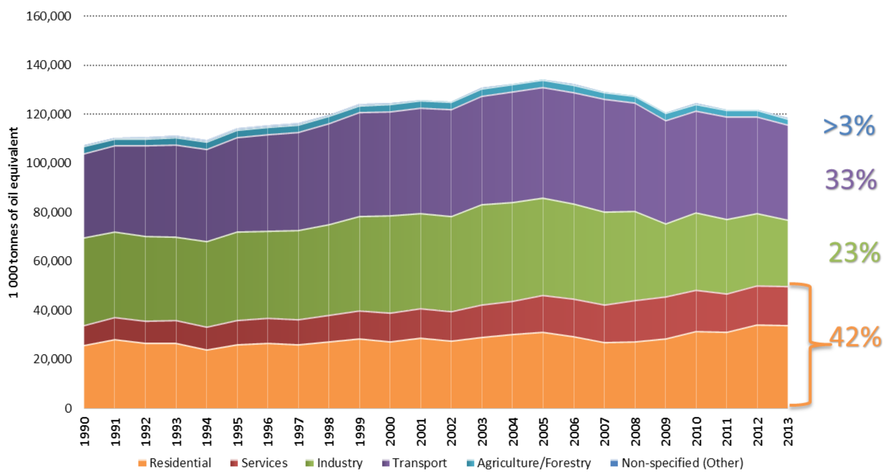


Figure 1.7 Historical final energy use in the residential sector in EU27, Norway and Switzerland. BPIE 2011

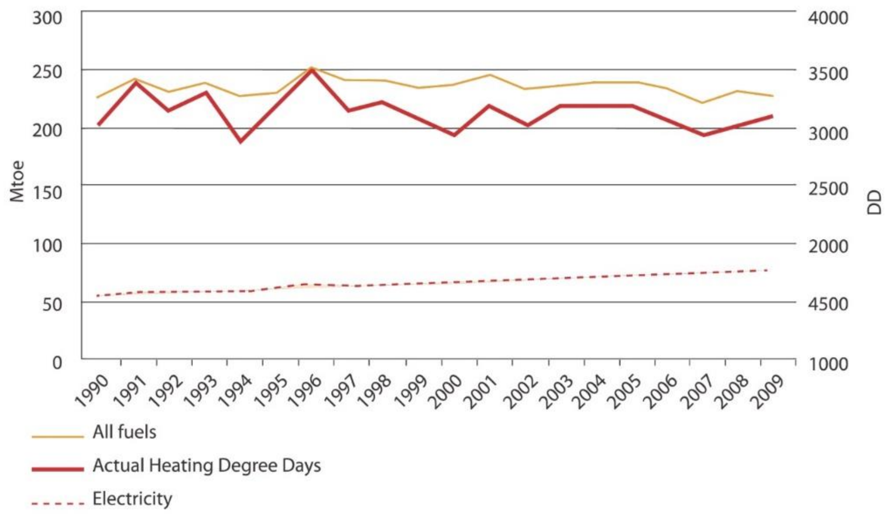


Figure 1.8 Final energy consumption in households by fuel. Own elaboration, source Eurostat (dataset: t2020_rk210)

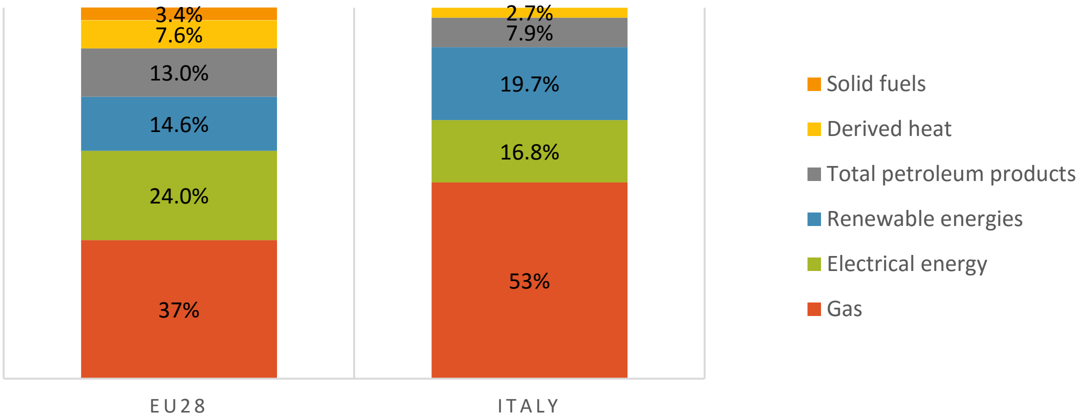
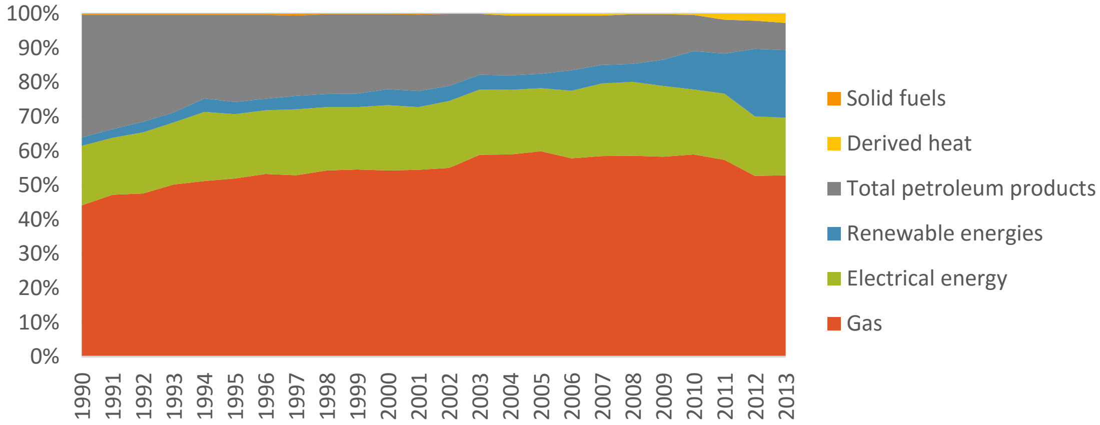


Figure 1.9 Final energy consumption in households by fuel in Italy over time. Own elaboration, source Eurostat (dataset: t2020_rk210)



1.2 ITALIAN KEY DATA ABOUT ENERGY & BUILDINGS ISSUE

To address the energy & buildings issue the role of the local administration is fundamental, thus this section gives a brief overview of the key data regarding Italian municipalities. Then follows the composition and features of the Italian building stock.

1.2.1 Italian municipalities

The Italian territory is quite varied in terms of climate, due to the extension in latitude, the varied orography and the influence of the sea and the Alps, and inhabited zones goes from Pantelleria, with semi-arid climate (Bsh) to Sestriere with subarctic climate (Dfc). Looking at the HDD in Table 1.1, we can see that a large share of Italians lives into the climatic zone "E", which corresponds to Cfa and Cfb according to Köppen climate classification.

In Italy, there are 8,092 municipalities[4], which are not homogeneous in land area or in number of inhabitants or dwellings. The demographic class of the municipality affects many environmental, economic and social aspects, i.e. the morphology of the urban space, the

[4] Data regarding municipalities and their buildings here presented derived from the National Census held in 2001 by the National Institute of Statistics (ISTAT).

features of the buildings stock, the regulatory framework related to the built environment and the human and economic resources available at the administrative level for the technical offices.

There are no established demographic class to define municipalities, for the purposes of the research it is useful to follows the demographic classes by the national association of municipalities (ANCI), integrated with thresholds linked to the following energy policies (see Chap. 0 for details):

- 10,000 inhabitants is linked to obligation to appoint the Energy Manager;
- 50,000 inhabitants is linked to obligation to produce a municipal energy plan.

Table 1.1 Number of municipalities and population per climatic zone and heating degree days (HDD). STREPIN 2015

climatic zone	HDD	no. municipalities	population	population %
A	HDD≤ 600	2	22,989	0.04%
B	600 <HDD ≤ 900	157	3,176,382	5.33%
C	900 <HDD ≤ 1,400	989	12,657,407	21.25%
D	1,400 <HDD ≤ 2,100	1,611	14,970,952	25.13%
E	2,100 <HDD ≤ 3,000	4,271	27,123,848	45.53%
F	HDD>3,000	1,071	1,619,003	2.72%

Figure 1.10 Number of municipalities per demographic class. Data from ISTAT 2011

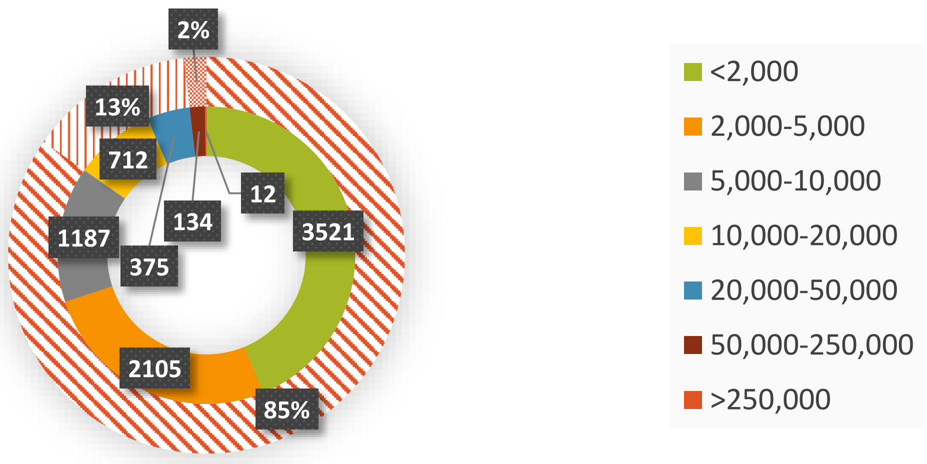


Figure 1.11 Surface of municipalities per demographic class. [thousand km²]. Data from ANCITEL 2015

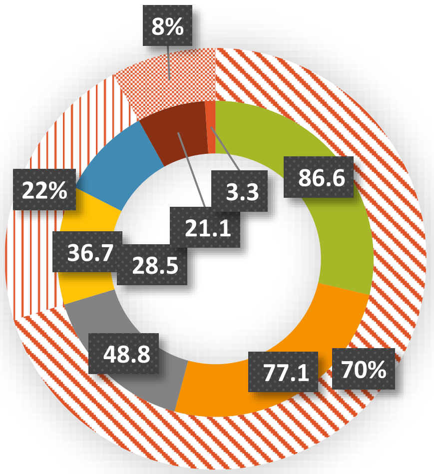
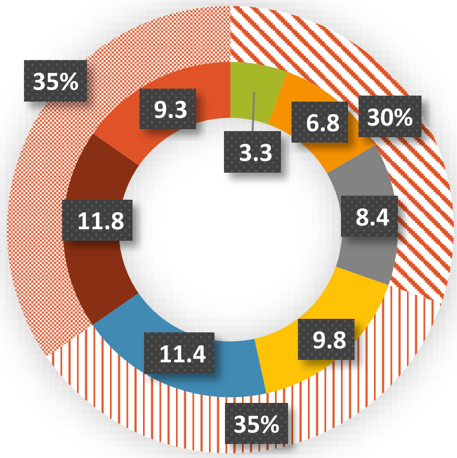


Figure 1.12 Number of inhabitants [millions] per demographic class. Source: Data from ISTAT 2015



The vast majority (85%) of the Italian municipalities has a small or very small demographic class (up to 10,000); medium-sized municipalities (10,000 to 50,000) account for 13% and only 142 municipalities are large, with more than 50.000 inhabitants, as shown in Figure 1.10. Small municipalities administer 70% of the Italian territory, medium ones 22% and large 8%, as shown in Figure 1.11. Population is split approximately into thirds into the small, medium and large classes, as shown in Figure 1.12. As could be seen in Figure 1.13, the population density increase with the increasing of the demographic class. For Italy the average value is 201 inh./km², and only in very large municipality the value is quite high and reaches about 2,835 inh/km².

It should be noted that demographic class of the municipality affects the number and competencies of the municipal employees. The number of municipal employees (Table 1.2) is bigger than the average for very small and for large municipalities the rate. The higher the municipal class the more the educational qualification of employees (Table 1.3). As regards competencies, municipalities in Italy can organize autonomously their offices. The only mandatory offices are: Registry, Civil Status, Electoral, Military Conscription and Statistics Service (limited to answer requests from ISTAT, the national institute of statistics). Typically, other services are: fiscal and tax department; local police; technical office; and other administrative services. Focusing on energy competencies, in municipalities with more than 10,000 inhabitants the figure of Energy Manager is mandatory and in municipalities with more than 50,000 inhabitants the municipal energy plan in mandatory (see Chapter 2 for details). These obligations should lead to energy competencies, regrettably these measures are scarcely applied.

A factor that may influence the private investments on the building stock is the average income. As could be seen in Figure 1.14, the average income increases with the increasing of the demographic class of the municipalities.

As a result, the Italian territory is highly fragmentized in climate, administration and population. This high fragmentation should be taken into account when addressing the energy & buildings issue and when comparing municipalities.

Figure 1.13 Population density per demographic class. Data from Ancitel 2015

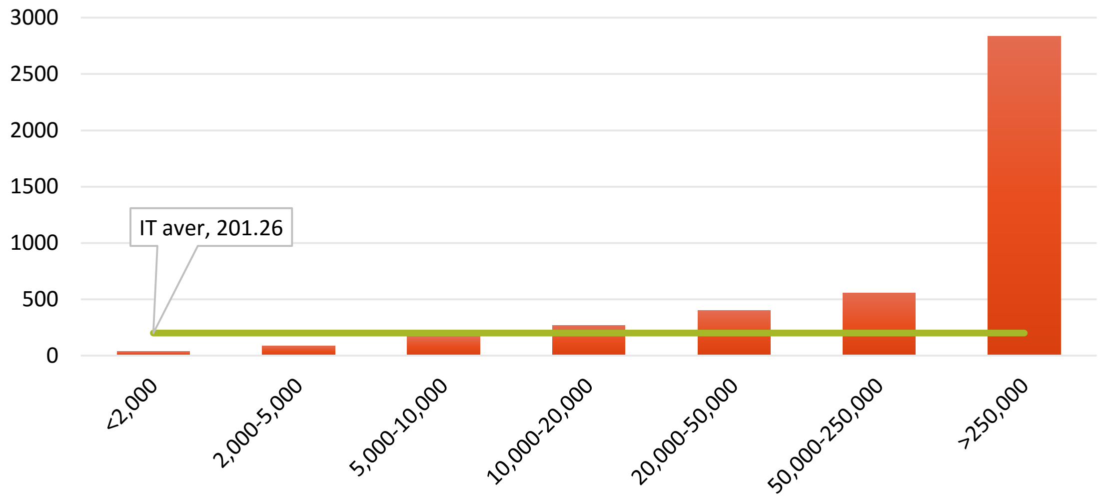


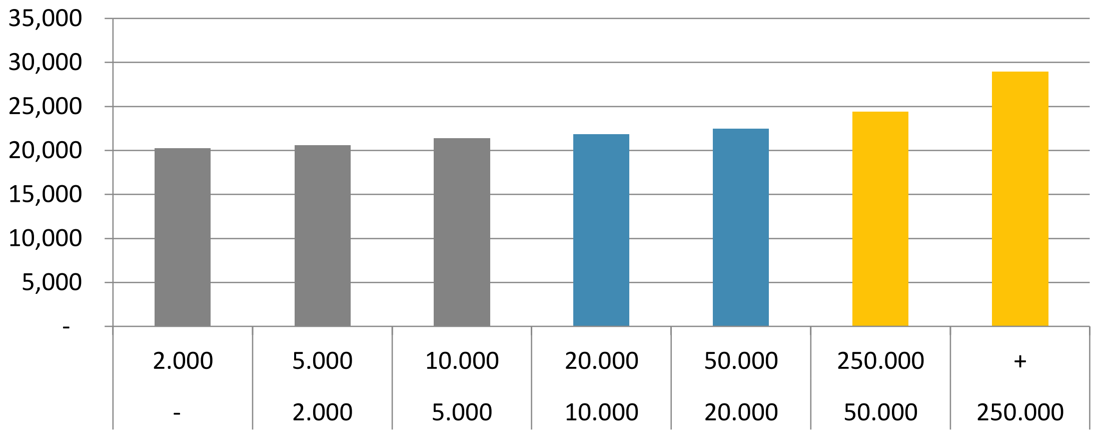
Table 1.2 Number of municipal employees. Elaboration IFEL 2015

demographic class	**no. municipal employees**	
	tot.	*Per 1,000 inhabitants*
0 - 1,999	27,132	8.21
2,000 - 4,999	43,052	6.28
5,000 - 9,999	46,988	5.64
10,000 - 19,999	55,366	5.65
20,000 - 59,999	79,925	5.88
60,000 - 249,999	69,477	7.3
>=250.000	96,101	10.36
total	**418,041**	**6.89**

Table 1.3 Educational degree of permanent staff. Data IFEL 2015

demographic class	**middle school**	**high school**	**Bachelor**	**Master**	**PhD**	**other post-graduate**	**lower education**	**higher education**
0 - 1,999	31.3%	57.2%	1.5%	9.9%	0.1%	0.1%	88.5%	11.6%
2,000 - 4,999	28.3%	57.1%	1.5%	12.8%	0.1%	0.1%	85.4%	14.5%
5,000 - 9,999	26.0%	56.1%	1.7%	15.8%	0.2%	0.2%	82.1%	17.9%
10,000 - 19,999	25.3%	55.0%	1.7%	17.2%	0.3%	0.5%	80.3%	19.7%
20,000 - 59,999	26.4%	54.4%	1.4%	17.0%	0.3%	0.5%	80.8%	19.2%
60,000 - 249,999	24.9%	54.8%	2.2%	17.2%	0.5%	0.4%	79.7%	20.3%
>=250.000	21.5%	60.6%	2.8%	13.9%	1.2%	0.02%	82.1%	17.9%

Figure 1.14 Average taxable income (IRPEF) per demographic class. Data from MiSE, 2010



1.2.2 Italian building stock

Residential buildings are prevalent in the composition of the Italian building stock, and this is also reflected by the availability and quality of data. ISTAT collects data about the number of buildings and complexes of buildings per use, but does not provide any other data about non-residential buildings. Statistic based upon the Building's Cadastre are published annually by the Revenue Agency; unfortunately, since the scope of the Building's Cadastre is to keep track of the economic value of the building stock, these statistics contain the number of building units[5] and not the number of buildings. For some categories, however, the Revenue Agency calculate an estimate of the floor area.

- In Italy there is not a complete database about the building stock, with data about number of buildings, floor area, energy performance and related features.

Since there is no a complete database of the Italian building stock, studies have to estimate values. An analysis of the Italian building stock and of the real estate market is done annually by the research centre Cresme[6]. In the BPIE data hub[7] a different analysis is present due to the different estimate methodology used in order to compare it with other European Countries. The analysis of the building stock in the national action plan - *Piano d'Azione italiano per l'Efficienza Energetica* (PAEE), see Chapter 2.1, was done by ENEA, on the basis of internal studies and data from ISTAT 2011, ANCE and CRESME.

In terms of number of buildings (Figure 1.15), residential buildings account for 84%, non-residential are 11% and there are also a share of non-occupied buildings (5%). However, a portion of non-residential buildings are organized in complexes as shown in Figure 1.16. Looking at the number of building units, is possible to make a rough assessment of what are heated and unheated units in the Building's Cadastre, as shown in Figure 1.17. As regards residential units, the Building's Cadastre estimate a floor area of 4 billions m^2, while estimate about non-residential building units floor area are not complete. For estimate about the non-residential activities it is possible to refer to the Cresme analysis. It should be noted that several non-residential activities are carried out in residential buildings, as shown in Figure 1.18. There is also a share of buildings in which there are only or predominantly (at least 75% of surface) non-residential activities, as show in Figure 1.19.

[5] Definition from Revenue Agency; building or its portion that, according to land registry rules, has functional autonomy and income potential, as it is. Are considered as building units: constructions anchored or fixed to the ground, made of any materials; buildings suspended or floating, stably anchored to the ground; prefabricated laid on the ground, as long as stable over time.

[6] http://www.cresme.it

[7] http://www.buildingsdata.eu

Figure 1.15 Number of buildings, value for 10,000. Data: ISTAT 2011

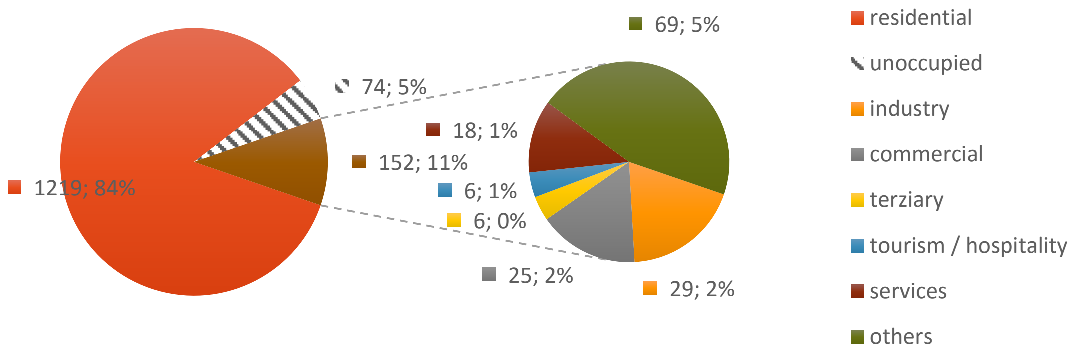


Figure 1.16 Number of complexes of buildings, value for 1,000. Data: ISTAT 2011

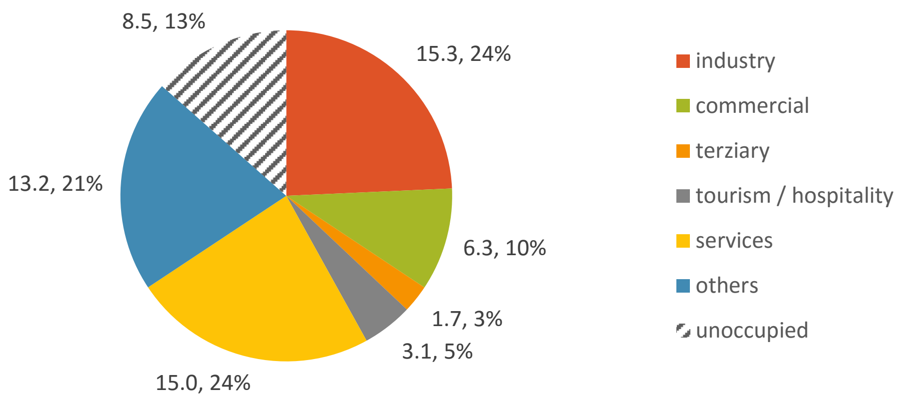


Figure 1.17 Number of building units [per 10,000], striped are not heated building units or are not buildings (e.g. shed). Own elaboration, data from Revenue Angency

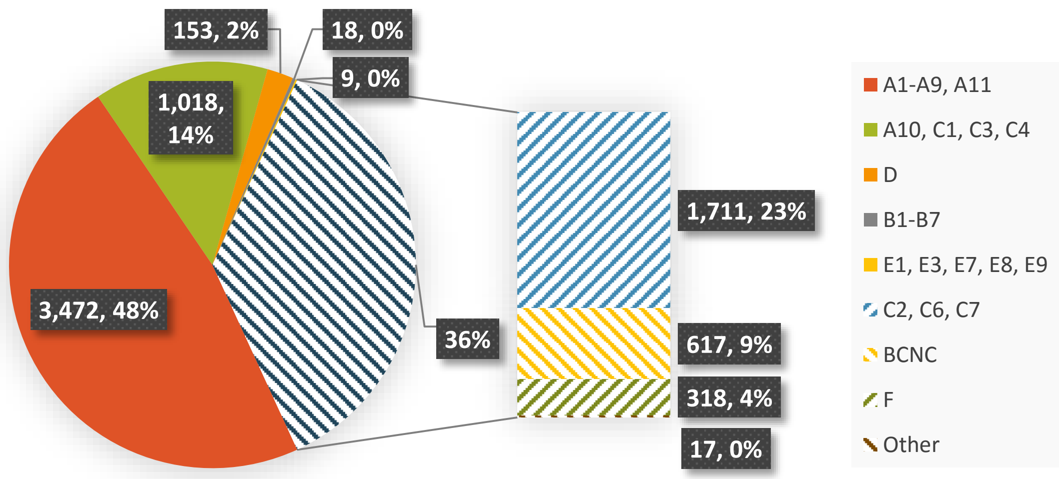


Figure 1.18 Non-residential building units. Inside: number of building units [%]; outside: area [million m²]. Data: Cresme 2013

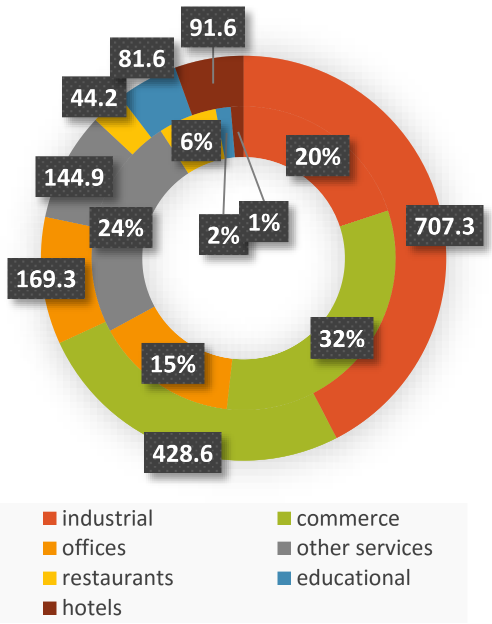


Figure 1.19 Non-residential buildings. Inside: number of buildings [%]; outside: area [million m²]. Data: Cresme 2013

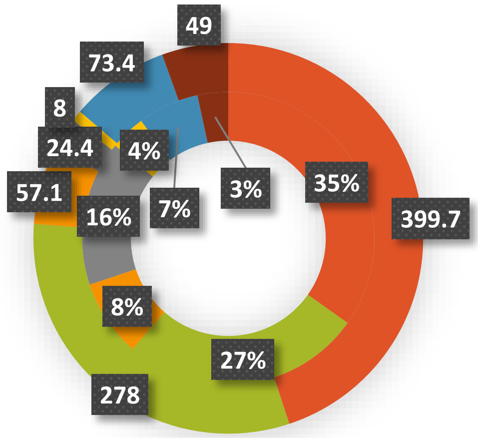
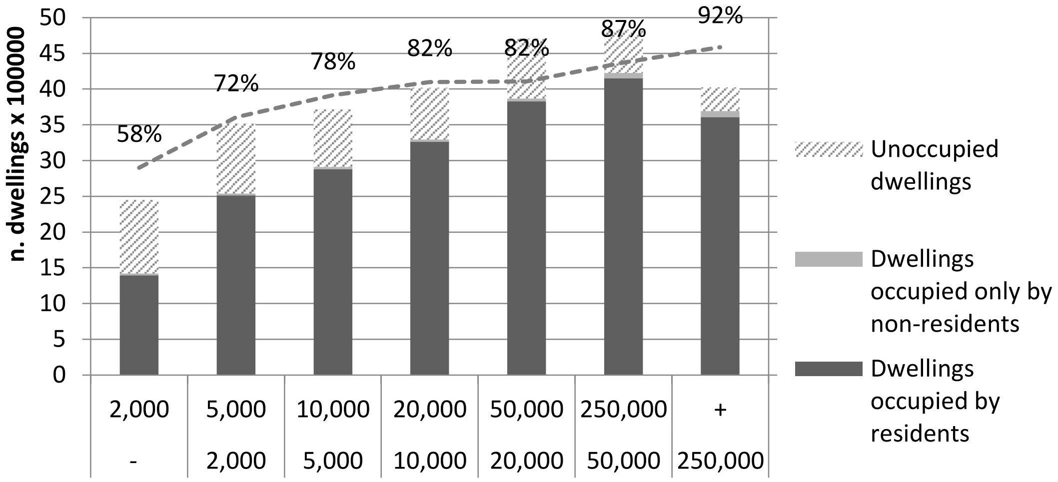


Table 1.4 Italian municipalities and building stock. Source of data: ISTAT 2011

demographic class	**less than 10.000**	**from 10.000 to 50.000**	**more than 50.000**	**total**
compulsory Italian energy regulation	-	-	*energy plan*	
	-	*energy manager*	*energy manager*	
no.municipalities	6,989	974	138	8,101
% on total municipalities	86%	12%	2%	
no. inhabitants	18,631,613	18,745,510	19,618,621	56,995,744
% on total inhabitants	33%	33%	34%	
no. households	10,026,838	8,503,362	8,761,793	27,291,993
% on total households	37%	31%	32%	
no. residential buildings	5,823,508	3,606,202	1,796,885	11,226,595
% on total residential buildings	52%	32%	16%	
buildings surface [m²]	935,634,130	796,586,519	775,428,454	2,507,649,104
% on total buildings surface	37%	32%	31%	

Figure 1.20 Occupancy of residential buildings. Data: ISTAT 2001



As regards the residential building stock, it is possible to divide into municipalities' demographic classes, as shown in Table 1.4. As regards the number of buildings, the share of buildings in small municipalities seems quite conspicuous (52%). However, they represent the 37% of the floor area and also the occupancy should be taken into account. Looking at the occupancy of dwellings plotted in Figure 1.20, only 58% of them are occupied in very small municipalities (less than 2,000 inhabitants) and the occupancy rate increases with the increasing of the municipality' demographic class.

Overall in Italy the residential stock consists of 58% of single family houses, 32% of small building houses (up to 4 household), 5% of medium building houses (up to 8 household), and 5% of apartment buildings. As can be seen in Figure 1.21, these percentages vary with the size of municipalities: in medium and small municipalities the large majority of the buildings have only one or two households. From the energy point of view, small buildings mean a high Surface to Volume ratio (S/V) - called also Thermal envelope area to Heated volume ratio or compactness ratio - and thus very likely high thermal dispersions.

The large number of small buildings mean a low density built environment (Figure 1.21). In small buildings it is possible to have greater surfaces available (i.e. in terms of available surface per people) for the integration of solar technologies and thus a higher coverage of the different final energy uses by renewable energy sources.

In Figure 1.21 it is also plotted, as percentage, the rate of buildings that are single-family houses or not managed condominiums: in Italy there is the obligation of a building manager only for buildings with more than 8 owners (L. 220/2012). It is possible to note that only in big municipalities managed condominiums are notably present (with a mean value of 32%). It should be noted that the majority of the dwellers own the house in which they live (76% of households). Thus, leaving out single family houses, decisions about interventions to the building should be taken collectively, as required by the Civil Code.

- ❖ The Italian residential building stock is fragmented in terms of number of buildings and ownership.

In Italy new buildings represent 28,8% of the construction market, while renewable energy sources (RES) the 4,3%; the largest share (66,9%) is the refurbishment of the existing building stock (Cresme, 2013). However, interventions on existing buildings are mainly on technical systems or aesthetic enhancement and not aimed at improving the building's energy performance (Cresme, 2012). The energy efficiency measures are carried out mainly when there is a failure or upgrade of the technical systems or the owners want to take advantage of government incentives. In fact, incentives for energy-saving measures have resulted in single interventions rather than a whole building approach (ENEA, 2013).

As regards the floor area, in ten years (ISTAT 2001-2011) the floor area of new residential buildings increase about 190 millions m^2, which correspond to an annual increase of 1.1%. The existing building stock undergone refurbishment on about 0.5% yearly of the actual floor area (PANZEB 2014).

As a result, the existing building stock is quite old with scarce energy performances. In Figure 1.21 data for the residential building stock show that 57% of the buildings were built before 1970, 29% of the buildings were built between 1971 and 1991, and 14% of the buildings were built after 1991. For non-residential buildings data are scarce, only as a reference the estimates[8] tell that 53% of office buildings were built before 1971, 23% between 1972 and 1991, 25% after 1992. The educational building stock consists of older buildings: 90% were built before 1971, 4% between 1972 and 1991, 6% after 1992.

The energy performance of the Italian building stock is scarce and not extensively investigated.

[8] Data from http://www.buildingsdata.eu

Table 1.5 reports the weighted average annual consumption estimated by ENEA for STREPIN. Thanks to the digitalized register of energy performance certificates (EPCs), it is possible to know the more detailed values in Lombardy Region[9]. In the residential sector, the average EPh (primary energy consumed for heating) for buildings built before 1976 is around 243 kWh/m^2year; it drops a little for buildings between 1977 and 1992 (206 kWh/m^2year) and between 1993 and 2006 (154 kWh/m^2year). The real enhancement took place in 2007 (98.67 kWh/m^2year) with continuous improvements; in 2012 EPh was 59 kWh/m^2 year; the average EPh of new buildings is a quarter of existing building.

- The Italian building stock is old and with poor energy performance, often not improved in refurbishment intervention.

[9] Data from http://www.energialombardia.eu/patrimonio_edilizio

Table 1.5 Average annual consumption weighted on climatic zone. STREPIN 2015

Building use	Electrical consumption [kWh/m² yr]	Heating consumption [kWh/m² yr]
residential (single family)	38	142
residential (condominiums)	35	125
Educational	20	130
Office	95	170
Hotel	110	150

Figure 1.21 Number of buildings per municipality size (classes defined by number inhabitants) with cumulative percentage of not-condominium buildings. Source: Data from ISTAT, National Census 2001

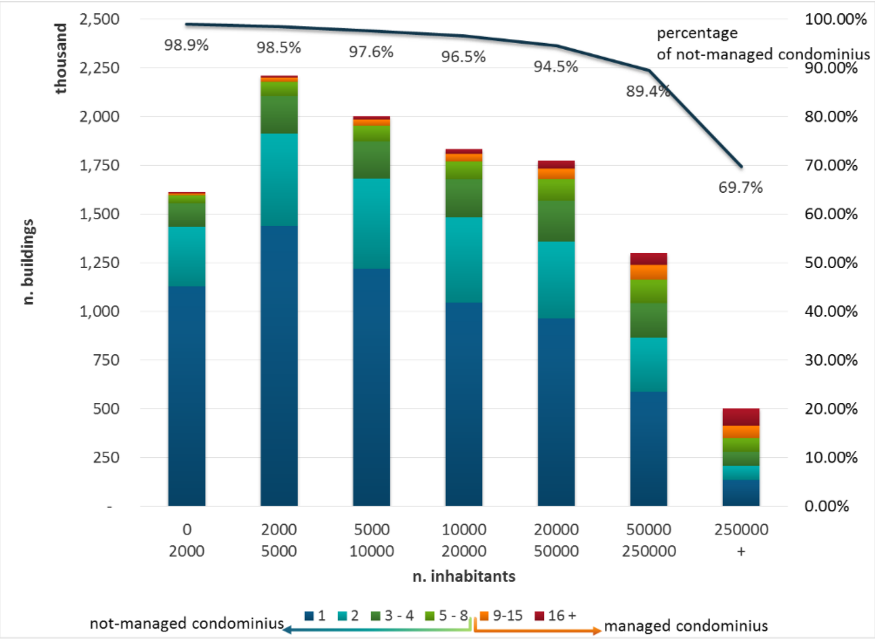
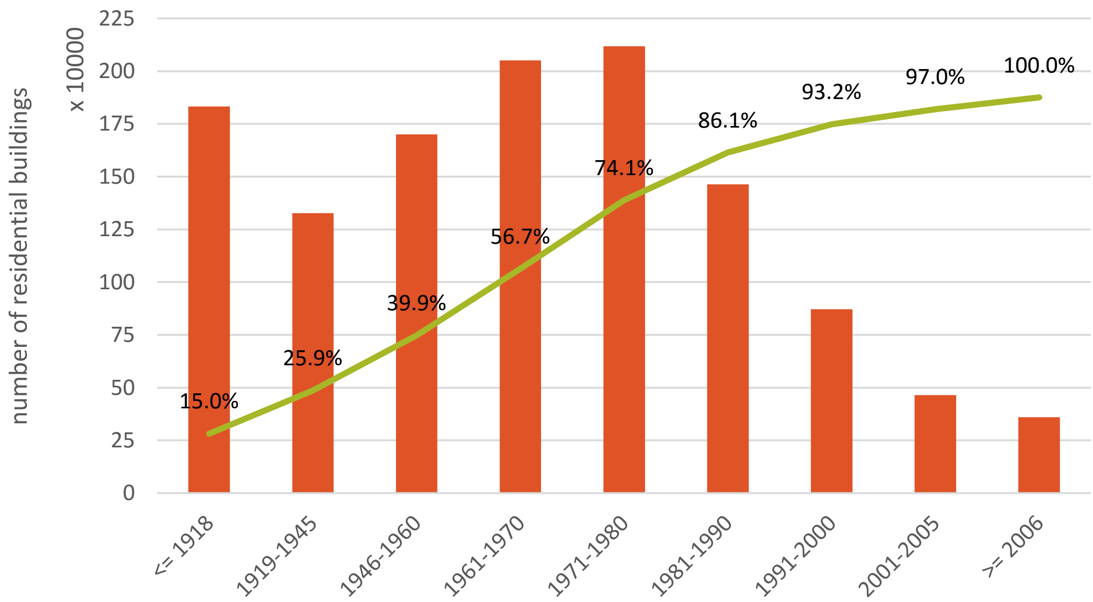


Figure 1.22 Residential buildings per age of construction. Data: ISTAT 2011



1.3 POTENTIAL OF BUILDING STOCK

The building stock is a great opportunity for the energy issue, since could be exploited within the threefold strategy:

- reduction of energy demand (energy efficiency): energy renovation of the existing building stock and new buildings as nZEB;
- optimization of energy generation and management: buildings are small distributed and deferrable energy consumers (unlike industrial processes);
- use of low carbon energy source (renewables): RES could be integrated on the buildings and produced energy directly used.

New dwellings built in 2009 consumed 30% to 60% less than dwellings built in 1990 (Odyssee, 2012) and by 2021 all new buildings will be “nearly zero-energy buildings”, thanks to the Energy Performance of Buildings Directive (2010/31/EU). However, it should be noted that most EU countries extend their dwelling stock by less than 1% per year, so the impact of the new energy-efficient buildings is limited and policies to regulate the energy performance of new buildings are not sufficient. The scientific community agrees about the need of operating on the already existing building stock.

Nowadays the existing building stock has roughly 25 billion m^2 of useful floor space (BPIE, 2011) with an average yearly energy consumption around 220 kWh/m^2 (Odyssee, 2012). Policies for increasing energy efficiency in buildings, in particular for space heating, are the central issue of this work. In fact, space heating accounts for 68% of end-use energy consumption while lighting and electrical appliances account for 15%, water heating for 12% and cooking for 4% (Odyssee, 2012).

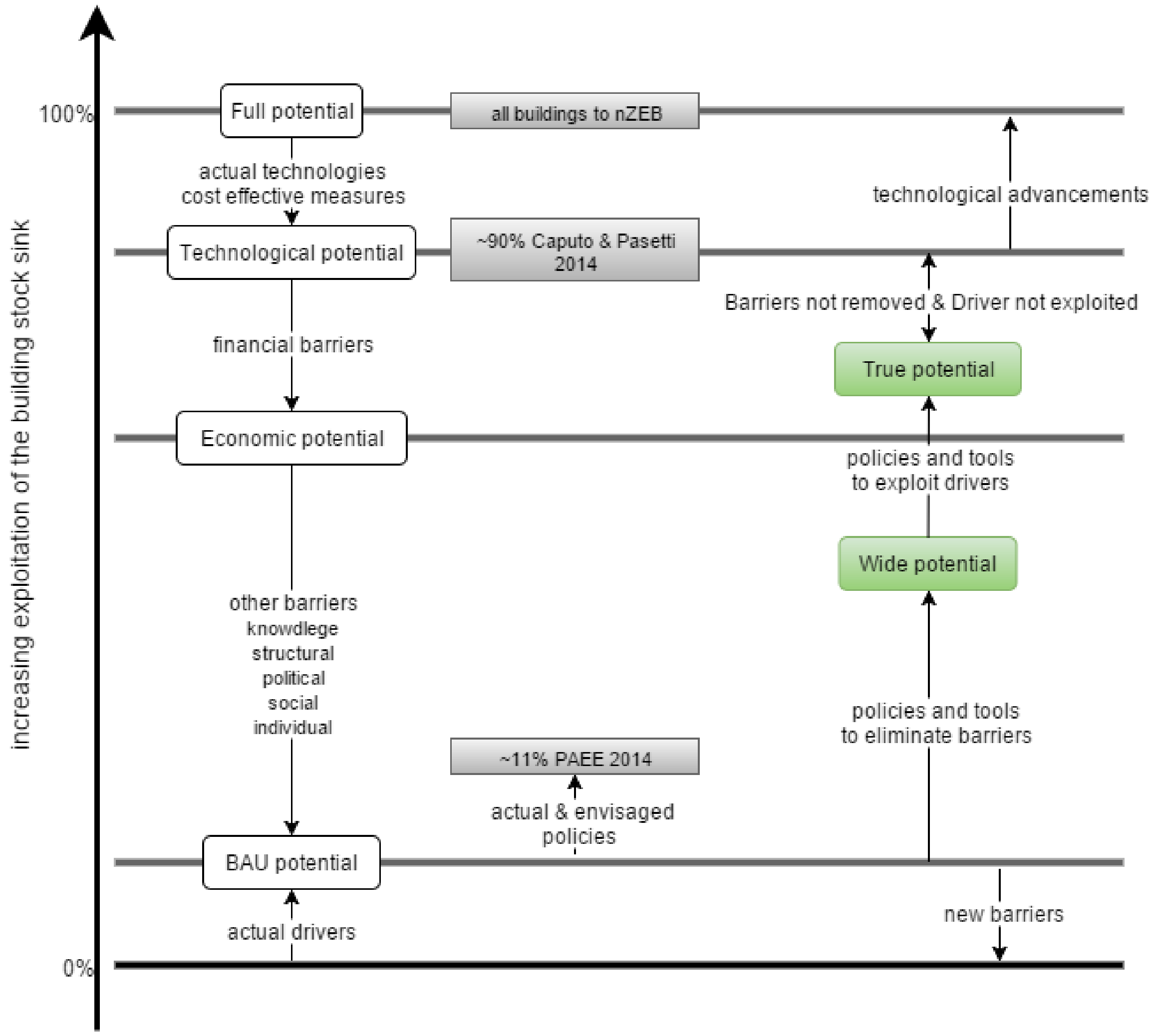
According to *Europe’s buildings under the microscope* (BPIE, 2011), an ambitious renovation strategy is necessary to increase greatly the renovation rate of existing buildings. The actual renovation rate in Europe, estimated around 1%, must more than double to reach a complete renovation of the European building stock by 2050.

The analysis of BPIE (2011) shows that, for the European building stock, it is possible to achieve in 2020 annual energy saving from 94 TWh (business-as-usual) to 527 TWh (best scenario) and in 2050 from 365 TWh (business-as-usual) to 2,896 TWh (best scenario).

In Italy, the potential energy saving expected by the National Energy Efficiency Action Plan (PAEE, 2014) from the refurbishment of the building stock in 2020 is 48.9 TWh/yr for the residential buildings and around 17.2 TWh/yr for non-residential buildings. Several organizations (CNAPPC, CNG and Legambiente, 2014; AICARR, 2015; Renovate Italy, 2015) evaluated as unambitious the PAEE and the linked STREPIN and PANZEB as insufficient action plans without time schedule and real implementation methodology. There is the need of a more ambitious strategy that fosters deep renovation of the building stock in a coherent framework.

First of all, there is the need to clarify what is the true potential of the Italian building stock and why the PAEE is seen as unambitious. I propose a scheme shown in Figure 1.23, on the basis of Jaffe and Stavins (1994), to represent the different potentials in exploiting the building stock energy sink. In fact, the magnitude of the energy-efficiency gap (Hirst & Brown, 1990) depends on which barriers are taken into account.

Figure 1.23 Scheme representing various potentials to exploit the building stock energy sink



The *full potential* is represented by the full exploitation of the building stock sink, i.e. the consumption of energy by the building stock - 582.4 TWh in 2013 for Italy (Eurostat tsdpc320). The full potential could be theoretically achieved upgrading all the building stock to nearly Zero Energy Building (nZEB) performances, obtaining a building stock that consume almost zero energy.

The *technological potential* is lowered by the actual technologies and the cost-effective measures that could be carried out on the building stock. For Italy, a rough estimation (Caputo & Pasetti, 2014) on the residential building stock gives an exploitation rate around 90% considering a cost-optimality approach on all the residential buildings. Obviously, it is still a hypothetical potential, but it should be noted that this potential might rise with the future technological advancements in the energy measure for the building stock.

The *economic potential* is the exploitation rate that considers economic and financial barriers, among the most important especially in the context of economic crisis. However, there are several barriers that hinder the exploitation of the building stock energy sink and drop down the actual exploitation to *BAU*[10] *potential*.

Although the BAU potential rate is quite low, it is worth noting that it is not zero since there are already some energy measures carried out on the building stock. This is the effect of the actual drivers that push building's owners to improve the energy performance of their proprieties. Likewise, new barriers could emerge and drop down the BAU potential.

As regards future strategies, in Italy the target set for 2020 (PAEE, 2014) is only around 11% of the full potential. Obviously, it is better than the BAU potential, but a more audacious target is possible and necessary to achieve the objectives for 2050 (EU Roadmap).

A more audacious target is set by the *wide potential*, exploited trough policies and tools aimed at eliminating barriers to the renovation of the building stock. Even more, the *true potential* could be reached by levering on the drivers that lead to energy measures carried out by public and private owners. The true potential is limited by the barriers that future policies could not remove (e.g. listed buildings) and by drivers that fail to be stimulated.

- In order to exploit the true potential of the building stock energy sink it is necessary a more widespread and detailed knowledge of the energy issue liked to the building stock; a better understanding of the barriers and drivers for energy measures on the building stock; and a set of new policies and tools to eliminate the barriers and exploit the drivers.

[10] Business As Usual

2 ACTIONS AND STRATEGIES FOR THE ENERGY & BUILDINGS ISSUE

As anticipated in Chapter 1, drastic programs and actions are required at global and local level in order to control climate change and relative effects, increase of urban population, migration, increase of global energy demand and non-renewable energy resources depletion, global economic and financial crisis.

As assessed by BPIE (2013b), some European State Member already have implemented policies and national plan to boost building renovation activities, but the regional and local level becomes increasingly important. This Chapter gives an overview of the main European and Italian strategies and regulation regarding the energy and building issue, of the current local policies and regulation and of the current approach and tools to support these policies.

2.1 EUROPEAN & ITALIAN STRATEGIES AND REGULATION

2.1.1 Energy Strategies

2.1.1.1 European energy strategy

The energy issue is one of the cornerstones of the European Union (EU), since the first agreements for the European Coal and Steel Community and Euratom, and energy European strategies are constantly improved. In fact, the now approaching 2020 energy policy and targets are updated with mid-term targets for 2030 and long-term targets and policy at 2050.

The target set for 2020 (COM(2010)639) are:

- reduce greenhouse gases by at least 20%, compared to 1990;
- increase the share of renewable energy in the EU's energy mix to at least 20% of consumption;
- improve energy efficiency by at least 20%.

The strategy focus on five priorities:

1. Achieving an energy-efficient Europe;
2. Building a truly pan-European integrated energy market;
3. Empowering consumers and achieving the highest level of safety and security;
4. Extending Europe's leadership in energy technology and innovation;
5. Strengthening the external dimension of the EU energy market.

As regards energy efficiency, a major role should be played by buildings and transport, while public authorities should lead by example. In order to ensure a shift the energy production away from fossil fuels the EU set up a Strategic Energy Technology Plan[11] and the European Industrial Initiatives[12] (wind, solar, bio energy, smart grids, nuclear fission and carbon capture and storage).

The target set for 2030 (COM(2014) 15) are:

- cut at least a 40% reduction in greenhouse gas emissions by 2030, compared to 1990;

[11] http://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

[12] https://setis.ec.europa.eu/activities/initiatives

- increase the share of renewable energy at least 27% of consumption;
- increase energy efficiency of at least 27%.

In order to meet this targets, the strategy added:

- a reformed EU emissions trading scheme (ETS);
- a new governance system based on national plans for competitive, secure, and sustainable energy;
- Systematic monitoring with key indicators for competitive, secure and sustainable energy.

As regards the energy efficiency in the building sector, the Communication underline the need for a significant acceleration of current efforts to tap the significant unexploited potential, supported by large investments, framework conditions, information to consumers and appropriate financial instruments.

In order to set a stable direction to the energy policies, EU decide to commit to a long-term goal for 2050 (COM/2011/885): a reduction of its greenhouse gas emissions by between 80-95 % below 1990 levels. Setting a clear direction provides certainty for investors, governments and citizens.

There are ten conditions to achieve this goal:

1. full implementation of EU's Energy 2020 strategy:
2. higher energy efficiency is the prime focus, especially in new and existing buildings transport, products and appliances;
3. higher share of renewable energy is the second major pre-requisite;
4. higher public and private investments in R&D and technological innovation to put on the market all low-carbon solutions;
5. fully integrated energy market;
6. energy prices need to better reflect costs, the sooner the better, taking care to avoid energy poverty;
7. development of new energy infrastructure, for electric vehicles for example, and storage capacities;
8. safety and security for either traditional or new energy sources remain paramount;
9. EU approach to international energy relations should be broader and more coordinated;
10. concrete milestones are needed for investors, governments and citizens.

In order to really tackle the energy issue the European Commission proposed a more integrate and coordinate framework, the Energy Union (COM(2015) 80). This strategy comprises five closely related and mutually reinforcing dimensions:

1. Energy security, solidarity and trust;
2. A fully-integrated internal energy market;
3. Energy efficiency;
4. Decarbonising the economy;
5. Research, Innovation and Competitiveness.

In order to bring the ideas of the Energy Union[13] closer to the Member States and to stakeholders the Vice-President Maroš Šefčovič set out an Energy Union Tour to confront with all Member States governments, national parliaments, energy and other industries,

[13] http://ec.europa.eu/priorities/energy-union

social partners, consumers, students, and citizens. The key results and findings are summarized in country factsheets.

2.1.1.2 Italian energy strategy

As assessed by the Energy Union Country factsheet (SWD(2015) 229), Italy is doing well on Energy Security, despite the high dependency on imported natural gas; Energy Efficiency, with the lowest energy intensity of the economy; Decarbonisation, Italy is on target and have one of the highest installed capacity of electricity RES; Research and Innovation, especially for smart metering. As regards the Internal Energy Market, Italy still has relatively high retail electricity and gas prices. Moreover, there are challenges for network management caused by the insufficient internal transmission capacity and a fast increasing share of RES; also cumbersome and lengthy permitting procedures slow down the development of key energy infrastructures.

The Italian energy strategy is expressed in the National Energy Strategy - *Strategia Energetica Nazionale* (SEN), which sets the guidelines to reach the 2020 European objectives. However, the SEN not a comprehensive medium to long term strategy for energy and climate to reach 2030 and 2050 objectives, but explicit only some general remarks and scenarios for 2050.

The SEN has four main objectives:

1. Competitiveness: significantly reduce the energy cost gap for consumers and businesses, with a gradual alignment to European prices;
2. Environment: exceed the environmental objectives set by the '20-20-20 Package' and take the lead in the 'Roadmap 2050' decarbonisation European;
3. Security: strengthen the security of supply, especially in the gas sector, and reduce dependence;
4. Growth: foster sustainable economic growth through the development of the energy sector.

The SEN spots seven priorities:

1. Energy efficiency;
2. Development of a competitive market and the South-European Gas Hub;
3. Financially feasible development of RES;
4. Development of electrical infrastructure and market;
5. Renovation of fuel refinery and distribution network;
6. National sustainable production of fuels;
7. Modernization of governance.

As regards energy efficiency, the heating of the building stock accounts for the largest share of energy consumption in the country. The enabling factors for energy efficiency are: ESCos strengthening; monitor and enforcement; communication and awareness; support to research and innovation. An important proposal in governance is to restore the central administration to legislative powers in energy matters regarding the activities and the energy infrastructure of national importance.

The national action plan - *Piano d'Azione italiano per l'Efficienza Energetica* (PAEE) is a tri-annual report requested by the Energy Performance of Buildings Directive (2012/27/UE). The PAEE, last updated in July 2014, describes the policies activated to reach the 2020 target and the actual results.

As regards the building sector, PAEE 2014 envisaged a specific strategy document to act on the energy requalification of the building stock; this plan, called *Strategia per la riqualificazione energetica del parco immobiliare nazionale* (STREPIN). A separate document, called *Piano d'azione nazionale per l'incremento degli edifici a energia quasi zero* (PANZEB), focuses on the strategies to increase the number of new and existing buildings that consume Near Zero Energy.

At the time of writing of this dissertation, these two documents were published by MiSE on 13th November 2015 for the public consultation phase that ended on 4th December 2015, so they are still draft.

STREPIN contains an analysis of the building stock, a cost-benefit analysis of energy measures; estimated potential savings; analysis of the technical and economic-financial barriers; list of the existing supporting policies and tools and proposals for more effective measures; assessment of the achievable annual savings by 2020.

PANZEB contains an overview of nZEB (definition, performance, costs), an analysis of the building stock, market trends, list of the existing supporting tools and proposals for more effective measures, list of regional supporting policies.

Table 2.1 Potential energy savings on the existing building stock. Own elaboration, data STREPIN

	floor area under renovation [m^2/year]	**energy savings at 2020 [TOE/year]**
residential (single family)	65,958,838	1.77
residential (condominiums)	104,283,522	2.43
Public offices	2,640,000	0.33
Public schools	4,950,000	0.50
Private offices	2,880,000	0.25
Private schools	1,000,000	0.05
Hotels	1,425,000	0.10
Banks	782,811	0.06
Shopping centers	2,289,163	0.19

Table 2.2 Forecast of nZEB development. Own elaboration, data PANZEB

	typology	floor area nZEB buildings per year [m²/year]	total floor area nZEB buildings 2015-2020 [m²]	energy savings at 2020 [toe]
new buildings	residential (single family)	46,800	280,800	1,448
	residential (condominiums)	25,200	151,200	593
	Public offices	5,900	23,598	192
	Public schools	30,492	121,968	687
	Private offices	22,131	132,791	839
	Private schools	3,388	20,328	89
existing buildings	residential (single family)	73,440	440,640	2,104
	residential (condominiums)	39,150	124,900	919
	Public offices	8,330	33,320	395
	Public schools	76,230	304,920	2,580
	Private offices	31,850	191,100	1,764
	Private schools	8,470	50,820	334

2.1.2 European Directives for energy efficiency in buildings and Italian transposition

The main directive on energy efficiency in the building stock is the Energy Performance of Buildings Directive (2002/91/CE) was recast in 2010 (2010/31/UE), known also as EPBD. Another important adaption is the energy efficiency directive (2012/27/EU) amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

In Italy the process of transposition of EPBD and EED was slow and tortuous with the first law in 2005 (DLGS 192/2005) and the last ten years later (interministerial decrees on 26/06/2015), with numerous amendments in between, reprimanded by EU in: IP/10/1561 (2010); IP-11-1100 (2011); IP-12-411 (2012); MEMO/13/22 (2013).

The fragmented legislation is caused also by the structure of the legislative powers: the central government has exclusive legislative powers in the environmental and ecosystem protection, however energy is a concurrent issue between the State and the Regions, according to article 117 of Constitution, modified on 2001 (l.c. 3/2001). As regards the central government, the Ministry of the Environment and Protection of Land and Sea - *Ministero dell'Ambiente e della Tutela del Territorio e del Mare* (MATTM) is in charge of the environmental issues, while the Ministry of Economic Development – *Ministero dello Sviluppo Economico* (MiSE) is responsible of the energy issue.

As regards the regional government, there is a coordination among regional authority (19 Regions plus 2 autonomous Provinces of Bolzano and Trento) through the *Conferenza delle Regioni e delle Province Autonome* (www.regioni.it), however this not result in a homogenous legislation. In fact, each regional authority could (and many have) legislate on energy issue and there are legislation also on the provincial and the municipal level.

It is possible definitely to say that the Italian regulatory framework is highly fragmented in time and on the territory. In order to figure out this complex legislative framework, several publications and services clarify and help to keep updated on the current legislation on the energy and building issue. Just to mention a few, the Italian Thermotechnical Committee – *Comitato Termotecnico Italiano* (CTI) dedicates a website (www.cti2000.eu) and an annual publication on the application of EPCs and linked legislation. ENEA (see description in Chap. 3) monitors the regional policies about energy and efficiency in the building stock and publish an annual report on energy efficency. The Legambiente[14] association monitors the municipal building code (*Rapporto ON-RE*) and the use of RES at municipal level (*Comuni Rinnovabili*). There are also several free or fee services held by privates, which are an indication of the need for clarity in the regulatory framework.

Fortunately, a recent set of decrees put some order in the regulation, and starting from the first of October 2015, becames operative (Decreti 26 giugno 2015, Gazzetta Ufficiale n. 162 del 15 luglio 2015). The main points of the new National guidelines are:

- National calculation methods (one complete, one simplified);
- National EPCs model and layout for advertisements;
- National information system for EPCs, heating plants and inspection (SIAPE), Regional authorities feed the database;
- Regional authorities that have already set out their own legislation, have to adhere to these guidelines within two year (15th October 2017);
- Underline the obligation of site visit to the dwelling;
- Regional authorities have to monitor at least 2% of EPCs each year.

The following subsections underline the key points of these directives and their transposing in Italy.

2.1.2.1 Mandatory Energy Performance Certificates (EPCs)

The EPBD require that all advertisements for the sale or rental of buildings have to include the EPCs.

In Italy, the publication of energy performance indicators on advertisements is mandatory starting from 1 January 2012, according to article 13 of d.lgs. 28/2011 that modifies article 6 of D.Lgs 192/05.

It should be noted that, until 2012 (d.m. 22 november 2012), it was possible to for the owners to self-certify their property in the lowest class, this was reprimanded by Europe with sanctions (ECLI:EU:C:2013:396).

Moreover, seven out of twenty-one regional authorities use a different EPC model and different calculation methodologies respect to the national one (CTI, 2014). Thus, energy classes can not be compared between different regions.

This issue should be solved by the new National guidelines (d.m. 26 june 2015), that oblige to follow a national model of EPC and of schema for advertisements and to adhere to national calculation methodologies.

[14] http://www.legambiente.it

2.1.2.2 *Sanctions and monitoring*

Obligations without sanctions are often unfulfilled. Only with the amendments of d.l. 63/2013, the D.Lgs 192/05 included sanctions for all parties. There was four regional authorities (Liguria, Lombardy, Valle d'Aosta, Trento) that set their own sanctions.

Actually the monitor is still not ongoing or on the experimental phase, the amendments by d.l. 63/2013 sets out, accordingly to EPBD, that monitoring should be conducted, if not decided otherwise, by the same authorities that conduct monitoring on the heating plants.

The new National guidelines envisage at least 2% of EPCs monitored by the regional authorities.

2.1.2.3 *Formation and competence of certifiers*

In Italy different university degrees allow to work as energy certifier or it is possible to pass an examination, after specific training courses, as required by d.p.r. 75/2013, updated by l. 9/2014. However, three regional authorities (Bolzano, Lombardy, Valle d'Aosta) have their own legislation, so an energy certifier could not work in the whole Country.

In Italy once enabled, a technician does not have restrictions on the type or size of the building; moreover, continuous professional updating is not requested.

This point is not resolved by the new National guidelines (d.m. 26 june 2015).

2.1.3 Other related Strategies

In addition to the complex framework just presented, there are also other strategies that influence the energy and building issue to be taken into account.

Spatial data

One important thing to consider is the use of spatial data, since the use of geographic information could enhances the spreading and quality of information about the building stock. In 2007 was adopted the directive establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)[15]. In the following years common Implementing Rules are adopted to ensure that spatial infrastructures of the Member States are compatible and usable.

Italy transposed the INSPIRE directive with D.Lgs. 32/2010 (amended by d.l. 91/2014, l. 116/2014, l. 115/2015). The MATTM is responsible for the application and monitoring, with the collaboration of ISPRA. As a result, are available:

- National Geoportal - *Geoportale nazionale* (www.pcn.minambiente.it/GN) access to the National Environmental Information System and the RNDT;
- Rete del Sistema Informativo Nazionale Ambientale (www.sinanet.isprambiente.it), giving access to the spatial data held by the public authorities;
- National Registry of Spatial Data - *Repertorio Nazionale dei Dati Territoriali* (RNDT) www.rndt.gov, which is the national catalogue of the metadata relating to spatial data sets and services.

[15] http://inspire.ec.europa.eu

As could be seen in the last report (one every three years) the actual implementation of the INSPIRE directive is quite scarce. Even data on number of visits and on the use of information resources are incomplete, since the variety of existing geospatial data management systems prevents uniform calculation (Member State Report: Italy, 2012).

Smart metering

Smart metering is a strong tool to empower final energy consumers thanks to the access to information from the metering and billing of their individual energy consumption.

As regards electricity, Directive 2009/72/EC requires that at least 80 % of consumers should be equipped with intelligent metering systems by 2020, where cost-effective, and Directive 2010/31/EU requires that individual meters should always be provided in a new building or a building undergoes major renovations.

As regards natural gas, Directive 2009/73/EC requires that Member States prepare a timetable to ensure the implementation of intelligent metering systems.

The European Union reinforced these directives with the Energy Efficiency Directive (2012/27/UE) and the Commission Recommendation (2012/148/EU). The JRC monitor the implementation, data and reports are available on the website http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union.

Italy has already reached the target for electricity, since smart metering deployment started already in 2001 and was completed in 2006 by ENEL Distribuzione. By 2020 is expected a penetration rate of 99%. While the smart meters accelerate the market liberalisation process and the use of mandatory Time-of-Use tariffs for residential customers (AEEG 2010), information for users has not increased.

As regards natural gas, the National Regulatory Authority introduced obligations for deployment of gas smart metering (decision no. 155/2008). In addition, the National Regulatory Authority promoted demonstration projects for multi-service smart metering (decision n. 393/2013).

Distributed generation & Smart Grid

The Energy Efficiency Directive (2012/27/EU) obliges Member States to carry out a comprehensive assessment of the potential for high-efficiency cogeneration and district heating and cooling by December 2015.

Italy has generous incentives for cogeneration (d.m. 20/2007) and has been recently[16] awarded of “COGEN Europe Recognition Award”, especially for the innovative White Certificates policy.

GSE keeps track regulatory developments in the sector on its website (http://www.gse.it).

Smart grid are the best way to integrate RES in the electricity grid, providing a more reliable power from intermittent sources (solar, wind) and in a more efficient way through timely demand response.

[16] May 2015

The European Commission set up a Smart Grid Task Force (SGTF) in 2009, which consist of five Expert Groups who focus on:

- Smart grid standards;
- Regulatory recommendations for privacy, data protection and cyber-security in the smart grid environment;
- Regulatory recommendations for smart grid deployment;
- Smart grid infrastructure deployment;
- Implementation of smart grid industrial policy.

An updated inventory of smart grid projects is the Smart Grid Projects Portal[17], managed by the Union of the European Electricity Industry (EURELETRIC) and JRC and launched in 2011. Moreover, a report is published periodically, the last (JRC 2014) included 459 smart grid projects of which 110 are in Italy, the third Countries per number of projects after Germany and Denmark.

[17] http://www.smartgridsprojects.eu

2.2 Local Policies and Regulation

In Europe, cities are currently responsible for approximately 70% of the overall primary European energy consumption, and this share is expected to increase to 75% by 2030.

As reported by the British Committee on Climate Change (UK CCC, 2012), local authorities could have a crucial role in reducing emissions to meet national carbon budgets and should develop low-carbon plans. To achieve a full refurbishment of the European building stock, a proactive role of the local authorities and effective municipal energy plans are therefore necessary.

The main European initiatives that involve local authorities to develop local energy plan are here listed, followed by regulation and initiative in the Italian context. It should be noted that, in order to tackle locally the energy & building issue, it is better a widespread effective local energy planning rather than local regulation that increase even more the regulatory fragmentation.

2.2.1 European initiatives

Covenant of Mayors

The European Covenant of Mayors (CoM)[18] was launched in 2008 to involve regional and local authorities to develop local sustainable energy action plan (SEAP). More than 6000 signatory cities voluntary commit to meet and exceed the EU 20% CO_2 reduction locally. On the great success of the Covenant of Mayors, the initiative evolved with the launch in 2014 of the Mayors Adapt[19] initiative to involve cities to take action for the climate change and commit for the EU 2030 objective.

JRC provided an assessment of the CoM in 2014 and 2015 (Kona et al. 2015) and an in-depth analysis of SEAPs (Rivas at al. 2015), the following key data are taken from these reports.

As 65% of them already submitted the SEAP, there are 126 million of people living in signatory cities with an adopted SEAP, representing one-fourth of EU population. A large part (44%) of CO_2 emissions reduction will be obtained through the improvement of the energy efficiency of the building stock and the integration of renewables in buildings. The large majority (88%) of signatories with submitted SEAP are small and medium towns with less than 50000 inhabitants, JRC suggest, as a more efficient approach, to encourage the development of Joint Action Plans and promote the rule of Covenant Territorial Coordinators.

The in-depth analysis of SEAPs (Rivas at al. 2015) underline as main strengths the involvement of civil society and the inclusion of energy savings and RES targets. Instead, the major weaknesses lay in how the plans were implemented and monitored and in the inconsistency of data. It should be noted that until May 2014 there were any specific monitoring guidelines.

[18] http://www.covenantofmayors.eu

[19] http://mayors-adapt.eu

As regards the plans, "for most of the signatories, the Covenant of Mayors initiative is a structured way of implementing national regulations" (Rivas at al. 2015). Nevertheless, for 'newcomers' to climate and energy planning especially, the CoM is a way of 'rethinking' the city. It should be noted that the commitment requires an adaptation of municipal departments and allocation of sufficient human and financial resources. The approach most followed is to organize work within pre-existing structures not specifically appointed for this purpose.

Smart Cities & Communities

The Smart Cities & Communities[20] was launched in 2011 with the aim to support ambitious and pioneer cities in transforming their buildings, energy networks and transport systems into those of the future, demonstrating transition concepts and strategies to a low carbon economy (COM/519/2009). This initiative was extended in 2012 both in budget and in sector, with the inclusion of transport and ICT. In 2014 370 commitments around smart city projects & solutions were submitted by more than 3 000 partners. Commitments are measurable and concrete smart city engagements/ actions from public and private partners. There are categorized in six Action Cluster:

- Business Models, Finance and Procurement;
- Citizen Focus;
- Integrated Infrastructures & Processes (including Open Data);
- Policy & Regulations / Integrated Planning;
- Sustainable Districts and Built Environment;
- Sustainable Urban Mobility.

The aim of the Partnership is to overcome bottlenecks impeding the changeover to smart cities, to co-fund demonstration projects and to help coordinate existing city initiatives and projects, by pooling its resources together.

Funded EU projects

The EU funds several projects with the Seventh Programme for research, technological development and demonstration[21] (FP7) and the current Horizon 2020[22], here a list of the projects signaled as "lighthouses" regarding local energy planning:

- CITyFiED, Replicable and Innovative Future Efficient Districts and cities http://www.cityfied.eu;
- SINFONIA, Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions http://www.sinfonia-smartcities.eu;
- R2 Cities, Residential Renovation towards nearly zero energy CITIES http://r2cities.eu;
- InSMART, Integrative Smart City Planning http://www.insmartenergy.com;
- STEEP,Systems Thinking for comprehensive city Efficient Energy Planning http://www.smartsteep.eu;
- STEP UP, Strategies Towards Energy Performance and Urban Planning http://stepupsmartcities.eu;

[20] https://eu-smartcities.eu

[21] https://ec.europa.eu/research/fp7

[22] http://ec.europa.eu/programmes/horizon2020

- PLEEC, Planning for energy efficient cities http://www.pleecproject.eu;
- TRANSFORM, Transformation Agenda for Low Carbon Cities http://urbantransform.eu;
- REMOurban, REgeneration MOdel for accelerating the smart URBAN transformation, http://www.remourban.eu;
- GrowSmarter http://www.grow-smarter.eu.

In addition the CONCERTO initiative, born in 2005, co-funded, with more than 175.5 € million, 58 cities and communities in 22 projects, with the aim to demonstrate that the energy optimisation of districts and communities as a whole is more cost-effective than optimising each building individually.

Moreover Concerto gathered and analyzed experiences and technology performance data of the projects, leading to an organized knowledge. This initiative now become Smart Cities Information System[23] (SCIS), which aim to be knowledge hub for the development of smart cities projects and technologies in Europe.

2.2.2 Italian context

As a result of the structure of the legislative powers, several regional authority have legislate on energy issue and there is regulatory power also at provincial and municipal level. With more than 8000 municipalities it is hard to get a clear picture of the local legislation. In the *Testo Unico Enti Locali* (d. lgs. 267/2000) all administrative functions concerning the population and the municipal territory are assigned to the municipality; the only services explicitly assigned to the municipality are the electoral services, civil status, the registry office, the military conscription and statistics, but municipalities can also provide other services. There are only two main obligation regarding energy for municipalities, set by (L 10/1991): the energy plan and the energy manager.

Energy obligations

The municipal energy plan is mandatory since 1991 (L 10/1991) for cities with more than 50,000 inhabitants. It is evident that this obligation encompasses only a small part of Italian municipalities, since only 142 of the 8,092 Italian municipalities (1.8%) have more than 50,000 inhabitants. The municipal energy plan involves the measurement of energy consumption of the city, grouped by sectors and the identification interventions for saving fossil fuels and for promoting the use of local renewable energy sources. To develop a municipal energy plan in Italy two guidelines are available (ENEA, 1997; ACEA, CISPEL, 1997), but they are not compulsory so it is possible to see plans different from each other and sometimes not comparable. Currently only 48 cities approved their energy plan (ISTAT, 2012) and also in these cases it has rarely been possible to put in practice and to monitor the effects of the various measures suggested by the plans.

Nonetheless, the huge participation of Italian municipalities to CoM, with the development of SEAPs, shows a great interest of local governments to the energy planning, though often practical results are not clear due to the weakness of the implementation and monitoring phases.

[23] http://smartcities-infosystem.eu

The appointment of the energy manager of local public administration (PA) is also another scarcely implemented obligation. The national law (L 10/1991) set as mandatory the energy manager for municipalities with an annual consumption over 1,000 toe. In Italy, municipalities with more than 10,000 inhabitants generally exceed this target. However, among the 1,206 municipalities larger than 10,000 inhabitants only 112 have appointed the energy manager until now (FIRE, 2012).

Building code

Actually each municipality have their own building code, thereby increasing regulatory fragmentation. In 2014 (l. 164/2014) was finally planned to provide a standard building code, considered an essential service to be guaranteed throughout the national territory. However, at the moment (December 2015) it has not yet been published and it has not been decided a deadline.

Legambiente, in addition to monitoring the building codes containing measures energy (ON-RE reports), proposes a standard building code with several energy measures, based on the analysis of innovative building codes currently in force in more than 1000 Italian municipalities.

Small municipalities unions and fusions

The limited demographic size of a municipality lead to limited services, expertise and resources to tackle the energy and building issue at the local scale. This is an important issue, since the large majority (85%) of municipalities have less than 10,000 inhabitants, with about 1/3 of the population living here, in 70% on the Italian territory.

There are 2,399 municipalities that gather voluntary in 451 unions of municipalities (data Ancitel 2015) to handle a plurality of functions and services that can not be provided by small municipalities separately.

A recent law (l. 56/2014) regulates unions and fusions of municipalities, providing for various facilitating measures and organizational arrangements. For new unions the law sets a minimum population limit of 10,000 inhabitants, lowered at 3,000 if the municipalities belong to Mountain Communities. For municipalities that merge into a fusion, the law provides for a special financial contribution.

The Minister of Internal Affairs commissioned a study (Pacella, Milanetti, Verde 2015) to verify the financial savings resulting from fusions of the small size municipalities. From 1995 to 2011 only 9 fusions have been implemented, while in 2014, thanks to the new regulatory framework 26 fusions born from 62 municipalities. The study focuses on merging municipalities with less than 3,000 inhabitants in order to reach at least 5,000 inhabitants: the merging could lead to a theoretical savings of 367.37 million € in total. Another study (SOSE, 2014) estimates savings between 310 and 983 millions € with fusions of municipalities up to 10,000 inhabitants.

2.3 Current Approaches and Available Tools

2.3.1 Successful case studies

The European and Italian strategies to tackle the energy & building issue place considerable importance on the implementation of effective local energy plans (LEPs) and the local administrations are willing to take action as demonstrated by the large participation in the CoM initiative. There are several projects that have been successful in achieving results in terms of energy savings and exploitation of RES at the local scale.

As underline by Manfren, Caputo & Costa (2011) best practice should not be recognized as a source of general technical expertise, but rather as a type of intervention that can identify problems and provide useful insights. Therefore the scope of this section is only to present few successful case studies that demonstrate that the energy & building issue could be tackled in the Italian context, rather than presenting best practices to be applied indiscriminately.

A good database on sustainable urban development in Europe was SURBAN, managed by the European Academy of the Urban Environment. SURBAN contained about 140 implemented projects, but unfortunately, this database is no longer maintained or available.

The Energy for Mayors[24] (E4M) project develop a Toolbox of Methodologies on Climate and Energy: a comprehensive and organized online database of resources for local governments and CoM coordinators that want to develop a LEP.

The new Smart Cities Information System[25] (SCIS) will collect knowledge for the development of smart cities projects and technologies in Europe from existing projects and case studies.

As regards the renewal of the building stock, two featured Italian projects are at Turin, project Polycity and at Alessandria, project Concerto AL Piano.

As regards the Polycity[26] project in Turin, the estimated population affected by the project is 2,500 and the expected CO_2 emissions saved through the initiative are 2,000 tCO_2/yr. The project focused on the requalification of the Arquata District, not only from the energetic point of view with the refurbishment of the council buildings and the integration of distributed generation but also looking at the social and occupational development of the district.

For Concerto AL Piano[27] the estimated population affected by the project is 9,500 and the expected CO_2 emissions saved through the initiative are 8,330 tCO_2/yr. Also in Alessandria the project refurbished existing social housing and foster private energy retrofit on buildings of the district. Moreover the new ecovillage and Elderly Housing are a showcase for mix of energy conscious solutions at the district level.

[24] http://www.energyformayors.eu

[25] http://smartcities-infosystem.eu

[26] http://www.polycity.net

[27] http://www.concerto-al-piano.eu

Even in small municipalities there is ample room for optimizing the distribution of energy and the use of RES, in fact a good example is set by Montieri, a municipality in Tuscany with 1,200 inhabitants, with the GeoCom[28] project. In Montieri was developed an innovative district heating network based on high enthalpy geothermal steam, together with energy retrofit of public buildings and integrated PV systems. Also private buildings where retrofitted, with major difficulties and delays since Montieri is a medieval village. Despite the difficulties, the district heating became operative on November 2014, and the entire project is expected to lead to a saving of 5,700 tCO_2/yr.

An innovative project in terms of management is the collective ownership of photovoltaic plants in Castellone, a municipality in province of Cremona with 9,500 inhabitants. Here the action started from citizens that gather in a "Gruppo di Acquisto Solidale" and seek collaboration with the local administration. Three PV systems were installed on the roofs of the public gymnasiums and funded through shares by the families. Actually, families receive an economic return of 5%, while the municipality rents its own roof € 8,000 decreasing year by year until the twentieth, when all PV production will be upon of the municipality.

These initiatives in Italy show that reducing CO_2 emissions in buildings and communities is a challenge that can be met through effective local energy plan. However, it is worth noting that, even when the implementation is successful, there are still weaknesses in monitoring and checking the results.

2.3.2 Available Energy Tools

There are several available tools that help to analyse and simulate the energy performance of buildings. A good directory where to find an updated list of energy tools is Building Energy Software Tools[29] (BEST), managed by the United States regional affiliate of the International Building Performance Simulation Association (IBPSA).

Several tools work at the building or room levels, with precise simulations, while for the purposes of the research, the most interesting tools are those managing cluster of buildings or neighbourhoods. The modelling approaches and tools for the simulation of district-scale energy systems is a topic of great interest, as demonstrated by several researches, summarized and analysed in a recent review (Allegrini et al., 2015).

Models and tools could be categorized as (Allegrini et al., 2015):

- district energy systems (including heat networks, multi-energy systems and low-temperature networks);
- renewable energy generation (including solar, bioenergy, wind and the related topic of seasonal storage);
- urban microclimate as it relates to energy demands.

It should be noted that, in order to model district energy use, the bottom-up archetype approaches requires detailed and widespread data, but are the only way to evaluate the impact of new technologies (Swan, Ugursal 2009). Data availability is a problem in the Italian context, as discussed in Chapter 3.

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[28] http://www.geothermalcommunities.eu

[29] http://www.buildingenergysoftwaretools.com

As underlined by (Allegrini et al., 2015), urban-level analysis of both buildings and systems see a rising importance of spatial information and modelling tools that exist within CAD and GIS environments may be more appropriate than exporting complex data structures to external analysis programs.

At the same time, since LEP is more a process than a methodology, energy planning requires relatively simple tools (Manfren, Caputo & Costa 2011) to help the participatory decision making process and to assess the local energy issue.

There are some tools that permit to do both detailed and simplified analysis of a cluster of buildings, the latter could be used in early stages of planning and design.

Obviously, to generate a rough assessment with few input data there is the need to regionalize the tools, thereby referring to the local climate, energy system and building characteristics with local database. An Italian example is the Odesse[30], a simulation and optimization model developed by ENEA.

There are also several tools to evaluate the environmental performances at the building or neighbourhood scale. The environmental issue is not the topic of this dissertation, but could be included in future development of the research.

Ad regards the involvement of private owners, there are simplified tools to help directly the private owners to grasp the energy potential of their own building. ENEA is developing, in the Request2Action[31] European project, a user-friendly online tool dedicated to owners to obtain information on the energy performance, on energy measures and available incentives. The project[32] will also develop a hub platform where it will be possible to do a "one stop shop for building low-carbon renovation". Outcomes are expected in 2017.

The major weakness of tools dedicated to owners is that the initiative to check the energy performance must spring from the owner, not considering the barriers that block the decision to undergone a retrofit or even check the actual energy performance.

There are also several tools to raise awareness about the renewable energy sources potential of the private building stock.

For example, Mapdwell[33], a Boston-based M.I.T. spin-off, developed several urban solar maps with indicators for PV installation. In the interactive webmap (see Figure 2.1) it is possible to select a building and obtain an estimate of rooftop PV potential, with financial indicators, system specs and carbon offsets.

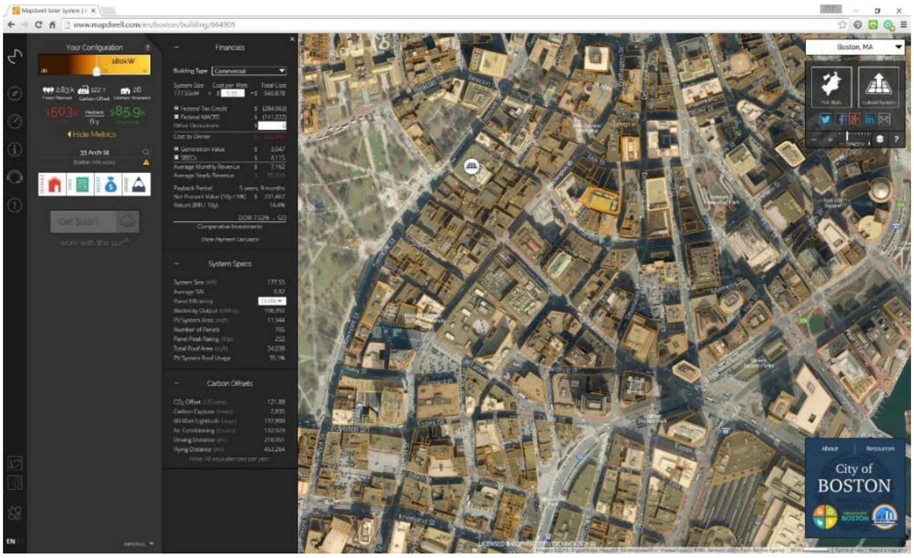
30 http://www.enea.it/it/Ricerca_sviluppo/ricerca-di-sistema-elettrico/Risparmio-energia-elettrica/tecnologie-per-lefficienza-energetica-nei-servizi/odesse-1

31 http://building-request.eu

32 http://www.agenziaefficienzaenergetica.it/progetti/request2action

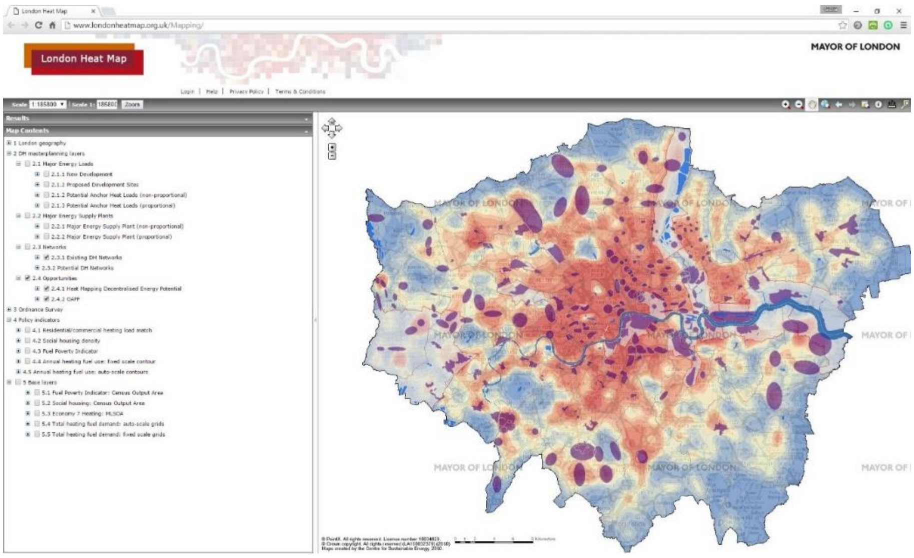
33 http://www.mapdwell.com

Figure 2.1 Web-based solar map of Boston developed by Mapdwell®



District heating potential maps are less numerous, but an example is set by the London Heat Map[34], developed within the Decentralised Energy Master Planning programme. The interactive web map (see Figure 2.2) allows users to identify opportunities for decentralised energy projects in London. Through the London Heat Map it is possible to know heat loads, heat supplies and heat network; in addition there are several layers to identify opportunities for utility companies and investors.

Figure 2.2 London Heat Map, developed by London Community Heating Development Study



Taking into account all these aspects, the research has focused on an energy model at municipal scale, called Municipal Energy Model (MEM), and on two tools dedicated to private owners, the Energy Advisor and the Energy Scout.

The MEM is a bottom-up hybrid model, since it use both collected data of the specific building and archetypal approach to fill the lack of data. The focus is on a model that could

[34] http://www.londonheatmap.org.uk

be quickly implemented for each Italian municipality, thus the research gave more importance to diffusion rather than accuracy of the model. The MEM also takes advantage of the potential of GIS to enable analysis on a municipal or district scale. Moreover, the MEM could be used to help local administration to overcome the barriers to LEP (see Chapter 4 and 5).

After an analysis of barriers and drivers to energy measures done by private owners, that could be found in Chapter 4, the research turned towards the proposal of two tools dedicated to stimulate the renovation of the building stock. The purpose of Energy Advisor is to give a tool, managed by municipal staff, to raise awareness and give data to citizens about the energy & building issue. The purpose of the innovative tool Energy Scout is to find work opportunities for companies in the energy-building sector, giving an active role to municipal administration for searching local opportunities to tackle the energy & building issue.

MEM, Energy Advisor and Energy Scout are described in Chapter 5, while Chapter 6 describes the development of MEM and Energy Scout on an Italian municipality.

3 FIGURE OUT THE ISSUE: ENERGY AND BUILDINGS ATLAS

In order to tackle the true potential of the building stock energy sink (Chapter 1.3) it is necessary first to have a more widespread and detailed knowledge of the energy issue liked to the building stock. As seen in Chapter 2, in Italy the regulatory and strategies for energy are not homogenous at national level, but scattered into regional, provincial and municipal levels.

The energy and buildings issue should be tackle both at the national and local level. This Chapter address the national level, presenting a data collection framework of indicators of the energy & buildings issue. This chapter carry out an analysis of the Italian data sources regarding the energy and buildings issue with detail at the municipal level. Moreover, an example of application of data collection framework is provided, an Energy & Buildings Atlas that allows viewing of spatial data and more advanced analysis.

3.1 A NEW NATIONAL FRAMEWORK FOR ENERGY AND BUILDINGS

At the national level, Italy lacks a database with indicators about the energy and buildings issue, with a level of detail of the smallest local administration, i.e. the municipality. As regards data in general, the Agency for Digital Italy - *Agenzia per l'Italia Digitale* (AgID), established in 2012 (l. 134/2012), is responsible for the realization of the Italian Digital Agenda objectives, in line with the Digital Agenda for Europe[35]. In 2014 AgID reviewed and redesigned the national repository of open data (http://www.dati.gov.it); AgID also manages the National Directory of Territorial Data – *Repertorio Nazionale dei Dati Territoriali* (RNDT). However, these are a collection and not an organized and aimed framework.

If existing data about energy and buildings are collected and georeferenced, analysis capabilities are enriched and future policies are supported by more sound datasets. Other countries have already a similar framework, in Italy such database is not present, thus a data collection database is a step toward a clearer picture of the energy & buildings issue.

The main data that are useful to depict the energy profile of the single municipality and of its building stock are:

- demographics;
- local energy policies;
- energy consumption per sector and per fuel;
- GHG emissions per sector;
- energy distribution, including district heating and smart grid;
- energy production, considering both conventional and RES power plants, with detail about number, power, production;
- District heating and RES potentials;
- general data about the building stock (e.g. number of buildings; floor area);
- energy and energy-related features of the building stock (e.g. energy performance, age of construction);
- building's systems stock (e.g. heating systems).

[35] http://ec.europa.eu/digital-agenda

I had the opportunity to collaborate in the creation of a similar database thanks to the project "Territori post-metropolitani" (www.postmetropoli.it). Within the research group, I worked especially on the energy-environmental aspects and the urban metabolism. A re-elaborated version of this work is presented here as "Energy & Buildings Atlas".

3.1.1 Post-metropolitan territories project[36]

The research project "Post-metropolitan territories as emergent forms of urban space: coping with sustainability, habitability, and governance", aims at exploring the new urban forms of contemporary Italy, with a particular attention to the production of processes of regionalization of the urban or regional urbanization (Soja, 2011). It is a three years research project funded by the Italian national Ministry of University and Research, in the framework of the PRIN program, "Programmi di Ricerca di Interesse Nazionale" (Research Programs of National Interest).

The project aims at exploring the new urban forms of contemporary Italy, studying the emergence of new "urban questions" and reflecting upon the capacities of these post-metropolitan territories and urban formations to cope innovatively and appropriately with the challenges produced by occurring transformations.

Recent programming documents look at cities, large urban areas and more recently to medium and small-size towns, as a resource towards social and territorial cohesion and sustainability (Territorial Agenda 2020, EUROPE 2020). The hypothesis is that if one aims at testing the capacity to cope with these challenges, classic categories of city and metropolis must be abandoned and new socio-spatial formations, which compose the post-metropolitan space, must be taken into consideration.

One of the objective of the project was to provide a first comparative reading of the main urban processes that affect the Italian territory, since:

- There is a strong demand for knowledge about the ongoing processes of urban transformation, especially at broad scale;
- A large amount of data are collected to describe the urban phenomenon in Italy, however a database dedicated to the urban environment and to its processes of transformation does not exist;
- University research programs and some institutions have already carried out important quantitative analysis, however these efforts have not generated an stable observatory of urban transformation processes in Italy;
- To really grasp the ongoing processes that overcome municipal borders it is necessary to have not discontinuous data (e.g. referring only to provincial capitals) but continuous data throughout the national territory.

A result of the research is the *Atlas of post-metropolitan territories*, which can be described as:

- an original database with the scope to gather and to map all the relevant data to describe the evolution of the areas observed;

[36] This chapter contains extracts of the project deliverable *Brief introduction to the Research Project,* Edited by Balducci, Fedeli and Curci for the research seminar held 19-20 February 2015, in Milan.

- a Web platform which allows to immediately map all the data included in the database and therefore to grasp the spatial dimension of the evolution;
- a limited number of synthetic indicators that the research probed and found meaningful to describe the evolution of post-metropolitan Italy; some of them are already commented, some others are still under elaboration;
- 9 synthetic regional portraits based upon the database and the maps produced through the web platform, offering a first description of the observable dynamics in each of the areas considered;
- a first group of issue papers in which researchers have raised some first interpretations of the new urban question and of the current trends in post metropolitan Italy.

The design and development of the *Atlas of post-metropolitan territories* is a conceptually complex methodological operation, which aims to verify if and how in a number of urban regions in Italy, one can find the dynamics described in the international literature that has interpreted contemporary urban processes.

During the research presentation seminary held 19-20 February 2015, in Milan several interesting comments arises from the international Advisory Board: Willem Salet (UvA); Simin Davoudi (Newcastle); Klaus R. Kunzmann (Dortmund); Peter M. Ache (Nijmegen); Christian Lefevre (IUP); Ivan Tosics (MRI); Louis Albrechts (Leuven).

Since the data collection phase absorbed too much time, a critical point is that the Atlas contains useful detailed analysis but lacks synthesis as reflected also by the large number of indicators. After this analysis phase, it is necessary to find the receivers and their needs. One of the suggestions was to analyse a smaller urban organism, however it should be taken into account that local administrations do not have experience or competencies to manage the increasing complexity of the urban environment. There is the need of a form of government that adapt to change quickly and the role of this research could be to develop scenario, list goals and stimulate to take action.

Research is under way to apply an urban metabolic model (Giordano, Caputo & Vancheri, 2014) to the municipalities of Lombardy region. The capabilities of the urban metabolic model could help in representing results; i.e., clustering municipalities based on selected parameters or performances. On the base of the comparison and taking into account ongoing policies, economic and technological conditions, possible scenarios could be defined for improving the territorial metabolism. Despite the regional complexity and the unpredictability of people behaviour, this activity will represent an important occasion for applying the metabolism approach to a territorial context. In the Italian debate, a metabolic analysis of an urban region is almost a new exploration that could help to understand interesting behaviours in terms of production and consumption of energy and resources. The exploration of energy and resource fluxes in a geographical context could help observing the emergence of new assemblages and transcalar actors and networks and identifying new challenges for policies.

3.2 DATA SOURCES IN ITALY

The aim of the Energy & Buildings Atlas is to gather data in a coherent framework with a level of detail (LOD) of the single municipality, or, when missing, of the Province. It was thus necessary to collect data form various sources that publish data about the energy issue and/or the building stock. The following sections present a description of the main data source in Italy, the availability of data and some remarks for future data availability. Table 3.1 summarizes this analysis.

3.2.1 Main sources of data

Sistan

The official statistical information is managed by National Statistical System - *Sistema statistico nazionale* (Sistan), established by national decree (d.lgs. 322/1989). Sistan[37] has the role to direct, coordinate, promote and give technical assistance and training to the statistical activities of associated institutions and offices. However, Sistan does not collect and organize the data of its network into a coherent framework.

Istat

The main statistical organization is Italian National Institute of Statistics – *Istituto nazionale di statistica* (Istat), created in 1926. The main products are the general censuses: population and housing, industry and services, and agriculture; but statistical production is continuous and wide about economic, social, territorial and environmental aspects. Press releases, publications, databases and information systems, datasets are published free of charge on the website (http://www.istat.it). Obviously, confidential data are not published, but some micro-data could be requested for research purposes.

ISPRA

The Institute for Environmental Protection and Research – *Istituto Superiore per la Protezione e la Ricerca Ambientale* (ISPRA) born from the fusion of three research institutions on environmental issues (d. 123/2010). In particular, the ISPRA systematically collects information on the state of the environment (air quality, water quality, waste, air emissions, use and land consumption and other indicators).

ISPRA is part of a federal system, the National System for Environmental Protection, that promotes the collaboration and coordination of the 21 Territorial Environmental Protection Agencies (ARPA / APPA), established by Regional Laws.

ENEA

The Italian National Agency for New Technologies, Energy and Sustainable Economic Development - *Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile* (ENEA[38]) is a major Italian research organization, derived from previous institutions, established in 2009 (L. 99/2009). The purpose of ENEA is to develop research

[37] http://www.sistan.it

[38] http://www.enea.it

and technology innovation as well as provide advanced services to the energy sector, notably the nuclear sector, and foster sustainable economic growth. Among other things, ENEA collects data and carries out analysis on the regional and national energy system, and gives support and advice to public administration and information dissemination through its Technical Unit for Energy Efficiency (UTEE)[39].

With the new National guidelines for EPCs (see Chap. 2), ENEA is in charge of:

- prepare and disseminate a guide about to read the EPC and an information brochure on the contents and legal obligations;
- Institution of an information system for EPCs, heating plants and inspection - *Sistema Informativo sugli Attestati di Prestazione Energetica* (SIAPE), ensuring interoperability with the regional registers and with the National Cadastre held by the Revenue Agency;
- create a section on its website dedicated to:
    - access to SIAPE;
    - annual statistics about EPC, inspections and average costs;
    - information on actions to increase the energy performance of buildings, technologies available for this purpose, the indicative costs, an update on national and regional incentives as well as a guide to the compilation of the recommendations;
- upgrade of the simplified calculation tool DOCET.

GSE

The Energy Services Operator - *Gestore Servizi Energetici* (GSE)[40] is a state-owned company which promotes and supports renewable energy sources, in particular the electrical ones. One of the three subsidiaries is Research on Energy System – *Ricerca sul Sistema Energetico* (RSE)[41], which is active in research in the electricity and energy sectors and in projects of strategic interest.

Terna

Terna is a large operator in electricity transmission grids and operates the National Transmission Grid and the electricity flows for Italy. Terna collect and publish data about energy grid, power plants, energy loads, energy production and consumption.

AEEG

Italian Regulatory Authority for Electricity Gas and Water - Autorità per l'energia elettrica il gas ed il sistema idrico (AEEG)[42], created to protect the interests of users and consumers, promote competition and ensure efficient, cost-effective and profitable nationwide services with satisfactory quality levels (l. 481/1995). One of the aims is to promote environmental protection and the efficient use of energy. Publish data about water, gas and electricity

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[39] http://www.agenziaefficienzaenergetica.it

[40] http://www.gse.it

[41] http://www.rse-web.it

[42] http://www.autorita.energia.it

Agenzia delle Entrate

The national Revenue Agency – Agenzia delle Entrate absorbed the functions of the Agency of the Territory (l. 135/2012) that managed the Cadastre of buildings and land and set up the observatory of the real estate market - O*sservatorio del Mercato Immobiliare* (OMI). PAs could access to databases through Sister[43].

[43] http://sister.agenziaentrate.gov.it

Table 3.1 Data sources and details

indicator	source	data	format	max LOD	update	time series	last update	avaiable at
Energy consumption	MiSE - BEN	energy consumption per sector and per fuel	table in PDF	national	annual	1998-2014	2014	http://dgsaie.mise.gov.it/dgerm
Energy consumption	MiSE - BEN	energy consumption per sector and per fuel, Eurostat methodology	table in xlsx	national	annual	1990, 1995, 2005, 2010-2013	2013	http://dgsaie.mise.gov.it/dgerm http://ec.europa.eu/eurostat/web/energy/data/energy-balances_
Energy consumption	MiSE - BEN	energy production per fuel, Eurostat methodology	table in xlsx	national	annual	1990, 1995, 2005, 2010-2013	2013	http://dgsaie.mise.gov.it/dgerm http://ec.europa.eu/eurostat/web/energy/data/energy-balances_
Energy consumption	MiSE	natural gas consumption per sector	table in xls	provincial	annual	2004-2014	2014	http://dgsaie.mise.gov.it/dgerm
Energy consumption	TERNA	electricity consumption per sector	table in PDF	provincial	annual	2000-2014	2014	http://www.terna.it/it-it/sistemaelettrico/statisticheeprevisioni/datistatistici.aspx
Energy consumption	TERNA	electricity consumption per sector (detailed)	table in html	provincial	annual	1977-2014	2014	http://www.terna.it/it-it/sistemaelettrico/statisticheeprevisioni/consumienergiaelettricapersettoremerceologico/consumienergiaelettricapersettoremerceologicoprovincie.aspx
Energy production	MiSE - BEN	energy production per fuel	table in PDF	national	annual	1998-2014	2014	http://dgsaie.mise.gov.it/dgerm
Energy production	TERNA	electricity production	table in PDF	regional	annual	2000-2014	2014	http://www.terna.it/it-it/sistemaelettrico/statisticheeprevisioni/datistatistici.aspx
Energy distribution	TERNA	electric grid & plants, 380 kV and 220 kV	maps in pdf	submunipal	annual	2000-2014	2014	http://www.terna.it/it-it/sistemaelettrico/statisticheeprevisioni/datistatistici.aspx
Energy distribution	SNAM	gas pipeline	maps in pdf	submunipal	annual	2012-2014	2014	http://www.snamretegas.it
RES	GSE	RES plants: number and power	maps in pdf	provincial	annual	2008 - 2013	2013	http://www.gse.it/it/Statistiche/RapportiStatistici
RES	GSE - Atlasole	PV plants: number and power	GIS	municipal	monthly	2006-2015	2015	http://atlasole.gse.it/atlasole
RES	GSE - Atlavento	Wind plants: number and power	GIS	provincial	monthly	2005-2015	2015	http://atlaimpianti.gse.it/atlavento
RES	RSE	Mini-hydro plants: number and power	GIS	provincial	not updated	2006	2006	http://minihydro.rse-web.it
RES	RSE	Mini-hydro plants: potential	maps in pdf	hydrological basins		2006	2006	http://minihydro.rse-web.it
Energy distribution	AIRU	District heating systems	table in PDF	municipal	annual	1972?-2012	2012	http://www.airu.it
Energy distribution	AEEG	Smart grid	table in PDF	municipal			2013	http://www.autorita.energia.it/it/operatori/smartgrid.htm
Energy potential	AIRU	District heating potential	maps in pdf	regional			2012	http://www.airu.it
Energy potential	ENEA	Biomass potential	GIS	provincial				http://www.atlantebiomasse.enea.it
Energy potential	RSE	Wind plants potential	GIS	submunipal			2009	http://atlanteeolico.rse-web.it
Energy potential	PVGIS	Solar Resource and Performance of PVs	GIS	submunipal			2012	http://re.jrc.ec.europa.eu/pvgis
Energy policies	Covenant of Mayors	signatories of Covenant of Mayors	table in html and xls	municipal	monthly	2008-2015	2015	http://www.covenantofmayors.eu/about/signatories_en.html
Energy policies	Legambiente Cresme	Innovative building codes	maps in pdf	municipal	annual	2008-2010, 2012-2014	2014	http://www.legambiente.it/contenuti/dossier/rapporto-onre
Energy policies	FIRE	Energy manager	table in PDF	municipal	annual	2003-2014	2014	http://em.fire-italia.org
Energy policies	ISTAT	Mandatory municipal energy plan	table in xls	municipal	annual	2000-2012	2012	http://dati.istat.it

3.2.2 Current data availability

Energy Consumption & Production

To analyse the energy issue it is necessary to know the energy consumption and production per each municipality.

The Ministry of Economic Development – *Ministero Sviluppo Economico* (MiSE), publishes each year the National Energy Balance - *Bilancio Energetico Nazionale* (BEN). MiSE recently published the energy balances compiled according to Eurostat's methodology[44]; however these balances are only at national level.

Though, MiSE publishes each year the natural gas consumption per sector with a provincial LOD, on the basis of data from gas grid operators (SNAM Rete Gas, S.G.I. s.p.a. et alter).

TERNA, which manages the national electricity system, publish data about the electricity production and consumption each year, with a maximum LOD at provincial level.

AEEG publishes data about the energy consumption, however they are only at the national level.

Unfortunately, there are no data about energy consumption and production for all Italian municipalities. Only in the forerunner Lombardy Region there is an organized information systems about the energy & buildings issue. It is thus possible, for each Lombard municipality, to have data about final energy consumption (per sector and per energy sources) and GHG emissions related to final energy uses, thanks to the Energy & Environment regional information system (Sirena).

GHG Emissions

Another important indicator to draw a baseline of the energy and building issues is the amount of greenhouse gas (GHG) emissions caused by the built environment.

The Greenhouse Gas Monitoring and the annual National Inventory Report, requested by the UN Framework Convention on Climate Change is done by ISPRA and published on its website. This data are available only with a national aggregation.

A more detailed inventory of the air emissions is done by each of 21 Territorial Environmental Protection Agencies, however often they give only point data resulting from monitoring stations. A good practice is set by ARPA Lombardia, that developed the Inventory of atmospheric emissions (INEMAR)[45] for each municipality. Since 2006 other regional authorities joined the service, that now covers Lombardy, Piedmont, Veneto, Friuli Venezia Giulia, Emilia Romagna, Marche, Puglia, Bolzano and Trento Provinces.

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[44] Refer to http://ec.europa.eu/eurostat/web/energy/data/energy-balances

[45] www.inemar.eu

Energy Distribution & Plants

As regards the electric grid, TERNA releases every year an updated map of the national electric grid at 380 kV and 220 kV, with the indication of thermal power, hydropower and wind power plants that supply them.

The natural gas grid is managed by SNAM, which releases every year an updated map of the national gas grid (obliged by the dlgs 164/2000).

District heating is monitored by the National Association Urban Heating- *Associazione Italiana Riscaldamento Urbano* (AIRU). AIRU publishes an annual report with the detailed data of all Italian district heating systems, in collaboration with Italian Producer of Renewable Energy Federation - *Federazione Italiana Produttori Energia da fonti Rinnovabili* (FIPER)[46].

Recently AEEG promoted pilot projects for smart grid, those admitted to incentive treatment are reported in detail on the AEEG website.

As regards the number and power of RES plants, the most complete source is the annual report published by GSE, "Rapporto Statistico – Energia da fonti rinnovabili". Regrettably, data are available only at provincial scale.

With a higher LOD, GSE manages also "Atlasole" and "Atlavento", two geographic information systems to monitor the PV and wind systems, respectively. These Atlases are part of the monitoring activities envisaged by national law (D.Lgs. 28/2011). Although the data are point by point, it is possible to download only the list of plants at municipal level for Atlasole and at provincial level for Altavento.

The RSE developed a GIS Atlas of mini-hydro, that includes the census of number and power of mini-hydro plants, regrettably this project is not updated.

It is important to note that there are no data available at the municipal scale for RES plants, except for PV systems.

Distric heating and RES potentials

The AIRU report analyses the district heating potentialities for cities with more than 25000 inhabitants.

As regard biomass, ENEA sets up an atlas with data about the production of biomass and biogas by several sources.

For the solar potential it is possible to refer to PVGIS, a European project that asses the solar resource for every coordinates and estimate the performance of PV systems.

The potentialities of wind-powered plants are available on the wind atlas developed by RSE. It should be noted that it is not related to the Atlavento developed by GSE.

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[46] http://www.fiper.it

The RSE developed also a GIS Atlas of mini-hydro, that includes hydropower potential for each hydrological basins, regrettably this project is not updated.

Energy Policies

In the annual report by ISPRA, available at http://annuario.isprambiente.it, there are several indicators for the promotion of the environmental culture, however they are only on national basis.

ENEA manages the procedures of tax deductions for energy efficiency of existing buildings and publish each year a report (ENEA, 2014) on the requests with a regional detail.

A monitor of the mandatory municipal energy plan (PEC) is done annually by ISTAT, within the research *Environmental data in cities;* it is only a statistical approach (yes/no to the adoption) and not an analysis of the contents.

The mandatory appointment of the energy manager (see Chap. 2) is monitored by the Italian federation for energy efficiency - *Federazione Italiana per l'uso Razionale dell'Energia* (FIRE) an independent non-profit organization, founded by ENEA and two energy manager associations. Currently, the procedure is done through paperwork and results are published annually on the FIRE website in pdf, however it was recently decided to implement an IT platform for the monitoring (Circolare MISE del 18 dicembre 2014).

A widespread European initiative among Italian municipalities is the Covenant of Mayors. On the website is it possible to have an updated list of the signatories and on which step they are. It is possible also to request a list in Excel format.

An initiative that is monitored by Legambiente is the adoption of energy-conscious building codes by municipalities: the results are published in an annual report, called ON-RE. More than 1,000 Italian municipalities have an innovative building code.

Data about the building stock & families

The most complete dataset about the residential building stock is acquired during the national Population and housing census held by ISTAT. Unfortunately, this census is held every 10 years and it takes about three years to publish the results, so the information is quickly out of date. In 2012 it was decided (CE 763/2008 and national law 221/2012) to transform the census in an annual survey, but it is still in the experimental phase[47].

Metadata of the Population and housing census are available on the ISTAT website. Data with a municipal LOD could be directly downloaded at http://dati-censimentopopolazione.istat.it . More detailed data could be downloaded at http://datiopen.istat.it , where data are aggregated by census section. Obviously, the Census survey collect data about the single dwelling, but the access to these micro-data is restricted since there are sensitive data. In Table 3.2 there is a synthesis of data available at the census section, it should be noted that in 2001 there were more detailed data about the dwellings.

[47] For information see http://www.istat.it/it/censimento-permanente

Table 3.2 Synthesis of data in national Population and housing census held in 2011 and 2001 .Data ISTAT

	Census held in 2011		Census held in 2001	
category	**cod**	**description**	**cod**	**description**
population	P1-P46	demo and age	P1-P46	demo and age
	P47-P59	education	P47-P59	education
	P60-P66, P128-P140	work	P60-P138	work with detail on working sector and role
	ST1-ST15	foreigners and stateless persons	ST1-ST7	foreigners and stateless persons
families	PF1-PF9	number of families and members	PF1-PF9	number of families and members
dwellings	A2-A7	occupation	A1-A5	occupation
	A46-A48	ownership or rental	A9-A11	ownership or rental
	A44	area	A23, A44	area
			A6,A7, A12-A17	number of rooms (class)
			A18-A22,A24,A25	facilities and systems
buildings	E1-E4	number and use of buildings	E1-E4	number and use of buildings
	E5-E7	material of construction (class)	E5-E8	material of construction (class)
	E8-E16	age of construction (class)	E9-E15	age of construction (class)
	E17-E20	number of floors (class)	E16-E19	number of floors (class)
	E21-E27	number of dwellings (class)	E20-E24	number of dwellings (class)
	E28-E31	state of conservation	E25-E27	state of conservation

Energy Performance of the Buildings

The Energy Performance Certificates Registers seem the most apt database to collect data about the energy performance of the building stock.

Currently Italian regional authorities[48] are in charge to update the register of energy performance certificates. Unfortunately, the implementation of the regional registries is not complete, since only 12 regional authorities out of 21 have an operating register (CTI, 2014). The data accessibility is complete only in Lombardy Regions, while for other five Regions it is possible to access to aggregate data. Further, the methodology for the energy certification is different among the several regions and the reliability of certificates is not guaranteed because monitoring activities are still in an experimental phase (CTI, 2014).

Starting from the first of October 2015, a new set of national laws became operative, as explained in Chapter 2. The most interesting novelty from the point of view of data availability is institution of an information system for EPCs - *Sistema Informativo sugli Attestati di Prestazione Energetica* (SIAPE), instituted by ENEA that have to ensure interoperability with the regional registers and with the National Cadastre held by the Revenue Agency. Unfortunately, the new National guidelines envisage a full data accessibility only for the PA and only about their own territory; citizens could access only to aggregate data.

Moreover, the National guidelines proposes a national standard format of energy performance certificate (EPC): actually seven regional authorities use their own format. Moreover, the CTI has developed a proposed standard XML for EPCs data exchange, available on the website www.cti2000.eu.

[48] Italian Regions plus the two autonomous provinces of Bolzano and Trento

Heating systems

The regional authorities[49] should set up a Register of heating systems (d.P.R n.74/2013) and a Register of geothermal heat pump (D. Lgs. n. 22/2010). However, these two register are scarcely implemented: the only Region with active and public-data registers is Lombardy Region. The Heating system Register is available at http://www.curit.it; while the Geothermal heat pump register is available at http://www.rinnovabililombardia.it/rsg.

Cartography

For analysis with a greater level of detail, e.g. municipal scale, it is necessary a digital cartography of the building stock. In each municipality the Master Plan is based upon a cartography, however it is often on paper, outdated or with a low level of details. An alternative source is the Technical Regional Map, for which the minimum scale is 1:5000. The website of the Regional cartographic services is reported in Table 3.3.

Another source of digital cartography of the building stock is the "Catasto Fabbricati" (building cadastre), managed by the National Revenue Agency. The database is reserved but accessible for municipalities and other PA bodies.

3.2.3 Future data availability

In future, thanks to smart metering, data about final energy consumption in buildings will be increasingly detailed and data accessibility will be more widespread, following the open data policy. In fact, the European Commission conveyed its policies with *Open data: An engine for innovation, growth and transparent governance* (COM 2011, n. 882) and, on smart metering, with *Preparations for the roll-out of smart metering* systems (2012/148/EU).

Further, in the Italian context there are already some initiatives to expand the data availability, such as that of the initiative by Authority for Electricity and Natural Gas (AEEG, 2013) to incentivise pilot projects for multi-service smart metering, so it will be possible to know the consumption of electricity, water, and natural gas. However, AEEG should have a larger role in collecting and verifying data, now simply gathered from distributors.

As example of good practice, Lombardy Region set up a data platform about energy (http://www.energialombardia.eu). The scope is to collect in a single platform data about energy consumption in all the sectors and for all the final uses, buildings energy performance (envelopes and systems), and integration of renewable sources (Cestec, 2012). These data are available at municipal level and derive from several regional databases; the most complete and updated are: SIRENA, Information system for energy and environment (http://sirena.finlombarda.it); CENED, Register of buildings' energy certificate (http://www.cened.it); and CURIT, Register of heating plants (http://www.curit.it).

[49] Italian Regions plus the two autonomous provinces of Bolzano and Trento

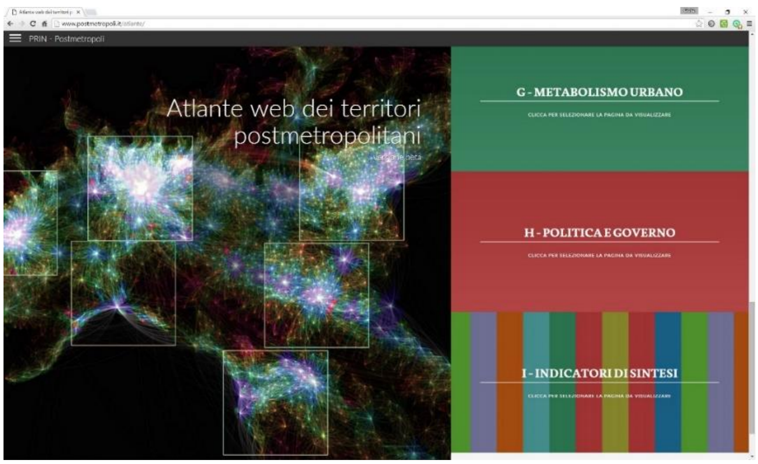
Table 3.3 Website of Regional Cartographic Services

regional authority	**website**
Abruzzo	http://geoportale.regione.abruzzo.it/Cartanet
Basilicata	http://rsdi.regione.basilicata.it
Calabria	http://pr5sit.regione.calabria.it/web/pr5sit/home
Campania	http://sit.regione.campania.it/portal
Emilia Romagna	http://geoportale.regione.emilia-romagna.it
Friuli Venezia Giulia	http://irdat.regione.fvg.it
Lazio	http://www.urbanisticaecasa.regione.lazio.it/cartografia_on_line
Liguria	http://www.cartografia.regione.liguria.it
Lombardia	http://www.geoportale.regione.lombardia.it
Marche	http://cartografia.regione.marche.it
Molise	http://cartografia.regione.molise.it
Piemonte	http://www.geoportale.piemonte.it
Pr. Trento	http://www.territorio.provincia.tn.it
Pr. Bolzano	http://www.provincia.bz.it/informatica/temi/cartografia-provinciale.asp
Puglia	http://www.sit.puglia.it
Sardegna	http://www.sardegnageoportale.it
Sicilia	http://www.sitr.regione.sicilia.it
Toscana	http://www.regione.toscana.it/-/geoscopio-wms
Umbria	http://www.umbriageo.regione.umbria.it
Valle d'Aosta	http://geoportale.partout.it
Veneto	http://www.regione.veneto.it/web/ambiente-e-territorio/sistema-informativo-territoriale

3.3 ATLAS OF POST-METROPOLITAN TERRITORIES AND ENERGY AND BUILDINGS ATLAS

The Energy & Buildings Atlas is an example of data collection framework and georeferencing data about the energy & buildings issue. It is not a stand-alone and closed tool, but is part of a more comprehensive and multidisciplinary project, the *Atlas of post-metropolitan territories* (Figure 3.1), developed within the *Post-metropolitan territories* project, described briefly in section 3.1.1. The scope of the Atlas is to fill out the important gap about information about the urban environment, gathering existing data at the municipal level or sub municipal levels. Thanks to this LOD and the spatial information, it is possible to provide a tool for advanced analysis of the whole Italian territory that was still missing in Italy.

Figure 3.1 Website of the Atlas of post-metropolitan territories



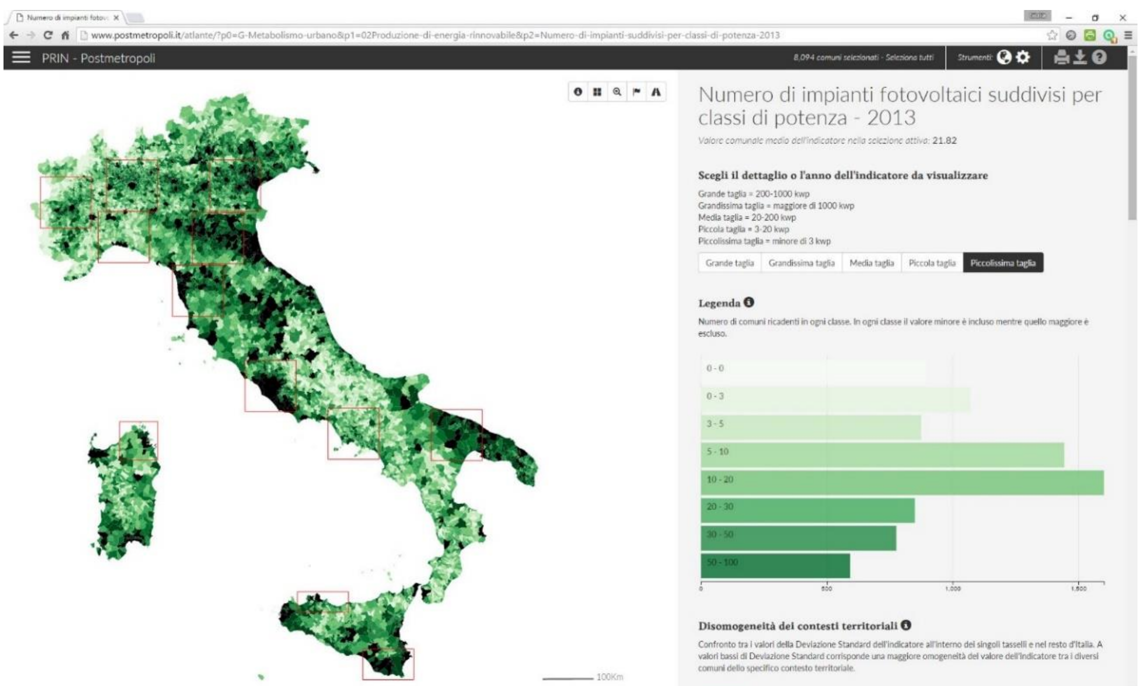
Originally, the Atlas focused on seven urban areas, more typically dense urban areas, which have experienced in different moments and ways processes of metropolization or are considered by the recent reform metropolitan areas (Turin, Milan, Veneto, Florence, Rome, Naples, Palermo). In addition, also two cases of not dense areas (Eastern Sicily and Olbia-Tempio) have been selected, for the emergence of peculiar processes. Actually three other dense areas have been selected (Bari, Bologna, and Genoa). This was possible because data are collected on the whole national territory, with a level of detail of the single municipality.

Thanks to the collaborative effort of research groups, the *Atlas of post-metropolitan territories* contains several indicators, organized as:

- morphology and dynamics of settlement;
- use and land cover;
- morphology and dynamics of socio-demographic context;
- economic processes;
- facilities and polarity;
- mobility and flows of people;
- urban metabolism;
- politics and government;
- summary indicators.

The Web platform allows to immediately map all the data and to grasp on-going processes (Figure 3.2). It is possible to filter dataset by geographic area, data classification and values, selecting also a single municipality. Often dataset are organized in time series, easily selectable. Moreover, the interactive map can be zoomed and moved easily to view areas of interest. The map is accompanied by graphics that help the understanding of the data. For each page of the Atlas is available for download a file of metadata useful to know information and methodology about data. All pages of the Atlas are optimized for printing, it is possible to save in pdf. In addition data can also be requested for further analysis. The accessibility and ease of use is fundamental for the dissemination of the tool.

Figure 3.2 Example of webmap in the Atlas of post-metropolitan territories



Unfortunately, with the current availability of data (see Chap. 3.2) it is not possible to organize a complete Energy & Buildings Atlas. As could be seen in Table 3.4 the worst shortcoming of data are GHG emissions, energy performance of the building stock and energy features of the building's energy systems. Some maps are reported in Annex A.

There is definitely a strong lack of data to fill and organizing a data collection framework like the Energy and Buildings Atlas help to understand the issue.

Currently, it is possible to elaborate some analysis, as done in the Post-metropolitan territories (deliverable 2: regional portraits). However, more interpretive efforts are still to be done, partly because of the lack of data covering all Italian municipalities.

With the development of the Energy & Buildings Atlas it is possible to have an overview of all Italian municipalities as regards the energy and buildings issue, that is actually lacking. With this tool and the linked dataset it is possible to compare municipalities and have a living picture of the building stock and energy systems. The Energy & Buildings Atlas could be used by national and regional government to set tailored policies on the actual context and the potentialities of the building stock, as example setting concerted municipal targets for energy savings. The Atlas is only a tool of the more comprehensive framework of policies needed in Italy, drafted in Chapter 5, to steer toward more effective energy policies.

Table 3.4 Current indicators in Energy & Buildings Atlas

category		indicator	notes
demographics		population	
		no. families and components	
local energy policies	compulsory	mandatory LEP	
		Energy Manager	
	voluntary	Covenant of Mayors	
energy consumption		per sector	provincial
		per fuel	provincial
GHG emissions			n.a.
energy distribution	conventional	electric national grid	
		natural gas national grid	
		energy distributors	
	distribuited	district heating	
		smart grid	
energy production	conventional	production per fuel	provincial
		number and power electrical plants	
	RES	production per source	provincial
		number and power PV	
energy production potential		solar radiation	
		wind potential	
general data about the building stock		no. Buildings	
		building density	
		ownership or rental of housing	
		unoccupied housing	
		no. dwellings in buildings	
		area of residential stock	
		undeclared buildings	
energy and energy-related features of the building stock	energy performance		n.a.
	proxy indicators	age	
		state of conservation	
		building materials	
building's systems stock			n.a.

4 Energy Renovation: a focus on Barriers and Drivers

In order to fully exploit the energy sink of the existing building stock it is necessary to take into account the barriers that block potential cost-effective energy measures and the drivers that conversely help the adoption of these measures. This chapter presents the analysis of the barriers to local energy planning for the public administrations (PAs) and the analysis of the barriers and drivers for the private actors in the Italian context.

4.1 Barriers for Public Administration[50]

Chapters 1 and 2 outlined that the Italian and European building stock is old and has poor energy performance (BPIE, 2011) and that it is necessary an energy renovation plan. As clearly mentioned also in a recent seminar by ECEEE[51], the European legal framework suggested an energy performance approach that was well implemented, but this positive effect is restricted by the often limited volume of construction. Efforts are needed in order to strengthen local and regional verification of national building codes and to accurately inform consumers of the energy performance of buildings for sale or rent, in combination with making full use of available financing

Within the Entranze Project (www.entranze.eu), has been carried out a literature review about the structure of key stakeholders, users and investors and their behaviour, preferences and interests, in order to analyse the most critical barriers to buildings retrofit. They underlined that the role of initial costs is dominant in most countries among housing owner-occupiers and they emphasized the role of grants in encouraging investments. In Italy, generally speaking, these limits are mainly related to financial aspects, lack of information and skills, collective decision problems and uncertainty in measurement and verification[52], but there are differences depending on the buildings' typologies (i.e. owner-occupied single-family homes; owner-occupied apartment buildings, social/professionally owned rental housing; public buildings).

Other important contributions in clarifying the existing barriers to retrofit of existing building in European countries and also in Korea and Canada are reported in Emmert et al. (2013), Baek and Park (2012a), Baek and Park (2012b), Galvin (2012) and Gamtessa (2013), Hoicka et al. (2014).

To focus on the European context, with particular regard to the barriers for PA at handling a local energy plan, this research analysed the contributions of (Chmutina et al., 2014; Comodi et al., 2012; Dowson et al., 2012; Zanon and Verones, 2013; EBC, 2013; BPIE, 2013a).

After analysing the available literature, non-technical barriers that block or slow down the processes of local energy planning in the Italian context have been focused(Caputo et al., 2013; Dall'O' et al., 2012; Ballarini et al. 2014).

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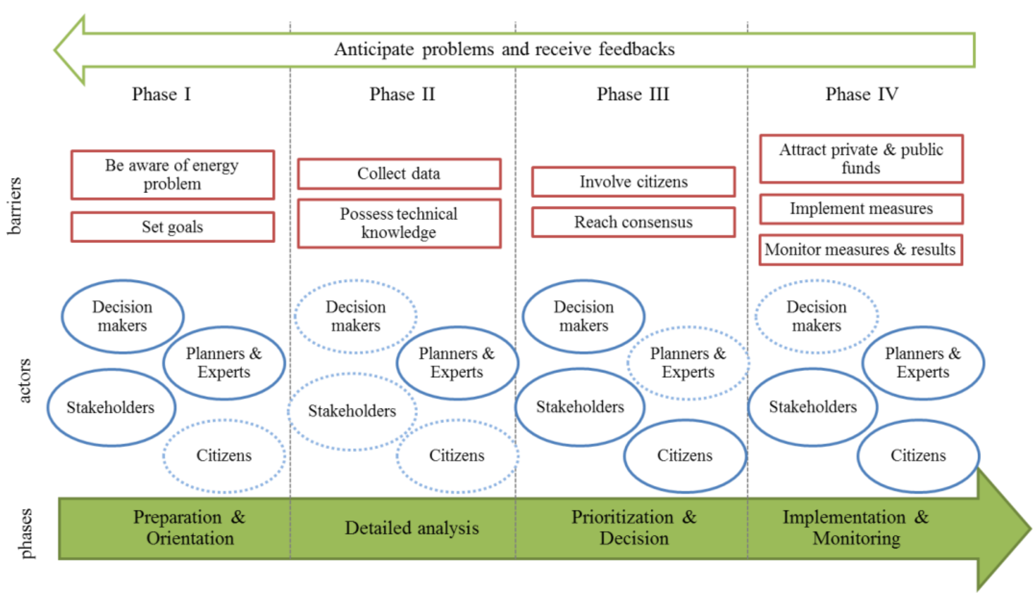
[50] This chapter contains extracts of the previously published Caputo, P., & Pasetti, G. (2015). The text is edited to integrate the publication in this dissertation.

[51] http://www.eceee.org/events/eceee_events/annual-policy-seminar-19-November-2014

[52] http://www.entranze.eu/files/downloads/D2_4/D2_4_Complete_FINAL3.pdf

Then, in order to better explore this topic, the hypothesis were checked arranging a questionnaire and sending directly to a selection of local administrations (see section 4.1.3). Since the response rate was low, some phone interviews were conducted with municipal technical offices, inquiring about the difficulties in compiling the questionnaire and about the barriers to undertake a local energy plan. The schematic process of integrated energy planning used as basis to depict identified actors and barriers in the various phases (Figure 4.1) is the one presented by Mirakyan and De Guio (2013). In *phase I: preparation and orientation,* the main barriers are the lack of awareness about the energy problem, and the difficulties to set significant goals for the local governments, since they are not aware of their municipality's potentials. *In phase II: model design and detailed analysis,* the data collection could be harder than expected. Moreover, the technical office, especially in small municipalities, may not have the expertise to collect and elaborate the data and then to develop an effective energy plan. In *phase III: prioritization and decision,* the decision makers have to involve stakeholders and citizens in order to select the best strategies; without any specific expertise, the municipal offices may have several difficulties in managing a participatory process that lead to a shared consensus. *Phase IV: implementation and monitoring* is the most critical and often projects fail during this phase. Especially in these years of economic crisis, the lack of financial availability could stop the planned actions, so the local governments should have the ability to attract private and public funds. The propriety fragmentation of buildings, the willingness of owners or tenants to start refurbishment and the regulation framework are the main critical points. The following sections mainly focus on the barriers of *Phase I* and *Phase II*, i.e. the barriers that particularly concern the PAs as shown in Figure 4.1.

Figure 4.1 Schematic process of local energy planning



4.1.1 Barriers to Preparation & Orientation Phase

Be aware of energy problem

Chmutina et alii (Chmutina et al., 2014) found that environmental awareness and concern is a prominent driver to energy projects, especially for private players, while stakeholders in the public sector are more influenced by the regulatory drivers. They also discovered that environmental awareness and concern could be instigated by the personal motivation of a project champion and by a variety of information sources about climate change and sustainability. As regards regulatory drivers, in Italy only municipalities over 50,000 inhabitants are obliged to develop a municipal energy plan (L 10/1991). However, the majority of Italians (66%) live in medium and small municipalities where energy planning is up to the willingness of the PA. By chance, there is a general concern in the local administration about the climate change and energy efficiency issues and also some willingness to take action. In fact, there are more than 1,000 Italian municipalities (more than 12% of the total) with innovative building code regarding energy efficiency and the use of renewable, as reported by Cresme and Legambiente (2013).

Further, in the Covenant of Mayors (www.covenantofmayors.eu), the European initiative that involve local and regional authorities into voluntary commitment for increasing energy efficiency and using renewable energy sources on their territories, Italy is placed first for the number of signatories, with currently 2,410 municipalities involved (30% of all Italian municipalities).

However, this kind of involvement is often unproductive, as confirmed by an Italian study that analyses some case studies: “translating a rhetorical commitment to energy efficiency into effective policies and programmes is far from being straightforward” (Zanon and Verones, 2013).

The feeling is that public administrators and citizens are informed about energy problems but they do not have the necessary awareness and consciousness to face these problems in order to solve them.

Set goals

Linked to the scarce awareness of the energy problems and relevant opportunities, there are criticalities in goals setting. Local administrations are generally aware of the general European targets and so they are interested in reducing CO_2 emissions and in promoting REs integration. Usually they believe that energy efficiency measures applied to the building stock, i.e. those devoted to improve the envelope and heating systems performance, are strategic in order to reduce fossil fuels consumption and CO_2 emissions. However, often they are not able to identify realistic, suitable, affordable, and cost effective goals for their own municipalities.

If the goals are simply the same for all the municipalities, it could be onerous or unsuccessful for some municipalities and undemanding for others. In other terms, goals definition is indeed a critical point and implies a deep knowledge of the features of the local built environment.

4.1.2 Barriers to Detailed Analysis Phase

Collect data

In order to develop a detailed analysis (*Phase II*) it is necessary to collect several data about the local built environment from the energy point of view (see also Table 4.3). Unlike other Countries, in Italy this step represents a great barrier, as reported in the technical literature and as recently assessed with four Italian municipalities with more than 100,000 inhabitants. Zanon and Verones (2013) underline an insufficient integration between energy and spatial planning and that actions and mechanisms are largely ineffective because of the multi-dimensional nature of energy issues. If this is true for large cities, it is expected that even more difficulties arise when a small municipality is involved.

Possess technical knowledge

A specific expertise is necessary to collect and analyse correctly data with the aim of defining energy saving goals and measures. Only in municipalities with mandatory energy plans or mandatory energy managers (see Chapter 2.2) some energy related expertise could be expected, but it is unlikely that other municipalities have such expertise. In most of cases, the municipal technical office has to manage all the issues related to the built environment, including energy issue. The competence to address issues related to energy is up to the profile and ethics of the technical staff of the single municipality.

4.1.3 Checking the assumed barriers

For a direct preliminary check of the assumptions about the barriers related to previously defined *Phase I* and *Phase II*, a survey on a sample of municipalities all over Italy was carries out, sending a questionnaire to the technical office. The selection was among the municipalities among the 1,064 municipalities with 10,000 to 50,000 inhabitants, corresponding to the 35% of Italians inhabitants: the medium demographic class municipalities should have more availability of human and economic resource respect to small municipalities but at the same time, they are not obliged to develop an energy plan as the large demographic class municipalities. Therefore, medium demographic class municipalities are the best to investigate the awareness, the policies and the resources for developing a LEP in a municipality not obliged to.

The questionnaire was send to municipalities, first divided into two municipal size classes (10,000-20,000 and 20,000-50,000). Municipalities was divided according to the sub-national geographic division used by Eurostat (i.e. North-West, North-East, Centre, South, and Islands). Municipalities were selected also in proportion to the number of municipalities in each province.
In

Table 4.1 is reported the aims and the data inquired about in the questionnaire. The questionnaire is made of three parts. The scope of the first part is to understand the level of awareness of the municipality in energy and buildings issues and if energy policies or other pertinent initiatives were carried out. The second part inquires about the ability of the municipal offices to collect energy data regarding the entire municipality. The third part requires a better knowledge of the building stock, inquiring about data necessary to develop and apply an energy plan focused on promoting energy saving in buildings by retrofit. It is wort noticing that the questionnaire did not request the mentioned data but only if these data were available (i.e. easily and directly accessible) in the database commonly used and managed by the municipal technical office.

The set of inquired data was selected taking into account the current development of the research in the national context. In particular three recent Italian methodologies were analysed to assess the energy performance of the built environment and to simulate improved scenarios: a methodology to assess the energy performance of large building stock (Fracastoro and Serraino, 2011); a methodology to assess the potential energy savings by retrofitting residential building stocks (Dall'O' et al., 2012); and a methodology to define energy strategies in the building sector at urban scale (Caputo et al., 2013). Table 4.2 summarizes the data and the sources used by the different methodologies. The main source of data for Fracastoro and Serraino (2011) is the National Census, integrated by energy standards and laws, literature and authors' assumptions. The methodology by Dall'O' et al. (2012) is based on detailed cartography and in-situ surveys, integrated by energy standards and laws, literature and authors' assumptions. Caputo et al. (2013) elaborated detailed data from National Census in a Geographic Information Systems and defined building archetypes for simulating the actual and improved performance of the building stock. An analoguous approach was recently followed by Ballarini et al. (2014) for defining and adopting reference buildings to assess the energy saving potentials of the residential building stock on the basis of the results of the European project TABULA[53]. Although there are differences and specificities, there is a common core of data adopted in the mentioned methodologies to characterize the energy efficiency of the building stock.

[53] www.building-typology.eu

Table 4.1 Structure of the questionnaire with aims and inquired data

level	aims	inquired data
Municipality	*Presence of energy awarness & policy*	energy policies
		energy office
General data	*Capability to gather general energy data about the municipality*	number of inhabitants
		actual heating degree days (HDD)
		energy consumption per sector (different classes of buildings, transportation, industry, agriculture etc) and use (electricity and fuels)
		energy production
Building stock data and supports	*Capability to gather specific energy data about the building stock*	digital cartography with buildings geometry
		buildings height
		buildings number of floors
		buildings roof shape
		age of construction
		regulatory constraints
		usage of the buildings (residential, commercial, etc)
		construction materials (structure, envelope, windows)
		state of conservation
		thermal transmittance of the envelope (U-value)
		n. inhabitants per household
		heating plant
		renewable energy sources

Table 4.2 Comparison between recent Italian methodologies on the use of data and sources for the characterization of the building stock.

		Fracastoro and Serraino, 2011		Caputo et al., 2013		Dall'O' et al., 2012	
categories	**data**	**raw data**	**source**	**raw data**	**source**	**raw data**	**source**
geometry	dipersing surface	floor area net floor height contiguity	ISTAT national census *derived* ISTAT national census	floor area perimeter height	cartography cartography cartography	floor area perimeter height	cartography cartography *derived*
	net floor area	floor area per room n° rooms per household n° household per building	ISTAT national census ISTAT national census ISTAT national census	gross floor area gross/net ratio	cartography authors	gross floor area gross/net ratio	cartography authors
	height	floor area h/Af ratio by age	ISTAT national census authors	-	cartography	number of floors floor height	cartography authors
	heated volume	net floor area net floor height	*derived* *derived*	net floor area net floor height	*derived* *derived*	net floor area net floor height	*derived* *derived*
	glazed area	net floor area Ag /Af ratio by age	*derived* authors	net floor area Ag /Af ratio	 D.M. 1975	Ag/Aw ratio wall area	sample survey cartography
	roof area for renewables					roof area south exposition	cartography survey
construction	age	-	ISTAT national census	-	ISTAT national census	-	cartography
	U-values	official U-values by age	UNI/TS 11300-1 laws 373/76 and 10/91	official U-values by age	UNI TS 11300-1 CNR 1982	official U-values by age	UNI/TS 11300-1 laws 373/76 and 10/91
	overall heating system efficiency	system efficiencies boiler efficiency	UNI TS 11300-2 literature	heating system efficiencies cooling system efficiencies systems' type	UNI TS 11300-2 UNI TS 11300-3 ISTAT national census	heating system efficiencies systems' type	UNI TS 11300-2 ISTAT national census
	state of conservation windows materials regulatory constraints					- - -	in situ survey in situ survey cartography
usage	Average indoor temperature	conventional value	authors	conventional value	authors	conventional value	authors
	residential/commercial			residential volume overall volume	ISTAT national census cartography		cartography in situ survey
	average numberof air changes per hour	technical standards	authors	technical standards	authors	technical standards	authors
	internal gains	occupancy rate persons	authors ISTAT national census	-	literature		
	DHW + cooking	energy consumption per person[kWh/(pers year)] square meters per person	literature ISTAT national census	-	UNI TS 11300-2	energy consumption per person[kWh/(pers year)] square meters per person	literature ISTAT national census
	electrical	energy consumption per person [kWh/(pers year)] square meters per person	literature ISTAT national census	-	literature	energy consumption per person [kWh/(pers year)] square meters per person	literature ISTAT national census
meteo	conventional DD	-	D.P.R. 412/1993	-	D.P.R. 412/1993	-	D.P.R. 412/1993
	actual DD	calculated	ARPA	typical meterological year	Energy Plus database	calculated	ARPA
	clima		ARPA	typical meterological year	Energy Plus database		ARPA
	solar irradiance	-	ARPA	typical meterological year	Energy Plus database	-	ARPA

4.1.4 Results of the Questionnaire

Unfortunately, the response rate to the questionnaire was very low: among 108 municipalities involved, just 10 partially answered and only 4 completed the entire questionnaire. Although from the statistical point of view the results are not significant, it can be seen as a clear sign of the lack of preparation of the municipal offices in facing energy issues related to the built environment.

In order to improve the collected information, some interviews to investigate better the energy problem at municipal level were conducted, calling the technical office. The phone interview inquired about the inability to compile the questionnaire, and on the barriers that represent the main obstacles in developing a building stock analysis and an energy balance. The outcome of the interviews consolidate the research's hypothesis on the main non-technical barriers.

The following common problems were detected:

- dispersion of data among several municipal offices and other administrative entities;
- lack of coordination among the different offices,
- different archives systems for data and/or lack of digital archives;
- lack of a statistical office;
- lack of interest at decision-making level.

The data scattering among several offices and other public entities could be overwhelming for smaller municipalities: they are not aware of data collected by other public entities and thus do not require nor use them.

Further the questionnaire helped understanding which data are available for small-medium Italian municipalities and if these data are suitable to develop an effective municipal energy plan for the built environment. Figure 4.2 and Figure 4.3 present the best and worst data availability found analysing the answers to the questionnaire. Data available are represented as green light; data not available are represented as red light; data that could be filled taking into account other sources are represented as yellow light, as depicted in Table 4.3. In particular, Figure 4.2 is referred to the municipality with the best data availability, among those investigated by the questionnaire. It is the case of a relatively large municipality, with 36 thousand inhabitants, located in North-East Italy, a relatively wealthy region. In this case, it is possible to calculate the energy consumption for heating, while other information (e.g. the thermal transmittance of the envelope, information about the current heating systems and plants) could be approximated by statistical data at national or regional level, as reported in Table 4.3. A feasibility analysis of the retrofit measures could not be fully done because there are no data about the technical features and state of conservation of the building stock (e.g. materials, state of conservation, etc.). Further, there are no data about the roof surfaces (materials, orientation, and inclination). This is an important gap because the surfaces of the roofs, if correctly oriented and not shaded, can be employed for the integration of solar systems (thermal collectors of PV modules) in order to exploit the solar potential of the municipal built environment. Furthermore, there is an annual report on the energy consumption at municipal level, but no data about the energy production. Of course, energy sources and conversion systems can be estimated taking into account the national or regional energy system, but all these approximations compromise the comparison between the current situation and possible future improved scenarios.

On the contrary, Figure 4.3 is referred to the municipality with the worst data availability, among those investigated by the questionnaire. It is clear that data are insufficient to develop a reliable building stock evaluation and an effective municipal energy plan, although some data could be filled with other sources of information. In particular, the lack of data about the energy consumption of the building sector and for the different final energy use does not permit to create a reference baseline.

It should be noted that these are the best and worst data availably founded: other municipalities have different data availability, although of similar size. Some technical offices are not aware of the availability of data at national or regional level and do not collect data at municipal level. The capability to collect energy data depends on the individual local administration and the results are quite different.

Figure 4.2 Municipal energy model required input and possible output: data availability and output achievability in the best case.

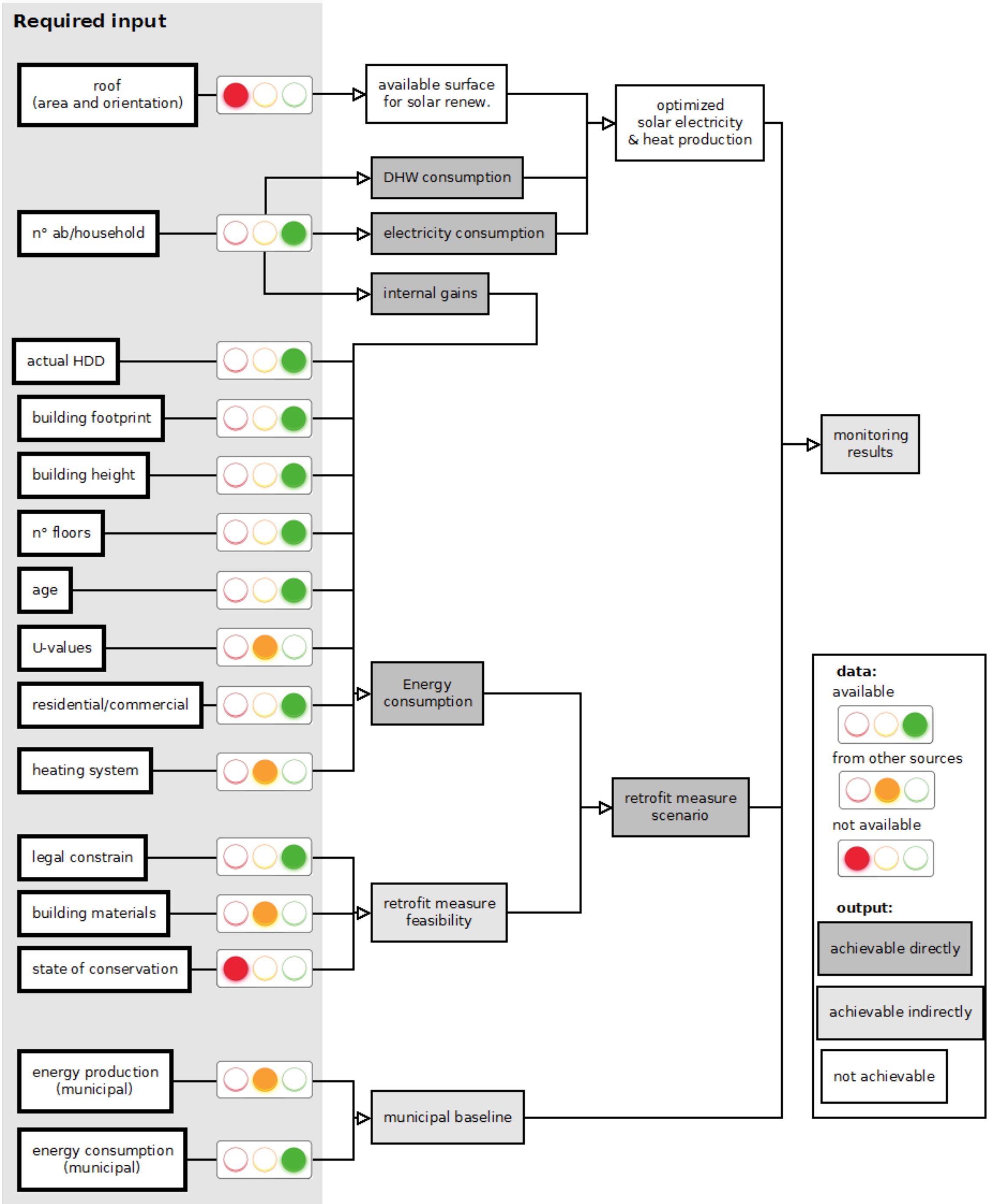


Figure 4.3 Municipal energy model required input and possible output: data availability and output achievability in the worst case.

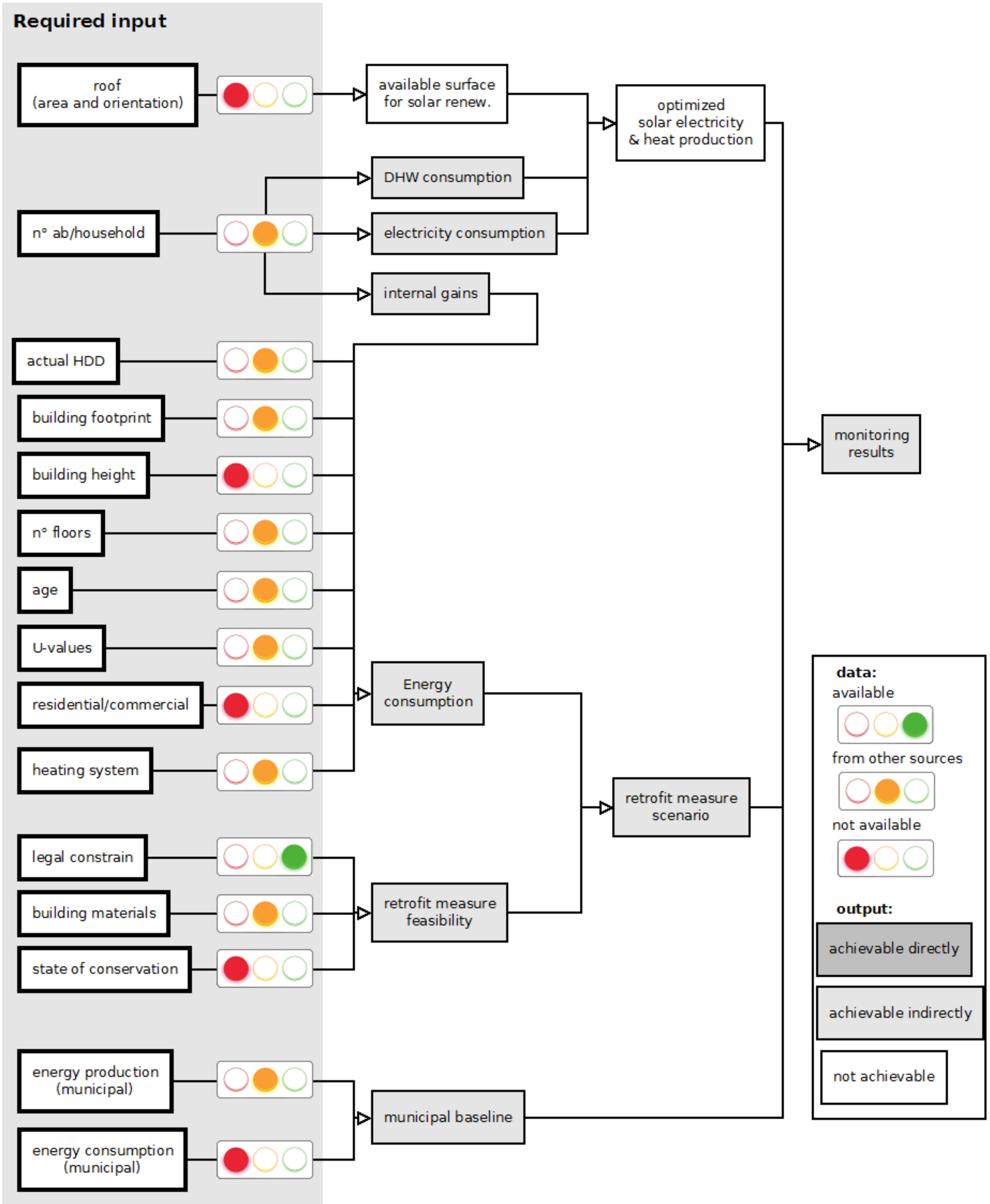


Table 4.3 Necessary data and possible source at different level; in light grey sources that may not be present.

	data	municipal sources	regional sources	national sources
	energy policies	Municipal legislation	Regional legislation	National legislation; ENEA
	energy incentives	Municipal legislation	Regional legislation	National legislation; ENEA
general data	inhabitants	Municipal register office		ISTAT: demograph statistics
	official Degree Days			D.P.R. 412/1993
	actual Degree Days		ARPA	
	design temperatures			D.P.R. 412/1993
	municipal energy consumption	*Municipal energy plan [only >50k inhab.]*	ARPA	TERNA
	energy production			GSE; MiSE
building stock	building footprint	*Municipal planning office*	Region: planning office CTR (1:5000)	National Revenue Agency : Land Registry
	building height	*Municipal planning office*		ISTAT: national census (n° floors)
	construction age	*Municipal planning office*		ISTAT: national census
	regulatory constraints	Municipal urban plan	Regional legislation	National legislation
	state of conservation			ISTAT: national census
	building materials			ISTAT: national census (brick or concrete)
	energy performance (Eph, U-values, heating systems, etc.)		Regional register of energy performance certificates	UNI TS 11300-1:2008
	inhabitants per household	Municipal register office		ISTAT: national census
	commercial/residential use	Municipal productive activities desk	Chamber of commerce: businesses cadastre	
	heating systems	*Municipality [>40k inhab.]: heating plant cadastre*	*Province: heating plant cadastre [for munic. <40k inhab.]*	ISTAT: national census (independent or centralized plant)
	renewable energy sources		Regional energy register	GSE

4.2 BARRIERS AND DRIVERS FOR PRIVATE ACTORS

To actually implement local energy plans with massive energy measure on the private building stock it is paramount to engage building owners, building managers, companies in the energy-building sector and investors. While researches to assess the energy saving potential of the building stock are quite mature and there are developed tools (refer to Chapter 3), the researches with focus on the barriers and drivers influencing private investment in the energy renovation of the building stock have yet to turn into practical applications. However, in order to reach European targets and exploit the full potential of the building stock acting on the private buildings is mandatory.

In order to identify such barriers and drivers, this chapter presents a literature review focused on the European context and an adaption of the findings to the Italian context.

First, I searched the main Italian and European studies regarding barriers and driver to energy measures and use of RES on the building stock, then I carried out a search on scientific databases (Scopus and Web of Science). Since the latter has given plenty of results, I decided to focus on the recent European researches since the context is more similar – compared to America or Asia – with regards to legislative framework, composition and technical features of the building stock, ownership and management of the building stock. It can therefore be expected that barriers and drivers are applicable to the Italian context.

4.2.1 Literature review

The National Energy Strategy (*Strategia Energetica Nazionale* - SEN) presents an analysis of the Italian energy context identifies priorities to be implemented to reach national objectives at 2020 and set a vision forward the 2050 Framework towards a low-carbon Economy. The SEN is the result of expert work, improved through an extensive process of public consultation. As regards RES and energy efficiency measures adaption in buildings, the SEN identifies the main barrier for civil sector, PA and industrial sector and gives a rough estimate of the relevance of the barrier.

The Italian Federation for energy efficiency – FIRE – is an independent non-profit organization, whose purpose is to promote the efficient use of energy. In 2011 published a study (FIRE 2011) about the barriers to energy efficiency in the use of electricity. The study points out that, since the investments in energy savings have a high financial return and a low risk, the economic aspect should not constitute a barrier. The study analyses thus the non-economic barriers and gives a ranking of importance.

In 2014 ENEA started the "Stati Generali Efficienza Energetica" iniziative[54] (SGEE): an annual national consultation, focused on energy efficiency sector. The sector is split in nine clusters: Water, Energy and Waste; Constructions; Condominiums; Agriculture and food industry; Transportation; Electrical and electronic equipment; Textile, wood and paper; Tourism; Health

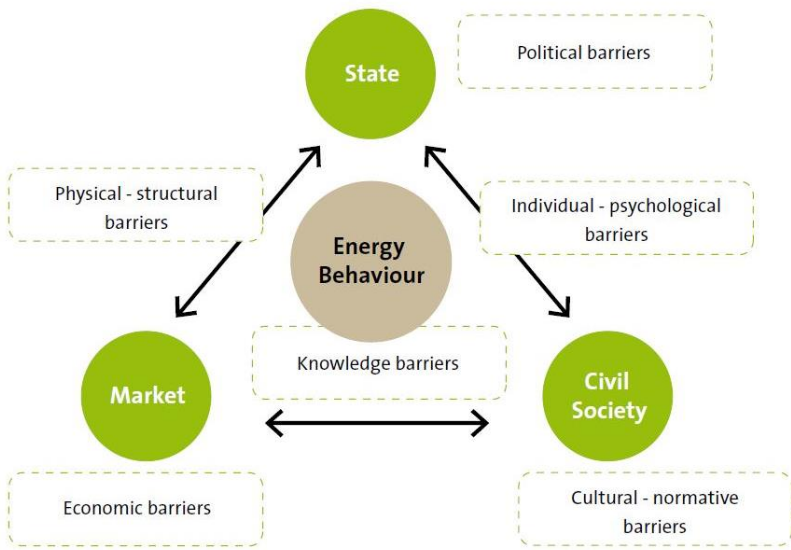
[54] www.statigeneraliefficienzaenergetica.it

& Education. The Constructions and Condominiums clusters point out several issues to energy measures in buildings.

The most complete work in the European context is *BarEnergy - Barriers to changes in energy behaviour among end consumers and households*[55], a study among six countries (Norway, Great Britain, Netherlands, France, Switzerland, Hungary). The developed methodology encompass encompassing three main empirical approaches: qualitative interviews with strategic stakeholders; representative quantitative consumer surveys; qualitative strategic focus groups among targeted consumer groups.

The project identify six types of barriers to change energy behaviour, that are no longer only technical, but a result from a complex interplay between various levels, as depicted in Figure 4.4.

Figure 4.4 Complex interplay between bahavior, barriers, institutions and regimes. BarEnergy



BarEnergy project considers three dimensions of energy behaviour: energy saving behaviour in practice; improvements in energy efficiency; changes towards more sustainable and renewable energy technologies. My analysis focuses on the barriers pointed out for heating behaviour, energy efficient refurbishment, photovoltaic panels, buying green energy, constructing low energy houses. The *Knowledge-based* barriers are first ranked for both Heating behaviour and Energy efficient refurbishment. Furthermore, these critical barriers are strongly interlinked with individual/psychological factors. The dimensions that require a novelty (i.e. installing photovoltaic panels, buying green energy, constructing low energy houses) are more seen as an investment, and so the economic barriers are first ranked.

[55] http://www.barenergy.eu/

The Buildings Performance Institute Europe (BPIE) performed a detailed survey of the barriers and challenges to building renovation across 29 countries, discussed in their *Europe's Buildings under the Microscope*. This study is based on report by individual experts and several organisations throughout Europe, supplemented by existing literature. There are four type of barriers: Financial; Awareness, advice and skills; Institutional and administrative; and Separation of expenditure and benefit[56]. In addition, BPIE (*BPIE, 2011*) point out that there could be other market or technical barriers that have no emerged, due to the lack of activity resulting from the other barriers. Moreover, BPIE (*BPIE, 2011*) analysed the building owner's decision-making process for undertaking renovation, pointing out some of the most prevalent decision factors.

One of the task of the European project ENTRANZE[57] is to investigate the structure of stakeholders, user and investor groups and their behaviour, preferences and interests (Task 2.4). The output of the research is an overview of the most commonly observed barriers and drivers of energy renovations split by building type and ownership and a focus on some countries, including Italy. The methodology used by ENTRANZE consists of an analysis of the existing literature and original research focused on identifying and filling in knowledge gaps trough questionnaire to partners, extensive review of available national and European statistics and statistics, expert interviews.

A study that uses survey data of 400 owner-occupiers from Germany (Achtnicht and Madlener 2014) identifies and ranked drivers and barriers for the adaption of building retrofits. In addition, they analyse experimental choice data econometrically in order to identify further factors that influence house owners' preferences.

A Swedish study (Nair, Gustavsson, and Mahapatra 2010) used the data from a survey of 3,000 owners of detached houses to analyse the factors that influence the adoption of investment measures to improve the energy efficiency of their buildings. They split factors into contextual and personal and match them with the respondent category, based on the energy measure undertaken.

As regards the interesting Green Deal scheme, a study points out that it could lead to only half of the expected results because of low consumer appeal and low incentives for investors (Dowson et al. 2012). Aside from the "hard-to-treat homes", there are other barriers that block the potential of the Green Deal.

An interesting and recent work on drivers and barriers (Wiencke, Meins 2012) was done by the Center for Corporate Responsibility and Sustainability for the City of Zurich to found why there are an insufficient number and deep of energy measure on the building stock. The study divides the stakeholders in four groups: investment company and pension fund; cooperatives, foundations and associations; Public-Legal ownership, Zurich city; privates. The decision

[56] BPIE decides to present this barrier as a separate category "due to its importance in retrofit strategies".

[57] http://www.entranze.eu

consists of two phases: first, if an energy measure has to be taken or not; and, second, how deep carry out the energy measure. The decision is based on a cost-benefit analysis that could be explicit or implicit. Not only the economic criteria are taken into consideration, but also other criteria such as the level of information, that could lead to a rational or irrational decisions.

4.2.2 Barriers and Drivers in the Italian context

4.2.2.1 Barriers

From the analysis of the literature I synthetize the most found and important barriers, verifying the presence and the importance in the Italian context.

Knowledge-based barriers

- Lack of both general and technical knowledge of the users;
- Unawareness of building energy potential;
- Lack of cost transparency – lifecycle costs and political incentives;
- Difficulty in identifying skilled professionals and competent artisans.

The knowledge-based barriers are the most important and should be noted that (Achtnicht and Madlener 2014) not only formal education but also informal environmental-related education plays a role in decisions.

In Italy there is a general awareness about the energy issue, but all stakeholders lack both a general and specific technical knowledge about energy measure for the buildings. For Italy (ENTRANZE, 2012), all the knowledge-based barriers are seen as critical for the residential buildings and less critical, although present, for public and office buildings. The SEN points out that the scarcity of internal competencies is an issue especially for small-medium enterprises, which are the large majority in Italy. The FIRE (2011) study underlines that energy measures are mostly not plug-and-play, but are complex and technical solutions that require a correct control and management by the user, who lacks competencies.

In Italy there is no coordination among public bodies that should give information to citizens and to professionals.

- ❖ At national level there is ENEA, one of its aims is to transfer knowledge and technologies from the research's context to the business world, the institutions and civil society (ENEA 2013).

Moreover, there is the need of more focused and specific information, since the owners are not aware of their building energy potential. Like in other countries (BarEnergy, 2010), in Italy there are some educational programs to increase awareness of energy-environment issue in schools. It should be noted that these programs could increase the energy saving and environment-friendly behaviours, but little they could do for financial investments in energy measures. The

BarEnergy participants called for face-to-face energy counseling about behaviours and energy measures apt for their own home. BPIE points out that the focus is often on individual products and not on entire end-to-end, holistic solutions. I think that this applies also in Italy, since there is not a coherent and nonpartisan stream of information, but often citizens are informed directly by companies that want to sell their products.

- ❖ In Italy there are some municipal Energy advisor front office but they could be organized in every Italian municipality and with more competencies and services.

The lack of knowledge of all data related to costs, including any incentives, creates the wrong foundation for proper cost-benefit evaluation. BarEnergy found very significant variation in the knowledge levels amongst the focus group participants. This should be true also for Italy, but probably there is also a major knowledge because the installation companies (especially of windows and heating systems) report nearly always incentives in their advertising.

- ❖ It should be noted that the National Revenue Agency publish an user-friendly and updated guide about incentives (Agenzia delle Entrate 2015) in its website.

(BarEnergy, 2010) For the owners, a significant barrier is to found skilled professionals both for the difficulty to identify a real competent professional and for the scarcity of competent professional (see Physical and structural barriers). The FIRE study (2011) points out that often the role of the designer and the supplier overlap, both for businesses and households, and an external energy consultant is lacking.

Economic/financial barriers

- Recurring energy cost (bills) not perceived as high;
- Energy measures have high initial cost that need funds or a loan difficult to obtain;
- Only financial cost/gain perspective without a clear knowledge of pros and cons.

These economic barriers are stronger for low-income households, which need most to reduce their energy costs. These barriers are less important for Countries and context with high average income: in the BarEnergy project, Swiss stakeholders explicitly stated that financial constraints were no longer considered the biggest issue. However, in Italy Tosi and Cremaschi (2003) report a general aversion to incurring debt.

As assessed by BPIE (2011), "*for most households, energy bills for the home account for 3-4% of disposable income, hence they are not a major concern*." In general, it seem easier to pay recurring costs than to make an investment that is perceived as high. Since in Italy the electricity and natural gas prices are quite high, the energy costs are higher than other European countries. Hence, in Italy this is probably a lesser barrier.

Even if the energy measure is cost-effective, the high initial investment is a barrier. This could be a mix of awareness and individual barriers, but the enduring economic crisis certainly plays an important role in blocking available funds or in the general difficulty to obtain loans. However, in Italy there are "Fondo di Garanzia Mutui Prima Casa" and "Plafond Casa" that make easier the access to loans. Moreover there are already credit lines dedicated to energy efficiency and integration of renewable energy sources in buildings. Table 4.4 reports the specific credit lines for the major banking institutions (with more than 250 branch offices in Italy).

Also several smaller banking institutions have specific credit lines, one of the most complete offer is of Banca Popolare Etica:

- Mutuo Fondario/Ipotecario Prima Casa Acquisto Ristrutturazione e Costruzione Efficiente;
- Purchase of a dwelling with a maximum EpH of 50 kWh/m² per year;
- Purchase and energy refurbishment of a dwelling;
- Energy refurbishment of a dwelling.
- Mutuo Chirografario Ristrutturazione Efficiente;
- Refurbishment of a dwelling with at least 50% if the loan for energy measures.
- Mutuo Micro Energia;
- Photovoltaic systems with power less than 20 kWp;
- Other renewable energy source systems;
- Small energy measures, including upgrading of the heating systems.

Furthermore, since 2006 a framework agreement between Legambiente (environmental non-profit association - www.legambiente.it) and Federcasse (network of 371 cooperative banks, with about 4.450 branch offices - www.creditocooperativo.it) is active. The agreement consists of low-interest loans aimed to promote broader utilization of renewable and alternative energy sources and energy efficiency measures. The added value of the project is that Legambiente manages the preliminary technical investigation, banks can therefore rely on experts in the energy sector to properly evaluate applications for funding.

It should be noted that aging owners have difficulties in accessing long-term credit, often needed for major renovations (BarEnergy, 2010).

Regarding the financial perspective, the energy label is not yet a decisive factor in the building market – especially for existing buildings – but there is more awareness about the importance of energy performance of the building in both buyers and sellers (ENEA, FIAIP e I-Com, 2015). However, energy performance has a low priority in the decision about the building and often is considered only along with other benefit (e.g. better comfort).

Table 4.4 Credit lines dedicated to energy measure for Banking institutions with more than 250 branches.

banking institution	no. branches	no. municipalities	credit line
Unicredit SpA	3,989	2,005	Mutuo Energia e Ristrutturazione
Banca Monte dei Paschi di Siena SpA	2,189	1,411	Prestito Tuttofare Natura
Intesa Sanpaolo SpA	1,787	1,000	Finanziamento Fotovoltaico Imprese
			Finanziamento Energia Imprese
			Finanziamento Sostenibilità Business
			Ædifica Bioedilizia
			Finanziamento sostenibilità breve termine
			Leasenergy
Banco Popolare - Società Cooperativa	1,651	1,037	-
Banca Nazionale del Lavoro Spa	895	402	Finanziamento BNL GREEN Famiglie
Banca Popolare di Milano Scarl	726	428	Finanziamento BPM Green
Banco di Napoli SpA (gruppo ISP)	663	383	same as ISP
Cassa di Risparmio di Parma e Piacenza SpA	592	336	Energicamente Gran Prestito
Banca Popolare di Vicenza SCpA	547	393	-
Banca Popolare Dell'Emilia Romagna - Società Cooperativa (gruppo BPER)	533	307	-
Credito Emiliano SpA	525	345	MUTUO ENERGIA
Banco di Sardegna SpA (gruppo BPER)	392	327	Prestito FinEnergiaPulita
Veneto Banca S.C.P.A.	386	311	Finanziamento HAPPY CASA
Cassa di Risparmio del Veneto SpA (gruppo ISP)	375	243	same as ISP
Banca Piccolo Credito Valtellinese, Società Cooperativa	366	259	Creval Energia Pulita
Banca Popolare di Bergamo SpA (gruppo UBI)	363	270	Prestito Forza Sole
Banca Carige Italia Spa	354	248	-
Deutsche Bank SpA	339	215	-
Banco di Brescia SpA (gruppo UBI)	324	213	Prestito Forza Sole
Banca Popolare di Sondrio SCpA	313	206	Finanziamento SOLARPlus
			Finanziamento SAVEnergy Plus
Banca delle Marche SpA	312	184	-
Banca Sella SpA	293	210	Prestito Prestidea Ambiente
Unipol Banca Spa	291	204	-
Cassa di Risparmio di Firenze SpA (gruppo ISP)	265	133	same as ISP
Banca Carime SpA (gruppo UBI)	260	212	Prestito Forza Sole
Banca Regionale Europea SpA (gruppo UBI)	257	192	Prestito Forza Sole

Technical, structural and social barriers

- Technical barriers, aesthetic and acceptance;
- Collective decision making barriers;
- Separation of expenditure and benefit;
- Lack of skill of relevant professionals and artisans;
- Black market and a desire to avoid an audit trail.

As regards technical barriers, often issues are solvable with extra costs and it is expected that the top of the range technologies become common over time. Moreover, advances in technology could lessen the aesthetic barrier, for example the Building-integrated photovoltaics (BIPV) are one of the fastest growing segments of the photovoltaic industry (BarEnergy, 2010). In Italy, the diffusion of BIPV is enhanced by the special premium tariffs for BIPV.

Other technical issues, such as the failure of components or a supply chain not developed are not a strong barrier since generally only tried and tested energy measures are proposed (FIRE, 2011).

Collective decision making process appears a very important barrier for energy efficient refurbishment. BPIE (BPIE 2011) assess that scattered ownership in apartment buildings raises many organizational barriers, common to several European countries. Since in Italy recently raised the threshold from 5 to 9 owners to be obliged to have a building manager ((L. 220/2012), the collective decision making could be more cumbersome for not managed condominiums.

BPIE report (2011) points out that the separation of expenditure and benefit barrier, also known under many names (e.g. “landlord/tenant dilemma”, “split incentives barrier”, “investor/user barrier”, “principal/agent barrier”,) is a complex barrier and it is difficult to categorized it: sometimes is considered a financial barrier, sometimes an institutional barrier. BPIE decided to present it separately due to its importance in retrofit strategies. I think that this barrier is more linked to the actual composition of the building stock, so I put it in the physical and structural barriers category.

The issue spring from the fact that who owns the building is different from who use it: if improvements are carried out on building, often the benefits are not exploited by those who have made the investment so no-one made improvement on the building. In Italy the share of residential rental is relatively small, so this barrier should be mild in the residential Italian context. The structure of occupancy in the non-residential sector is more complex and less investigated, so it is difficult to estimate the extension of this barrier in the commercial and industrial sectors.

In the separation of expenditure and benefit could be included also the share of owners that have no interest in renovate their building, mainly retirees and aging owners that do not expect to exploit fully the benefit of the investments. In BarEnergy (2010) this is seen as an individual/psychological barrier, in BPIE (2011) is more between the lines, in Wiencke, Meins 2012 is seen as an uncertainty about usage.

The lack of skilled professionals is an important barrier in Italy due the high fragmentation of construction companies: a large majority are individuals. Accordingly to ANCE (2014) the companies in construction sector, including systems installers, were 572 thousand, of which 95.9% with less than 10 employees.

The risk of technical failure (BPIE) is mainly due to the lack of competencies: the FIRE study (2011) mention the Italian campaign "Hot water from the sun" promoted in the 80s failed due to immature technologies and unskilled installers and maintenance operators.

As regards the design professionals (engineers, architects and *geometri*[58]), a recent reform of Professional associations obliges to lifelong ongoing education of professionals (art. 7 DPR 137/2012), however does not intervene in topics to be covered.

❖ It would be desirable that the Associations of Engineers, Architects and *Geometri*, pushed toward the topic of energy efficiency.

The endemic black market in the construction sector in Italy (shadow economy is estimate 17~21% of GDP – Eurostat) places a strong barrier to energy measures on the building stock and the control of energy performance of the building stock.

Political barriers

- Lack of consistency and coordination in policy framework/regulations;
- Insufficient, unreliable and bothersome subsidies or regulation;
- Lack of both general and technical knowledge of local planning authorities.

As assessed in Chapter 2, the Italian regulations and strategies framework is inconsistent and highly fragmentized, so it is an important barrier in Italy.

In the Italian context, there are generous incentives for PV systems, refurbishment and construction of new low energy houses. Therefore, the main problems are the stability and ease of access to the incentives.

The lack of competencies among the local PA is a huge barrier in Italy, as found in Chapter 4.

Individual/psychological barriers

- Energy measures require huge personal effort (change in behaviours, troublesome works, complicated administration);
- Competing purchase decisions;
- Lack of visibility of energy-efficiency measures.

In BPIE the disturbance of occupiers during major renovation was found as a barrier; for troublesome works due to energy measure, the BarEnergy project found "*that this barrier is temporarily removed when participants are moving house or renovating, although these 'windows of opportunity' are not always realized*".

[58] Professionals with high school diploma with specialization in building construction, could do the function of engineers and architects with some limits

❖ Seize the “windows of opportunity” could lead to a greater number of energy measures in the building stock.

Investments in energy measures have to compete with other purchase since are not considered a priority (BarEnergy, 2010; BPIE, 2011). For businesses energy measures are not the core business, while for households energy measure have to compete even with consumer or household goods (e.g. a new smartphone).

Especially for energy savings measure, the barrier is increased by the fact that the investments give no or little visible results and as such cannot be displayed as a symbol of success: they have no “social benefit”.

The aging population also put the energy issue down on the priority scale and they are less willingness to make any big investment in the house.

In BarEnergy (2010) the lack of trust in new technology or in in individual effort making a difference are seen as individual barriers, but could be seen also as a lack of knowledge.

4.2.2.2 Drivers

The analysed literature had few references to the drivers that could stimulate energy measures on the building stock. Some barriers could also be seen, reversed, as a driver (e.g. insufficient vs. generous financial incentives). The decision to renovate of two phases: first if an energy measure has to be taken or not; and second how deep carry out the energy measure (Wiencke, Meins 2012). Following this concept, I selected two types of drivers to be exploited: the ones that activate the decision process and those that improve the depth of the intervention.

Activation Drivers

- Maintenance of a failure or obsolete component;
- Need of more comfort;
- Willingness to improve the house aesthetic;
- Willingness to change or improve the house functionality;
- Willingness to mantain or improve the house market/rental value;
- High energy cost.

In the decision-making process for undertaking renovation work, there could be “trigger points” (BPIE 2011) that set off the building owner’s decisions. The BarEnergy project called them “windows of opportunity”, in (Achtnicht and Madlener 2014) “favourable opportunities”.

When there is already some intervention to be done on the building, the owners are already in the decision-making process and it is easier to add the energy dimension to the process.

The need to improve comfort is a driver widely cited (BPIE, Entranze, Nair, Gustavsson, and Mahapatra 2010, Wiencke, Meins 2012, Achtnicht and Madlener 2014). The very poor energy performance of the Italian building stock (see Chap. 1) surely leads to a low level of comfort.

As regards the willgness to improve the house, the increase in market/rental value may be weak in Italy since the rate of owners that have only one propriety and live in it is quite high.

The high electricity and natural gas prices in Italy lead to higher energy costs, thus this could be a stronger driver.

Deep of measures Drivers

- Trustworthy information & advice;
- Incentives in building codes;
- Ancillary benefit;
- Construction period;
- Education;
- Smooth process (clear legislation, easy decision-making).

After the decision to intervene on the building is taken, there are some factors that could influence the presence and the deep of energy measures.

Of course, all knowledge-based factors are very important and depend on specific policies or on personal education. The best policies are those who give tailored and independent information, such as energy consultant services (BarEnergy, 2010; Achtnicht and Madlener 2014). In Italy there are already some municipal Energy advisor front office, but are up to the local administration.

Personal education should not only encompass formal education, but also informal education and awareness about the energy and environmental issue (Achtnicht and Madlener 2014).

If the building code and regulation are clear and encourage energy measures, some owners could decide to exploit it (Wiencke, Meins 2012). In Italy the legislation and subsides are favourable, but too much fragmentized and unreliable (see Chap. 2).

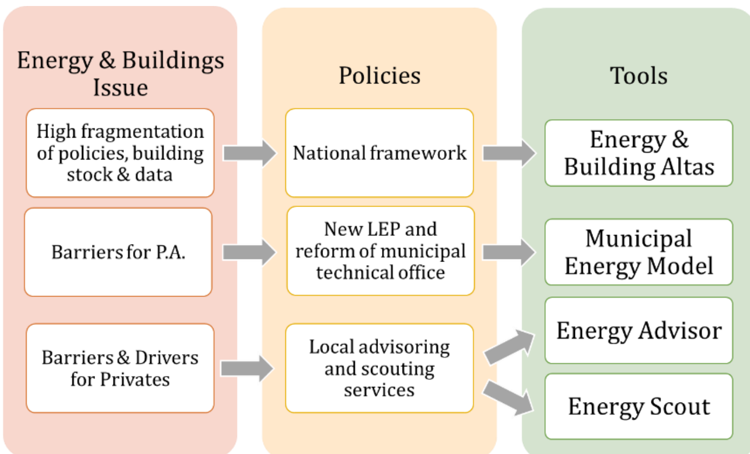
There are also technical factors such as the presence of ancillary benefit (improved thermal comfort, improved aesthetic, lower noise levels) and the period of construction of the building (an owner would not intervene on a relatively new buildings).

As assessed by Entranze, the level of professionalism with which buildings are managed is important in the decision-making process, since more rational factors are taken into account (i.e., measurement and verification of savings, returns on investment and the financial value of time). In Italy the building manager, which is mandatory for buildings with nine owners or more, has the obligation to complete a short training course and follow annual updates (see Chap. 2). However, actually the building manager figure is problematic and the large majority lack competencies and professionalism (SGEE, 2015).

5 POLICIES AND TOOLS TO BOOST BUILDINGS ENERGY RENOVATION

In order to tackle the energy & buildings issue there is the need to overcome barriers and to leverage on drivers found in the previous chapter. As depicted in Figure 5.1, this dissertation proposes a new data collection framework and new policies supported by georeferenced tools: Municipal Energy Model (MEM), Energy Advisor and Energy Scout.

Figure 5.1 Scheme of the energy & buildings issue and proposals



This chapter propose a national framework to implement policies and tools to boost energy renovation in the building stock. The first part focuses on policies to overcome the barriers for effective Local Energy Plan (LEP), while the second part focuses on policies and tools to persuade private owners to undergone energy measures carried on their buildings. Policies and tools should be interlinked to really exploit the building energy potential.

5.1 POLICIES AND PRACTICES FOR MORE EFFECTIVE LOCAL ENERGY PLAN[59]

In order to overcome barriers it is paramount a change in how the public administration (PA) manage the energy & buildings issue. To foster more effective LEP, a national framework implementing the following the policies and practices is proposed:

- national coordination and support;
- local burden sharing and monitoring;
- national data collection;
- reform and an upgrade of the existing technical office (energy and statistics expertise);
- new approach to LEP.

Although the suggestions presented may seem obvious, in Italy the implementations of these policies can deeply change the approach of municipal energy planning. In fact, a correct and updated knowledge of the features of the built environment could help in developing achievable

[59] This chapter contains extracts of the previously published Caputo, P., & Pasetti, G. (2015). The text is edited to integrate the publication in this dissertation.

and cost effective plans and interventions, taking into account local conditions and pertinent targets.

5.1.1 National coordination and support

From the technical literature and from our survey we can state that among the local administrations there is a diffuse interest about the energy problem, but there is no real awareness of the possible active role of their own municipality. The energy issue cannot be left to the willingness of the single local governments; there is a need for a better organization and coordination of the bodies involved in energy planning.

The central (national) government should be more supportive, providing all the necessary information, resources and help to the local governments. More stability, continuity, uniformity and coordination in rules, regulations, supports, and tools represent an urgent need. Support mechanisms should be optimized on the basis of the lessons learned in the past and economic-financial incentives must be better advertised along with the possibility to create new local activities and jobs.

5.1.2 Local burden sharing and monitoring

In order to obtain effective LEP, it is mandatory to define tailored goals at municipal level. This is not possible in the absence of coherent problem awareness and local energy data, since goals should be defined taking into account local peculiarities and reasonable efforts. The major risk is to correlate energy policy goals to political mandates and administrative duties with a limited duration.

Further, a methodology to verify and monitor the achievement of the goals should accompany the goals definition from the beginning. Affordable intermediate milestones should be also precisely indicated.

As regards tailored goals, an approach similar to the "burden sharing" could be used, obtaining a local burden sharing for emissions and energy efficiency goals.

The national burden sharing decree (D.M. 2012) quantifies the intermediate and final goals that each Region must achieve in order to reach national targets for 2020 in terms of share of energy from renewable sources. However, the regional goals are not enough: for an effective local energy planning it is also necessary to define the municipal goals. A project lead by three Regional Authorities (http://www.factor20.it) considers the mandatory regional objectives set by the national burden sharing decree (D.M. 2012) and the real opportunities of the territories, developing tailored municipal goals. If the results of the testing phase are satisfactory, the methodology (Factor20, 2012) could be applied to the other Italian municipalities, obtaining tailored local burden sharing.

To confront municipalities and monitor results, it is important to establish a set of supporting indicators in order to compare targets and achieved results to national or average values and to benchmark other municipalities, suggested in (EBC, 2013). For example, as city-wide key indicators related to the municipal energy performance, the following can be suggested: electricity per capita (kWh_{el}/cap); thermal energy per capita (kWh_{th}/cap); and tonnes of equivalent carbon dioxide per capita (t CO_2eq/cap). Referring to buildings, the following indicators can be considered: thermal energy per floor area (kWh_{th}/m^2) and electricity per floor area (kWh_{el}/m^2). Further indicators can be adopted in order to verify the economic effectiveness of energy and CO_2 emissions savings and the willingness to pay.

5.1.3 National data collection & framework

The data collection seems the most engaging barrier because of the dispersion of data among several municipal offices and other administrative entities and the lack of interoperability among the data collection systems. The need to make data of building stock sharable, accessible and compatible for different scopes and by different offices is very urgent.

An example of effort in data collection is the Homes Energy Efficiency Database (HEED): the Government of United Kingdom developed a data-framework that draws together data on energy efficiency retrofits in approximately 13 million homes. This high quality data-framework helps the UK Government to develop and monitor ambitious energy retrofit programmes such as the Green Deal (DECC, 2010). In a recent work, Hamilton et al. (2013) describe the data and the policy implication of such detailed database. They underline that HEED is not the product of a large omnibus survey or a concerted monitoring and reporting exercise, but offers a repository and framework for of a range of disparate activities that are centred on home energy efficiency.

As regards Italy, data about the energy & buildings issue are collected by several entities but not organized in a coherent framework (see Chapters 1.2 and 3.2.). We imagine this new national data collection and framework as template able to collect real and statistic data about energy and public and private building stock and to create effective policies for an operative refurbishment. An example of georeferenced data collection and framework is the Energy & Buildings Atlas, explained in Chapter 3.3. The development of a more complete national data collection and framework could be assigned to ENEA (see Chap. 3.2), that has recently started a pilot project[60] to develop a system architecture model to process and combine the variety of data types and to integrate datasets about the energy & buildings issue.

5.1.4 Reform and an upgrade of the existing technical office

To start an effective local energy plan, there is the need of more expertise at the local level. Argyriou, Fleming, & Wright (2012) find that senior leadership, cross departmental collaboration, interdisciplinary work, and a critical mass of local administration personnel would be factors of success in tackling climate change at the local level.

[60] "Optimizing retrofit data and information for market actors" in the European project Request2Action http://building-request.eu

In order to start this virtuous path, we suggest that all municipalities should have a mandatory office dedicated to climate and energy issues. In Italy, the energy manager is already compulsory (L 10/1991) for PA with an annual consumption over 1,000 TOE but currently only 10% of the compelled municipalities have an energy manager. We suggest to enforce the law and extend it to all municipalities, also increasing the scope and expertise of the energy manager.

The same law define the tasks of the energy manager, which can be briefly resumed as the quantification of energy consumption, the optimization of energy supply and the promotion of good practices. The field of action concerns the energy directly consumed in public buildings and not a broader action on the entire municipality. We suggest to enlarge the operation of the energy manager in the framework of the mentioned energy office, dealing both with the energy consumed directly by the local administration (public buildings), and with the energy consumed within the municipality.

A reform and an upgrade of the existing technical office can accompany this process, since energy is a multidisciplinary issue. Typically, the municipal offices are divided into sectors or thematic areas and only in the major municipalities there is a coordination for cross-sectoral project. However energy planning can not be tackled by a single sector, nor seen as a timed project. The proposal is therefore to expand the traditional concept of technical office. Actually, in small municipalities, the existing Technical Office usually gather Private Building, Town Planning and Public Works, sometimes also Environmental office. Instead of thinking as an office that brings together several sectors, it must be reformed as an office that coordinates all the competencies of the Municipality. As regards energy planning the main sectors to be coordinate are shown in Figure 5.2, but the reformed Technical Office will also be able to address other complex projects in a multidisciplinary manner, such as water management, waste, etc. As assessed by the conducted interviews, it is paramount to inject expertise in the energy sector, which is entirely missing in small to medium municipalities. The conducted interviews highlighted also the lack of a statistics office, who can gather all the necessary data and respond to requests.

Figure 5.2 Municipal offices to be coordinate for energy planning

Obviously, if you want to affect the energy profile of the municipalities is essential that they have staff with necessary expertise. This proposed reform implies efforts in terms of human and economic resources, information and training. It is possible to find resources with the planned abolition of Provinces (l. 56/2014) and with the fusions of all small municipalities proposed by the Spending Review (Bordignon et al., 2014). These two policies will lead to financial savings and a surplus of employees. Thus, the staff required for the proposed new Energy Office could be composed of up-to date local engineers, provincial and municipal engineers reallocated or new high profile jobs.

5.1.5 New approach towards effective local energy plan

.1.1.1 Participatory Planning

To tackle the energy issue in buildings effectively and renovate the building stock adequately it is necessary a combined top-down and bottom-up participatory strategy. The central government must act as leader and coordinator and must ensure that local administrations have adequate information on the energy issue and knowledge about support mechanisms. The central government should encourage local administrations to act on their territory, through local energy plans, to achieve shared goals. With a deeper knowledge of the territory, it is possible to ask each municipality to meet a goal tailored to its real potential in terms of energy saving, acting also on the building stock retrofit. The regional administration could monitor and compare results obtained in different municipalities helping to find best practices and to avoid unsuccessful or non-effective interventions. The definition and calculation of precise indicators such as, public and private cost of avoided TOE or of avoided ton of CO_2 emissions could support the evaluation of the effectiveness of the undertaken interventions to improve energy efficiency in buildings. This is particularly useful in the present context due to the long lasting economic and financial crisis.

On the other hand, the local administration, in the early phases, must involve citizens, building manager and owners, energy savings companies (ESCOs), and other stakeholders.

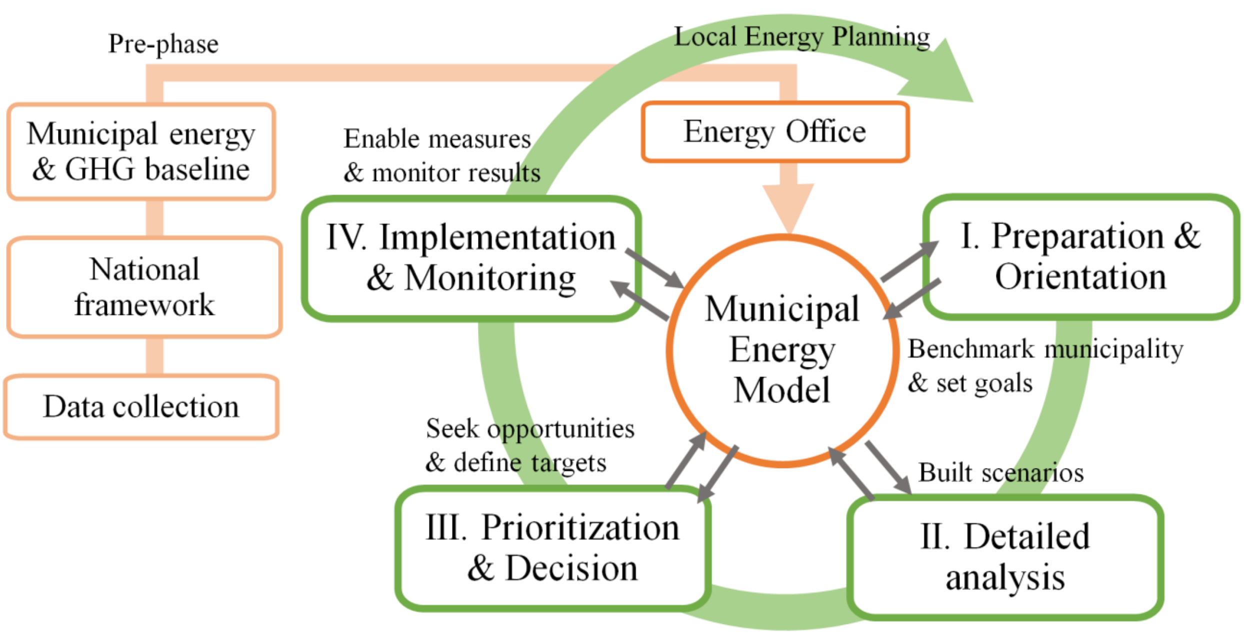
.1.1.2 A new model of LEP

As seen in Chapter 4.1, the actual local energy planning is quite linear, while the process have to be a continuous improvement of the energy profile of the municipality. It is thus necessary to change paradigm and go for a recursive LEP, with the same model for every Italian municipality.

This new model of mandatory municipal energy plan has to be focused on possible, affordable, effective and monitorable (from the economic and environmental point of view) interventions. The new energy plan must arise from consultations among local and central administrations, in order to make the plan effective. Economic and financial aspects are very important also in this phase, as pointed out in many references including also I. Theodoridou et al. (2011) and H. Tommerup and S. Svendsen (2006).

The new LEP proposal is schematized in Figure 5.3 and is composed by a pre-phase and by a recursive four phases process.

Figure 5.3 New framework for local energy planning



Pre-phase

In order to set up an effective energy planning at local scale it is first necessary to carry out a preceding phase (pre-phase). The purpose of the pre-phase is to improve data availability and management in every Italian municipality, with an effort at national or regional level. Energy and building stock data that are actually scattered among several sources, as described in Chapter 3.2, must be collected and organized. With the proposed national framework, it will be possible to provide an up to date energy and environmental baseline for each Italian municipality. With a better knowledge of energy and building stock, it is possible to ask each municipality to meet a goal tailored to its real potential in terms of energy saving and exploitation of renewable energy sources. With a common framework, it is also possible to monitor and compare results obtained in different municipalities.

Recursive Local Energy Plan

The recursive LEP is based on an up-to-date database with information about each single building in the municipality. In fact, with a consistent database and the proper expertise at the local level, it is possible to think of an advanced tool to collect energy information and manage effective local energy plan. The proposal is a new Municipal Energy Model (MEM), able to give a geo-referenced representation of the state of the entire building stock of the municipality, with information about energy consumption, production, and features. This tool is described in Chapter 5.2.

This barrier can be overcome with a concerted effort at the national and local levels, gathering all the needed data into a new Municipal Energy Model (MEM).

The energy office may use the MEM as a tool in each energy planning phases both to provide support and to modify the model according to the feedback received. In the *Preparation & Orientation* phase, the MEM could be used to benchmark the municipality and set feasible goals targeted on the municipality. In the second phase, the MEM could be very useful to depict a detailed analysis of the building stock and to propose plausible scenarios. During the *Prioritization & Decision* phase, the MEM allows to give transparent information to all stakeholders about the building stock and the possibility to renovate it. Using the MEM to seek the real opportunities for energy measures, it is possible to define reachable targets with the involvement and consensus of citizens and other stakeholders. In the last phase the technical office could update the MEM according to the measures actually implemented, thus having a timely control on the progress of the energy plan and the actual results. When a local energy planning cycle is finished, we will be left with an updated Municipal Energy Model, ready for the next planning cycle.

5.2 TOOLS TO BOOST ENERGY MEASURES ON THE PRIVATE BUILDING STOCK

An effective LEP could not be pragmatic and effective without the involvement of the private sector in the last two phases (*Phase III: Prioritization & Decision and Phase IV: Implementation & Monitoring*). With the implementation of the proposed policies, it will possible to develop for each Italian municipality a georeferenced energy database with a level of detail (LOD) of single building, called Municipal Energy Model (MEM).

The potentialities of MEM are not limited to a support tool for the local energy planning, as described in the previous section, but it is possible to think of tools dedicated to boost energy measures on the private building stock. In fact, the renovation of the building stock must be seen as an ongoing process that have to be fostered.

Figure 5.4 Municipal Energy Model and proposed tools

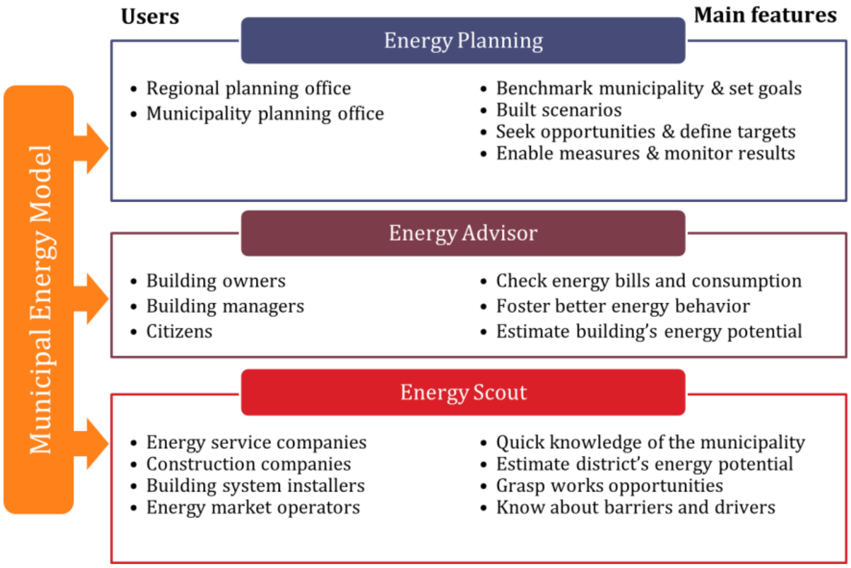


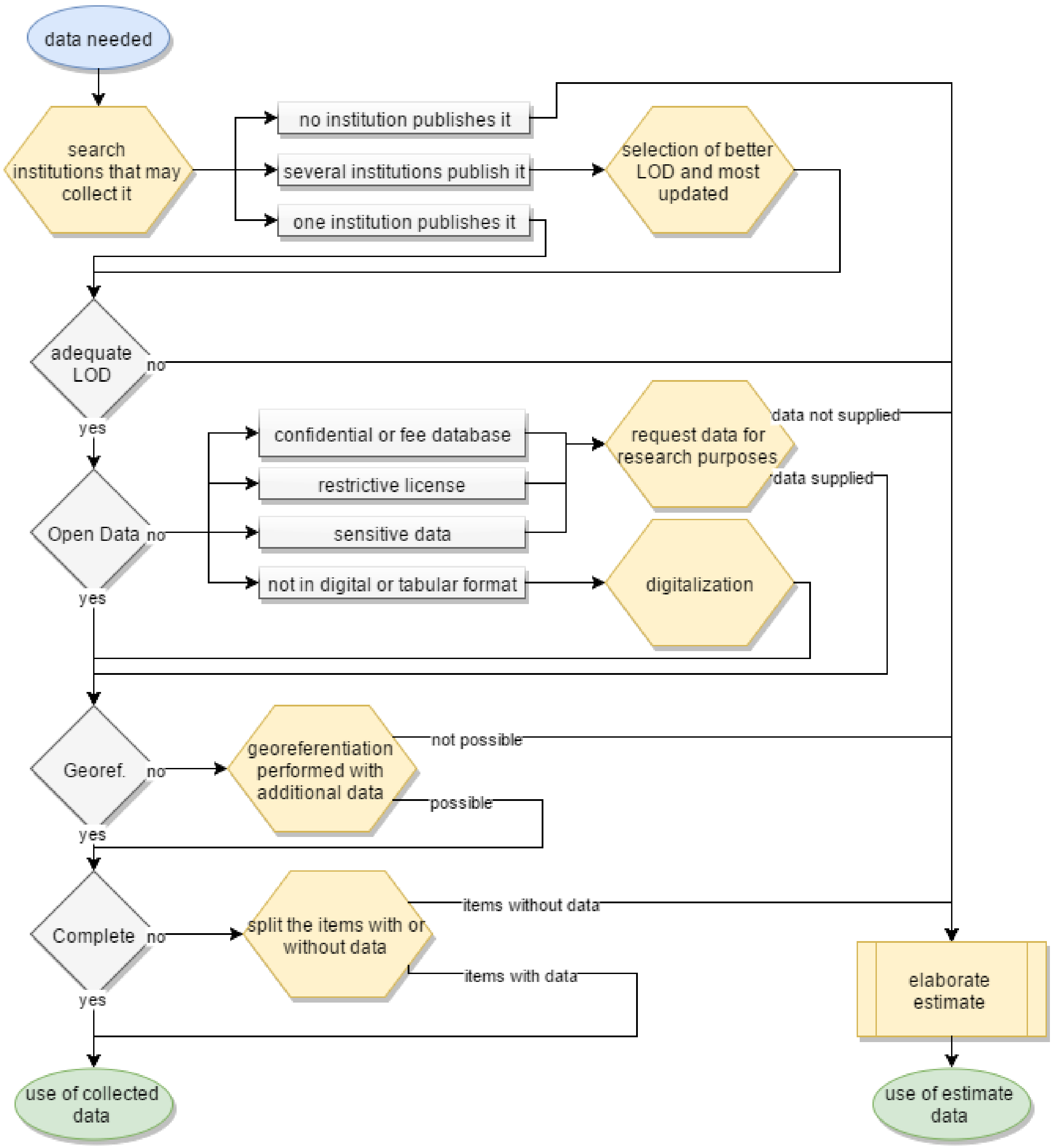
Figure 5.4 synthetizes the tools that arise from the MEM, managed by the municipal Energy Office. Beside a tool to support energy planning, to stimulate energy measure on the private building stock, I propose two tools that derive from data in MEM, that meet different needs. The Energy Advisor is designed to advise building owners, building managers and citizens, described it in the next section; while the Energy Scout is designed for companies in the energy-building sector. Since the latter is the most innovative and interesting tool to stimulate the requalification of the building stock, I have developed taking a real Italian municipality as case study (see Chapter 6).

Policies and tools should be interlinked to really exploit the building energy potential, overcoming barriers and taking advantage of the drivers. Table 5.1 reports the barriers and drivers found in Chap. 4, the actual policies to address them and the proposed policies and supporting tools. These should not be seen as separate proposals, but as specific points of a single and coherent policy to tackle the energy & buildings issue.

Table 5.1 Proposed policies and tools

categories	description	existing policies	proposed policies	tool
Knowledge-based barriers	Lack of both general and technical knowledge of the users	ENEA	Tailored information campaigns for private owners Energy competencies for building managers	Energy Advisor: Locate target audience for information campaigns
	Unawareness of building energy potential	Mandatory EPC for sale or lease ENEA tool for owners (future)	Vis-a-vis custom advice Advanced scouting service for energy & building companies	Energy Advisor: rough energy audit Energy Scout: Technical potential of energy savings Energy Scout: Technical potential of RES energy production
	Lack of cost transparency – lifecycle costs and political incentives		Vis-a-vis custom advice	Energy Advisor: rough energy audit and fast estimate from local professionals
	Difficulty in identifying skilled professionals and competent artisans	ENEA one stop shop hub (future)	Local register of skilled professionals	
Economic/financial barriers	Recurring energy cost (bills) not perceived as high		Tailored information campaigns Vis-a-vis custom advice Advanced scouting service for energy & building companies	Energy Advisor: Check energy bill and consumption Energy Advisor: find households that may be in fuel poverty Energy Scout: current energy cost vs disposable income
	Energy measures have high initial cost that need funds or a loan difficult to obtain	Plafond Casa Existing credit lines dedicated to energy measures	Advanced scouting service for energy & building companies	Energy Scout: low disposable income
	Only financial cost/gain perspective without a clear knowledge of pros and cons		Tailored information campaigns Vis-a-vis custom advice	Energy Advisor: Locate target audience for information campaigns
Technical, structural and social barriers	Technical barriers, aesthetic and acceptance			
	Collective decision making barriers		Advanced scouting service for energy & building companies	Energy Scout: number of owners
	Separation of expenditure and benefit		Advanced scouting service for energy & building companies	Energy Scout: presence of tenants; presence of aging owners
	Lack of skill of relevant professionals and artisans		Mandatory energy-related ongoing education for professionals	
	Black market and a desire to avoid an audit trail			
Political barriers	Lack of consistency and coordination in policy framework/regulations	Central government regains exclusive legislative powers on energy (future) Standard building code (future)	National framework New LEP Advanced scouting service for energy & building companies	MEM: supporting tool for LEP Energy Scout: Planning restictions
	Insufficient, unreliable and bothersome subsidies or regulation	Revenue Agency guide on fiscal incentives	Support by local Energy Office	
	Lack of both general and technical knowledge of local planning authorities		Reform of municipal Technical Office, with energy competencies	
Individual/psychological barriers	Energy measures require huge personal effort		Tailored information campaigns Vis-a-vis custom advice	Energy Advisor: Locate target audience for information campaigns
	Competing purchase decisions		Tailored information campaigns Vis-a-vis custom advice	Energy Advisor: Locate target audience for information campaigns
	Lack of visibility of energy-efficiency measures		Local awards for energy efficiency	MEM: up-to-date information about energy consumption and efficiency of the building stock Energy Advisor: Show your energy bills
Activation drivers	Maintenance of a failure or obsolete component		Advanced scouting service for energy & building companies	Energy Scout: building interventions to be carried out (failure or obsolete components)
	Need of more comfort		Advanced scouting service for energy & building companies	Energy Scout: low thermal comfort
	Willingness to improve the house aesthetic		Advanced scouting service for energy & building companies	Energy Scout: state of conservation
	Willingness to change or improve the house functionality		Advanced scouting service for energy & building companies	Energy Scout: changes in family
	Willingness to mantain or improve the house market/rental value		Advanced scouting service for energy & building companies	Energy Scout: high real estate value Energy Scout: rental in upscale neighborhood
	High energy costs		Advanced scouting service for energy & building companies	Energy Scout: Energy cost; high potential energy saving
Deep of measures drivers	Trustworthy information & advice		Tailored information campaigns Vis-a-vis custom advice	Energy Advisor: Locate target audience for information campaigns
	Incentives in building codes	Standard building code (future)		
	Ancillary benefit		Advanced scouting service for energy & building companies	Energy Scout: improved thermal comfort, improved aesthetic, lower noise levels
	Construction period		Advanced scouting service for energy & building companies	Energy Scout: old building's age of construction
	Education		Advanced scouting service for energy & building companies	Energy Scout: Estimate of residents' education
	Smooth process (clear legislation, easy decision-making)		Advanced scouting service for energy & building companies	Energy Scout: Presence of building manager or single owner

Figure 5.5 Data collection procedure



5.2.1 Municipal Energy Model

The purpose of Municipal Energy Model (MEM) is to give a geo-referenced representation of the state of the entire building stock of the municipality, with information about energy consumption, production, and features with a level of detail of the single building. Of course, the MEM can be updated with more recent or detailed data, such as new EPCs, new energy audits or new data deriving from smart meters.

To develop an energy model that could be easily and quickly implemented in each Italian municipality I comply with the following points:

- for a quick implementation, the methodology has a hybrid approach, using data relating to the specific building and data assigned by an archetypal approach;
- for a widespread implementation, the methodology uses data publicly available, or will be available, for each Italian municipality;
- for interoperability, the methodology integrate different existing databases, linking information instead of starting anew, and use existing base maps to define buildings;
- for an open tool, I decided to develop MEM and Energy Scout using a free and open source software (QGIS[61]), although it is possible to use a proprietary software (e.g. ArcGIS by Esri) for both viewing the completed tools or developing them from scratch.

The hybrid approach consists of two methods for assign data to buildings: first trying to assign building its collected data, if no collected data are available an archetypal approach. The archetypal approach consists of classify the housing stock according to vintage, size, house type, etc.; develop archetype definitions for each major class of house and utilize these descriptions as the input data for energy modelling (Swan & Ugursal, 2009).

The hybrid approach on data helps to build a model quickly, with data that could be rough at the beginning and then they can be gradually refined when the national collection data framework is complete or when new sources of data are available, such as the new possibilities by smart metering and open data policies.

The used procedure for data collection is outlined in Figure 5.5. In order to build the MEM, it is necessary to have data with a LOD at least sub-municipal. Moreover data have to be open, to speed up the process and avoid problems of privacy and licenses, and preferably already in digital format. In addition, data should be georeferenced, or have some reference (e.g. street address) that makes it possible georeferencing. One must also take into account that sometimes the data is not collected for all buildings, but are collected gradually or only for certain categories. If one of these conditions is not met, it is necessary to elaborate an estimate. The result of an application to a real municipality are reported in Chapter 6.4.

[61] http://www.qgis.org

As regard the availability of data, as demonstrate by the application to a case study (see Chapter 6), it is possible at the present to develop the MEM for municipalities in the Lombardy Region. With a national data collection framework it will be possible to develop MEM for each Italian municipality, since the methodology uses data publicly available, or will be available, for each Italian municipality:

- National Land Register (CAT), managed by Revenue Agency;
- National Census dataset and cartographic base managed by ISTAT;
- Regional Topographic Database (DBTR), managed by a Regional Body for the Territorial Information;
- Regional Register of Energy Performance Certificates (EPCR), managed by a Regional Body designed for Energy;
- Regional Register of heating systems managed by a Regional Body designed for Energy;
- Regional Register of Geothermal heat pump managed by a Regional Body designed for Energy.

If data about energy are not available, it is still possible to use a full archetypal or typology approach, assigning energy features on the basis of statistics.

It is important not to start anew with isolate database and surveys, but to use the already existing databases, linking this energy-oriented model with other existing databases regarding buildings. Thus, in MEM each building has the identification fields of the other energy and buildings databases. In addition, each MEM building has fields with energy features.

An innovation bring from this research is the detection of buildings: CAT or DBTR are not energy-oriented, but for MEM buildings have to be defined in a different way. A MEM building is a building with a single use, a heating or cooling system, a sole management and geometrically defined by the conditioned volumes. Obviously, since there is no a census of these characteristics, it was necessary to use some simplifications to detect the MEM buildings:

- Single use: from the energy point of view the distinction between residential and non-residential building is important because you use different indicators. In addition, if you can distinguish between the different non-residential uses, the related energy statistics are more accurate. In MEM, I split the buildings according to their use.
- Heating or cooling system: to be affected by energy measures, the buildings have to consume energy. I considered only the conditioned buildings, excluding those who consume energy only for appliances (e.g. lighting). I selected the main buildings and eliminated the minor buildings such as garages, sheds and similar.
- Sole management: building management can be individual, if there is a single owner, or managed with condominium meeting if there are more owners. The management of the building is relatively easy to detect for isolated buildings, while it is more complicated for adjacent buildings as courtyard or a block with a continuous perimeter of buildings - two common typologies in Italy. I selected the management taking into account the land register.
- Conditioned volumes: from the energy point of view the building is delimited by the conditioned volumes. As simplification, I excluded underground and attics volumes,

without a survey is not possible to know whether they are conditioned. The height considered is therefore the height up to the eaves.

Chapter 6.2 explains how, in an actual application, these features have been selected and therefore MEM buildings detected.

As regards energy features, each MEM building has data derived from its Energy Performance Certificates (EPCs), or failing that, by the typology. I defined the building's typology as a matrix of use, period of construction, and compactness ratio. For each typology, I have developed statistics, derived from the EPCs database, about the energy characteristics. This allows that energy features of the buildings are consistent in the MEM, since the energy data are those recorded in the energy certificate, which will be uniform at the national level (see Chapter 2.2). A real case application is explained in Chapter 6.

5.2.2 Energy Advisor

The purpose of the Energy Advisor is to help the municipal Energy Office to advise and involve building owners, building managers and citizens about energy measures that could be taken on their buildings. Indeed, among the barriers expressed by privates (see Chapter 4.2) there the lack of technical knowledge to evaluate an energy measure and the need of trustworthy advice. The local administration is best placed to provide a non-partisan energy advice to their citizens. Moreover, there is the need of more tailored campaign to raise awareness about the energy & buildings issue and lead to action.

The Energy Advisor is based on the MEM, with specific function for the municipal Energy Office. Data about the building should be integrated with:

- tools for a quick and rough energy audit;
- list of accredited local professionals;
- sensible data (accessible only by the office) about family composition and income.

As regards the energy audit, there are already some tools that help to create a quick and rough assessment (see Chapter 2.3); the work to be done is to verify the tool more suitable for the purpose and to users.

For the list of accredited local professionals there is the need to implement a policy that certifies energy competencies of the professionals of the building sector – difficulty in identifying skilled professionals and competent artisans is one of the barrier for private investment (see Chapter 4.2).

Since this tool will be managed only by the energy office, it is possible to use sensible data to enrich the functionalities. Data about the family composition are already collected at the municipal level, by the registry office, but often the database is printed or with interoperability issues. Data about family income are collected by the national Revenue Agency, thus an agreement for the transfer of sensible data is needed.

Since this tool could be developed using already existing simulation tool, policies not yet implemented and integrating reserved data, I decided not to develop it in a real case application, for now. However, it is possible to think of some possible functionalities for Energy Advisor, arising also from the suggestions found in the literature review done (Chapter 4.2).

- Check energy bill and consumption: lay people often could not understand if their energy bills are too high respect to the dwelling. With data in the Energy Advisor it is possible to estimate the energy consumption and compare it with the real data.
- Foster better energy behaviours: sometimes the dwelling or the systems have energy performance good or normal, but are used incorrectly and to use up more energy. Elaborating a rough estimate it is possible to show the possible savings and thus foster better energy behaviours, which are "zero cost energy measures".
- Estimate building's energy potential: owners are unaware of their building potential, the Energy Advisor could give estimate about interventions to envelope, to heating or cooling systems, about adding renewable energy sources.
- Get rough estimates from reliable companies: a barrier is the difficulty in identifying competent companies; the PA could select a reliable companies list. Moreover, integrating the data in the MEM with those provided by owner, it is possible to create a package with the building's key data to be sent to reliable companies and thus get a rough estimate of the energy measures.
- Locate target audience for information campaigns: Effective information campaigns need to be targeted. Embedding data from the municipal Registry office and other offices, it is possible to give tailored information to families.
- Alleviate fuel poverty by finding households that may be in distress.

5.2.3 Energy Scout

The main purpose of the Energy Scout is to find opportunities for energy measure on the private building stock, mobilizing private investments and looking for work opportunities for companies of the building/energy sector such as energy service companies (Esco), construction companies, building systems installers, energy market operators.
The methodology to develop the Energy Scout is the same of the MEM, although the Energy Scout is enriched with the indicators reported in Table 5.2, that emerged from the analysis of barriers and drivers in Chapter 4 and that are possible to geo-reference. For the applied methodology, refer to Chapter 6 that presents an application to a real Italian municipality.

The barriers and drivers are explained in Chapter 4, while for the renewable energy source I have considered only the RES that could be integrated in buildings and are available on the Italian market, thus not considering hydroelectric systems or micro wind turbines.

❖ A further deepening that could be done is a consultation with sector operators that could lead to more and better features and indicators for the Energy Scout.

The objective is that the MEM and the Energy Scout are easily feasible for all Italian municipalities, so I preferred to use data that are - or will be - available throughout Italy.

The main features of the Energy Scout, that meet the needs of the companies of the building/energy sector, are:

- Quick knowledge of the municipality: the Energy Scout may provide general energy data about the municipality (e.g. municipal energy consumption for heating) and data about building's features (e.g. no. building and floor area per use) to grasp the size of the local market.
- Estimate district's energy potential: thanks to georeferenced data it is possible locate areas where to develop micro grid or where to make some mass energy measures.
- Grasp works opportunities: in Energy Scout it is possible to select buildings that need energy measures (e.g. which are the building with poor heating systems).
- Know about barriers and drivers: to really exploit the technical potential is necessary to know barriers and drivers that might limit or facilitate interventions, in Energy Scout there are some indicators to help choosing buildings.

Table 5.2 Energy Scout indicators

Category	Indicator	Sub-indicator
Energy characterization of the building stock	Current energy consumption	
	Technical potential of energy savings	
	Current RES energy production	photovoltaic
		geothermal pumps
		solar heating
	Technical potential of RES energy production	solar heating and photovoltaic
Barriers	no. owners	
	no. retirees	
	Average costs of energy measures	
	planning restrictions	
	recent building's age of construction	
	low disposable income	
	Low level of education	
	rental property not in upscale neighborhood	
Drivers	building manager	
	high real estate value	
	changes in family	moving work-related
		childbirth
		sons leaving home
		retirement
	building interventions to be carried out	poor state of conservation
		obsolete heating plant
		obsolete walls
		obsolete roof
		obsolete basement
		obsolete windows
		years from last renovation
		lack of heat meter
	High energy costs	
	high potential energy saving	
	low payback time	
	low thermal comfort	
	young age owners	

6 ENERGY SCOUT: TOOL IMPLEMENTATION

This chapter describes the implementation of the innovative tools Municipal Energy Model (MEM) and of the Energy Scout to a real medium-sized Italian municipality. In particular, the research addresses the issues arising from building the model starting from available real data. Among the proposed solutions, is noteworthy the development of a set of plugins for QGIS ad hoc for the thesis. Finally, this chapter shows the results achieved for the analysed case of study.

It should be remembered the research and the point of view is of an energy and buildings expert and not an urban planner.

6.1 APPLICATION TO A CASE STUDY

In order to verify the approach described in Chapter 5, MEM and Energy Scout are applied to a medium size municipality near Milan, in Lombardy Region. Moreover, using real database led to clashes with problems of data interoperability and reliability of database that must be addressed in order to apply the tool potentially to all Italian municipalities.

6.1.1 Municipality of Senago

The municipality selected as case study is Senago, a medium municipality located near Milan, the principal data are collected in Table 6.1. Senago is quite an average municipality in the Lombardy Region. Senago is in the climatic zone "E", in which live 46% of the Italian population, with a flat orography, since it is located in the Po valley. The population density is quite higher than the Italian average but is close to the provincial average of 2,029 hab./km².

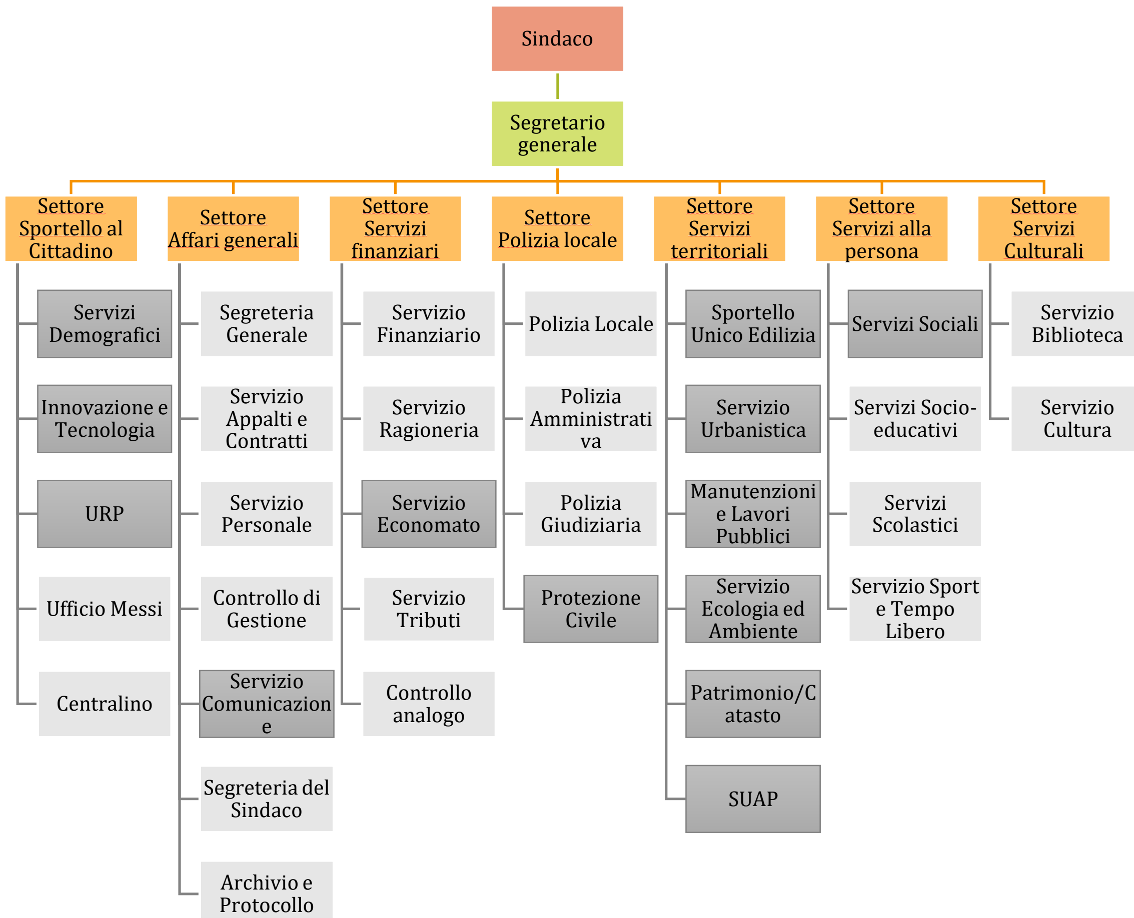
Table 6.1 Principal data about Senago municipality

	Senago
Province	Milan
Region	Lombardy
ID ISTAT	015206
ID Cadastre	I602
Official website	www.comune.senago.mi.it
Population	20,914 habitants (2011)
Area	8.60 km^2
Density	2,432 hab./km^2
Heating Degree Days	2485
Altitude	176 m

Municipalities in Italy can organize autonomously their offices, however the organizational structure of Senago does not differ from ordinary. The actual organizational structure has recently been modified (Municipal Council n. 182, 30/12/2014) and is shown in Figure 6.1.

Offices that may be involved in the development, management and use of the MEM are highlighted.

Figure 6.1 Official organigram, highlighted offices that may collaborate at MEM



As mentioned in Chapter 5, it would be better an interlinked organization of municipal offices, but it is also possible to develop the MEM with the actual organization and with the resources currently available.

The sector that could manage primarily the MEM is *Servizi Territoriali* (Territorial Services), which includes the following offices:

- *Sportello Unico Edilizia* (Building bureau)
- *Servizio Urbanistica* (Planning bureau)
- *Manutenzioni e Lavori Pubblici* (Maintenance and Public Works)
- *Servizio Ecologia ed Ambiente* (Ecology and Environment Service)
- *Patrimonio / Catasto* (Heritage / Cadastre), service held at the municipality of Bollate
- *SUAP – Sportello Unico Attività Produttive e commercio* (Productive Activities and Commerce bureau)

Other sectors and offices that may collaborate to the development of MEM are:

- Sportello al Cittadino (Citizen Services)

- *Servizi Demografici* (Demographic services): Register Office
    - *Innovazione e Tecnologia* (Innovation and Technology): Statistics Office
    - URP – Ufficio Relazioni con il Pubblico (Front Office)
- Settore Affari Generali (General Affairs)
    - *Servizio Comunicazioni* (Communications Service)
- Settore Servizi finanziari (Financial Services)
    - *Servizio Economato* (Treasurer's Department)
- *Settore Polizia Locale* (Sector Local Police)
    - Protezione Civile (Civil Defence)
- Settore servizi alla persona (Personal Care Services)
    - *Servizi Sociali* (Social services)

It should be noted that the Ecology and Environment Service has no competencies in energy and the Statistics Office is mainly devoted to elaborate statistics for ISTAT.

The regulations and planning tools concerning buildings and energy are as follows:

- PGT – Piano di Governo del Territorio (Municipal Urban Planning)
- *Regolamento Edilizio* (Building Code): in 2008 it was integrated with the Annex "Regulations for energy and environmental planning", promoted by Province of Milano and InfoEnergia
- *PAES - Piano di Azione per l'Energia Sostenibile* (SEAP - Sustainable Energy Action Plan): Covenant of Mayor signed on February 2009, SEAP transmitted on November 2011, monitoring started on 2015. The SEAP has been prepared by InfoEnergia.

Buildings and energy data

Compared to the Italian average, Senago is a rather urbanized Municipality: inhabited areas are 50.3 % of the total municipal area, while the regional average is 12,4% and the national average is 6.4 %. Moreover, only 1.7% of the buildings are unused (data from ISTAT). As could be seen in Figure 6.2, the largest majority of the residential buildings was built after the Second World War, with 66% of 2,447 residential buildings in Senago. This is due to the economic boom after the War and the massive migration of the population from south to north Italy. The agricultural and industrial (furnaces and foundries) economy is shifting toward a services economy.

The energy quality of the buildings is scarce: on average, the residential buildings have an EP_h of 209 kWh/m^2 year, while the non-residential buildings have an EP_h of 73 kWh/m^3 year (data from CENED, www.cened.it/focus_ceer).

As regards Final Energy Consumption shown in Figure 6.3, buildings consume 61% of the share, the residential sector being responsible for half the overall consumption and the tertiary sector responsible for 11%. It should be noted (Figure 6.4), that 61% of the energy comes from natural gas, which is the most used heating fuel.

Hence, it is very important to reduce the energy consumption from the residential sector and, in particular, the consumption of natural gas for heating.

Figure 6.2 Number of residential buildings per age (Data from ISTAT)

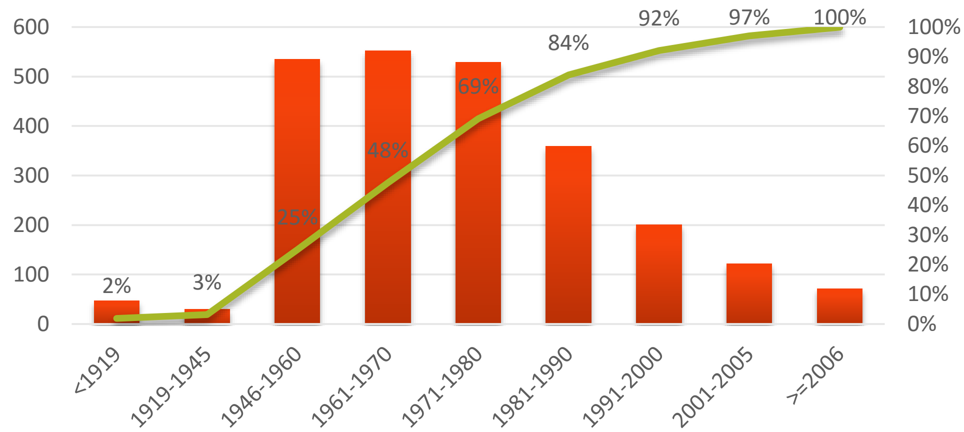


Figure 6.3 Final Energy Consumption in 2010 per Sector [MTOE]. Source: Finlombarda - Regione Lombardia, SIRENA

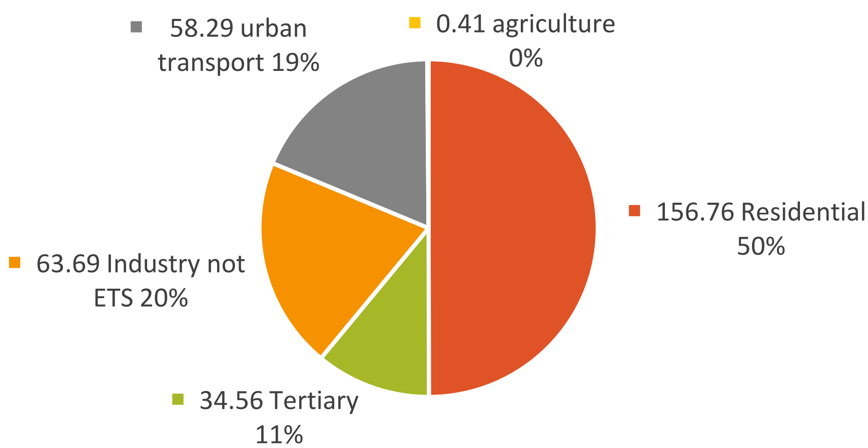
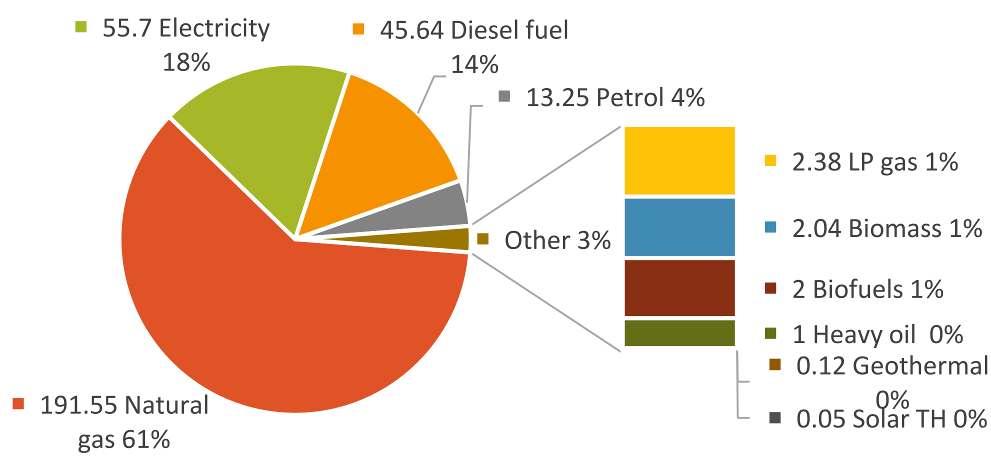


Figure 6.4 Final Energy Consumption in 2010 per Vector [MTOE]. Source: Finlombarda - Regione Lombardia, SIRENA



6.1.2 From model to tool

To move from the abstract model to the tool implementation the first step is to verify if there are available data to implement the indicators. I have carried out, for each indicator the procedure described in Chapter 5.2 to check whether there are the needed data or it was necessary to calculate estimates.

The result of this procedure for Senago case study is reported in Table 6.3, while Table 6.2 shows the detailed legend. As may be noted, very few indicators could use collected data (✓), some could be used for a part of the building stock, but need estimate data for the other buildings (✓), while the majority of the indicator use estimate data for all the buildings (×). As described in the following chapters, it was still possible to develop the MEM for the case study of Senago municipality, in particular the description and development of the indicators is in Chapter 6.3.

Table 6.2 Detailed legend of Table 6.3

	✓	✓	×	?
LOD	adequate Level Of Details (sub municipal)	-	not adequate Level Of Details	uncertain
open access	accessible to everyone	access on demand	private or fee required	uncertain
license	free to use data	Municipalities could use data	limited data	uncertain
sensitive data	there are no sensitive data	is possible to eliminate existing sensitive data	there are sensitive data that cannot be used	uncertain
digital	it is digital and in a ready to use format	it is digital but have to be formatted	it is not digital (paper archive)	uncertain
georefer.	it is georeferenced	it is possible to georeference	it is not possible to georeference	uncertain
complete	It is collected for all items (buildings)	-	It is not collected for all items (buildings)	uncertain
use of collected data	it is possible to use the collected data for all items (buildings)	it is possible to use the collected data for some items, other items require estimate data	it is possible to use the collected data, all items (buildings) need estimate data	-

Table 6.3 could be seen as a list of current data availability issues, that could be used as a reference to improve the data collection. Moreover, having a clear picture of the data availability help in updating the model when the situation changes or data sources are improved or updated.

For a medium sized municipality in Lombardy Region it is currently is necessary to develop and use several estimate data, nevertheless, it should be noted that Lombardy Region is a precursor as regards the data availability. In fact, Lombardy municipalities have already several detailed and open data about the building stock and the energy profile.

In May 2013, data management about energy has been centralized by Infrastrutture Lombarde S.p.A in a single website, www.energialombardia.eu. This platform contain the following dataset:

- SIRENA, *Sistema Informativo Regionale ENergia e Ambiente* - Regional Informative System for Environment and Energy;
- CEER, *Catasto Energetico degli Edifici* - EPC register;
- CURIT, *Catasto Unico Regionale degli Impianti Termici* - Regional Heating Systems Register;
- RSG, *Registro regionale delle Sonde Geotermiche* - Regional Register of Geothermal heat pump.

In these years Lombardy Region has also developed a Regional Topographic Database (DBTR), therefore for the majority of Lombardy municipalities is available a detailed digital cartography.

Lombardy region has established (LR n. 12/2005) and implemented a regional topographic database, available at www.geoportale.regione.lombardia.it, along with other regional maps. Local databases provided to the Region, are verified, conformed, mosaicked and transposed into regional format. At the moment (July 2015), 1264 out of 1546 municipalities have their DBT published in the regional DBTR.

As regards other Italian regions, as described in Chap. 3.2, the current data availability is scarcer than Lombardy Region and non-homogeneous. However, with the recent new National guidelines for EPC there will be a standard national EPC and the institution of an information system for EPCs, heating plants and inspection.

It is thus expected in future the same availability of data of the Lombardy Region in all the other Italian Regions.

Table 6.3 Data collection for Senago municipality

Category	Indicator	Sub-indicator	Source	LOD	Open Data: open access	Open Data: license	Open Data: sensitive data	Open Data: digital	georefer.	complete	use of collected data
Energy characterization of the building stock	Current energy consumption		CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
	Technical potential of energy savings		×[a]								×
	Current RES energy production	photovoltaic	GSE Atlasole	✓	×	?	?	✓	✓	✓	×
			CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
		geothermal pumps	RSG	✓	✓	✓	✓	✓	✓	✓	✓
		solar heating	CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
	Technical potential of RES energy production	solar heating and photovoltaic	×[a]								×
Barriers	no. owners		Agenzia delle Entrate: Catasto Fabbricati	✓	✓	?	×	✓	✓	✓	×
	no. aging dwellers		ISTAT [microdati]: Censimento Popolazione 2011	✓	×	✓	×	✓	✓	✓	×
	Average costs of energy measures		×[a]								×
	planning restrictions		Comune: PGT	✓	✓	✓	✓	✓	✓	✓	✓
	recent building's age of construction		ISTAT [microdati]: Censimento Popolazione 2011	✓	×	✓	✓	✓	✓	✓	×
			Agenzia delle Entrate: Catasto Fabbricati	✓	✓	?	×	✓	✓	✓	×
			CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
			Comune: concessioni edilizie	✓	✓	✓	?	×	✓	✓	×
	low disposable income		Agenzia delle Entrate	✓	×	?	×	✓	?	✓	×
	Low level of education		ISTAT [microdati]: Censimento Popolazione 2011	✓	×	✓	×	✓	✓	✓	×
	rental property not in upscale neighborhood		Agenzia delle Entrate: Registrazione contratto affitto	✓	×	?	×	✓	?	✓	×
Driver	building manager		×								×
	high real estate value		Agenzia delle Entrate: OMI	✓	×	?	×	✓	✓	✓	×
	changes in family	moving work-related	×								×
		childbirth	Asl (gravidanze)	✓	×	×	×	×	×	✓	×
		sons leaving home	Comune: Anagrafe	✓	×	?	×	×	✓	✓	×
		retirement	INPS	✓	×	?	?	✓	?	✓	×
	building interventions to be carried out	poor state of conservation	×								×
		obsolete heating plant	CURIT	✓	✓	✓	✓	✓	✓	×	✓
		obsolete walls	CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
		obsolete roof	CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
		obsolete basement	CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
		obsolete windows	CENED: CEER	✓	✓	✓	✓	✓	✓	×	✓
		years from last renovation	Comune: Archivio pratiche edilizie	✓	×	?	?	×	✓	✓	×
	low thermal comfort		×								×
	High energy costs		×[a]								×
	high potential energy saving		×[a]								×

a: the indicator is an estimate but there are no official estimates

6.2 CARTOGRAPHIC BASE

Since the MEM and the Energy Scout are a GIS based tools, it is thus important to obtain a cartographic base suited for the energy purpose. The available general-purpose maps have to be modified in order to get a map that reflect the energy features of the building stock.

A detailed digital map of the building stock is a prerequisite for MEM and Energy Scout, unfortunately topographic databases are not yet available for all Italian municipalities.

- ❖ To develop MEM and Energy Scout, the essential cartographic data of the single building are: footprint; height; use (residential or non-residential); and age of construction (it is possible to obtain it with a statistical approach). For the hybrid approach is also necessary an ID linking with the EPCs register, otherwise it is possible to use only the archetypal approach.

For Senago municipality the sources for the cartographic base are:

- *Regional Topographic Database (DBTR): needed to know footprint, height and other useful data.*
  Lombardy region has established (LR n. 12/2005) and implemented a regional topographic database, available at www.geoportale.regione.lombardia.it, along with other regional maps.
  Local databases provided to the Region, are verified, conformed, mosaicked and transposed into regional format. At the moment (July 2015) 1264 out of 1546 municipalities have their DBT published in the regional DBTR, including Senago.
- *Municipal Cartography (DBT_Senago): needed to know use and other useful data.*
  The Municipality of Senago has realized the municipal cartography according to the regional specifications contained in d.g.r. n. 6650 of 20/02/2008. The DBTR is based on the municipal DBT, but some there are some fields useful for the energetic model that are not listed in the DBTR.
- *ISTAT Census Sections: needed to link with age of construction and other useful data collected by ISTAT.*
  The Italian National Institute of Statistics (ISTAT) conducts the Population and Housing National Census. The last one was held in 2011 and the data disclosed in open format are available for census section. The spatial and cartographic information are available at http://datiopen.istat.it.
- *National Building & Land Cadaster (CAT): needed to link with EPCs register and other useful statistical data.*
  The national Revenue Agency maintains the national Building & Land Cadastre, which for Lombardy region is visible at www.catasto.servizirl.it.

Since the different sources contain different data, it is necessary to merge the needed data in a single cartography as base for the MEM. The fields selected for the construction of the base map are summarized in Table 6.4. For the description of energy fields' filling, refer to Chapter 6.3.

Table 6.4 Input Fields for Basemap

source	layer	source field	sample value	basemap field
CAT	Particelle	CHIAVE	I602||14|5	ID_EPC
CAT	Fabbricati	COMUNE	I602	ID_EPC
CAT	Fabbricati	FOGLIO	14	
CAT	Fabbricati	NUMERO	5	
DBTR	Edificato-Unita_volumetrica_polygon	UN_VOL_AV	11.48	HEIGHT
DBTR	Edificato-Unita_volumetrica_polygon	UN_VOL_POR	al suolo	for processing
DBTR	Edificato-Ingombro_al_suolo_corpo_edificato_polygon	CR_EDF_CT	edificio minore	for processing
DBTR	Edificato-Ingombro_al_suolo_corpo_edificato_polygon	CR_EDF_ST	costruito	for processing
DBT_Senago	Edificio	EDIFC_USO	0201	USE
DBT_Senago	Edificio	EDIFC_STAT	0403	for processing
DBT_Senago	Edificio minore	EDI_MIN_TY	0101	for processing
ISTAT	ISTAT_Senago	SEZ	22	ID_ISTAT

Since the listed available cartographic bases are general-purpose, there is the need for a process that transforms data contained in an energy-oriented cartographic base. An innovation bring from this research is the detection of buildings by energetic point of view: a MEM building is a building with a single use, a heating or cooling system, a sole management and geometrically defined by the conditioned volumes. Obviously, since there is no a census of these characteristics, it was necessary to use some simplifications to detect MEM buildings with the current available data:

- Single use: from the energy point of view the distinction between residential and non-residential building is important because you use different indicators. In addition, if you can distinguish between the different non-residential uses, the related energy statistics are more accurate. In MEM, I split the buildings according to their use.
- Heating or cooling system: to be affected by energy measures, the buildings have to consume energy. I considered only the conditioned buildings, excluding those who consume energy only for appliances (e.g. lighting). I selected the main buildings and eliminated the minor buildings such as garages, sheds and similar.
- Sole management: building management can be individual, if there is a single owner, or managed with condominium meeting if there are more owners. The management of the building is relatively easy to detect for isolated buildings, while it is more complicated for adjacent buildings as courtyard or a block with a continuous perimeter of buildings

- two common typologies in Italy. I selected the management taking into account the land register.
– Conditioned volumes: from the energy point of view the building is delimited by the conditioned volumes. As simplification, I excluded underground and attics volumes, without a survey is not possible to know whether they are conditioned. The height considered is therefore the height up to the eaves.

The following sections explain the process to obtain the cartographic base of MEM, which is composed by two layers: buildings layer and related volumetric units layer. In fact, a building can have parts with different heights, called volumetric units, which in DBTR are the part of building with same eaves' height. In Table 6.5and Table 6.6 are shown layer's fields; it should be noted that there is a field, *build_MEM*, to link the volumetric units to the building to which they belong.

In order to implement and automate the realization of the cartography and to allow a faster development of the model a set of plugins for QGIS has been developed[62] ad hoc for the thesis. In fact, QGIS supports plugins, thus it is possible to add a customized script that extend the functionality of QGIS, using Python programming language. The plugin handbook is available as Annex D and the code is reported in Annex E.

Two plugins serve as support the manual editing of cartographic bases:

- Navigate through features: easily displays one by one the features in a selected layer;
- Spatial join max area: performs a spatial join assigning to the feature the value of the feature on the other layer that cover it more.

A three steps plugin serves to build the Building and Volumes layers of MEM, as follows:

- Step 1 - Assign ID_CAD: assigns the Cadastre ID to the volumetric units;
- Step 2 - Create energy layers: creates the Building and Volumes, estimating the external walls and calculating the compactness ratio;
- Step 3 - Assign EPC and Typology: finds if there is a corresponding EPC, assigns building's Typology and fills out the energy information on the basis of ID_EPC or Typology.

These plugins, as well as facilitating the work for the development of MEM for the case study, can be used to easily develop the model in other municipalities.

[62] In collaboration with Matteo Valdina, source code and documentation available at https://github.com/zanfire/qgis-utils

Table 6.5 Fields of Basemap volumetric units layer

ID fields	unit	description
un-vol_MEM	-	identifier of the MEM volumetric unit
build_MEM	-	identifier of the MEM building belongs to
height	m	height of the volumetric unit
area_gross	m^2	gross area
vol_gross	m^3	gross volume
wall_surf	m^2	walls surface
disp_surf	m^2	dispersing surface
area_r	%	net area to gross area ratio
area_net	m^2	net area
vol_r	%	net volume to gross volume ratio
vol_net	m^3	net volume
level_h	m	average level's height
n_level	-	number of levels
floor_area	m^2	net floor area

Table 6.6 Fields of Basemap buildings layer

ID fields	unit	description
build_MEM	-	identifier of the MEM building
USE	-	residential (E1) or non-residential (En1) building
ID_EPC	-	identifier of EPCs data
TYPOLOGY	-	identifier of compactness-age typology
ID_ISTAT	-	identifier of ISTAT zone
ID_OMI	-	identifier of OMI zone
foot_area	m^2	footprint building area
floor_area	m^2	net floor area
vol_net	m^3	net volume
disp_surf	m^2	dispersing surface
compact_r	m^{-1}	S/V
wall_surf	m^2	walls surface
age	-	age of construction
wind_r	%	window ratio (to dispersing surface)
wind_surf	m^2	window surface
Uenv	W/m^2K	Envelope U-value
Uroof	W/m^2K	Roof U-value
Uground	W/m^2K	Ground U-value
Uwind	W/m^2K	Window U-value
Eph	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Primary Energy for Heating
Eth	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Thermal Energy for Heating

ID fields	unit	description
ETC	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Thermal Energy for Cooling
EFER	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Energy from RES
EPW	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Primary Energy for domestic hot water (DHW)
EPT	E1: kWh/m^2 yr | En1: kWh/m^3 yr	Primary Energy Total
E_HEAT	-	overall efficiency of the heating system
E_DHW	-	overall efficiency of the dhw system
E_H-DHW	-	overall efficiency of the heating & dhw system
SUP_FV	m^2	surface of photovoltaic panels
SUP_ST	m^2	surface of solar thermal panels

6.2.1 Clean volumetric units' layer

The cartographic bases contains all the buildings in the municipality, but for the MEM only buildings that use a heating or cooling systems are needed. Therefore, a cleaning of the base layer, "Edificato-Unita_volumetrica_polygon" from the DBTR, is necessary.

Using the field CR_EDF_CT of "Edificato-Ingombro_al_suolo_corpo_edificato_polygon" layer and "Edificio minore" layer, I deleted the buildings listed as minor. Despite this, they remained clearly smaller buildings but not listed as minor.

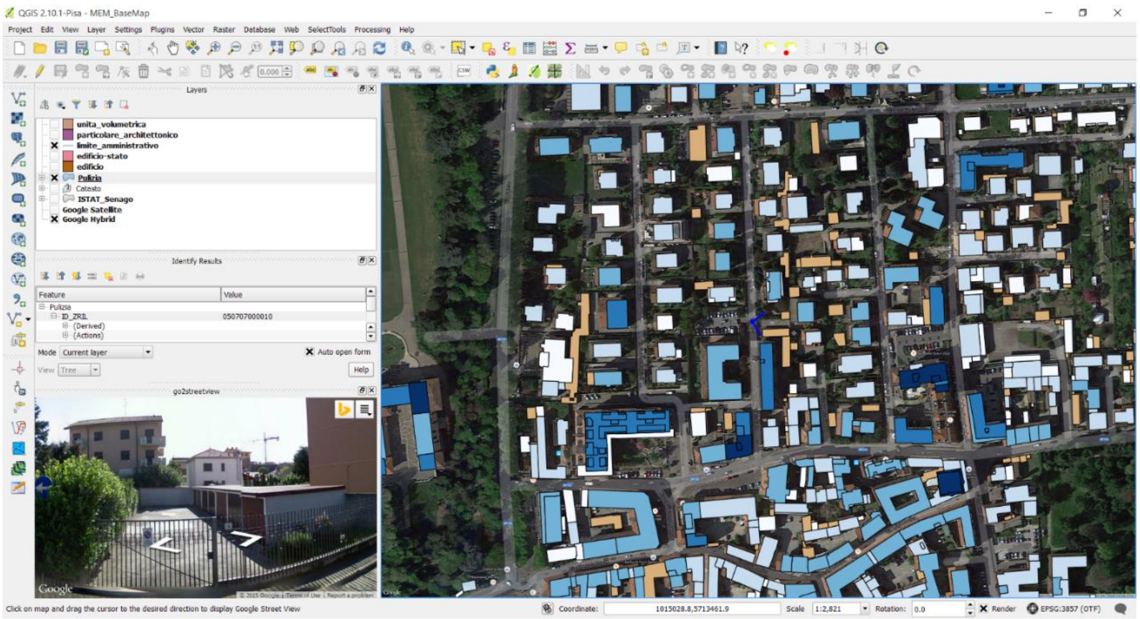
I performed an automatic clearing selecting feature that have no neighbors and have an area less than 30 m^2.

Then I performed a manual clearing, highlighting records with height less of 3 m, checked with Google Satellite and eventually with Google Street View, as could be seen in Figure 6.5Figure 6.5. This is faster than a field survey and improves the quality of the cleaning operation.

While doing this step I took the opportunity to remove even the technical volumes (e.g. elevator shafts, chimneys), elements that protrude from the main body but which are not heated or cooled, bringing them to the same height of the main body.

This manual clearing required more than a full week of work for Senago municipality.

Figure 6.5 QGIS setup for cleaning the volumetric units layer



6.2.2 Match base maps

In order to link data from EPCs and the buildings is necessary to assign the cadaster code (ID_CATASTO), to the features in the volumetric units' layer.

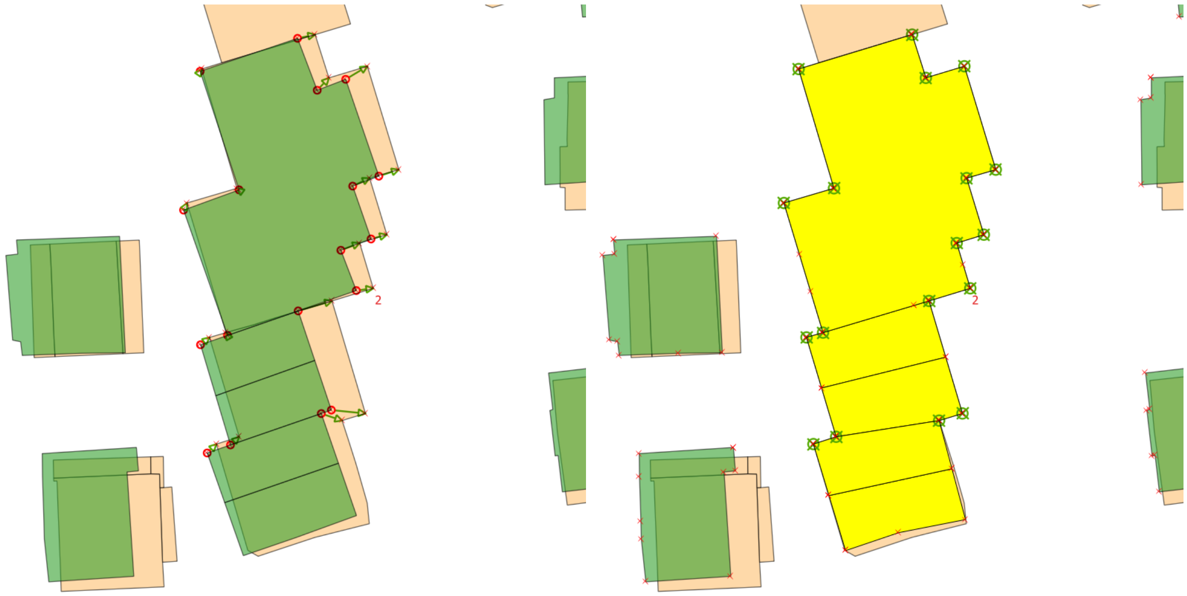
Unfortunately, because the DBTR and the Cadaster maps are managed by different agencies, the buildings are misaligned and an automatic spatial join leads to numerous errors in assign the correct ID_CATASTO. Moreover, some buildings in the volumetric units' layer are a single features, while in the Cadaster the buildings are divided into several properties.

In addition, the update is not synchronous, so there are buildings that exist in the DBTR and not in the Cadaster and vice versa.

Therefore, it is necessary to do a manual matching of the volumetric units' layer with the Cadaster layer. I used the Vector Bender plugin (available at https://plugins.qgis.org/plugins/VectorBender) since the buildings are so misaligned that affine transformations are not possible.

As could be seen in Figure 6.6, I aligned the Cadaster layer to the volumetric units' layer, trying to use reference points of the buildings. After the alignment, if necessary, I divided the volumetric units' features consistent with the Cadaster layer.

Figure 6.6 Example of manual alignment of Cadastre and volumetric units layers



I do not consider buildings that are outside the administrative boundary and outside the Cadaster boundary since it is not possible to assign a cadastral code to the buildings.

I considered instead the buildings on the volumetric units' layer that are not on the Cadaster layer, since the cadastral code could be assign from the land cadaster (*Catasto Particelle*).

There was 55 buildings that are on the Cadaster but not in the DBTR, I copied the features to the volumetric units' layer and assigned to them a likely height using Google Street View to check the number of floors and the height of neighbouring buildings.

In the end, I double-checked every features on the volumetric units' layer, using the "Navigate through features" plugin developed for this purpose (see Annex D).

In order to link data from ISTAT and the buildings is necessary to assign the census code (ID_ISTAT), to the features in the volumetric units' layer. Also in this case the layers are not perfectly aligned, because the DBTR and the Census maps are managed by different agencies. However, in this case the problems are minor because the census sections are much larger than buildings. Some buildings intersect more than one census section and some building are outside the census section.

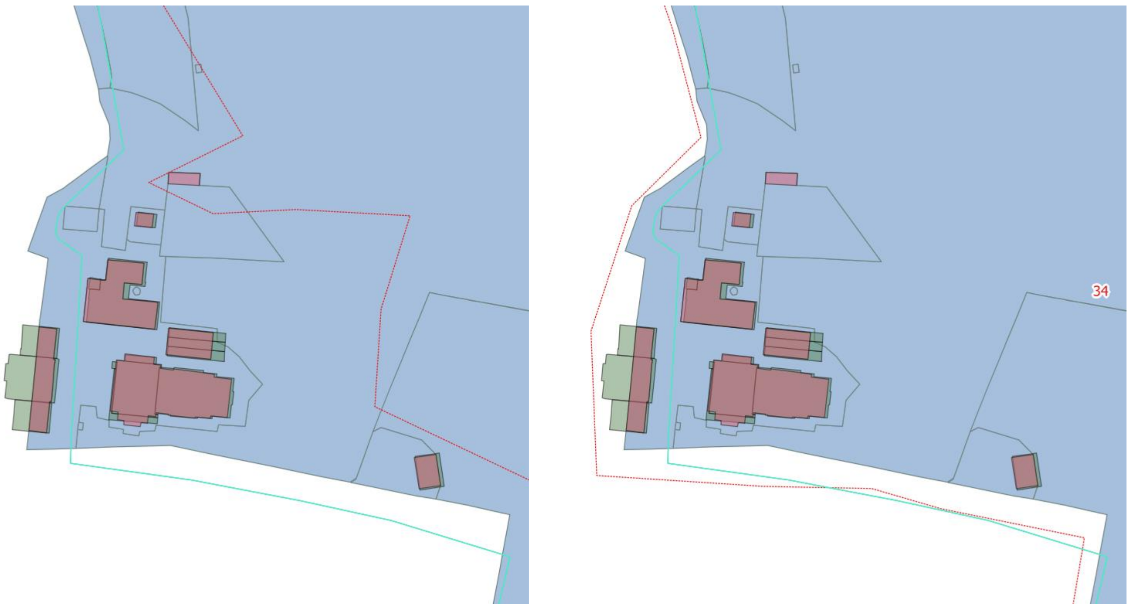
In the former case, to assign the correct ID_ISTAT I used "Spatial join max area" plugin developed for this purpose (see Annex D).

In the latter case, I modify the shape of the census section in order to encompass features in the DBTR and assign to them an ID_ISTAT, as could be seen in Figure 6.7.

Overall, this manual matching required more than two full week of work for Senago municipality.

- ❖ The National Land Register cartography and the Regional Topographic Database are not aligned. It is thus necessary a manual alignment or an unification of the two spatial databases, to be carried on at regional level.

Figure 6.7 Manual editing of the ISTAT layer to encompass features in DBTR



6.2.3 Assign build_MEM and ID_EPC

In order to assign the unique identification field build_MEM, I used as a base the existing fields USE and ID_CATASTO. Since there could be more than one building per ID_CATASTO, I decided to add a progressive number that identify the building with the same USE and ID_CATASTO (e.g. E1_I602-7-4_1).

Since there are some buildings on the volumetric units' layer that are not on the Cadaster layer, I assigned the cadastral code from the land cadaster (Catasto Particelle).

The build_MEM assignment has been automated with the "Step 1 - Assign ID_CAD" plugin developed for this purpose (see Annex D).

The other information linked to ID_CATASTO are the EPCs data: the ID_EPC field is not null when there is a corresponding EPCs in the EPCs database. In that case it is composed with USE and ID_CATASTO (e.g. E1_I602-7-4), in order to join correctly with the EPCs database.

The ID_EPC assignment has been automated with the "Step 3 - Assign EPC and Typology" plugin developed for this purpose (see Annex D).

6.2.4 Calculate Compactness Ratio

The compactness ratio (Dispersing Surface to Gross Heated Volume) is an important energy indicator and I used this value to assign a Typology class to the buildings (see next Section), as done in other research (Costa 2011).

The volume calculation is rather straightforward, once known height from DBTR and accepted the simplification that the entire volume is heated (less the bodies already removed previously).

On the contrary, the calculation of the dispersing surface is complex, since it is necessary to know which portion of the volumetric unit outline are towards another volumetric unit and if it is part of the same building or not. This is easily calculated in energy programs at the building scale, but thanks to the potentiality of GIS, it is possible to calculate the dispersing surface even for large building stock. Since a dedicated tool was not available for QGIS, compactness ratio calculation have been embedded in "Step 2 - Create energy layers" plugin, developed for this purpose (see Annex D).

The calculations made in the plugin are as follows:

a. For each volumetric unit:
    a. find if it intersect other features and eventually the length of the intersection $inter.length$;
    b. find the lowest height between the two touching features and use it to calculate the adjacent surface area $Adjac.Surf = inter.length \times Height_{minor}$;
    c. calculate the external walls' surface $Wall.Surf = (Perimeter \times Height) - Adjac.Surf$;
    d. calculate the dispersing surface as $Disp.Surf = (Area \times 2) + Wall.Surf$.
b. For each building:
    a. sum of the volumes of volumetric units belonging to that building;
    b. sum of the dispersing surface of volumetric units belonging to that building;
    c. calculate the compactness ratio $\text{compact. r} = \frac{\sum Disp.Surf}{\sum Volume}$.

I used the following simplifications:

- the ground area is equal to the roof area;
- there are no sloping walls;
- unless eliminations already carried out, the whole building is heated/cooled.

6.2.5 Assign building's Typology

If there are data from EPCs, energy data are assigned using the ID_EPC field. Otherwise, energy data are assigned depending on the building's typology (TYPOLOGY field).

The building's typology depends on the use (USE field), the construction age (AGE field) and the compactness ratio (COMPACT_R field), already explained in the previous section.

Assign building's use

The field "EDIFC_USO" in DBT_Senago have information about the use of the buildings. Since the energy data are grouped by use in a different manner in the CEER, it is necessary to match the DBT_Senago and the CEER building's use. The proposed matching is shown in Table 6.7.

Unfortunately in the DBT_Senago it is reported only the prevalent use, so professional's studios or small businesses located in residential building are not detected.

Table 6.7 Building's use matching

EDIFC_USO (DBT_Senago)	use Description (DBT_Senago)	use description (CEER)	USE
0201	Residential	Buildings used as residence and similar: housing used as residence on a continuous basis, such as residential buildings and rural colleges, convents, prisons and barracks	E1
020201	Administrative - Town Hall	Office buildings and similar: public or private, independent or contiguous buildings used also to industrial or craft, provided that such buildings be separated from the effects of thermal insulation	E2
02030102	Local Health Authority - hospital	Buildings used as hospitals, clinics and nursing homes and similar including those used for hospitalization or care of children or elderly and the protected facilities for the care and recovery of drug addicts and other assignees for public social services	E3
020303	Public service - schools, universities, research laboratory	Buildings used for school activities at every level and similar	E7
020304	Public service - Post offices	Office buildings and similar: public or private, independent or contiguous buildings used also to industrial or craft, provided that such buildings be separated from the effects of thermal insulation	E2
020401	Military - barracks	Buildings used as residence and similar: housing used as residence on a continuous basis, such as residential buildings and rural colleges, convents, prisons and barracks	E1
0205	Religious	Buildings used for recreational or religious and similar: such as exhibitions, museums and libraries, places of worship	E4.2
0207	Commercial	Buildings used for commercial and similar: such as shops, warehouses of wholesale or retail, supermarkets, fairs	E5
020704	Commercial - supermarket, hypermarket	Buildings used for commercial and similar: such as shops, warehouses of wholesale or retail, supermarkets, fairs	E5
0208	Industrial	Buildings used for industrial and crafts and similar	E8
020801	Industrial - industrial plant	Buildings used for industrial and crafts and similar	E8

EDIFC_USO (DBT_Senago)	use Description (DBT_Senago)	use description (CEER)	USE
02100101	Center of cultural activity - library	Buildings used for recreational or religious and similar: such as exhibitions, museums and libraries, places of worship	E4.2
021002	Recreational - sports activities	Building used for sports activities	E6
02100202	Sports activities - gym	Building used for sports activities: gyms and similar	E6.2
0293	Not Available		En1

Assign construction age

There could be several sources to know the construction age of the building stock, but the one which is available uniformly nationwide is the General Census of Population and Housing provided by ISTAT, that refer only to residential buildings.

The AGE field is derived from the EPC database, unfortunately, it must be underlined that sometimes the value present in the EPC refer to the year of renovation and not, as it should be, the year of construction.

If there is no EPC available, the AGE field is derived from statistics derived from ISTAT. As done in previous work (Pasetti 2011; Dall'O', Galante & Pasetti 2012), there is the need to create a correspondence between age classes of ISTAT and those of EPC register. The classes used in this work are reported in Table 6.8. Since there are some buildings that do not have ISTAT age nor CEER age, I introduced a seventh class for data not available.

The ISTAT source provides the number of buildings for each age of construction, so it is possible to derive the prevalent age of construction of the cadastral section, as already done by Costa(2011). The prevalent age of the section is simply the one with the largest number of buildings, unfortunately not always the maximum is a clear peak, as show in Table 6.9. In fact, using a kurtosis index (the degree of peakedness of a distribution), it shows in 9 sections a relatively flat distribution. This problem is less relevant for large municipalities, such as Milan investigated by Costa (2011), because the census sections are more homogenous.

There are issues with the value of age construction either assigned by EPC or assigned by statistics that should be resolved in order to obtain a more robust model.

- Municipalities should have the correct age of construction thanks to the building permits and previous analysis on their building stock. However this information is not collected in a database. For the future, the age of construction should be collected by the municipality and incorporated into the MEM.

Assign Typology

The typology is assigned as a concatenation of use, construction age class and compactness ratio class, shown in Table 6.10. An example for residential buildings is shown in Table 6.11. The TYPOLOGY assignment has been automated with the “Step 3 - Assign EPC and Typology” plugin developed for this purpose (see Annex D).

Table 6.8 Construction age correspondence and classification

ISTAT	CEER	MEM	construction age class
<1919		<=1945	A
	<1930		
1919-1945	1930–1945		
1946-1960	1946–1960	1946–1960	B
1961-1970	1961–1976	1961-1980	C
1971-1980			
	1977–1992	1981-1990	D
1981-1990			
1991-2000	1993–2006	1991-2005	E
2001-2005			
>=2006	>=2007	>=2006	F
		n.a.	X

Table 6.9 Prevalent construction age of the cadastral section

SEZ2011	<=1945	1946–1960	1961-1980	1981-1990	1991-2005	>=2006	SEZ_period	kurtosis
152060000001	10	47	38	15	9	4	1946–1960	-1,23483
152060000002	31	29	29	7	13	0	<=1945	-2,19339
152060000003	0	25	71	24	15	1	1961-1980	2,828314
152060000004	5	31	58	22	15	2	1961-1980	1,222237
152060000005	15	22	44	10	4	0	1961-1980	1,665418
152060000006	4	28	57	2	9	4	1961-1980	2,045809
152060000007	1	36	79	9	14	4	1961-1980	2,488857
152060000008	0	40	69	4	31	5	1961-1980	-0,27204
152060000009	0	49	103	41	51	6	1961-1980	0,635397
152060000010	0	8	11	1	3	0	1961-1980	-0,98138
152060000011	0	0	8	57	1	14	1981-1990	4,663418
152060000012	0	1	4	0	10	0	1991-2005	2,863415
152060000013	0	5	0	0	0	0	1946–1960	6
152060000014	0	19	61	68	10	2	1981-1990	-1,78655

SEZ2011	<=1945	1946–1960	1961-1980	1981-1990	1991-2005	>=2006	SEZ_period	kurtosis
152060000015	0	12	15	6	10	1	1961-1980	-1,83283
152060000016	0	8	25	4	11	1	1961-1980	2,17842
152060000017	1	22	36	2	7	2	1961-1980	0,341184
152060000018	0	45	87	14	19	4	1961-1980	1,579464
152060000019	0	23	86	4	4	0	1961-1980	4,594599
152060000020	0	24	76	32	17	6	1961-1980	2,638437
152060000021	0	11	45	21	12	3	1961-1980	2,212357
152060000022	0	14	32	4	6	3	1961-1980	2,822712
152060000023	0	1	5	2	25	1	1991-2005	5,314927
152060000024	0	19	26	4	16	3	1961-1980	-1,90298
152060000025	0	0	4	0	1	1	1961-1980	3,958333
152060000026	10	4	2	0	0	0	<=1945	2,666468
152060000027	0	3	1	0	0	4	>=2006	-1,2051
152060000032	0	5	5	1	8	0	1991-2005	-1,64328
152060000033	0	4	0	0	0	0	1946–1960	6
152060000035	0	0	0	0	0	0		
152060000036	0	0	2	5	2	1	1981-1990	1,852811
152060000037	0	0	1	0	0	0	1961-1980	6
152060000038	0	0	1	0	0	0	1961-1980	6
152060000039	0	0	0	0	0	0		
152060000040	0	0	0	0	0	0		
152060000041	0	0	0	0	0	0		
152068888888	0	0	0	0	0	0		

Table 6.10 Compactness ratio classes

COMPACT_R value	compactness ratio class
<0.3	1
0.3-0.4	2
0.4-0.5	3
0.5-0.6	4
0.6-0.7	5
0.7-0.8	6
>=0.8	7

Table 6.11 Typology matrix: age of construction versus compactness ratio matrix for residential buildings

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	E1-A.1	E1-A.2	E1-A.3	E1-A.4	E1-A.5	E1-A.6	E1-A.7
1946-1960	E1-B.1	E1-B.2	E1-B.3	E1-B.4	E1-B.5	E1-B.6	E1-B.7
1961-1980	E1-C.1	E1-C.2	E1-C.3	E1-C.4	E1-C.5	E1-C.6	E1-C.7
1981-1990	E1-D.1	E1-D.2	E1-D.3	E1-D.4	E1-D.5	E1-D.6	E1-D.7
1991-2005	E1-E.1	E1-E.2	E1-E.3	E1-E.4	E1-E.5	E1-E.6	E1-E.7
>=2006	E1-F.1	E1-F.2	E1-F.3	E1-F.4	E1-F.5	E1-F.6	E1-F.7
n.a.	E1-X.1	E1-X.2	E1-X.3	E1-X.4	E1-X.5	E1-X.6	E1-X.7

6.3 GEOREFERENCING DATA

6.3.1 Energy characterization of the building stock

The Municipal Energy Model characterize the entire building stock through a hybrid bottom-up approach, using data relating to the specific building and data assigned by an archetypal approach. Data relating to the specific building derive from the EPC database, while the archetypal data are assigned by the Use-Age-Compactness_ratio typology (see section 6.2.5).

For specific data it is necessary the EPCs of the building stock of the analysed municipality. Since often the EPC refers to a single dwelling an elaboration it is necessary to transpose value at the building level. If there are no EPCs for the buildings of the municipality, it is possible to use only the archetypal approach.

For archetypal data I elaborate the EPCs referring to buildings in the Province of Milano (NUTS 3 level), excluding EPCs into the Milano's municipality since the capital city is quite different from the surroundings municipalities. From the climate, orography and construction features point of view the municipalities in the Province of Milan are quite similar, other contexts could be different.

Since both specific and statistic data are taken from the same database, energy values are homogenous.

- The MEM uses energy data referring to the single building, derived from EPCs, and archetypal energy data, derived from provincial EPCs database. If the former are lacking, it is still possible to build up the MEM with only archetypal data.

It should be noted that energy values in EPC are calculate in standard conditions, so are useful to compare buildings and not to assess directly the energy consumption of the building stock.

6.3.1.1 Cleaning the Energy performance certificate database

The EPCs database for Senago is maintained by the regional CENED and it is available as open data at https://www.dati.lombardia.it .

The database has been downloaded in July 2015 and contained 2,999 records for the Senago municipality. The data contained in the database are not verified, therefore I proceeded to check the consistency of the data for the EPCs of Senago.

In 399 records there are only values in the first identification fields: it means that there is a EPC but it is not digitalized, it is only in printed copy. These records should refer to EPCs older than October 2009, because before this date EPC were not digitalized. However, there are 8 records more recent than October 2009.

There are also 89 duplicate records that refer to the same dwellings: I discarded the older records referring to the data field (i.e. "DATA_CHIUSURA_PRATICA").

In a correct database, records referring to the same dwellings should be duplicate only if there were some energy measures on the building: but I found that only 13 of them could be traced to changes in energy performance (see Figure 6.8). The majority are complete duplicate, with usually the same date or few days of difference: probably caused by a simple double entry. Some EPCs differ for minor values and are usually close in time: I assumed that this is caused by finding some filling error and uploading the correct EPC. There are also a large number of duplicate for which is it not easy to trace the cause: there are spaced in time, with different values or different energy certifier but often with the same motivation value ("MOTIVAZIONE_APE") – rental, sale, voluntary, other – that it does not explain why it was made a new EPC.

Figure 6.8 Duplicate EPCs

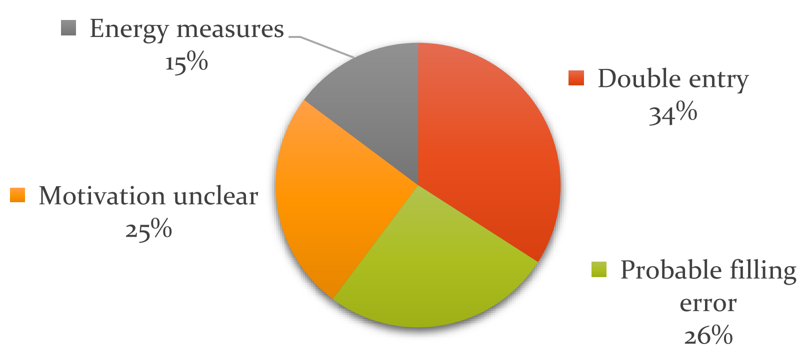


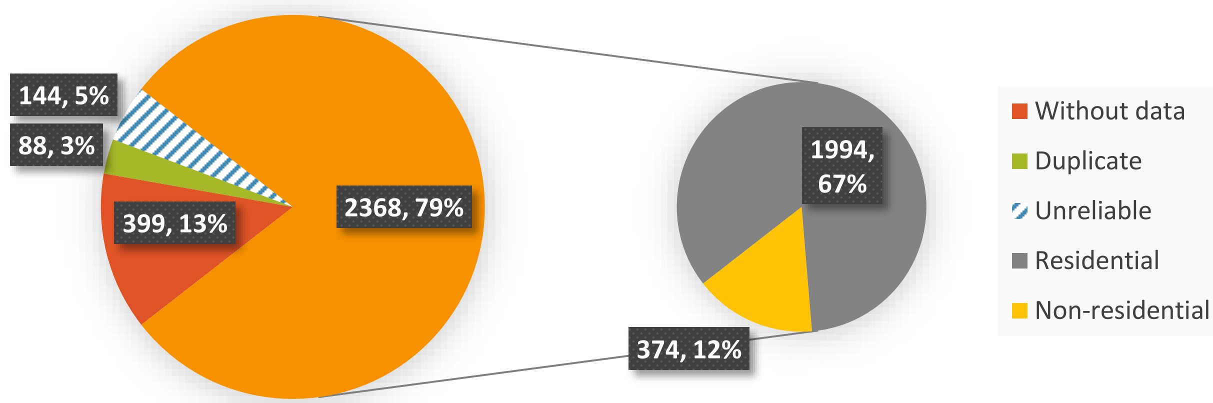
Table 6.12 Unreliable residential EPCs

Value	**limit**		**no. EPCs**
Eph [kWh/m² year]	>	700	5
Average h (Area/Volume) [m]	<	2	4
	>	5	8
Net floor surface (An) [m²]	<	30	3
U-values for opaque surfaces [W/m² K]	<	0.10	1
	>	3.60	0
U-values for transparent surfaces [W/m²K]	<	0.50	21
	>	6.00	0
EFGh	<	0.4	53
EFGh>1 with RES and high efficiency checks			5

Table 6.13 Unreliable non-residential EPCs

Value	limit		no. EPCs
Eph [kWh/m³ year]	>	300	5
Average h (Area/Volume) [m]	<	2	0
Net floor surface (An) [m²]	<	30	8
U-values for opaque surfaces [W/m² K]	<	0.10	0
	>	3.60	1
U-values for transparent surfaces [W/m²K]	<	0.50	7
	>	6.00	1
EFGh	<	0.4	13
EFGh>1 with RES and high efficiency checks			9

Figure 6.9 Number of EPCs for Senago municipality



I split the remaining 2,511 records in residential and non-residential dwellings, as the key energy values have different units of measurement (e.g. EP is kWh/m² year for residential buildings and kWh/m³ year for non-residential buildings).

On this records I made a rough value checking to discard records that probably contain errors, as synthetized in Table 6.12 and Table 6.13.

The regional law D.d.g. 15 dicembre 2009 - n. 14009, identifies factors to select untrusty EPCs for inspection, including the value of EPh. I used the non-suspect value to discard records with too high EPh values. Moreover I discarded also records with room height clearly wrong. There are also 212 EPCs with blank values for dispersing surface, glazed surface or U-values: I have included those EPCs because it could be only a filling error, since the other values are acceptable.

For the U-values I considered not reliable values higher than the worst standard values in UNI TS 11300 or lower than the best values, except for the best opaque U-value, for which I consider the value from the Passive House Institute: *for Central European climate U-values (thermal* *transmittance) of external walls, floor slabs and roof areas of Passive Houses range from 0.10 to 0.15 W/(m²K).*

I performed also a rough check on the Average Global Seasonal Efficiency of Heating System (EFGh). For the lower limit, I considered the system efficiency given by worst efficiencies presented in UNI TS 11300. For the upper limit when the EFGh is higher than 1 I check the condition that justified this value: the use of renewable energy sources or the use of highly efficient thermal plants.

In the end, the database contains 1,994 valid EPCs for residential dwellings and 374 valid EPCs for non-residential dwellings, as show in Figure 6.9.

6.3.1.2 Appling EPCs energy data to buildings

The next step was to apply data to buildings: EPCs often refer to apartments but the available database contains only the cadastral references of the building and not of the single apartment.

I calculate the value for the single building referring to the cadastre code (i.e. foglio-particella) that identify the single building, using the value from the EPCs referring to the dwellings with that cadastre code.

For energy performance indicators (i.e. EPh, ETh, ETc, EFER, EPw, EPt) and for system efficiencies (i.e. EFGh, EFGw, EGHW) I used the weighted arithmetic mean on the neat surface for residential buildings and on the neat volume for non-residential buildings. For the U-values (envelope, roof, ground, windows) I used the weighted arithmetic mean on the surface relative to the performance investigated, if the surface value is blank I have assigned the value 1 in order to consider also U-values in records with blank value for surface. For the photovoltaic and solar thermal systems I have simply summed up the installed surface for each building.

Starting with 2,368 EPCs, I obtained energy values for 1,046 buildings.

6.3.1.3 Calculate energy data for archetypal approach

For buildings with no energy values from EPCs it is necessary to use estimate data: I calculate some statistical energy data from the provincial EPCs database.

Sort out reliable data

The database has been downloaded from https://www.dati.lombardia.it in July 2015 and contained 302,553 records for the Province, excluding Milan. The data contained in the database are not verified and may refer to single dwelling not to entire building, therefore I proceeded to check the database.

There are 48,640 records with values only in the first identification fields: these records should refer to EPCs older than October 2009, which are not digitalized and therefore not usable for statistics.

To pick out only records referring to entire building I excluded records with blank values for surfaces or U-values; as a result there are 58,713 record that should refer to an entire building.

On this records I made a rough value checking to discard records that probably contain errors, as synthetized in Table 6.14 and Table 6.15Table 6.15.

The regional law D.d.g. 15 dicembre 2009 - n. 14009, identifies factors to select untrusty EPCs for inspection, including too high EPh's value that I have discarded. Moreover I discarded also records with compactness ratio, room height and Net floor surface clearly wrong.

For the U-values I considered not reliable values higher than the worst standard values in UNI TS 11300 or lower than the best values, except for the best opaque U-value, for which I consider the value from the Passive House Institute: *for Central European climate U-values (thermal transmittance) of external walls, floor slabs and roof areas of Passive Houses range from 0.10 to 0.15 W/(m²K).*

I performed also a rough check on the Average Global Seasonal Efficiency of Heating System (EFGh). For the lower limit I considered the system efficiency given by worst efficiencies presented in UNI TS 11300. For the upper limit when the EFGh is higher than 1 I check the condition that justified this value: the use of renewable energy sources or the use of highly efficient thermal plants.

In the end, I obtained 39,197 EPCs for residential buildings and 15,289 EPCs for the non-residential buildings.

Calculate energy statistical data

Energy statistics have been calculated taking into account the Use-Age-Compactness_ratio typology. The USE value is the same used by MEM. The age value in EPCs could be a given year or a CEER age class, thus I converted every record year value in age class. Using surface and volume values present in EPC, I calculated the compactness ratio and assigned the compactness ratio class (Table 6.10). Assuming that buildings that have no EPCs probably have not undergone energy measures, I calculated energy statistical data considering only EPCs with a motivation field that do not refer to energy measures (see Table 6.16Table 6.16).

With the resulting filtered dataset, I calculate the simple average for each needed energy value. For the "X" age class the average is calculated on all age of construction.

Results for residential buildings could be seen in Table 6.17 to Table 6.26. Results for non-residential uses are reported in Annex B.

Table 6.14 Unreliable residential building EPCs for Province of Milan

value	limit	no. EPCs
Eph	> 700 kWh/m2 year	206
Average h (Area/Volume)	< 2 m	264
	> 5 m	259
S/V	< 0.2	39
	> 1.5	57
Net floor surface (An)	An<30 m2	441
U-values for opaque surfaces	U<0.10 W/m2 K	217
	U>3.60 W/m2 K	21
U-values for transparent surfaces	U<0.5 W/m2K	285
	U>6.00 W/m2 K	14
EFGh (ETh/EPh)	<0.4	142
	>1 without RES or high eff. plants	66

Table 6.15 Unreliable non-residential building EPCs for Province of Milan

value	limit	no. EPCs
Eph	> 300 kWh/m3 year	108
Average h (Area/Volume)	< 2 m	55
S/V	< 0.2	136
	> 1.5	123
Net floor surface (An)	An<30 m2	291
U-values for opaque surfaces	U<0.10 W/m2 K	98
	U>3.60 W/m2 K	553
U-values for transparent surfaces	U<0.5 W/m2K	141
	U>6.00 W/m2 K	50
EFGh (ETh/EPh)	<0.4	405
	>1 without RES or high eff. plants	256

Table 6.16 Selection of motivation field

MOTIVAZIONE_APE	translation	energy measures
Ace volontario	voluntary EPC	no
Altro	other	no
Ampliamento volumetrico sopra il 20%	volumetric expansion above 20%	yes
Contratto di locazione	lease contract	no
Contratto servizio energia o servizio energia plus	energy service contract	no
Demolizione e ricostruzione in ristrutturazione	demolition and reconstruction refurbishment	yes
Incentivi fiscali	fiscal incentives	yes
Nuova costruzione	new building	no
Nuova installazione d'impianto termico	installation of new heating system	yes
Recupero sottotetto	attic refurbishment	yes
Ristrutturazione d'impianto termico	heating system refurbishment	yes
Ristrutturazione edilizia sopra il 25%	building renovation above 25%	yes
Sostituzione di generatore sopra i 100 kW	replacement of generator above 100 kW	yes
Trasferimento a titolo oneroso	sale agreement	no

Figure 6.10 Average EPh for residential buildings

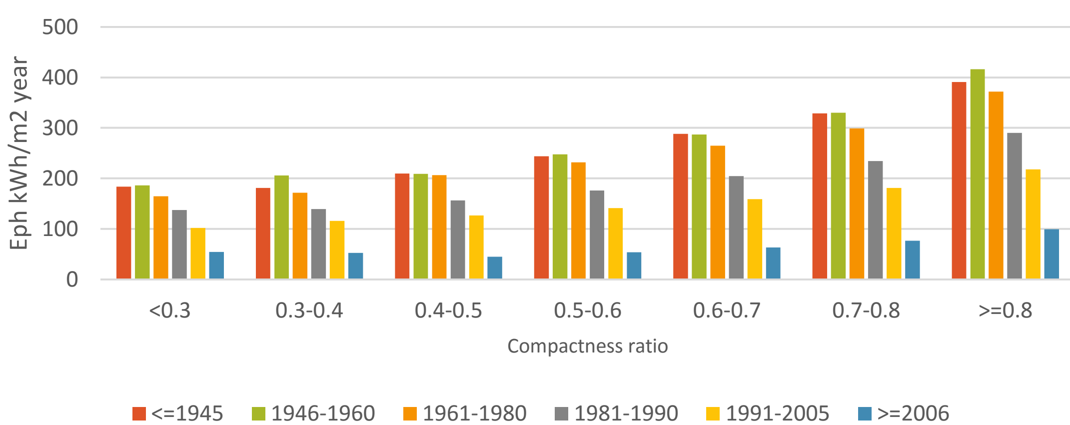


Table 6.17 Average envelopes' U-values for residential building in archetypal approach [W/m² K]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	1.22	1.25	1.30	1.23	1.29	1.29	1.28
1946-1960	1.26	1.36	1.33	1.26	1.27	1.30	1.32
1961-1980	1.18	1.30	1.27	1.21	1.17	1.20	1.18
1981-1990	1.01	1.03	1.05	1.01	0.99	0.99	0.96
1991-2005	0.99	0.83	0.78	0.78	0.76	0.77	0.73
>=2006	0.30	0.44	0.34	0.36	0.36	0.37	0.41

Table 6.18 Average roofs' U-values for residential building in archetypal approach [W/m² K]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	1.12	1.25	1.17	1.17	1.20	1.20	1.21
1946-1960	1.43	1.44	1.24	1.23	1.22	1.24	1.27
1961-1980	1.24	1.38	1.30	1.25	1.21	1.19	1.21
1981-1990	1.06	1.13	1.09	1.04	1.04	1.03	1.05
1991-2005	0.87	0.84	0.82	0.78	0.76	0.79	0.79
>=2006	0.28	0.43	0.32	0.33	0.34	0.35	0.39

Table 6.19 Average basements' U-values for residential building in archetypal approach [W/m² K]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	1.16	1.40	1.32	1.31	1.35	1.33	1.28
1946-1960	1.38	1.35	1.30	1.29	1.33	1.35	1.30
1961-1980	1.19	1.29	1.29	1.30	1.30	1.32	1.24
1981-1990	1.11	1.22	1.18	1.17	1.18	1.15	1.11
1991-2005	1.07	1.02	0.95	0.95	0.92	0.93	0.90
>=2006	0.40	0.46	0.37	0.40	0.41	0.42	0.46

Table 6.20 Average windows' U-values for residential building in archetypal approach [W/m² K]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	3.44	3.43	3.49	3.51	3.62	3.58	3.60
1946-1960	4.14	3.63	3.68	3.61	3.61	3.64	3.71
1961-1980	3.83	4.26	3.86	3.72	3.62	3.56	3.62
1981-1990	3.43	3.38	3.33	3.29	3.27	3.26	3.33
1991-2005	2.93	3.01	3.08	3.05	3.02	3.01	2.92
>=2006	1.84	1.99	1.78	1.78	1.80	1.85	1.97

Table 6.21 Average Eph for residential building in archetypal approach [kWh/m² year]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	183.35	180.98	209.74	243.70	287.90	328.86	390.59
1946-1960	186.03	205.79	208.79	247.50	286.90	329.72	416.29
1961-1980	164.26	171.64	206.24	231.86	264.80	298.96	371.62
1981-1990	137.01	139.23	156.62	176.29	204.41	234.29	290.01
1991-2005	101.60	115.80	126.49	141.41	159.10	181.25	217.65
>=2006	54.31	52.29	45.00	53.92	63.45	76.72	99.05

Table 6.22 Average Eth for residential building in archetypal approach [kWh/m² year]

	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
<=1945	141.46	131.18	151.61	178.55	213.30	242.91	290.43
1946-1960	133.25	141.23	152.04	177.11	208.46	239.74	303.81
1961-1980	114.70	126.92	142.44	165.24	191.46	219.69	270.08
1981-1990	96.39	99.54	113.24	130.04	150.70	172.74	213.82

1991-2005	71.61	83.22	89.05	102.62	116.20	132.66	156.71
>=2006	41.34	47.60	42.08	50.20	57.64	67.52	84.64

Table 6.23 Average Etc for residential building in archetypal approach [kWh/m² year]

	<0.3	**0.3-0.4**	**0.4-0.5**	**0.5-0.6**	**0.6-0.7**	**0.7-0.8**	**>=0.8**
<=1945	16.79	19.54	18.18	18.96	18.51	18.22	18.95
1946-1960	21.68	19.61	20.55	20.80	19.41	19.10	19.19
1961-1980	24.40	22.86	21.61	20.26	19.52	19.64	19.85
1981-1990	19.04	19.36	18.79	17.88	18.48	18.66	21.04
1991-2005	17.82	21.56	21.03	19.76	19.60	20.84	23.75
>=2006	37.76	26.10	24.67	23.97	23.73	24.05	25.37

Table 6.24 Average EGh for residential building in archetypal approach [-]

	<0.3	**0.3-0.4**	**0.4-0.5**	**0.5-0.6**	**0.6-0.7**	**0.7-0.8**	**>=0.8**
<=1945	0.80	0.74	0.74	0.75	0.75	0.75	0.76
1946-1960	0.72	0.70	0.74	0.73	0.74	0.74	0.74
1961-1980	0.70	0.76	0.71	0.72	0.74	0.75	0.74
1981-1990	0.72	0.72	0.73	0.75	0.75	0.75	0.75
1991-2005	0.72	0.73	0.72	0.74	0.74	0.74	0.73
>=2006	0.93	1.15	1.09	1.08	1.03	1.02	0.97

Table 6.25 Average EGw for residential building in archetypal approach [-]

	<0.3	**0.3-0.4**	**0.4-0.5**	**0.5-0.6**	**0.6-0.7**	**0.7-0.8**	**>=0.8**
<=1945	0.68	0.56	0.54	0.55	0.55	0.54	0.51
1946-1960	0.47	0.49	0.50	0.53	0.53	0.53	0.49
1961-1980	0.43	0.35	0.41	0.49	0.54	0.55	0.47
1981-1990	0.56	0.53	0.55	0.58	0.58	0.58	0.51
1991-2005	0.57	0.57	0.54	0.57	0.58	0.56	0.51
>=2006	1.03	13.44	0.75	0.88	0.79	0.72	0.71

Table 6.26 Average EGhw for residential building in archetypal approach [-]

	<0.3	**0.3-0.4**	**0.4-0.5**	**0.5-0.6**	**0.6-0.7**	**0.7-0.8**	**>=0.8**
<=1945	0.74	0.69	0.69	0.70	0.72	0.71	0.72
1946-1960	0.66	0.64	0.67	0.69	0.70	0.70	0.71
1961-1980	0.61	0.58	0.60	0.65	0.69	0.71	0.70
1981-1990	0.66	0.66	0.67	0.71	0.71	0.71	0.71
1991-2005	0.66	0.69	0.66	0.69	0.70	0.70	0.69
>=2006	0.87	0.79	0.84	0.85	0.85	0.82	0.81

6.3.1.4 *Renewable energy sources generation*

It should be noted that for the renewable energy source I have considered only the RES that could be integrated in buildings and are available on the Italian market, thus not considering hydroelectric systems or micro wind turbines.

Photovoltaic systems and solar heater

The most complete source if data for photovoltaic system is Atlasole, a GIS atlas containing data and information on photovoltaic systems that are incentivized trough Conto Energia (D.M. 5 luglio 2012). Unfortunately, the data owners, Gestore Servizi Energetici, does not provide data with a sub-municipal LOD, so for the scope of the MEM this data are not usable.

The EPCs database contains also data about installed photovoltaic systems, but is not complete: the Altasole reports 79 photovoltaic systems in Senago while in the EPCs database there are 24 records.

There are no registers regarding the solar thermal, so the only source of data is the EPCs database, which reports 78 solar heaters in Senago.

Therefore, I used data from EPCs database for building that have a EPCs, while I have considered photovoltaic systems and solar heater absent in the other buildings.

Data about photovoltaic systems and solar heater in the EPcs database are shown in Table 6.27.

Table 6.27 Data about photovoltaic systems and solar heater in EPCs database (CENED)

field	description
TIPOLOGIA_PANNELLO_ST	Type of thermal solar panels
TIPOLOGIA_PANNELLO_FV	Type of photovoltaic solar panels
SUPERFICIE_CAPTANTE_FV	Active area of the photovoltaic system [m^2]
SUPERFICIE_APERTURA_ST	Active area of thermal solar panels [m^2]
SUP_PAN_FV_SUP_UTILE	Ratio between the active of the photovoltaic system and the total floor area served
SUP_PAN_ST_SUP_UTILE	Ratio between the active of the thermal solar panels and the total floor area served

Geothermal pumps

For Region Lombardy it is available the Regional Register of Geothermal heat pump (RSG) that counts about 900 geothermal plants. Data are distributed as open data at https://www.dati.lombardia.it and are also displayed as a map, since there are fields that allow georeferencing. In Senago there are 14 records that refer to two buildings.

6.3.2 Technical potential

In addition to EPCs data, that are calculated in standard conditions, it is interesting to know data related to energy consumption and energy cost in usual conditions and after refurbishment. At the present, neither data from Energy Audits or Smart Metering are not accessible, so it is only possible to estimate data.

There is already an European project, Tabula (http://episcope.eu) that collect national building typologies and give useful energy data such as: typical energy consumption values; possible energy saving given by refurbishment; energy cost before and after energy measures. For Italy the result are available only for residential buildings, whereas for other five European Countries the project encompass also non-residential buildings.

The Italian Building Type Matrix has been done for the climatic zone "E" (from 2100 to 3000 heating degree days), in which lives 46% of Italian population. The Building Type Matrix consist of four building typologies and eight construction year classes. The correspondences with MEM typologies is shown in Table 6.28.

Table 6.28 Correspondences between MEM and TABULA building typologies. [AB: Apartment Block; MFH: Multi-Family House; TH: Terraced House; SFH: Single-Family House]

	compactness ratio						
	<0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	>=0.8
≤1945	AB average <1900; 1901-1920; 1921-1945	AB average <1900; 1901-1920; 1921-1945	MFH average <1900; 1901-1920; 1921-1945	TH average <1900; 1901-1920; 1921-1945	TH average <1900; 1901-1920; 1921-1945	SFH average <1900; 1901-1920; 1921-1945	SFH average <1900; 1901-1920; 1921-1945
1946-1960	AB 1946-1960	AB 1946-1960	MFH 1946-1960	TH 1946-1960	TH 1946-1960	SFH 1946-1960	SFH 1946-1960
1961-1980	AB 1961-1975	AB 1961-1975	MFH 1961-1975	TH 1961-1975	TH 1961-1975	SFH 1961-1975	SFH 1961-1975
1981-1990	AB 1976-1990	AB 1976-1990	MFH 1976-1990	TH 1976-1990	TH 1976-1990	SFH 1976-1990	SFH 1976-1990
1991-2005	AB 1991-2005	AB 1991-2005	MFH 1991-2005	TH 1991-2005	TH 1991-2005	SFH 1991-2005	SFH 1991-2005
≥2006	AB ≥2006	AB ≥2006	MFH ≥2006	TH ≥2006	TH ≥2006	SFH ≥2006	SFH ≥2006
n.a.	AB all ages average	AB all ages average	MFH all ages average	TH all ages average	TH all ages average	SFH all ages average	SFH all ages average

6.3.2.1 *Energy consumption in typical conditions*

The TABULA project gives adaptation factors in order to calculate a more realistic energy consumption, adapting the energy consumption given by calculation in standard conditions. The adaptation factor is used to calculate the "typical level of measured consumption" and the simple proposed approach is a factor which depends on the calculated energyware use.

The delivered energy (q_{del}) is calculated in TABULA as follows:

$$q_{del} = q_{del,h} + q_{del,dhw}$$

From the EPCs database I could calculate q_{del} as follows:

$$q_{del} = EtT = EtH + EtW = EtH + EpW \times e_{dhw}$$

Regrettably, the EpW values are not reliable in the Lombardy EPCs database. This is a known but not solved issue, due to the different method of calculation than UNITS11300. Therefore I calculated for all MEM residential buildings the EtW accordingly to UNITS11300, which is a function of the floor surface of the dwelling, using the following script.

```
CASE
    WHEN  "FLOOR_AREA" <=50 THEN 19.09
    WHEN  "FLOOR_AREA" >200 THEN 13.8
    ELSE  47.9*("FLOOR_AREA" ^ -0.2356)
END
```

In Tabula, the adaptation function is given in form of tabled values for 6 nodes of delivered energy (q_{del}), as shown in Table 6.29 interim values should be interpolated.

Table 6.29 Adaptation factor. (Tabula)

qdel kWh/m² year	adaptation factor
0	1.1
100	0.95
200	0.795
300	0.65
400	0.55
500	0.475

In order to implement more easily the adaptation factor into the Energy Scout I derived the following function, with a $R^2 = 0.9989$, and used with the following script.

$$f_{adapt} = 1.092 \times 10^{-6} q_{del}^2 - 1.839 \times 10^{-3} q_{del} + 1.115$$

```
CASE
    WHEN  "EtT"  = 0 THEN 1.1
    WHEN  "EtT"  > 500 THEN 0.475
    ELSE          1.09293354497099E-06*("EtT"^2)-1.83945319782486E-03*    "EtT"
+1.11517864765645
END
```

In the Energy Scout is thus possible to display, for residential buildings, the energy consumption adapted to typical levels.

6.3.2.2 Actual energy costs

I derived from Tabula the energy costs that depend on the EpH, and thus calculate energy costs per each residential building, using the following script.

```
CASE
WHEN  "AGE"  =  '>=2006'  THEN  "EpH_adapt" *0.074
ELSE "EpH_adapt" *0.076
END
```

Multiplying the energy cost values per m² for the floor area is possible to know the estimate of energy costs for the entire building.

$$EnCost = EnCost_{area} \times FLOOR\_AREA$$

Moreover, since the MEM contains an estimate of the number of dwellings per building, it is possible to know the energy cost per dwelling.

6.3.2.3 Energy consumption & energy costs after refurbishment

Using the correspondence Table 6.28 between Tabula and MEM typologies, I derived the savings rates after "usual" and "advanced" refurbishment, as shown in Table 6.30.

Table 6.30 Savings rate [%] after usual (us.) and advanced (adv.) refurbishment. Own elaboration on Tabula data

	<0.3		0.3-0.4		0.4-0.5		0.5-0.6		0.6-0.7		0.7-0.8		>=0.8	
	us.	*adv.*	*us.*	*adv.*	*us.*	*adv.*	*us.*	*adv.*	*us.*	*adv.*	*us.*	*adv.*	*us.*	*adv.*
≤1945	45.0	27.3	45.0	27.3	47.0	28.0	46.7	34.4	46.7	34.4	50.7	35.6	50.7	35.6
1946-1960	44.5	26.9	44.5	26.9	44.5	27.2	47.0	34.7	47.0	34.7	49.1	34.8	49.1	34.8
1961-1980	45.9	27.8	45.9	27.8	46.1	27.6	47.6	34.8	47.6	34.8	50.5	35.4	50.5	35.4
1981-1990	49.9	30.6	49.9	30.6	50.6	30.4	56.4	40.7	56.4	40.7	56.4	40.4	56.4	40.4
1991-2005	52.8	32.6	52.8	32.6	55.6	33.4	60.1	43.8	60.1	43.8	60.2	43.8	60.2	43.8
≥2006	64.3	14.8	64.3	14.8	60.8	11.1	55.2	10.0	55.2	10.0	57.1	13.0	57.1	13.0
n.a.	50.4	26.6	50.4	26.6	50.8	26.3	59.7	33.1	59.7	33.1	54.0	33.8	54.0	33.8

6.3.3 Renewable energy sources potential

In addition to monitoring the current situation, it is possible to provide an estimate of potential distributed generation, which can be well integrated in the building stock. This research does not focus on these potentials, in order to concentrate on the most innovative aspect to exploit the potential of the building stock, but could be implemented in further developments.

In particular, with GIS potentialities, it is possible to know the solar potential and the district heating potential. Other RES could be taken into account depending on the potentialities of the municipality, e.g. biomass for municipalities located in mountain areas.

In order to develop an urban solar map the solar irradiation and a 3-D Digital Urban Model (with Digital Terrain Model) are necessary. As regards solar irradiation, JRC developed and maintains the PVGIS[63] solar radiation and photovoltaic electricity potential maps. For Lombardy Region a Digital Terrain Model is available on the regional geoportal[64], while the buildings could be represented with a simplified 2.5 model, i.e. considering only the height of building as elevation.

As regards district heating, a simple heat mapping based on the building energy consumption could be represent in Energy Scout, thought further analysis are needed to develop a proper district heating potential map. In fact, it is necessary not only to know the heat loads, but also data about heat supplies and heat network as well as the topography of the district.

- With further elaboration, it is possible to integrate an urban solar map district heating potential map into Energy Scout, as well as other RES potential maps taking into account the features of the single municipality.

6.3.4 Barriers

In order to stimulate the energy renovation of the private building stock, this thesis proposes some policies and tools to overcome the existing barriers, as expressed in Chapter 5. The innovative tool Energy Scout maps the barriers that could be georeferenced, helping to find work opportunities for companies of the building and energy sector. Table 6.31 list the possible indicators for the barriers, developed in the following sections. In grey is signaled the indicator that could not be implemented in Energy Scout, i.e. the low disposable income.

In fact, the Revenue Agency collect data about the income but the database contains sensible data, therefore they are not publishable. What's more, the published statistics are not a sub-municipal level of detail, so it is not possible to calculate an estimate for Energy Scout.

[63] http://re.jrc.ec.europa.eu/pvgis

[64] http://www.geoportale.regione.lombardia.it

Table 6.31 Barriers and indicators proposed

categories	description	policy or tool	indicator in Energy Scout
Knowledge-based barriers	Lack of both general and technical knowledge of the users	Energy Advisor	-
	Unawareness of building energy potential	Energy Advisor & Energy Scout	Technical potential of energy savings
			Technical potential of RES energy production
	Lack of cost transparency – lifecycle costs and political incentives	Energy Advisor	-
	Difficulty in identifying skilled professionals and competent artisans	Policy	-
Economic/financial barriers	Recurring energy cost (bills) not perceived as high	Energy Advisor & Energy Scout	current energy cost vs disposable income
	Energy measures have high initial cost that need funds or a loan difficult to obtain	Energy Scout	*low disposable income*
	Only financial cost/gain perspective without a clear knowledge of pros and cons	Energy Advisor	-
Technical, structural and social barriers	Technical barriers, aesthetic and acceptance		-
	Collective decision making barriers	Energy Scout	number of owners
	Separation of expenditure and benefit	Energy Scout	presence of tenants
			presence of aging owners
	Lack of skill of relevant professionals and artisans	Policy	
	Black market and a desire to avoid an audit trail		-
Political barriers	Lack of consistency and coordination in policy framework/regulations	Policy & MEM	
		Energy Scout	Planning restictions
	Insufficient, unreliable and bothersome subsidies or regulation	Policy	
	Lack of both general and technical knowledge of local planning authorities	Policy	
Individual/psychological barriers	Energy measures require huge personal effort	Energy Advisor	
	Competing purchase decisions	Energy Advisor	
	Lack of visibility of energy-efficiency measures	Energy Advisor	

6.3.4.1 Current energy cost vs disposable income

As explained in section 6.3.2.2, in Energy Scout it is possible to know the actual annual energy cost per dwelling. The disposable income, collected by the Revenue Agency, is not available at sub-municipal level, but only the municipal average. It is still possible to check the cost per dwelling with 4% of the average disposable income, a threshold identified as not worrying (BPIE 2011).

6.3.4.2 Number of owners

The national Building Cadastre has detailed information about the owners of a buildings, with the detail of the single dwelling, even with indication of joint ownership among several persons. However such data could not be distribute because they contain sensitive data, so it is necessary to use estimate data.

In the ISTAT Census database there are the following useful data:

- A2: no. dwellings occupied by at least one person resident;
- A44: total dwellings' surface occupied by at least one person resident [m^2];
- A47: no. families in owned dwellings.

For each census section, it is possible to calculate:

$$FamilyOwner_{av} = \frac{A47}{A2} = \frac{FamilyOwner}{Dwellings}$$

$$FloorArea_{av} = \frac{A44}{A2} = \frac{TotalFloorArea}{Dwellings}$$

For each residential building in MEM, it is possible to calculate:

$$Dwellings = \frac{FloorArea}{FloorArea_{av}}$$

$$FamilyOwner = FamilyOwner_{av} \times Dwellings$$

In the Energy Scout is thus displayed the estimated number of families that live in owned dwellings per building.

6.3.4.3 Number of tenants

In Italy it is mandatory to register the rental contract at the Revenue Agency, which therefore collect detailed data for each rent dwelling, including the rent value. Unfortunately there are not sensitive-free database that the Revenue Agency discloses, it is thus necessary to estimate data.

In order to estimate the number of tenant, I used the following data from the ISTAT Census database:

- A46: Families in rental housing;
- A48: Families inhabiting the dwelling differently entitled;
- A2: no. dwellings occupied by at least one person resident.

I decided to include also families inhabiting the dwelling differently entitled because the landlord/tenant dilemma may arise also when the family live in a dwelling free of charge but it is not owner.

For each census section, it is possible to calculate:

$$Tenant_{av} = \frac{A46 + A48}{A2} = \frac{FamRent + FamOther}{Dwellings}$$

For each residential building in MEM, it is possible to calculate:

$$Tenant = Tenant_{av} \times Dwellings$$

In the Energy Scout is thus displayed the estimated number of tenants that live in each building.

6.3.4.4 Number of elderly

In order to estimate the aging residents, I used the ISTAT Census database, in particular:

- A2: no. dwellings occupied by at least one person resident;
- P27: residents with age 65-69;
- P28: residents with age 70-74;
- P29: residents older than 75.

For each census section, it is possible to calculate:

$$Elderly_{av} = \frac{P27 + P28 + 29}{A2} = \frac{Population_{\geq 65y}}{Dwellings}$$

For each residential building in MEM, it is possible to calculate:

$$Elderly = Elderly_{av} \times Dwellings$$

In the Energy Scout is thus displayed the estimated number of people that have 65 years or more that live in each building.

6.3.4.5 Planning restrictions

The planning restrictions are reported in PGT, so it is possible to implement them in Energy Scout, however the restrictions regards mainly new constructions.

In Lombardy Region, planning restrictions are digitalized in the digital mosaic of municipal planning instruments -*Mosaico Informatizzato degli Strumenti URbanistici* Comunali (MISURC), available on the Lombardy geoportal[65], so the implementation in Energy Scout is quite straightforward.

6.3.5 Driver

In order to stimulate the energy renovation of the private building stock, this thesis proposes some policies and tools to exploit the possible drivers, as expressed in Chapter 5. The innovative tool Energy Scout maps the drivers that could be georeferenced, helping to find work opportunities for companies of the building and energy sector. Table 6.32 list the possible indicators for the drivers, developed in the following sections. In grey are signaled the indicators that could not be implemented in Energy Scout.

The need of more comfort is a difficult indicator to calculate, since the comfort is a subjective sensation. It is possible to think of proxy indicators such as building materials or the age of the window frames, however there are no availability of data for such indicators.

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[65] http://www.cartografia.regione.lombardia.it

The willingness to improve the house aesthetic could be indicate by the state of conservation of the building. The ISTAT Census contains indicators about the state of conservation, however they are not released at sub-municipal scale. Moreover, the ten year timespan and the release time make data quickly out-of-date. To get the real data on the conservation of buildings it is necessary to do a field survey, such as previously done for another medium municipality in Lombardy Region (Pasetti, 2011). Services like Google Street View could speed up the process and are quite widespread on the territory. Anyhow, this is time consuming and should be done by the municipality at regular intervals of time, preferably carried out in conjunction with other surveys, to optimize costs.

The windows of opportunity given by changes in family are difficult to monitor and apply to single building. Changes in the family unit, such as birth of child or member exit from the family unit, are recorded into the municipal registry (Anagrafe). Obviously these are sensitive data, but no statistics are available at the sub-municipal level. The INPS knows who is close or just entering into retirement, but such data are not publicly available, nor releasing sub-municipal statistics. At the present, it is therefore not possible to provide data, even estimated, on the dynamics of families in the Energy Scout.

Also the ancillary benefit of an energy renovation could not, at the moment, been represented in Energy Scout. For improved comfort and improved aesthetic the previous remarks, while it is possible to think about other indicators, such as the lowering of the noise levels thanks to new windows in buildings facing a busy road. Actually, there are no availability of data for such indicators.

Table 6.32 Drivers and proposed indicators

categories	description	policy or tool	indicator in Energy Scout
Activation drivers	Maintenance of a failure or obsolete component	Energy Scout	building interventions to be carried out
	Need of more comfort	Energy Scout	*low thermal comfort*
	Willingness to improve the house aesthetic	Energy Scout	*state of conservation*
	Willingness to change or improve the house functionality	Energy Scout	*changes in family*
	Willingness to mantain or improve the house market/rental value	Energy Scout	high real estate value
		Energy Scout	rental in upscale neighborhood
	High energy costs	Energy Scout	Energy cost
Deep of measures drivers	Trustworthy information & advice	Energy Advisor	-
	Incentives in building codes	Policy	
	Ancillary benefit	Energy Scout	*improved thermal comfort, improved aesthetic, lower noise levels*
	Construction period	Energy Scout	old building's age of construction
	Education	Energy Scout	Estimate of residents' education
	Smooth process (clear legislation, easy decision-making)	Energy Scout	Presence of building manager or single owner

6.3.5.1 Building interventions to be carried out

Obsolete heating plant

For Lombardy Region, it is available the CURIT - Catasto Unico Regionale Impianti Termici (Regional Heating Systems Register) with opendata database (http://www.curit.it/opendata). It should be noted that CURIT data, shown in Table 6.33, derive from maintenance inspections, thus are instantaneous values taken on any day. Moreover, data may not be reliable as a verification procedure it is not yet operational.

Table 6.33 CURIT fields and description

field	description
CODICE_IMPIANTO	Id heating system in CURIT register
PROGRESSIVO_GENERATORE	Progressive ID of the boiler within the system
NUMERO_GENERATORI	Number of generators in the system
POTENZA_FOCOLARE_NOMINALE_IMPIANTO	System's power, in kW
POTENZA_FOCOLARE_NOMINALE	Boiler's power, in kW
POTENZA_UTILE_NOMINALE	Thermal power of the boiler, in kW
POTENZA_UTILE_IMPIANTO	Thermal power of the system, in kW
TOPONIMO	Address typology (e.g. street, square, ...)
INDIRIZZO	Address
CIVICO	House number
COMUNE	Municipality
PROVINCIA	Province
CAP	Postal code
COSTRUTTORE_GENERATORE	Boiler manufacturer
DATA_INSTALLAZIONE	Boiler installation date
DATA_CONTROLLO	Date of the inspection of energy efficiency
ESITO_CONTROLLO	Inspection outcome, expressed as P / N (positive / negative)
RENDIMENTO_COMBUSTIONE	Boiler thermal efficiency, in %
VOLUMETRIA_RISCALDATA	Heated volume, in m^3
COMBUSTIBILE	Fuel
BACHARACH	Smoke index in Bacharach scale, expressed in scale from 0 to 9, given only for the boilers that use liquid fuels

To asses an obsolete heating plant I used the inspection outcome (field: ESITO_CONTROLLO), also the installation date (field: DATA_INSTALLAZIONE) could be used, however this field is always filled with "n.a.". For heating system installers might be interesting also the other fields, especially the power of the boiler and the used fuel.

The CURIT database is not georeferenced nor have the Cadastral ID such as in CEER, thought have complete address for each record. It is thus possible to geocode the addresses using geocoding services. For Senago municipality I use the free Google and Bing services, through a web Address Locator (http://www.gpsvisualizer.com/geocoder). It is possible also to include information on the precision of geocoding, in order: “country”, “city/town”, “street”, “intersection”, and “address”.

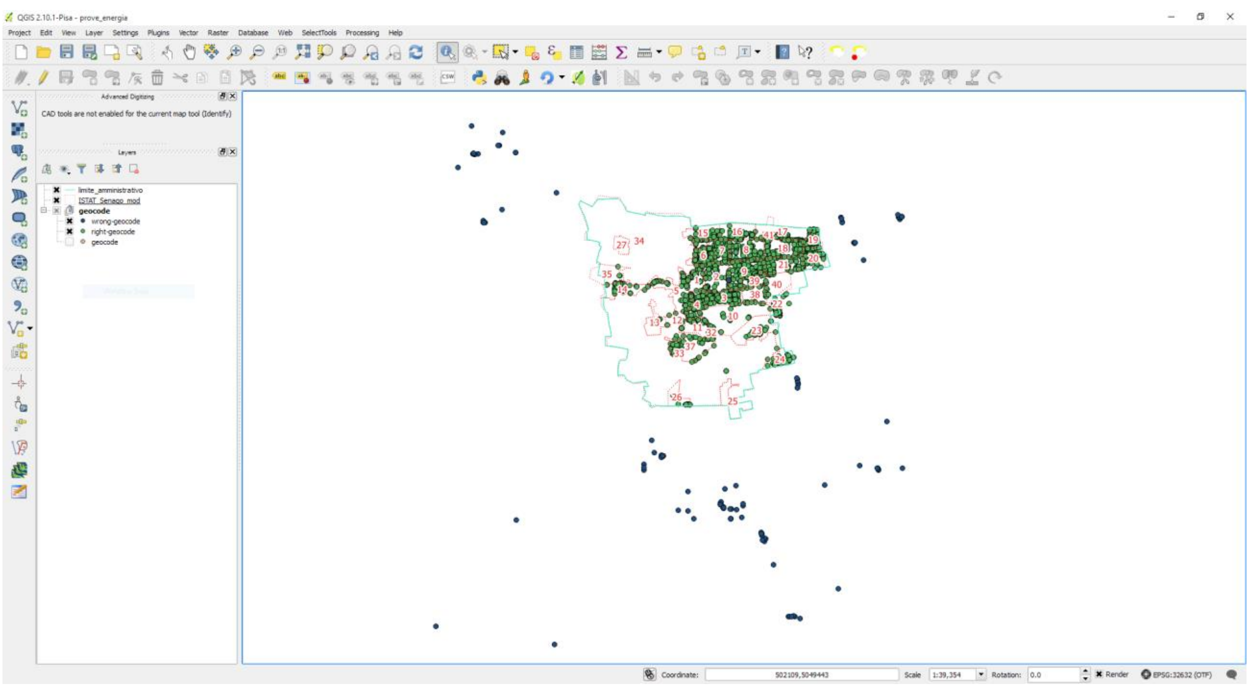
The addresses in the CURIT database need some cleaning:

- addresses in data format have been modify into text strings (e.g. 20 settembre into XX settembre);
- some addresses have a postal code that refer to another municipality, those have been modify into Senago postal code (i.e. 20030).

I selected for geocoding the unique addresses, discarding duplicates: the 6668 records in the CURIT database have been reduced to 2063 addresses.

I first run the geocoding process using Google maps on batches of 200 addresses. After the initial processing, the vast majority of addresses had been georeferenced, as shown in Figure 6.11, with 119 wrong addresses that have been georeferenced to other municipalities or with a precision “city/town” to the center of Senago.

Figure 6.11 First batch geocoding result



Since in the wrong addresses there are recurring street names, I checked how these streets are named on Google Maps and modified the addresses accordingly. I run a second geocoding process, always using Google Maps geocoding services.

I then run a third geocoding process with remaining wrong addresses plus the addresses with house number but geocoded into a “street” precision, using Bing geocoding services, obtaining 81 geocoded address.

At the end of the geocoding process, as shown in Figure 6.12, 2053 address were geocoded, only 10 addresses were wrong or not found. Also the precision is quite high, with 93% of records with precision "address". It should be noted that in the CURIT database some record are without house number and the 2 record with "city/town" precision refer to farmsted. In Table 6.34, some result as an example.

Figure 6.12 Geocoding precision

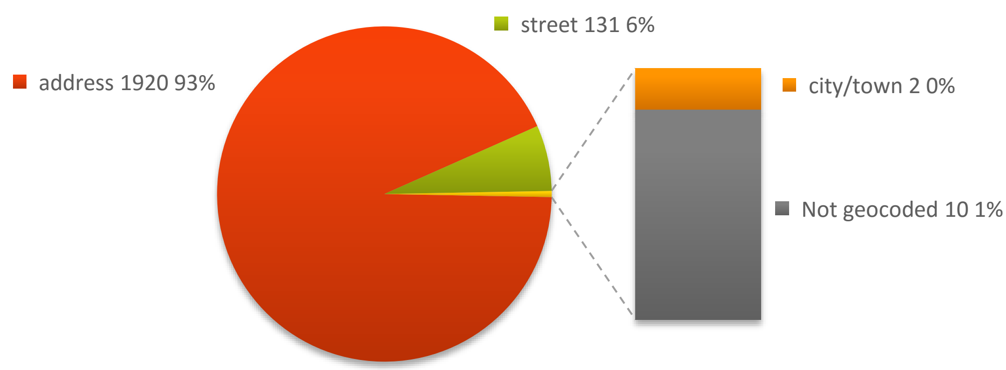


Table 6.34 Geocoding result examples

latitude	longitude	input	found	source	precision
45.5750074	9.1050881	VIA Giordano Bruno, 6, 20030 Senago MI, Italy	Via Giordano Bruno, 20030 Senago MI, Italy	Google	street
45.5758794	9.1029054	VIA MASCAGNI, 36, 20030 Senago MI, Italy	Via Mascagni, 36, 20030 Senago MI, Italy	Google	address
45.5596747	9.1146541	CASCINA TRAVERSAGNA, , 20030 SENAGO Milano Lombardy Italy	Cascina Traversagna MI, Italy	Google	city/town
45.5689319	9.1228195	VIA SILONE IGNAZIO, , 20030 Senago MI, Italy	Via Ignazio Silone, 20030 Senago MI, Italy	Google	street
45.568864	9.13592	VIA CORRIDONI F., 22, 20030 SENAGO Milano Lombardy Italy	Via Filippo Corridoni, 20030 Senago MI	Bing Maps	street
45.5769234	9.137785	VIA COSTA ANDREA, 7, 20030 SENAGO Milano Lombardy Italy	Via Andrea Costa 7, 20030 Senago MI	Bing Maps	address

Then I matched the geocoded addresses with the CURIT records, as a result only 19 records could not be georeferenced. It is thus possible to visualize in Energy Scout the obsolete heating plant, regrettably not linked directly to the building but to the house number or street. While it is possible to geocoding the centroids of the buildings to obtain the addresses, it is not recommended because it does generate non-detectable errors. In fact, geocoding the centroid could assign the parallel or perpendicular street instead of the correct address to the building.

❖ The new national standard EPC, mandatory from 15 October 2015, includes a field for the heating plant ID, so for new EPCs this geocoding process is no longer necessary.

Obsolete components of the building envelope

Thanks to the data recorded into MEM, it is possible to highlight obsolete walls, roofs, basements and windows on the basis of the U-values performance.

The three categories - low, medium and high performance – are delimited by the following thresholds: lower value is the best among the low-performing installed components in the building stock; upper value is the minimum to access fiscal incentives, so every component over this limit is already high performing.

The used thresholds are relative to the current state of the building stock and the climatic zone; obviously it is possible to can change the thresholds for different contexts or if the building stock improves its energetic features.

Wall's categories:

- Low_env : walls with U-value >= 0.9 [best value of non-insulated wall from UNI TS 11300];
- Med_env: walls with 0.9 < U-value < 0.27;
- Hig_env: walls with U-value <= 0.27 [value for access to fiscal incentives, according to DM 26/01/2010].

Roof's categories:

- Low_roof : roofs with U-value >= 1.30 [best value of non-insulated roof from UNI TS 11300];
- Med_roof: roofs with 1.30 < U-value < 0.24;
- Hig_roof: roofs with U-value <= 0.24 [value for access to fiscal incentives, according to DM 26/01/2010].

Basement's categories:

- Low_ground : basements with U-value >= 1.15 [best value of non-insulated basement from UNI TS 11300];
- Med_ground: basements with 1.15 < U-value < 0.30;
- Hig_ground: basements with U-value <= 0.30 [value for access to fiscal incentives, according to DM 26/01/2010].

Window's categories:

- Low_wind : windows with U-value >= 4.5 [value for single glass windows in UNI EN ISO 10077-1];
- Med_wind: windows with 1.8 < U-value < 4.5;
- Hig_wind: windows with U-value <= 1.8 [value for access to fiscal incentives, according to DM 26/01/2010].

Creating a QGIS style, it is thus possible to select only low or medium performance components in Energy Scout, with an estimate of the area of the selected component.

Years from last renovation

Building interventions should be authorized and data archived by the Municipality, but the Municipality of Senago does not have a digital archive and the data is not accessible. At the present it is thus not possible to include this indicator in Energy Scout.

- A digital archive, at least with the main data, is necessary. In addition, with the implementation of MEM, it will be possible to assign the *build_MEM* ID to every building intervention, thus building up an integrated archive.

Central heating system

In the CURIT database it is not specified whether the heating system it is a centralized or not. It is possible to estimate that heating plant with power less than 35 kW is part of an autonomous system.

Using the Thermal power of the boiler (see Table 6.33), it is possible to show in Energy Scout the heating system that are autonomous or centralized.

6.3.5.2 High real estate value

In Italy it is mandatory to register the real estate sales contract at the Revenue Agency, which therefore collect detailed data for each sold dwelling, including the value. Unfortunately there is not sensitive-free database that the Revenue Agency discloses, it is thus necessary to estimate data.

The Osservatorio del Mercato Immobiliare publish half-yearly data on real estate values for each OMI zone, divided in the uses and the state of conservation and maintenance. In Senago there are only two monitored areas: B1 (central) and D1 (Outskirts).

The OMI database uses building's typologies from the Catasto Fabbricati, regrettably this information has not been provided on the cadastral map. I therefore had to match the uses in the MEM with the OMI typologies, as shown in Table 6.35. Using restricting rules on the MEM buildings, I aligned the EPCs use with the OMI typologies, considering the full description that could be retrieved from OMI website (www.agenziaentrate.gov.it).

Table 6.35 Correspondence between OMI typology and EPCs use

OMI typology	OMI description	EPCs USE	restricting rules used
1	Ville e villini	E1	WHEN "USE" = 'E1' AND "dwelling" <=4 AND "FOOT_AREA" >=100
20	Abitazioni civili	E1	E1 buildings excluded from the previous rule
5	Negozi	E5	-
6	Uffici	E2	-
8	Capannoni industriali	E8	WHEN "USE" = 'E8' AND "FLOOR_AREA" >=1000 THEN 8
7	Capannoni tipici	E8	WHEN "USE" = 'E8' AND "FLOOR_AREA" >=150 THEN 7
10	Laboratori	E8	E8 buildings excluded from the previous rule

Since there are EPCs USE that are not monitored in OMI database, at the following USEs could not be assigned an OMI value: E3, E4, E6, E7 (buildings that usually are not on the market) and En1.

Using the OMI zone and the OMI typology, I assigned the minimum value of the market per square meter (€/m²) present in the OMI database. Knowing the floor area, thanks to the MEM, it is possible to show in the Energy Scout the minimum value of the market for the majority of the buildings in Senago.

- ❖ To improve the precision of this indicator it would be useful OMI database is disclosed with a higher LOD and cartography, derived from Cadastre, aligned to the DBTR.

6.3.5.3 Rental property in upscale neighborhood

As regards the rental property you can make the same considerations in section 6.3.4.2, combining the data relating to rental market.

Within the Revenue Agency, the Osservatorio del Mercato Immobiliare (Property Market Observatory) develops statistics about the real estate values and the rental market. Data are thus available at sub-municipal detail, the OMI zones described in Table 6.36, which are different from the census sections.

Table 6.36 OMI zones code and description

OMI Zone Code		description
B	Central	Urban center of the municipality
C	Semi-central	Contiguous zone to the urban center and directly connected to it for services, transport, infrastructure
D	Outskirts	Contiguous zone to the urban center or to the central area and delimited by outer edge of the municipal conurbation
E	Suburbs	Urbanized area separated by a unbuilt land from the municipal conurbation

R	Rural	Area where the main activity is agriculture or where the edification is almost or entirely absent

For Senago there are four OMI zones: B1, D1, R1, R2. For the Energy Scout I considered as upscale neighborhood only the central OMI zone B1.

6.3.5.4 High energy costs

The actual energy cost are calculated as explained in section 6.3.2.2. It is possible to considerer the energy cost high when are over the 4% of the average disposable income, a threshold identified as not worrying (BPIE 2011). However, it should be also considered that of 10% of the disposable income is considered the threshold of fuel poverty (AEEG, 2014).

6.3.5.5 Building's age of construction

The MEM already contains information about the building's construction age, from the EPCs database or from the prevalent age of construction of the cadastral section, as explained in section 7.2.5. The Energy Scout simply point out buildings built before 1981.

6.3.5.6 Level of education

For the level of education the ISTAT Census collect data about every single person, but obviously these data are sensible. However it is possible to use data at the census section to elaborate an estimate.

In the ISTAT Census database there are the following useful data:

- P19+P20+P21+P22+P23+P24+P25+P26+P27+P28+P29: Resident population older than 24 years;
- P47: Resident population with graduation, university degrees, or non-university diplomas;
- A2: no. dwellings occupied by at least one person resident.

The ISTAT Census database contains also data about resident population with secondary school diploma (P48), resident population with middle school diploma (P49), resident population with primary school diploma (P50), literate and illiterate resident population (P51, P52). But these data are not linked to the age so they count also person that are following the curriculum. The Energy Scout shows rather adults who have not achieved a higher educational level, but which probably are involved in decisions concerning the dwelling.

For each census section, it is possible to calculate:

$$LowEdu_{av} = \frac{(\text{P19} + \text{P20} + \text{P21} + \text{P22} + \text{P23} + \text{P24} + \text{P25} + \text{P26} + \text{P27} + \text{P28} + \text{P29}) - P47}{A2} = \frac{Pop > 24y - HighEdu}{Dwellings}$$

For each residential building in MEM, it is possible to calculate:

$$LowEdu = LowEdu_{av} \times Dwellings$$

In the Energy Scout is thus displayed the estimated number of adults that have a lower level of education per building.

6.3.5.7 Presence of building manager or single owner

Since there is no register for the building manager, this indicator should be estimated. According to law 220/2012, buildings with more than 8 owners have to nominate a building manager. Using the number of owners, as estimated in 6.3.4.2, it is possible to show in Energy Scout the buildings that should have a building manager and buildings that have only a single owners, thus making the decision making process easier.

6.4 Results

The application to a case study demonstrate that, with the current data availability in Lombardy Region, it is possible to develop MEM and Energy Scout. Certainly, some data and indicators can be improved, but it is precisely the aim of this research to create a methodology that leads to quickly implement, and fine tuning later, an energy model and tools for all Italian municipalities.

In the current data availability, the Energy Scout could display maps listed in Table 6.37 and reported in Annex C.

Apart from the more advanced analysis that can be made through GIS, it is possible to get some key data about the building stock of the municipality.

MEM in Senago has identified 3,086 buildings of which 388 non-residential. The number of residential buildings in MEM is quite similar to the number surveyed by 2011 Census (ISTAT). Unfortunately, given the problems reported in section 6.2.5 for the assignment of the age of construction, the number of MEM buildings in the class 1961-1980 is 1,640 versus the 1,081 buildings surveyed by ISTAT. The exceeding buildings are likely to be mostly in the adjacent age class 1946-1960, that is under-represented in MEM (see Figure 6.13). From the energy point of view these two classes are quite similar, so this issue it not too much relevant. The same considerations could be done for non-residential buildings, shown in Figure 6.14.

Figure 6.13 Number of residential buildings per age of construction

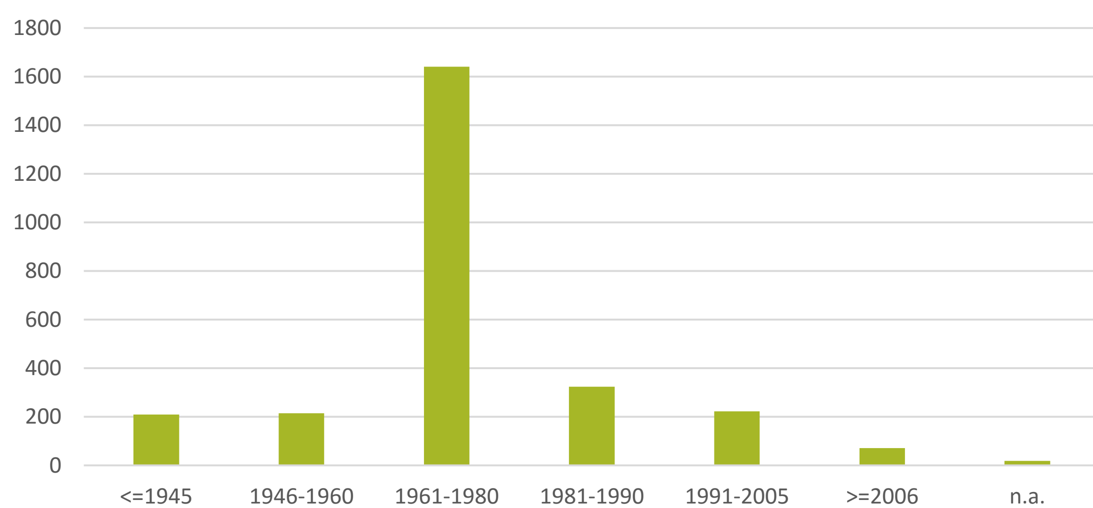


Figure 6.14 Number of non- residential buildings per age of construction

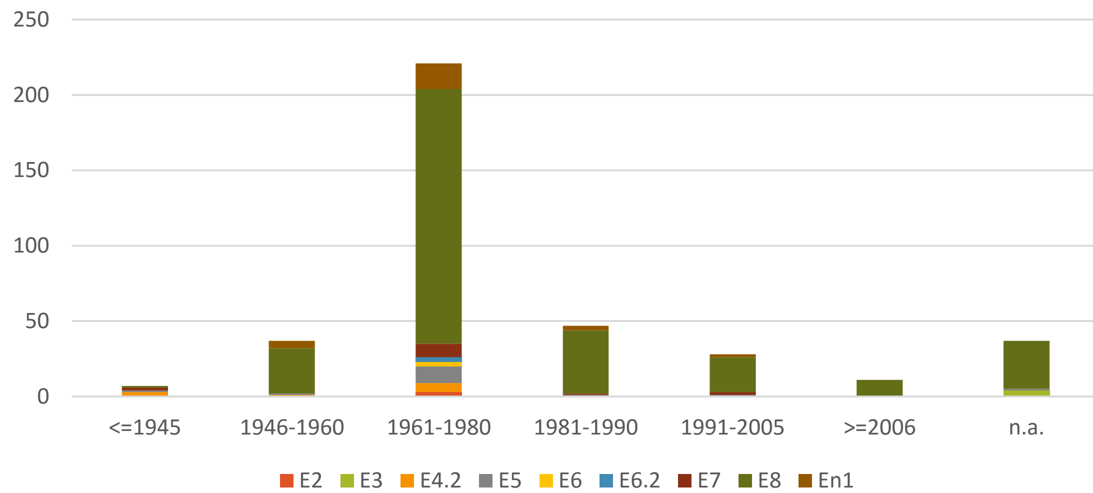


Table 6.37 Maps displayed in Energy Scout

category	map	unit	buildings
Geometrical & info data	Footprint area	m^2	all
	Gross floor area	m^2	all
	Net floor area	m^2	all
	Gross heated volume	m^3	all
	Net heated volume	m^3	all
	External walls' area	m^2	all
	Windows surface	m^2	all
	Dispersing surface	m^2	all
	Compactness ratio	m^{-1}	all
	Age of construction	7 range	all
	Building 's use (DPR 412/1993 classification)	string	all
	Building 's use (OMI classification)	string	all
	Source of energy data	EPCs | TYPOLOGY	all
Energy characterization of the building stock	Typology (use-age-compact_r)	string	all
	Envelope U-value	W/m^2K	all
	Roof U-value	W/m^2K	all
	Basement U-value	W/m^2K	all
	Window U-value	W/m^2K	all

category	map	unit	buildings
	Energy classification	string	all
	Eph	kWh/m^2 year kWh/m3 year	residential non-residential
	Eth	kWh/m^2 year kWh/m3 year	residential non-residential
	Etc	kWh/m^2 year kWh/m3 year	residential non-residential
	Efer	kWh/m^2 year kWh/m3 year	residential non-residential
	CO_2 emissions	kg CO_2eq/m^2 year kg CO2eq/m^3 year	residential non-residential
	Epw	kWh/m^2 year	residential
	Ept	kWh/m^2 year	residential
	Overall efficiency of the heating system	%	all
	Overall efficiency of the dhw system	%	all
	Overall efficiency of the heating & dhw system	%	all
	Surface of installed photovoltaic panels	m^2	all
	Surface of installed solar thermal panels	m^2	all
	Presence of installed geothermal heat pump	Y|N	all
	Heating system power	kW	all
	Fuel for heating system	string	all
Technical potential	Actual Eph adapted to typical level of measured compution	kWh/m^2 year	residential
	Eph after usual retrofit	kWh/m^2 year	residential
	Eph after advanced retrofit	kWh/m^2 year	residential
	CO_2 emissions	kg CO_2eq/m^2 year	residential
	CO_2 emissions after standard retrofit	kg CO_2eq/m^2 year	residential
	CO_2 emissions after advanced retrofit	kg CO_2eq/m^2 year	residential

category	map	unit	buildings
	Actual annual energy costs for heating and dhw	€/m² year	residential
	Annual energy costs for heating and dhw after standard retrofit	€/m² year	residential
	Annual energy costs for heating and dhw after advanced retrofit	€/m² year	residential
	Roof area available for integrated solar systems	m²	all
	Average yearly electricity production of installable pv system	kWh/year	all
	Average daily dhw production of installable solar heating system	l/day	all
Barriers	Number of families that live in owned dwellings	-	residential
	number of retirees	-	residential
	Planning restrictions	-	all
	Recent buildings	-	all
	Number of adults that have a lower level of education	-	residential
	Rental property not in upscale neighborhood	-	residential
Driver	Presence of building manager	Y|N	residential
	High real estate value	€	all
	Obsolete heating plant	Y|N	all
	Obsolete walls	high | medium | low	all
	Obsolete roof	high | medium | low	all
	Obsolete basement	high | medium | low	all
	Obsolete windows	high | medium | low	all
	Central heating system	5 ranges	all
	High energy costs	high | medium | low	residential

As regard the source of data for the energy features, 27.1% buildings derive data from EPCs, while 72.9% from typology. The value of energy performance for heating depicted in Figure 6.15, is slightly worse for MEM building respect to CENED average for Lombardy EPCs, however it should be taken into account that the energy values of typologies are calculated considering that buildings have not undergone energy measures.

Thanks to Tabula elaborations used for residential buildings, it is possible also to get a rough estimate of the actual energy consumption and of the energy savings potential after a standard or advanced refurbishment, as shown in Figure 6.17. Moreover, it is possible to get estimate about energy cost per building and per dwelling, as shown in Figure 6.18. The energy cost per building is useful for energy measures carried on the whole building (e.g. thermal insulation of external walls), while the energy cost per dwelling is useful for energy measures carried on the single dwelling (e.g. windows replacement).

Another useful features is the possibility to have an estimate about obsolete building components and their surface for a building, a district or the entire municipality. Table 6.38 shows the obsolete building components for all the building stock of Senago.

The application to a case study demonstrates that is possible to develop the proposed tools in medium municipality, also due to the hybrid approach that includes the use of estimate data. Thanks to the good data availability of Lombardy Region and also to the QGIS plugins developed ad hoc, it is already possible to implement quickly MEM and Energy Scout for Lombardy municipalities.

These are just some of the possible outputs that is possible to obtain through MEM and Energy Scout. Using GIS capabilities more advanced queries and analyses are possible.

- ❖ A consultation with all stakeholders may lead to define better users and their needs, leading to different user friendly interfaces according to their profiles. In the open data frame, the tools have to be made freely accessible, preferably through a web service.

Figure 6.15 Average Eph [kWh/m² year] for residential building in MEM and in CENED

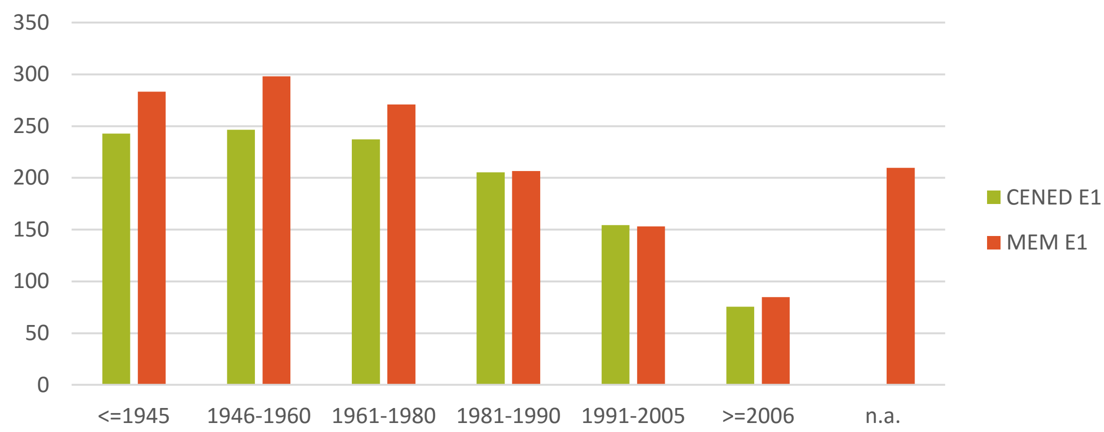


Figure 6.16 Average Eph [kWh/m³ year] for non residential buildings in MEM

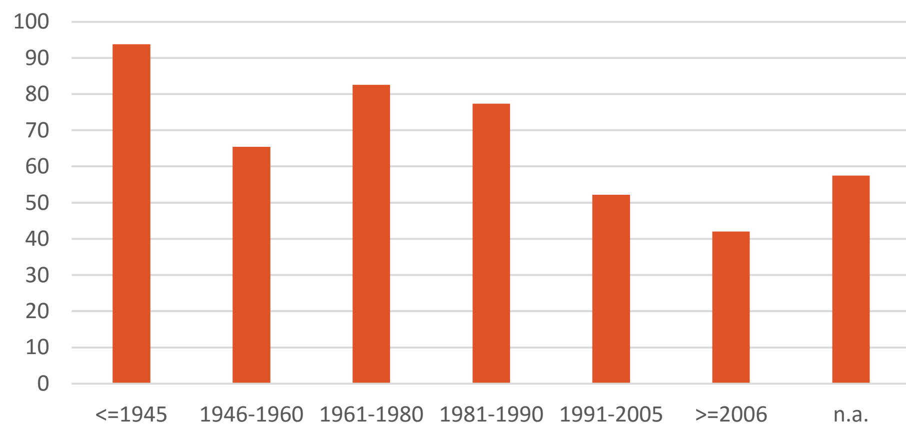


Figure 6.17 Average Eph_adapt, Eph_usual and Eph advanced [kWh/m² year] for residential building

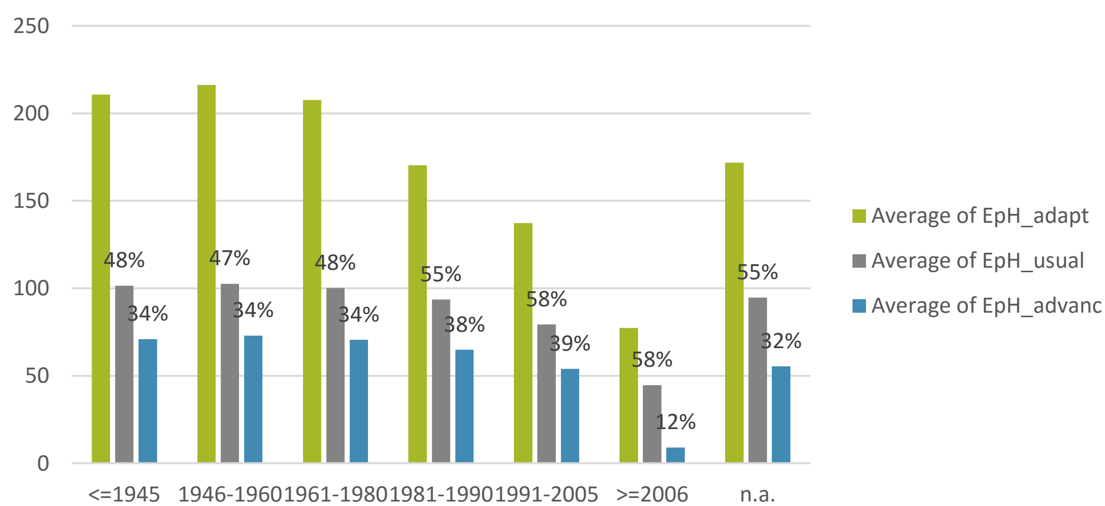


Figure 6.18 Average energy cost per building and per dwelling [€/year]

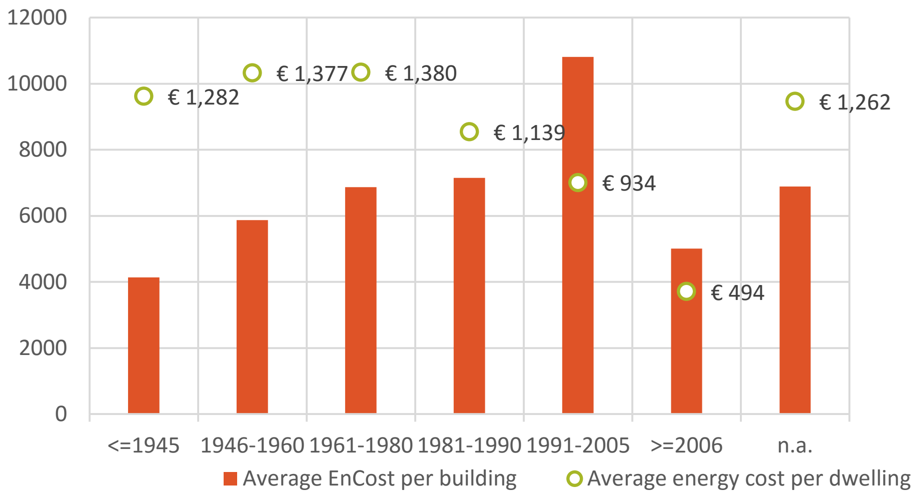


Table 6.38 Obsolete components: number of buildings and area

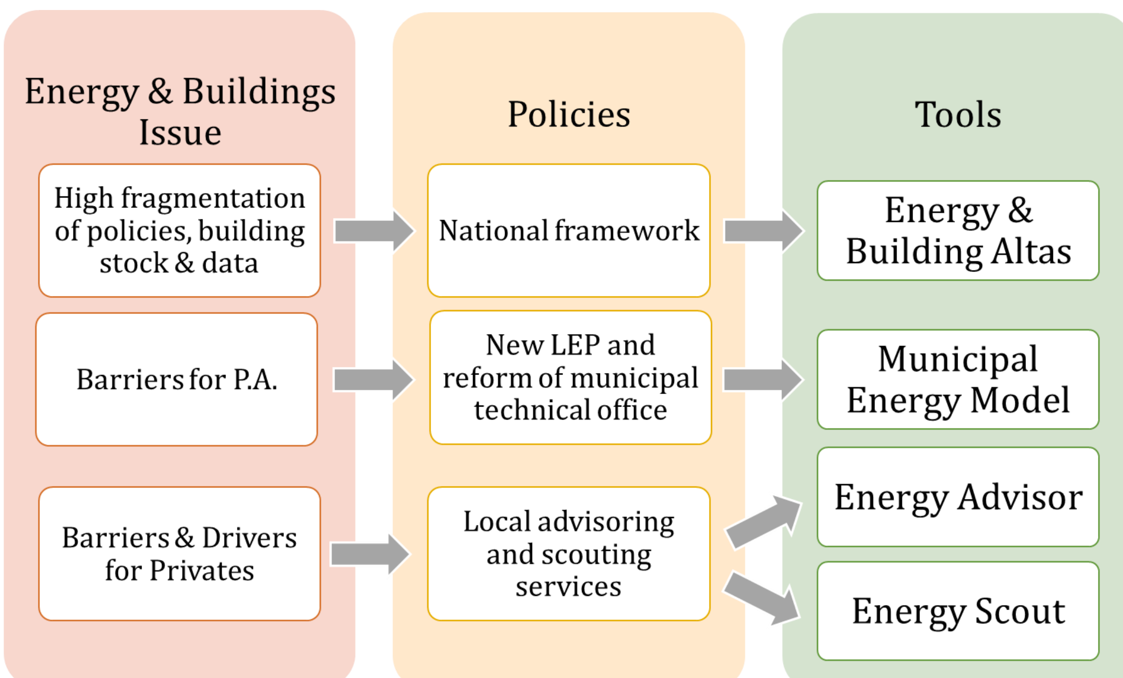
building component	performance	no. buildings	area [m^2]
walls	high	52	31,535
	medium	342	262,115
	low	2,304	959,127
roofs	high	189	49,419
	medium	331	98,086
	low	2,178	309,028
basements	high	245	63,049
	medium	215	69,081
	low	2,238	324,403
windows	high	56	7,564
	medium	2,566	179,308
	low	76	6,685

7 CONCLUSIONS

As seen in Chapter 1, to tackle the energy issue is paramount to exploit the huge sink of energy savings within the existing building stock. In Italy and Europe the building stock is old and with scarce energy performances, yet the renovation rate is only around 1%. The renovation rate has to more than double to reach the European objectives at 2050 for energy efficiency. In the Italian context, the exploitation of this sink is complicated by the high fragmentation of the territory in climate, administration and population and the high fragmentation of the building stock in terms of number of buildings and ownership.

There are already Italian and European regulation and strategies, as outlined in Chapter 2, but they have not yet succeeded in substantially exploit the building stock energy saving sink. Regrettably, at the moment the Italian regulatory framework is unstable and not homogeneous among the Regions and even varying in each municipality. In order to achieve significant results it is fundamental the role of local public administration (PA), especially by using local energy plan (LEP). Municipalities demonstrate commitment in tackling the energy issue with local projects, however there are still weaknesses in monitoring and checking the results. There are already tools that to help to analyse and simulate the energy performance of buildings, but a different approach is needed in order to develop homogenous ad effective LEP in each Italian municipality.

Figure 5.1 Scheme of the energy & buildings issue and proposals



Chapter 3 propose a data collection framework of indicators of the building and energy issue, with an analysis of Italian data sources. Moreover, it is presented the Energy & Buildings Atlas, an example of application of data collection framework and georeferencing data for new analysis, at national level with a level of detail of the single municipality.

At the present, the available tools focus on the technical potential, overlooking the barriers and driver to effective LEPs. In Chapter 4, this research analyses the barriers to LEPs for PA sending also a questionnaire to a sample of small and medium Italian municipalities in order to check the assumptions. Data scattering and the lack of personnel with energy expertise are important barrier for PA. Still, in order to really tackle the energy efficiency sink in the building stock, it is fundamental to involve private into renovate their buildings. Hence, this research analyses also barriers and drivers influencing private investment in the energy renovation of the building stock.

Following these analysis, the research proposes in Chapter 5 some policies and tools to boost energy renovation in buildings. Here the proposals to develop effective and widespread LEPs:

- creation of a national framework to tackle the energy & buildings issue, including data collection done through the Energy & Buildings Atlas;
- reorganization of the municipal offices with the introduction of an Energy Office;
- mandatory LEP, supported by a municipal energy model (MEM), which is a georeferenced tool that allows evaluating the energy characteristics of each building in the municipality.

In order to engage building owners, building managers, companies in the energy-building sector and investors, the research proposes local policies supported by two tools based on data contained in MEM:

- Energy Advisor, a tool designed to advise building owners and managers;
- Energy Scout, designed to help companies in the energy-building sector and investors to find work opportunities.

In addition to geometric and energy features of the building stock, the Energy Scout shows indicators for non-technological barriers and drivers to the implementation of energy measures on private buildings. It is thus possible to localize buildings that seem most promising for an actual realization of energy measures.

The developed methodology uses data publicly available, or will be available, for each Italian municipality, so it is possible to obtain homogenous and georeferenced data about the building stock potentially on the whole Country.

In Chapter 6, the methodology is applied to a real case study, an Italian medium-sized municipality, developing the Model Municipal Energy and Energy Scout. As real maps and databases have been used, several processing were necessary: some have been carried out using a set of plugins for QGIS developed ad hoc for the thesis. The application to a case study demonstrates that is possible to develop the proposed tools in the current context, also due to the hybrid approach that includes the use of estimate data.

Although the suggestions presented may seem obvious, in Italy the implementations of these policies can deeply change the approach of municipal energy planning. In fact, a correct and updated knowledge of the features of the built environment could help in developing achievable and cost effective plans and interventions, taking into account local conditions and pertinent targets. Moreover, the essential involvement of building owners, building managers, companies in the energy-building sector and investors may be more easy and effective with the proposed innovative tool called Energy Scout, leading to a larger number of energy renovation of the building stock.

7.1 From Case Study to Universal Application

One of the objectives of this research is to propose a methodology easily applicable for each Italian Municipality. MEM and Energy Scout use a free and open source software (QGIS[66]) and dedicated plugins were developed ad hoc to automatize and speed up the realization of the tools. Using also the solutions proposed to overcome some flaws of the actual data, it will be possible to replicate the tools to a wide number of Italian municipalities.

Hybrid approach

The MEM is a bottom-up hybrid model, since it use both collected data of the specific building and archetypal approach to fill the lack of data. The focus is on a model that could be quickly implemented for each Italian municipality, thus the research gave more importance to diffusion rather than accuracy of the model. The hybrid approach on data helps to build a model quickly, with data that could be rough at the beginning and then they can be gradually refined when the national collection data framework is complete or when new sources of data are available.

Data collection

To develop MEM and Energy Scout, the essential cartographic data of the single building are: footprint; height; use (residential or non-residential); and age of construction (it is possible to obtain it with a statistical approach). For the hybrid approach is also necessary an ID linking with the EPCs register, otherwise it is possible to use only the archetypal approach, that need only statistical data.

The MEM uses energy data referring to the single building, derived from EPCs, and archetypal energy data, derived from provincial EPCs database. If the former are lacking, it is still possible to build up the MEM with only archetypal data.

Data for energy features and for indicators for barriers and drivers should have a sub-municipal LOD: since in Italy data are scattered, it was necessary to implement a data collection procedure. MEM and Energy Scout are based on data that are or will be available for each Italian municipality.

Data availability

The structured data collection procedure helps to point out the current data availability issues that could be used as a reference to improve the data collection. Moreover, having a clear

[66] http://www.qgis.org

picture of the data availability help in updating the model when the situation changes or data sources are improved or updated.

In Energy Scout, some indicators for barriers and drivers could not be developed and several use estimates: with more effort by agencies that already collect data it is possible to greatly improve the tool.

Energy-oriented cartography

Since the MEM and the Energy Scout are a GIS based tools, it is thus important to obtain a cartographic base suited for the energy purpose. The available general-purpose maps have to be modified in order to get a map that reflect the energy features of the building stock. In particular, the definition of building for energy evaluation is different. An innovation bring from this research is the detection of buildings by energetic point of view: a MEM building is a building with a single use, a heating or cooling system, a sole management and geometrically defined by the conditioned volumes.

Identification fields

In order to share data among several database it is important to use common identification fields and to report them in records. As regard the build environment current researches[67] are carried out within the ABC department. A good practice is also set by the new national standard EPC, operative since 15th October 2015, that has a dedicated field for the ID of the heating plant, for which data are collected by the regional register of heating plants.

Cartographic base mismatch

At the present, the National Land Register cartography and the Regional Topographic Database are not uniform and buildings are misaligned. It is thus necessary a manual alignment, as done for the case study, or a unification of the two spatial databases, to be carried on at regional level.

Age of construction

Even if it is possible to estimate the age of construction of the buildings, as done in the case study, it is advisable that the municipality collects data about the age of construction using the building permits or surveys and incorporates it into the MEM.

7.2 FURTHER ADVANCEMENTS

Since this personal contribution has an open-ended approach, it is possible to upgrade the data and enrich the capabilities of the tools, as signalled by boxes in the text.

[67] PhD. Candidate Pasquinelli A. is working on “Topographic Database for constructions and built environment: use of the TDB for the creation of a city-wide Building Information System”. Department of Architecture, Building Environment and Construction Engineering – Politecnico di Milano

It is important to underline that the innovative tools will be more accomplished when the issues relating to policies will be resolved – possibly through the proposed national framework – and new data become available, for example with the smart meters.

In the completed framework, it also important the role of the Energy Advisor, an innovative supporting tool, here only outlined as scopes and capabilities, that has yet to be developed.

With further elaborations, it is possible to integrate an RES potential maps and a district heating potential map into Energy Scout. Moreover, this research focused on heating energy consumption and related energy measures, but it is possible to focus on electricity demand.

The Energy Scout features and indicators may be improved and enriched with a consultation with sector operators and actors. Moreover, this consultation may lead to define better users and their needs, leading to different user friendly interfaces according to their profiles. In the open data frame, the tools have to be made freely accessible, preferably through a web service.

In fact, the MEM and the tools should be seen as a customizable base, that municipalities could modify in relation to their characteristics such as size of the municipality, climate, local economy and local stakeholders, features of the building stock, potentials of the territory as geothermal sources or extensive forests.

With better data availability and enriched capabilities in a widespread application overall the Country, it will be easier to tackle the energy & buildings issue and to exploit the building stock energy sink.

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