Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design
Epoka University, Tirana, Albania, 08-10 May 2014
Paper No. 173

Energy performance analysis of residential buildings in Bari, in the South of Italy

Silvia Di Turi
DICAR - Department of Sciences of Civil Engineering and Architecture, Politecnico di Bari
Via Orabona 4, Bari, Italy
silvia.dituri@alice.it

ABSTRACT

Refurbishment of existing residential buildings and energy saving represent important aspects of environmental sustainability, against the problems of greenhouse gas emissions and scarcity of resources.

Many economic interests have turned built heritage into a global energy problem: they have not respected the places and the different climatic areas. It has caused damage to urban landscape and the deterioration of living conditions.

Nevertheless, built heritage is an opportunity to apply many technologies to achieve significant improvements in comfort and thermal performance.

Therefore, this work focuses on thermal analysis about one of the most common building types in the city of Bari, in the South of Italy.

The aim is to obtain an estimate of energy consumption of a part of the city: energy simulation softwares, such as DesignBuilder / EnergyPlus and Mc4, are useful to evaluate the thermal performances of studied buildings and to compare dynamic and steady state results.

In fact, in Mediterranean area, the evaluation of their thermal performance is necessary because if, on one hand, buildings have low insulation in winter, on the other hand, they need cooling in summer.

These data are essential to understand the influence of this building type on the heat balance of the city. The results permit us to obtain a detailed analysis of a significant area in the city of Bari using GIS technologies that allow us to estimate the energy needs of built heritage on a territorial level.

In this context, it is possible to carry out a mapping of the studied area and its energy needs. In this way, it can be used to choose some retrofit strategic actions in order to improve the energy performance of buildings for sustainable energy planning.

KEYWORDS: Built heritage, thermal analysis, energy needs, energy planning

1 INTRODUCTION

The theme of the refurbishment of existing buildings is very important to fight against the reduction of the non-renewable resources and of the CO_2 emissions into the atmosphere. In fact the development of a profit-oriented economy has turned the built heritage in a global energy problem and has caused the urban landscape degradation and the living conditions deterioration.

Buildings are responsible for 40% of the consumption of natural resources in the industrialized countries and the most of them are far from efficient.

In fact, a big amount of energy is spent every day for ventilation, heating, cooling and lighting of the buildings. Although of this, building stock is a great resource to face global challenges, but it needs an analysis of its energy performance to improve its quality.

For this reason, the aim of this work was to provide an example application of a methodology for optimal energy planning. In fact more and more studies try to understand the trends of energy efficiency in European countries (Bosseboeuf, 2009) and to develop new methods to evaluate urban energy needs. (Corgnati et al., 2008).

Therefore, the work uses a methodology according to the so-called "hybrid models": they study the energy needs of some buildings types and adapt them in order to evaluate the consumption on the urban scale, using detailed spatial representations of the building stock, so that it is possible to associate with each building its own consumption and to obtain an accurate estimate on a global level (Mutani et al., 2013).

2 EVALUATION OF THE ENERGY NEEDS OF THE BUILDING STOCK: METHODOLOGIES AND TOOLS

In order to determine the energy needs of building stock, it is necessary to analyze the diffusion of the types, the levels of insulation, the air-conditioning systems commonly used and the level of obsolescence of the buildings (Dascalaki et al., 2011).

For this reason, the first step is the identification of the most significant building types in the studied area, from the point of view of constructive characteristics and heating systems.

In this way, it is possible to study the most widespread building types and assess their energy performance (Ballarini et al., 2009).

Once the buildings are selected, it is necessary to know the thermo-physical properties of materials and geometric data, in order to characterize the components of the building envelope.

On the basis of these data, it is possible to derive the index EP_H, which is the primary energy need, absorbed by the heating system in a given period of time $Q_{p,\,H}$, referred to the unit of surface area and expressed in kWh/m^{2}year. It is obtained by the equation (1):

$$EP_H = \frac{Q_{p,H}}{A_f} \tag{1}$$

The average seasonal efficiency of the heating system is expressed by the equation (2) and it represents the ratio of the building energy need for heating $Q_{H,nd}$ to seasonal primary energy need for heating $Q_{p,H}$:

$$\eta_{H,g} = \frac{Q_{H,nd}}{Q_{p,H}} \tag{2}$$

Finally, it is possible to evaluate the summer energy performance index $EP_{C,env}$, that is the building energy need for cooling $Q_{C,nd}$ referred to the unit of surface area and expressed in kWh/m^{2}year, as it is obtained by the equation (3):

$$EP_{C,env} = \frac{Q_{C,nd}}{A_f} \tag{3}$$

Table 1 Nomenclature

Symbol	**Quantity**	**Unit**
$EP_{C,env}$	Energy performance index in the summer for building envelope	kWh/m^2 year
EP_H	Energy performance index in the heating season	kWh/ m^2 year
$Q_{C,\ nd}$	Building energy need for cooling	kWh
$Q_{H,\ nd}$	Building energy need for heating	kWh
$Q_{p,\ H}$	Seasonal primary energy need for heating	kWh
A_f	Conditioned floor area	m^2
$h_{H,g}$	Heating system global efficiency	%

Table 1 summarizes the nomenclature, in order to clarify the equations.

In this work, two models of simulation have been used for the analysis. The first one uses the semi-stationary method: the main simplification assumptions of this method are the stationary aspect of the thermal exchanges within the period of calculation; the mono-dimensionality of the thermal flows through the elements of the building envelope, with a consequent simplified treatment of thermal bridges; the assumption of monthly average values of climate data; the simplified evaluation of the contributions of internal heat gains and of solar gains.

Instead, the second model uses the dynamic method, that is more accurate than the first one because it takes into account the temporal variation of climate data, without resorting to seasonal or monthly average values (Filippi et al., 2012).

In the absence of an experimental validation, the results of the dynamic method are assumed as reference results.

After the calculation of the energy needs of the buildings, the evaluation can be extended to the urban level through the use of the Geographic Information System. Necessary characteristics, called “attributes”, are associated with each building. The attributes of a building’s geometric characteristics, like area, perimeter and number of the floors, allow the surface area to volume ratio and the distribution of building types in the urban area to be obtained by GIS, providing maps useful to calculate the energy needs on local or regional level.

In fact, the use of GIS platform allows the creation of a database of the characteristics necessary to assess the energy performance of built heritage within broad energy planning.

3 THE CASE STUDY: A CITY IN THE SOUTH OF ITALY

In recent years, the energy planning has become one of the most important aspect of the political strategies in the city of Bari, in the South of Italy. In fact, sustainability is considered the key to increase the competitiveness of the city, both from economic and environmental point of view, and to improve the quality of life of citizens.

As many studies stresses, most of the emissions are generated by the buildings (61%), mainly in the services and household sectors, followed by the transport sector (Web-1).

The most significant weakness of the city is represented by construction stock, about 130,000 houses, built largely in the 1960s and 1970s: buildings are characterized by poor thermal performance and high heat loss.

In fact, the majority of the buildings was carried out during the post-war reconstruction, or in the period preceding the legislation on the reduction of energy consumption in the civil sector. This criticality is accentuated by the presence of predominantly autonomous heating and cooling systems and, therefore, inherently with lower efficiency than those of the systems with centralized boilers.

3.1 The energy performance of a characteristic building type in the city of Bari

One of the most common construction types in Bari is the multi-storey building; it has generally a central staircase that gives access to two apartments per floor. The ground floor is characterized by garages, alternating with stilts.

The study was carried out on an example-building that can be considered representative of this building type. The figure 1 shows the floor plan of the case study, that was built in 1960s.

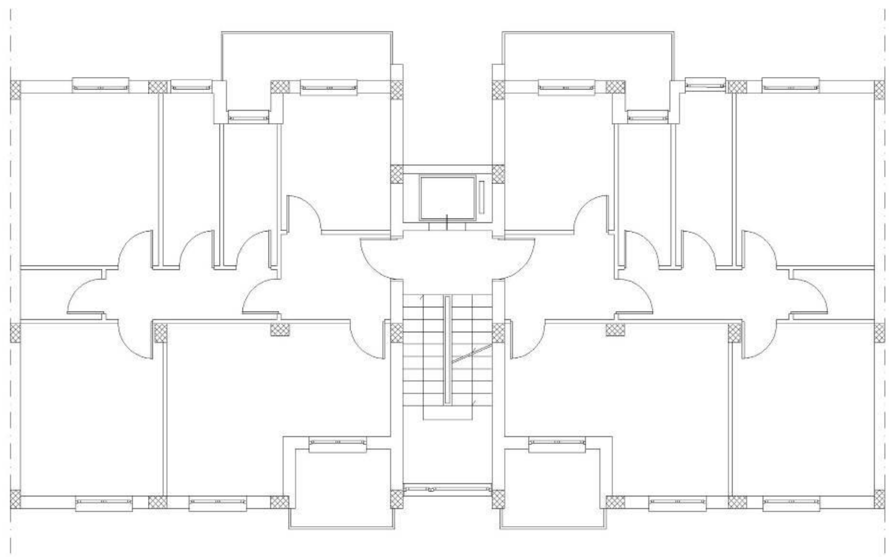


Figure 1: Floor plan of the studied building

At the first, it was decided to study the building in the quasi steady-state conditions, through the certificate software for energy simulation Mc4Suite 2012 (Web-2).

The city of Bari is located in Mediterranean climatic zone, that belongs to group C in the Koppen climate classification. The climate is characterized by hot summers and mild winters, with moderate temperature.

The software takes into account this data and needs typological and dimensional characteristics of envelope components, as well orientation and exposure of the building.

All the components of the envelope, both opaque and transparent structures, were studied and the energy performance of the building was found in accordance with *UNI TS 11300*, that is the national standard on *Energy Performance of Buildings*.

The building has a reinforced concrete framed structure, with brick external cavity walls. The floors are a mixed structure of reinforced concrete or pre-stressed concrete and brick, while the roof is a reinforced concrete hollow-tile floor with low thermal insulation. The single-glazed windows have galvanized steel frame.

Regarding heating system, originally the distribution subsystem was centralized, but, between the 1970s and 1980s, it was converted into autonomous subsystem, separated for each apartment.

It was pointed out that the majority of boilers is installed outside and their efficiency values are higher than 80%.

The type of emission subsystem consists of radiators. UNI TS 11300 defines the conventional emission efficiency of different types of radiators, in order to calculate energy needs.

Table 2 Features of the studied building

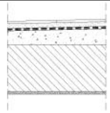
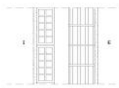
Building Feature	**Image**	**Description**	**U (W/m²K)**
Roof		Reinforced concrete hollow-tile floor, low insulation	0.91
Intermediate floor		Reinforced concrete hollow-tile floor	1.33
Opaque external wall		Cavity wall, without insulation (30 cm)	1.38
Window		Single-glazed window, galvanized steel frame	U_W = 5.10 U_g = 4.64

Table 2 summarizes the data related to opaque components of the building envelope with the corresponding thermal transmittance, also known as U-value, that is the rate of transfer of heat through one square meter of a structure divided by the difference in temperature across the structure.

The data related to the transparent components and the thermal transmittance of the glass U_g and of the window U_W are also reported. These data were obtained thanks to the knowledge of composition of every component: in fact, we know thermal properties of materials and we can calculate this values through the software.

In terms of thermal loss, the final result of the calculation was a high value, equal to 80.682 W, which influences heavily the performance of the building. The analysis showed that the heating system has the average seasonal efficiency $\eta_{H,g}$ equal to 60.43%, while the energy performance index for heating EP_H is 128.13 kWh/m^2 year. Moreover, the CO_2 emissions are about 27.44 kgCO_2/m^{2}year. These data highlights how the building is poor both from the constructive and heating system point of view. Instead, during the summer, the energy performance index $EP_{C,env}$ results equal to 19.16 kWh/m^{2}year.

Subsequently, Design Builder (Web-3) was used for the dynamic analysis of the building. This software is the interface to the EnergyPlus dynamic thermal simulation engine.

The dynamic method takes into account the temporal variation of the boundary conditions, such as the external climatic data and the users profiles. This aspect is highlighted by the figure 2 that shows the temperatures during the year, obtained by the simulation through Design Builder: the trend of the indoor temperature is obviously more regular than the outdoor one.

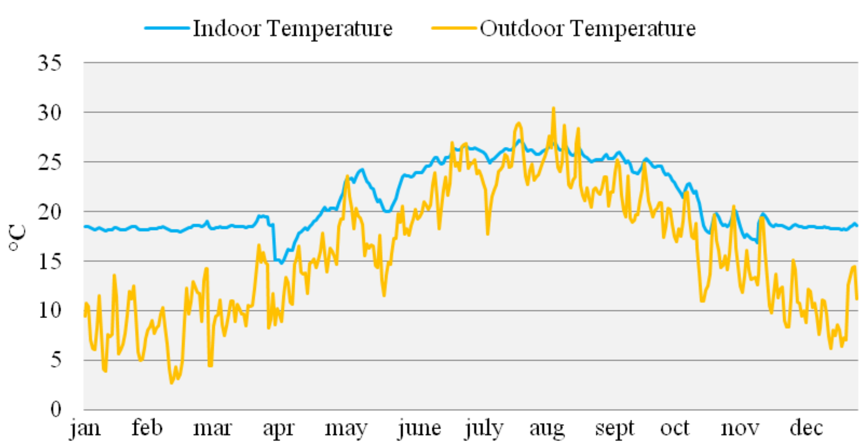


Figure 2: Trend of indoor and outdoor temperature during the year.

Moreover, the thermal storage of building components and heating and cooling plant systems is considered. In this way, dynamic method is more complex than quasi steady-state one and becomes more effective when the phenomenon changes over time.

According to this method, the energy performance index for heating EP_H was equal to 127.59 kWh/m^2 year and the energy performance index $EP_{C,env}$ is equal to 14.17 kWh/m^2 year.

So, in winter conditions, the results of the two simulations are similar, with a minimum deviation of only 0.42%: in fact, during the heating season, the approximations of the semi-stationary method are acceptable because there is a minor variability of solar radiation during the day.

Instead, during the summer, the difference between the results of the two simulations is greater with a deviation of 26%. In this case, the dynamic method is more accurate than the quasi steady-state one because it considers the extreme variability of daily temperatures during the summer as well as the unsteady solar radiation.

So, the result in dynamic condition takes into account the thermal inertia of the structures, improving summer estimation of the energy performance.

Finally, the dynamic method has the advantage of showing how the energy need for heating and cooling changes during the year, depending on external climate conditions, as shown in figure 3.

Obviously the months with nearly zero consumption are May and October, that don't need heating or cooling energy, thanks to mild climate conditions.

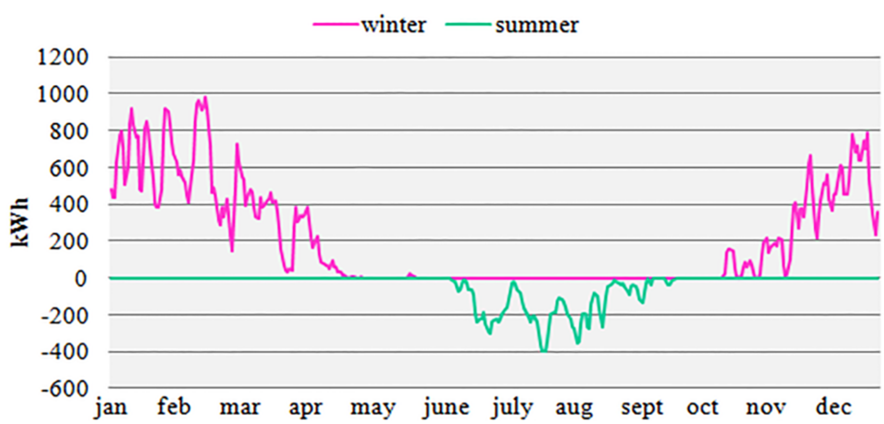


Figure 3: Trend of building energy need during the year

Moreover, in the figure 4 it is possible to see how the CO_2 emissions vary during the year.

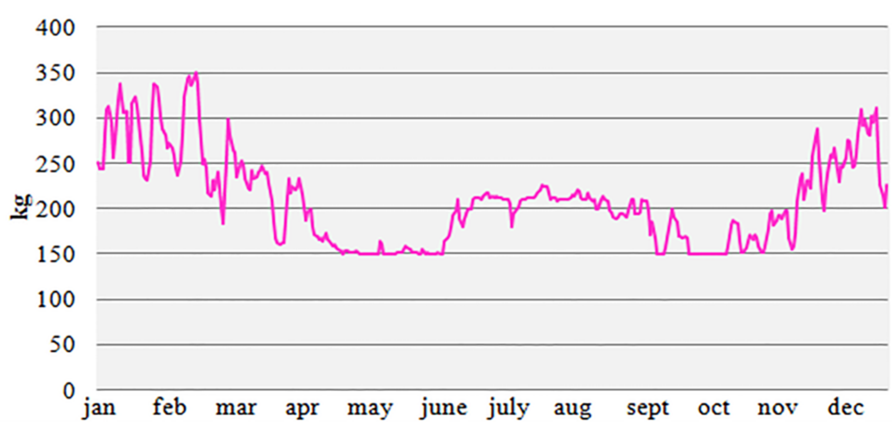


Figure 4: Trend of CO_2 emissions during the year

3.2 Estimation of primary energy needs for the housing stock of a district area in Bari

The studied building type is characteristic of the city of Bari and is particularly widespread in the district of Japigia. It is a peripheral urban area characterized by the presence of a large percentage of public housing, that was built after 1950. For this reason, the district is a significant case study to switch from an architectural level to a larger territorial level in order to evaluate the energy needs.

To do this, the applied methodology uses Gis (Geographic Information System) to give a better understanding of parameters necessary for the analysis of an urban area in terms of energy and environment. In fact, the building heritage of a city is too difficult to study in its details because of its extent. Gis allows a territorial mapping of building characteristics, providing a valuable solution to this problem (Cardinale et al., 2013).

The creation of ArcGis (Web-4) database is a way to analyze the urban fabric.

The corresponding number of floor was assigned to each building of the studied area, as resulting from the height of buildings, derived from aero-photogrammetric survey and direct investigation of the urban fabric, as shown in the figure 5.

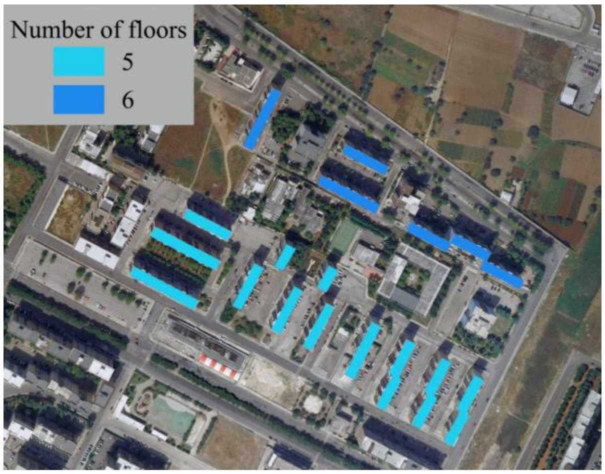


Figure 5: Thematic map of buildings of studied area, according to the number of floors

Through ArcGis, geometric characteristics of the buildings, like surfaces, perimeter and volume, were calculated and, combining this data with the results of semi-stationary simulation on the studied building type, we obtained the primary energy need for the heating season of the analized area. It results equal to 1,209 MWh.

This value reveals that the built heritage is not efficient and highlights that a real problematic situation exists.

However, these data are essential to understand the influence of this building type on the heat balance of the area and to choose suitable technologies to achieve significant improvements in comfort and thermal performance.

4 CONCLUSION

This work shows that the analysis of the energy needs of a city is currently a difficult problem to deal with, because of the lack of data which allow a detailed estimate through the study of each building.

For this reason, the proposed methodology explains how it is possible to extend the evaluation of energy needs to urban areas, studying building types that are extremely common in the analyzed context.

The diffusion of common building types allows us to consider the energy needs value related to the example-building as the starting point to derive an average value, which can be used to assess the energy performance of buildings belonging to the same type.

However, this estimate is closely linked to the need for a territorial mapping that takes into account the differences between the various buildings.

In fact, city is made up of complex urban fabric and the refurbishment of existing buildings is one of the essential challenges to be addressed, in a sustainable way, because built heritage represents an opportunity for the future of our cities.

Finally, in order to identify the right interventions, it is necessary to know the context in which we have to work. Estimated data can help to undertake highly efficient strategies in order to reduce energy needs, consumption of non-renewable sources and CO_2 emissions of a city.

REFERENCES

Ballarini, I., Corrado, V. 2009. Application of energy rating methods to the existing building stock: Analysis of some residential buildings in Turin, in "Energy and Buildings" 41, Elsevier, pp. 790–800.

Bosseboeuf, D. 2009. Energy efficiency trends and policies in the household & tertiary sectors in the EU 27. Results from the ODYSSEE/MURE project, Paris.

Cardinale, T., Di Turi, S. 2013. The high-resolution computer models and the information system in the heat balance of the city., in EARSeL 2013, Lasaponara, Masini, Biscione Editors, pp. 343-352

Corgnati, S.P., Corrado V. and Filippi, M. 2008. A method for heating consumption assessment in existing buildings. A field survey concerning 120 Italian schools, in "Energy and Buildings" 40, Elsevier, pp. 801–809.

Dascalaki, E.G., Droutsa, K.G., Balaras, C.A., and Kontoyiannidis, S. 2011. Building typologies as a tool for assessing the energy performance of residential buildings – A case study for the Hellenic building stock, in "Energy and Buildings" 43, Elsevier, pp. 3400–3409.

Filippi, M., Fabrizio, E. 2012. Introduzione alla simulazione termoenergetica dinamica degli edifici.(Introduction to dynamic thermoenergetic simulation of buildings*)* Ed. Delfino, Milano.

Mutani, G., Vicentini, G. 2013 Analisi del fabbisogno di energia termica degli edifici con software geografico libero. Il caso studio di Torino (Analysis of thermal energy needs of buildings with geographic information software. The case study of Turin), in "La Termotecnica", pp. 63–67.

WEBSITES

Web-1: www.comunedibari.it (Sustainable Energy Action Plan), December 2013.

Web-2: www.mc4software.com (Mc4Suite2013), November 2013.

Web-3: www.designbuilder.co.uk (DesignBuilder, v3.4.0.033), January 2014.

Web-4: www.esri.com/software/arcgis, (ArcGis, 10.2.1), December 2013.