POLITECNICO DI TORINO
Repository ISTITUZIONALE

Introducing a hybrid energy-use model at the urban scale: the case study of Turin (IT)

(Article begins on next page)

21 September 2024

Introducing a hybrid energy-use model at the urban scale: the case study of Turin (IT).

Marta Carozza – M. Sc. student in Architecture Construction City, Politecnico di Torino, Italy – marta.carozza10@gmail.com

Guglielmina Mutani - Department of Energy (DENERG), Politecnico di Torino, Italy - guglielmina.mutani@polito.it

Silvia Coccolo - Solar Energy and Building Physics Laboratory (LESO-PB), École Polytechnique Fédérale de Lausanne, Switzerland - silvia.coccolo@epfl.ch

Jérôme Kaempf - Haute École d'Ingénierie et d'Architecture Fribourg (HEIA-FR), Switzerland - jerome.kaempf@hefr.ch

Abstract

As in the past, the urban morphology plays an important role for the liveability of the city and for both outdoor and indoor human comfort. Nowadays, the relationship between the urban form and energy consumption has been estimated by many researchers, showing how the morphological aspects influence the energy consumption of the buildings, the thermal comfort of the urban spaces and the district air quality. Conversely, in recent urban planning processes, these morphological aspects are undervalued or no more considered. To reinforce their importance, this paper presents an optimization of a previous statistical model made by the complementary use of bottom-up and top-down models to evaluate the energy-use for residential buildings. The average intensity of energy-use data for residential buildings with different age, shape and heated volume has been corrected using the urban energy modelling tool CitySim Pro. This hybrid approach describes how the urban form, the solar exposure of buildings, the outdoor spaces and the material characteristics of urban surfaces impact on the energy performance of buildings. This research analyzed a case-study in the city of Turin (Italy) to quantify the space heating energy-use of residential buildings. To estimate the buildings heating energy-use, the urban energy simulation tool CitySim Pro was used, and the building information model of Turin was validated with the real consumptions data using two years of monitoring data. The results of this research show a direct correlation between the buildings energy-use and the following five urban variables: Building Coverage Ratio, Aspect ratio, Main Orientation of the Streets, Solar factor and albedo coefficients of outdoor surfaces. The building density and the urban canyon phenomenon play an important role, reducing the heating energy-demand in medium density urban contexts. Furthermore, the solar exposure strongly influences energy demands, especially for high buildings density contexts, as well as the presence of green surfaces.The proposed methodology, based on a multi-variate compensative approach, can support urban planning to improve the energy sustainability of the cities.

1. Introduction

According to the European Commission (European commission, 2016), buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU. In this frame, the buildings energy efficiency is an increasingly important instance for environmental sustainability. Recent studies demonstrate that the building energy consumption depend not only on the climate, the envelope characteristics and systems' efficiencies, but also on the surroundings urban texture (Delmastro 2015). This means that, in order to decrease the buildings consumption, the urban context design plays an important role, as well as the design at the building scale. Several studies show the impact of urban form on

buildings energy consumption. The first studies dates back to the 70s, when Martin and March (1972) analyzed the urban form for what concern the soil occupancy. Although this study does not take into account the effects of urban density on energy consumption for heating or cooling demand of buildings, it laid the foundations for future researches. Baker and Steemers' study (1996) focuses on the importance of using tool, in the early stages of architectural design, which can provide the annual primary energy consumption for lighting, cooling, heating and ventilation as output results. For this purpose, Steemers developed the LT method (Lighting and Thermal) for non-residential buildings, which takes into account the orientation of the facades and solar gains, by defining passive and not passive zones inside buildings. Thanks to the development of new software, capable of taking into account the complexity of the urban texture, the impact of urban form on building energy consumption is becoming an increasingly important research topic. In his study, Kaempf (Kaempf et al. 2000) proposes a methodology to minimize the buildings energy consumption in urban areas by using a new evolutionary algorithm, so called hybrid CMA-ES/HDE. Through this methodology, three urban typologies have been parameterized (terraces flat roofs, terrace courts and sloped roofs) in order to find an optimal urban form for the exploitation of solar gains. The study by Ratti et al. (Ratti et al., 2005) analyzes the impact of the urban form on building energy consumption, by taking into account some urban parameters such as the Aspect Ratio and the orientation of the facades, and tries to overcome the concept that the Surface to Volume ratio (S/V) is the main influential factor in urban energy consumption. In 2014 Rode (Rode et al., 2014) tries to determine theoretical energy efficiency as a function of the city's spatial conformation. For this purpose, the authors take as case studies standard urban areas of 500X500m in the cities of Amsterdam, Berlin, Paris and Istanbul and some urban parameters such as the Building Density, the Building Coverage Ratio, the Building Height and Sky View Factor. As a conclusion, this study shows that the highest and compact buildings have greater energy efficiency than the

low and isolated buildings. Moreover, Delmastro's study (Delmastro et al., 2015) takes into account some urban parameters (such as the Building Coverage Ratio, Building Density, Building Height, Aspect Ratio and Solar Factor) to show how the urban form influences the heating demand of residential buildings in Turin (Italy). The vastness and variety of the studies, carried out in the field of energy sustainability at the urban scale, show how a good design of the urban texture is crucial for buildings energy consumption reduction. Conversely, there are still few researches that demonstrate the impact of the urban form on buildings energy demand in a quantitative manner. This study aims to propose a methodology to analyse how some urban parameters affect the buildings heating energy-use.

2. Methodology

This study starts from the energy consumption models for residential buildings at the urban scale, developed from the research project "Cities On Power" (Mutani 2015, Mutani et al. 2016). With these simplified models, the energy-use for space heating and hot water production was represented for about 50 municipalities of the Metropolitan City of Turin. The energy-use models were based on energy consumptions data at buildings and municipal scales with a statistical approach and applied with a GIS-based tool. The results of this paper will improve the previous models, taking into account the differences in buildings heating energy needs, due to their surrounding context. The assumption is that the buildings measured heating consumption is partly influenced by its characteristics and climate but also by the surrounding context and its microclimate variations:

$$\frac{kWh}{m^2 \cdot year}\bigg|_{measured} = \frac{kWh}{m^2 \cdot year}\bigg|_{building} \pm \frac{kWh}{m^2 \cdot year}\bigg|_{context} \quad (1)$$

For this analysis, a territorial unit called "census parcel", corresponding to a buildings block, was considered and the buildings heating demand variations were correlated to the urban form, the solar exposure and the outdoor materials. In

particular, six urban parameters, calculated with ArcGIS 10.1.2 (ESRI), were taken into account:

- the Building Coverage Ratio (m^2/m^2) is the ratio between the built area and the total census parcel area;
- the Aspect Ratio, or H/W ratio, (m/m) is the ratio between the building height (H) and the distance between buildings (W);
- the Main Orientation of the Streets (-) defines the quality of the streets orientation. A MOS=1.3 defines the best orientation (East-West), while a MOS=0.8 corresponds to the worst one (North-South) (Delmastro 2015).
- the Albedo of external surfaces (-) indicates the reflecting power of a surface;
- the Solar Exposure, or H/H_{av}, (m/m) is the ratio between the building height (H) and the surrounding buildings average height (H_{av});
- the Solar Factor, a statistical parameter equal to $MOS*H/H_{av}$ (Delmastro 2015).

In order to analyse different urban layouts, the software CitySim Pro was used, proposing consistent variations on the urban form and outdoor materials, compared to the real case study. CitySim is an urban energy modelling tool (Robinson 2009), able to quantify the energy demand, from the building to the urban scale. The thermal model of buildings is based on an analogy with the electrical circuit, more precisely on a resistor-capacitor network (Robinson et al., 2009, Kämpf and Robinson, 2007). The radiation model is based on the Simplified Radiosity Algorithm (SRA), where the radiant external environment is represented by two hemispheres, discretized into several solid angles (Robinson and Stone 2005). CitySim was also certified by the IEA BESTEST (Waltr and Kämpf, 2015). In order to understand the impact of greening the outdoor environment, further models are under development, able to quantify the evapotranspiration as well as the impact of trees on the urban microclimate (Upadhyay et al. 2015, Coccolo et al. 2015). CitySim provides the energy needs of buildings, on hourly values, by including the interactions within the built environment. As an example, the interrelations between buildings, as well as the mutual shading are calculated. In order to perform the calculations, hourly weather data are required,

as the one created by the software Meteonorm (Remund, Müller and Kunz 2015), or by on-site monitoring. The geometry of urban layouts is created by CAD modelling tools, and it is directly imported in the software. The physical properties of buildings (i.e. envelope, glazing ratio, occupancy profile and energy systems) as well as the ground covering are defined within CitySim Pro. The proposed case study is a traditional settlement in the central district of the city of Turin (IT) called "Crocetta" characterized by old and high rated row buildings.

3. Results

Turin is an important city in the north-western part of Italy with about 900,000 inhabitants, 10 Districts, 3,839 census parcels and about 40,000 residential buildings. The 86% of residential buildings in Turin were built before the 70's and 43% are characterized by a Surface to Volume ratio S/V <0.4 and a compact form. "Crocetta" district (Figure 1) is a portion of the District 1, in the historic centre of Turin, with 16 census parcels and a total area of about 160 km^2. Thanks to a Geographical Information System model, the data on the buildings period of construction have been obtained. These informations allowed us to associate for each building its construction system, in terms of materials, type of envelope and level of thermal insulation (Table 1).

Table 1 - Physical characteristics of Crocetta buildings (in brackets the number of buildings used for the energy-use models validation).

Construction period	U_{wall} W/m²/K	U_{window} W/m²/K	g_{value} (-)	Glazin ratio (%)	N° of Buildings
Before 1945	1.5	4.7	0.85	18	150 (24)
1946-1970	1.15	4.2	0.75	19	69 (16)
1971-1980	0.81	4.9	0.75	34	18 (2)

The roads and the courtyards in Crocetta district are composed by asphalt with an average value of the albedo coefficient of 0.17. The average buildings height is about 20 meters and the urban

form can be considered homogenous, as the urban parameters of the census parcels are similar (Table 2).

Fig. 1 – Crocetta district with census parcels numbers and buildings period of construction: before 1945 (yellow), from 1946 to 1970 (orange) and from 1971 to 1980 (red).

Table 2 – Crocetta urban parameters: Building Coverage Ratio (BCR), Aspect Ratio (H/W), Main Orientation of the Streets (MOS) and Albedo (A).

Crocetta	BCR m²/m²	H/W m/m	MOS (-)	A (-)	H/H$_{av}$ (m/m)
Average	0.41	0.89	1.3	0.17	1.02
Dev.st	0.07	0.17	0.25	0.01	0.34

The building heating energy-use was calculated with CitySim Pro, considering the following input data: an internal temperature of 20 °C, a number of air changes per hour of 0.5 as infiltration rate, an occupancy profile based on ASHRAE Standard for residential buildings (ANSI/ASHRAE/IESNA Standard 90.1-2007 - Energy Standard for Buildings Except Low-Rise Residential Buildings) and a traditional heating system connected with the district heating network. As regards the outside temperature, two hourly climate files were generated by Meteonorm (Remund, Müller, and Kunz 2015), and further calibrating the air temperatures according to the data measured by the weather station "Via della Consolata" in Turin. Meteonorm is a worldwide well known meteorological database; the hourly data provided by the software are based on the average irradiance data for the period 1991-2010 and the average

temperature data for the period 2000-2009. For the dynamic simulations two heating seasons have been considered (in Table 3 the average monthly air temperatures): the season from 15th of October 2013 to 15th of April 2014 and the season from 15th October 2014 to 15th April 2015.

Table 3 – Average monthly air temperatures in Turin for the heating seasons 2013-14 and 2014-15.

Air temperature [°C]	Oct	Nov	Dec	Jan	Feb	Mar	Apr
2013-14	14.6	9.2	5.5	5.7	7.1	12.0	15.6
2014-15	16.2	10.6	6.6	5.6	5.4	10.8	15.1
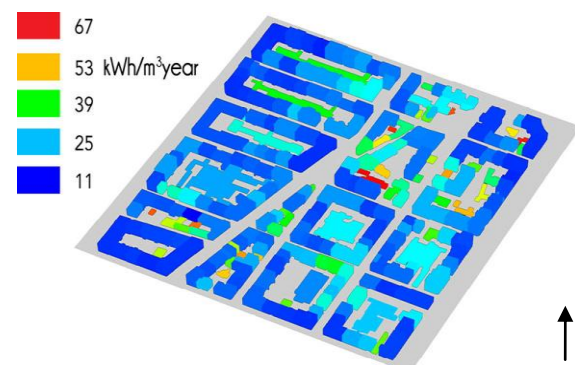
Fig. 2 – Yearly heating demand of Crocetta District calculated by CitySim Pro.
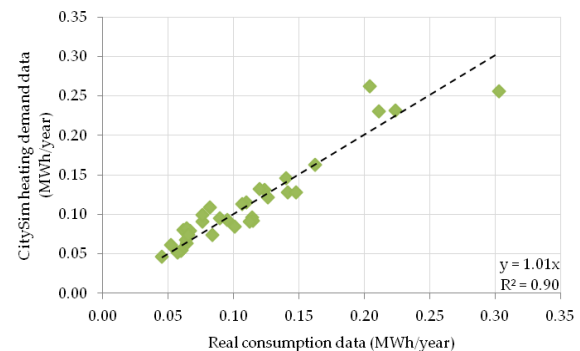
Fig. 3 - Linear relationship between the buildings heating demand calculated by CitySim Pro and the real consumption data.

The buildings space heating consumption data, calculated by the software, were compared with real buildings consumption data, provided by the district heating company "IREN". The validation of the model took into account 42 buildings, with different periods of construction. As shown in Figure 3, there is a strong correlation between the calculated data and the real data (R²=0.9). As mentioned before, the aim of this research was to

define how urban variables can influence space heating consumptions. Since the urban texture in "Crocetta" district is very homogeneous, new urban layouts were created in order to achieve greater changes in urban form, useful for determining major differences in buildings heating energy-use. For this purpose, the census parcels number 1,154 and 1,163 (Figure 4), which have the highest number of validated buildings belonging to the same period of construction (before 1945), have been taken into account.
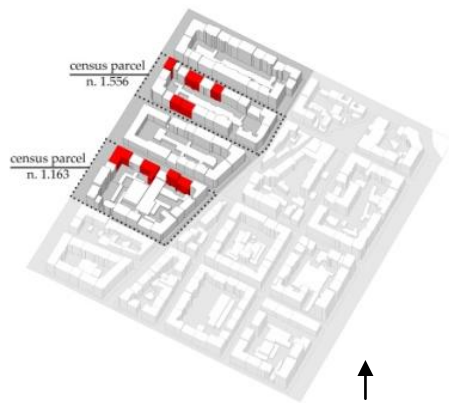

Fig. 4 – Census parcel n. 1,156 (top) and 1,163 (bottom) taken into account in order to analyse the influence of urban form on buildings heating demand.

In this research, every single urban variable was changed one at the time to evaluate their influence on energy consumptions, while the buildings characteristics, such as the surface to volume ratio, the physical characteristics of the envelope and systems performances, remain unchanged (figures 6 and 7). First of all, new urban layouts were created varying BCR from 0.25 to 0.55 (Figure 5). Next, the width of the roads has been changed to evaluate the H/W parameter effect. In this case new models were created with values of aspect ratio H/W from 0.4 to 1.9. New layouts were also created by rotating the blocks of 30°, 60° and 90° in order to have configurations with MOS of 0.9, 1 and 1.1 (Fig. 6). Finally, new configurations were created with different values of Albedo coefficient: 0.07 (new dark asphalt), 0.5 (light asphalt), 0.25 (dark green) and 0.35 (light green).

After creating the new configurations, the dynamic simulations were performed with CitySim Pro, in order to obtain the new buildings heating consumption data.

cens. parcel 1156
BCR (m/m) = 0.25
H/W (m/m) = 0.97
MOS =1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.22
H/W (m/m) = 0.82
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.37
H/W (m/m) = 0.97
MOS =1.3
H/H$_{av}$ (m/m) = 0.82
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.35
H/W (m/m) = 0.8
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.5
H/W (m/m) = 0.97
MOS =1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.55
H/W (m/m) = 0.82
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.5
MOS =1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.4
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.7
MOS =1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.6
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 1.9
MOS =1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 1.3
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.17

Fig. 5 - New layouts of BCR and H/W

Marta Carozza, Guglielmina Mutani, Silvia Coccolo, Jérôme Kaempf

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 0.9
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 0.9
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 1
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 1
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 1.2
H/H$_{av}$ (m/m) = 0.8
A = 0.17

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 1.2
H/H$_{av}$ (m/m) = 1.54
A = 0.17

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.07 (asfalto)

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.07 (asfalto)

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 1.3
H/H$_{av}$ (m/m) = 0.8
A = 0.5 (pavimentazione chiara)

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 1.3
H/H$_{av}$ (m/m) = 1.54
A = 0.5 (pavimentazione chiara)

cens. parcel 1156
BCR (m/m) = 0.43
H/W (m/m) = 0.97
MOS = 1.3
H/H$_{av}$ (m/m) = 0.97
A = 0.3 (verde)

cens. parcel 1163
BCR (m/m) = 0.47
H/W (m/m) = 0.82
MOS = 1.3
H/H$_{av}$ (m/m) = 0.82
A = 0.3 (verde)
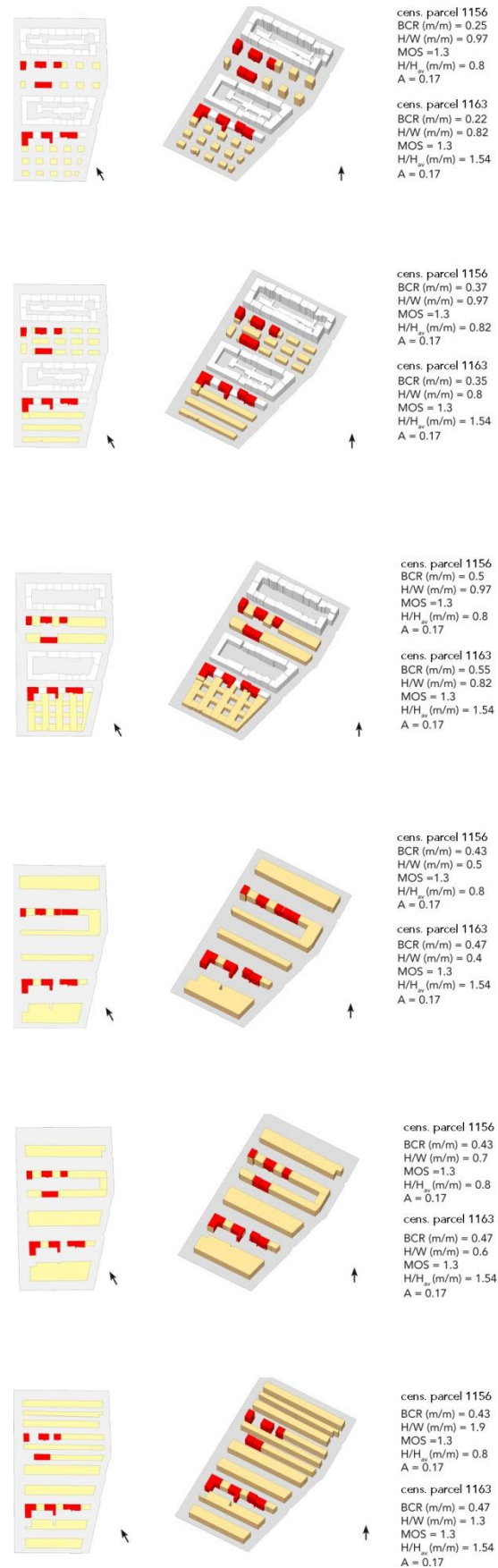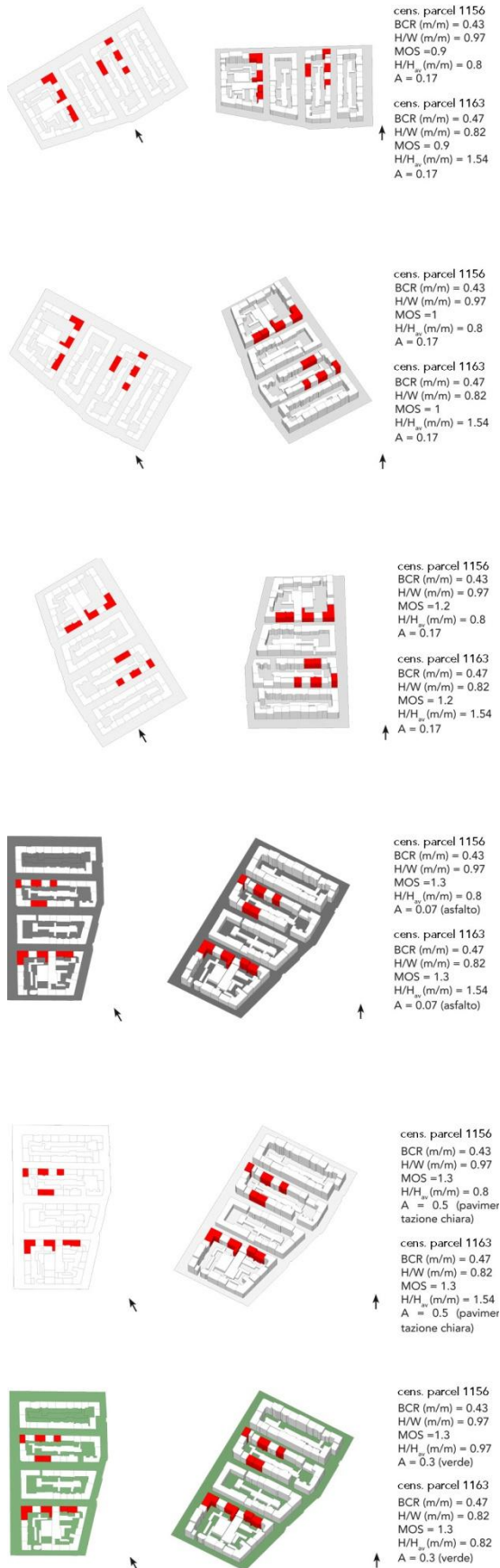
Fig. 6 - New layouts of Albedo and MOS.

The results show how the energy consumption varies in the different urban layout as a function of the urban variables. The trend of the heating energy-use as a function of the BCR and H/W parameters is parabolic as shown in Figure 7. In particular, for high and very low values of BCR and H/W the heating demand is higher, while for medium values of the parameters, the energy consumptions are lower.
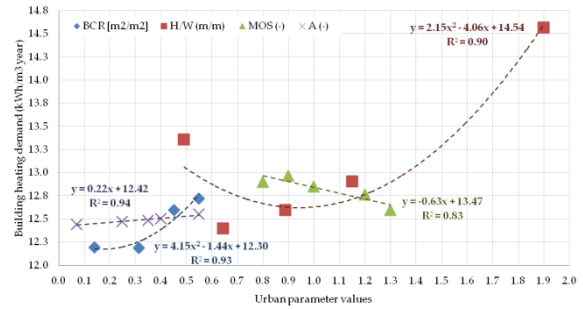

Fig. 7 – Buildings heating demand trend as a function of urban parameters: BCR (rhombus), H/W (squares), MOS (triangles) and Albedo (crosses).

The results show an inversely proportional correspondence between buildings heating energy-use and MOS: the best orientation, in order to reach reductions in heating consumption, is West-East (MOS=1.3). The heating consumptions increase linearly varying the albedo coefficient A: the buildings heating energy-uses are lower with darker surfaces in the surrounding outdoor spaces (i.e. with new asphalt: A=0.07). Finally, knowing how the buildings heating energy-use vary with the different urban variables BCR, H/W, MOS, H/Hav and A, a further analysis was performed considering all the buildings heating consumption results. Starting from equation 1, the aim of this analysis was to define a correlation that allows calculating the buildings heating energy-use as a function of the urban parameters, specifically for the Turin case study. For this purpose, a multiple regression analysis was performed, considering the urban variables mentioned in paragraph 2, minimizing the differences between measured and calculated energy consumption data:

heating energy-use intensity [kWh/m^3/year] =
$-0.40*(BCR)^2 +1.23*BCR -0.05*(H/W)^2$
$+1.95*H/W -1.96*H/H_{av} -3.52*MOS$
$+0.63*A +0.12*G +17.78.$ (2)

In equation (2), the G value is a discrete variable that indicates the presence of greenery: equal to 1 when the surrounding ground surface is green or equal to 0 if there are no green outdoor surfaces. In Figure 8 the influence of the different urban variables of equation 2 is represented for the analysed urban layouts. The aspect ratio H/W, the solar exposure H/Hav and the main orientation of the streets MOS are the most energy-consumption related variables. This demonstrates the high influence of the urban canyon phenomenon and the solar exposure in space heating energy consumptions.
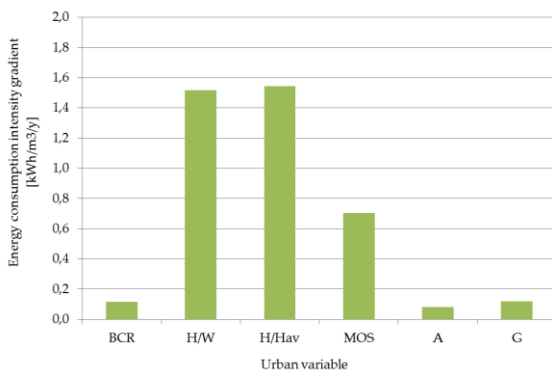

Fig. 8 – Heating intensity gradients related to variations in the urban variables (on 199 buildings' simulations).

Figures 7 and 8 reveal also how the surrounding environment can play an important role in energy sustainability. It is possible to guide the urban design with compensatory measures to reduce energy consumptions; for example, the high buildings density requires high values of H/W and then high heating consumptions, but with a good solar exposure (high MOS and H/H$_{av}$) the energy-use decreases. Also the selection of materials for outdoor spaces (i.e. A and G) can help in increasing the energy sustainability of a district.

4. Discussion and conclusions

Reducing buildings energy consumption is one of the crucial problems that architects and urban planners are called to solve every time they compare themselves with the design of new buildings or the renovation of existing parts of the city. The initial goal was to demonstrate the incidence of the urban form on buildings space

heating demands. The results show that the heating energy-use trend as a function of BCR and H/W parameters is parabolic. In a very dense urban context, in fact, solar gains are lower and the shadows, generated by the buildings, cause a lowering of the outdoor air temperature, and so, an increase of buildings heating demand. In less dense urban contexts, instead, the buildings are more exposed to solar radiation but there is no urban canyon effect, i.e. the incident solar radiation is not trapped in the urban texture and the outside air temperature is not increased. For this case study, the optimum values of BCR, in order to reach a reduction in heating demand, is 0.3, which means an urban context in which the built area is the 30% of the total site area. Moreover, very high values of H/W parameter (considering the buildings height constant) indicate the presence of very narrow streets. In these conditions too, there is not the urban canyon effect and the solar radiation cannot penetrate. For very low Aspect Ratio values, however, the roads are very wide and, even in this case, the effect of the urban canyon does not occur, since the solar radiation is not trapped within the external walls of buildings. The optimal situation is for H/W values equal to 0.9, a situation in which the road width is approximately equal to the buildings height. Additionally, the results show that the best orientation of the streets is West-East, which means that if a census parcel (or a buildings block, or a district) has that main orientation, the buildings energy efficiency is optimal. The trend of energy consumption as a function of Albedo is increasing linear, which means that very dark surfaces (characterized by low values of Albedo) absorb more solar radiation and cause a rise in outside air temperature. This corresponds to a decrease of the thermal gradient between the buildings internal air temperature and the outside air, and a reduction of heat losses. This study doesn't want to be the arrival point in the definition of new urban strategies to reduce buildings energy consumptions, in fact it tries to define a common methodology. The future developments of this research may provide for the application of the illustrated methodology in situations of hot or arid climates. In South America or Saudi Arabian cities, in fact, the control of the

incident solar radiation plays an important role for the reduction of buildings cooling energy demands. By analyzing how the urban parameters influence the buildings cooling demand a complete picture of the problem could be delineated, because the rules that we had found for a temperate climate (such as the case of Turin) may not be valid for an arid context.

This research tries to define a method for the determination of the urban form influence on the buildings heating demands. In this sense, the illustrated methodology could be useful for the design of the new Zero Energy Building districts as it could provide a valuable tool to increase the buildings energy efficiency, since it would not only optimize the envelope or system performances, but also the form of the urban context in which the building is located.

References

ANSI/ASHRAE/IESNA Standard 90.1-2007 - Energy Standard for Buildings Except Low-Rise Residential Buildings.

Baker N., Steemers K. 1996. "LT Method 3.0: A strategic energy-design tool for Southern Europe." *Energy and Buildings* 23: 251–256.

Coccolo S., Kämpf J. and Scartezzini J. -L. 2015. "Outdoor Human Comfort and Climate Change. A Case Study in the EPFL Campus in Lausanne." in *ICUC9 - 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment*.

Delmastro C., Mutani G., Vicentini G., Pastorelli M. 2015. "Energy consumption and urban morphology." *Proceedings of ICRERA: 4th International Conference on Renewable Energy Research and Applications, Palermo*, pp 1603-1608.

European commission. "Energy Performance of Buildings." Accessed on November 2016. https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings.

Kämpf J. H., Montavon M., Bunyesc J., Bolliger R., Robinson D. 2010. "Optimization of buildings' solar irradiation availability." *Solar Energy* 84: 596–603.

Kämpf, J. H., and Robinson D. 2007. "A Simplified Thermal Model to Support Analysis of Urban Resource Flows." *Energy and Buildings* 39(4):445–53.

Martin Leslie and March Lionel. 1972. *Urban space and structure.* Cambridge: Cambridge University Press.

Mutani G. 2015. "Buildings' energy efficiency and RES potential in urban contexts." *Spatial Data for Modelling Building Stock Energy Needs, JRC Conference and Workshop Report*, pp 146-152.

Mutani G., Gamba A., Maio S. 2016. "Space heating energy consumption and urban form. The case study of residential buildings in Turin (Italy)." *11th Conference on Sustainable of Energy, Water and Environmental Systems, SDEWES2016.0441, 1-17, Lisbon, September 2016* ISSN 1847-7178.

Ratti C., Backer N., Steemers K. 2005. "Energy consumption and urban texture." *Energy and Buildings* 37: 762–776.

Remund J., Müller S., and Kunz S. 2015. "Meteonorm. Global Metereological Database. Version 7."

Robinson D., Haldi F., Kämpf J., Leroux P., Perez D., Rasheed A., Wilke U. 2009. "Citysim: comprehensive micro-simulation of resource flows for sustainable urban planning." *11th International IBPSA Conference, Glasgow, Scotland.*

Robinson D. and Stone A. 2005. "A Simplified Radiosity Algorithm for General Urban Radiation Exchange." *Building Services Engineering Research Technology* 26(4): 271–84.

Rode P., Keim C., Robazza G., Viejo P., Schofiled J. 2014. "Cities and energy: urban morphology and residential heat-energy demand." *Environment and Planning B: Planning and Design* 41: 138–162.

Upadhyay G., Mauree D., Kampf J. and Scartezzini J.-L. 2015. "Evapotranspitation Model to Evaluate the Cooling Potential in Urban Areas - a Case Study in Switzerland." *BS 2015 - 14th Int. IBPSA Conference*

Walter E., Kämpf J. H., 2015. "A verification of CitySim results using the BESTEST and monitored consumption values." *2nd Building Simulation Applications BSA 2015, Bozen-Bolzano, Italy.*