TeMA

Journal of Land Use, Mobility and Environment

The special issue collects the proceedings of the Session "Smart and Resilient Cities: Ideas and Practices from the South of Europe" of the European Conference On Climate Adaptation (ECCA), held in Copenhagen in May 2015. The contributions shed light on the relationships between the emerging paradigms of Smart City and Resilient City, providing hints for developing integrated strategies in the face of climate change.

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SMART AND RESILIENT CITIES
IDEAS AND PRACTICES FROM THE SOUTH OF EUROPE

SPECIAL ISSUE ECCA 2015

ECCA
2nd European Climate Change Adaptation conference (ECCA)

TeMA

Special Issue ECCA (2015)

SMART AND RESILIENT CITIES

IDEAS AND PRACTICES
FROM THE SOUTH OF EUROPE

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SMARTNESS AND URBAN RESILIENCE

A MODEL OF ENERGY SAVING

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ABSTRACT

Climate change, energy issues and urban population growth are among the main themes on which the scientific debate focuses today. Over the last decades, the literature has proposed different approaches to face these challenges. This paper focuses on two widely debated approaches: the smart and the resilient city paradigms, that continue to draw the attention of scholars and institutional bodies worldwide.

The need to find strategies to reduce energy consumption and mitigate climate change impacts has been a prerequisite for the Smart Energy Master project for territorial governance of energy. One of the results is the Urban Saving Energy Model that "looks" at the several characteristics of a city in an integrated manner. This paper presents the results of a scientific and technical procedure that, starting from a thorough investigation of the physical and environmental characteristics of the city of Naples, has identified which variables have the greatest effect on energy consumption.

The results have shown that the possibility of identifying an "ideal" sustainable urban form, able to maximize energy efficiency, still remains theoretical, opening up the possibility that there are different consumption patterns due to the different physical, environmental and building characteristics of urban areas.

KEYWORDS:
energy consumption, urban built environment, building density, smart and resilient city

1 INTRODUCTION

Since the first IPCC assessment report in 1990, research and national governments have been addressing their knowledge and actions both to limiting the sources of GHG emissions and to adapting to the effects of climate change effects (Schipper 2006; Marsh et al., 2009; Gilardi, 2010). According to the latest assessment report, overall anthropogenic GHG emissions have increased, especially during the period from 1970 to 2010, growing on average by 1 $GtCO_2eq$ per year and by a total of about 75% (IPCC, 2014). The increase in GHGs, mainly due to a still high dependence on fossil fuels, could determine an increase of 4.8°C in the mean global surface temperature in 2100, referring to the baseline scenarios and compared with pre-industrial levels. The effects of global warming, such as heat stress, flooding, tropical diseases and crop failures, are already affecting millions of people, resulting in more than 150.000 deaths a year (WHO, 2005).

The Earth's average temperature has increased by 0.7°C compared to the pre-industrial period, and needs to be contained below 2°C, in order to avoid catastrophic consequences, reducing GHG concentrations to at least 80% by 2050.

A key element in achieving these goals is the reduction of energy consumption, as the energy sector is responsible for about two-thirds of global GHG emissions, "an amount that is increasing at a faster rate than for any other sector" (WWF, 2011). In particular, the energy demand is strictly tied to urban and economic development (Jones, 1989; Burney, 1995; Imai, 1997; Lenzen et al., 2006). In fact, the population shift from rural to urban areas typically occurs as people seek to improve their quality of life, also conditioned by the possibility of using all the services based on electricity (Liddle & Lung, 2013). Then, within urban areas, factors such as the increase in residential household demand can lead to a growth in transport, production of building materials and activities that, in turn, bring about a rise in energy consumption (Zhou et al., 2011). In other words, demographic growth leads to urbanization that, in turn increases energy consumption (Zaman et al., 2012; Shahbaz et. al. 2015).

World urban areas occupy 4% of the Earth's land area, growing on average twice as fast as their population, and 65% of all land surface will have become urbanized by 2030 (Creutzig et al., 2014). If cities are responsible for a rate of energy consumption ranging from 67% to 76% of total consumption, accounting for more than 70% of global CO_2 emissions, "global city energy use is projected to grow by 1.9% per year (compared to an overall global growth rate of 1.6% per year), to 12.374 Mtoe in 2030" (IEA, 2008).

For instance, in Europe per capita energy consumption will increase from 3.5 Mtoe (2006) to 3.6 Mtoe by 2030 and total urban energy consumption will increase by 0.5 % per year by 2030, ranging from 1259 Mtoe (2006) to 1427 Mtoe by 2030. This last rate is more than double that of the entire European Union.

From the state of the art described above, it is clear that urbanization, both in developed and developing countries, is reshaping the Earth's economy, land use, energy systems and climate. This consideration can represent an opportunity for policy makers to accomodate the relationship between urban built environment and energy in a more efficient way, especially because 2030 is now approaching.

We aim to contribute to the debate on energy consumption in urban areas by providing a comprehension model that, based on the systemic approach, seeks to identify which physical and environmental elements most influence energy consumption.

The paper is divided into four sections: section 2 describes the smart and resilient city approaches that can help urban planners and policy makers deal with energy and climate change challenges; section 3 illustrates the research methodology so as to identify the main physical, environmental and building elements that can be considered as determinants of urban energy consumption; section 4 describes the results of the research; the last section discusses these findings by providing some food for thought about the scientific debate on energy consumption in urban areas.

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2   THE SMART AND RESILIENT CITY APPROACHES

Up to the 19th century, environmental issues affecting urban areas, mainly related to air and water pollution, were considered solely from the perspective of human health. In the 20th century, the four-fold rise in world population and the fast increase of economic and productive activities, mostly due to technological changes, meant that these issues had to be considered from a broader perspective, taking into account the different elements of a given territory (infrastructure, buildings, social and economic aspects, etc.). This change in approach occurred also as a result of the spread of systems theory (Von Bertalanffy, 1950) and the paradigm of complexity (Ruelle, 1992). These represent the theoretical foundations that also led to the definition of the concept of sustainability that still plays a prominent role in development policies.

The complexity of urban phenomena, combined with that of environmental issues, has led to the development of different approaches to meeting these challenges that need to be addressed primarily at the urban level. Rather than trying to review the plethora of city paradigms (green city, digital city, low-carbon city, etc.), that have developed over time to tackle the different challenges that cities are called to face, this section concentrates on the smart and resilient city approaches that continue to draw the attention of scholars and institutional bodies worldwide.

The smart city concept has been developing since the end of the last century, when the new technologies and the fast spread of computable devices drove urban scholars to imagine cities as places where technology could replace collective interaction, travel needs, overcoming spatial distances (Atkinson, 1998; Graham, 2004; Mitchell, 2004) and "pasting the reality of what was possible at that time" (Angelidou, 2015).

To date the smart city has become a label, rather than a paradigm or approach to be adopted, heavily overused, and a trend to adhere to, thanks to the substantial financial resources allocated too.

The opportunity to take advantage of the significant funding aimed at favouring a large and widespread use of Information and Communication Technologies (ICT) has led to the development of many different definitions and approaches, because each stakeholder involved in urban transformation proposes its own vision, often not connected with the others (Fistola, 2013; Moraci, 2013; Mosannenzadeh and Vettorato, 2014). In a way similar to what happened in the past regarding the concept of sustainable development, the notion of smart city too seems to be defined essentially as a kind of large "container" that is sufficiently generic to contain just about anything and obtain a wide consensus; in this regard it is worthy quoting Hollands: "Which city, by definition, does not want to be smart, creative and cultural?". Hollands, in a 2008 article with a simple but thought-provoking title (Will the real smart city please stand up?), disapproves the weakness of the definitional framework as one of the most problematic and risky elements.

However, although a clear and shared definition of the smart city is still lacking, it is possible to identify two main characteristics, which studies and research agree on. The first one is the use of ICT in order to make cities more efficient, attractive and competitive, by understanding and analysing what happens in real time and predicting urban functions (Batty, 2012; Berst, 2013). The second is sustainability and, consequently, a better quality of life, as energy consumption can be reduced through ICT. Solutions such as smart meters, smart grids or smart mobility, just to name a few, may allow a more efficient management of infrastructure and networks and can help increase consumer awareness about the possibilities of energy saving. It is worth noting that ICT should be put to green use, able to combine energy and environmental sustainability with the potential use of technology, in order to avoid a scenario where the more ICTs are used, the more energy is consumed (ITU, 2014; Viitanen and Kingston 2014).

Like smart city, also the term resilient city "may collapse into the meaningless that results from having too many meanings" (Vale, 2015). Even though the notion of resilience has been gaining increasing influence within various disciplinary fields since the fifties, only during these last years has the resilient city concept been developed, mainly in relation to urban adaptation to climate change.

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In fact, according to Evans (2011) "the attraction of resilience [...] is farily obvious", as cities increasingly need to withstand, absorb or transform a broad range of shocks, threats and stresses. And adaptation to all the ongoing changes takes place while a city continues to operate, retaining the same function and identity (Colding, 2007; Leichenko, 2011; Malalgosa, 2013).

Even though the resilient city is a complex and multidisciplinary concept, it is linked to that of sustainability. According to Folke et al. (2002), Chelleri (2012) and Colucci (2012), the target of sustainability can be achieved by enhancing urban resilience, especially "optimizing available resources, making a rational use of them, and contributing to increasing the amount of available resources" (Galderisi and Ferrara, 2012).

Cities, in fact, are key players in energy and climate challenges, as they are responsible for the most energy consumption, and at the same time they are vulnerable to the effects of climate change, such as urban heat islands, water supply scarcity and so on. Therefore, urban systems are compelled to define short-term and long-term strategies related to these issues. The former aim to prevent climate change related events (heat waves, etc.) and the latter aim to decrease energy consumption and GHG emissions, promoting a low-carbon urban future. In other words, if a city wants to be smart, it has to be resilient too, in order to make cities places where a wide network of infrastructure and sensors allows a more efficient use of resources and can increase user awareness regarding their energy habits. On this subject, it should be remembered that ICT is not sufficient to transform and improve the urban system, as "the critical factor in any successful community has to be its people and how they interact" (Nam and Pardo, 2011). In order to reduce energy consumption, users need to be informed and aware of their role, being involved in an energy performance improvement strategy that includes them from the very first phases defining critical points and needs.

In summary, the improvement of urban resilience should take place together with the enhancement of urban smartness, as these can be considered two sides of the same coin: the application of smart technology provides innovative opportunities to pave the way towards a low-carbon city. This, in turn, enables cities to face the imminent energy crisis and therefore become more resilient.

3   THE URBAN SAVING ENERGY MODEL

Awareness of the importance of fielding strategies to reduce energy consumption and to mitigate climate change impacts, especially in urban areas, was a prerequisite for the Smart Energy Master project for the energetic governance of the territory, by the DICEA (University of Naples).

Among the project results, there is the Urban Saving Energy Model that represents the starting point for the development of a support tool for local policy makers who will be able both to identify the highest energy consumption elements and energy-critical areas and to define energy saving strategies and actions.

The UrbanSEM, in fact, is a comprehension model designed to identify which of the main urban components (physical, socio-economic, mobility) relationships can be identified as determinants of energy consumption.

This paper provides the results of a scientific and technical procedure that identified which physical and environmental variables mostly affect energy consumption from among all these components of urban systems aiming to save energy.

3.1   DATA AND DEVELOPMENT OF THE INTERPRETATIVE MODEL

This work aims to develop of an interpretative model that, at neighbourhood level, and based on a systemic approach, makes it possible to identify the urban and environmental elements that have the greatest impact on energetic consumption. This approach refers to the general system's theory that seems to have great significance on the theme of energy.

If the city is indeed a place of complexity, because the system of interactions and activities that takes place within it is complex, the implementation of a systemic approach and the paradigm of complexity seem to be

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the most efficient way to find out the impacts of its elements and its interactions (activities) on energy consumption and to measure the actions according to its characteristics (Papa et al., 2014a).

Choosing this type of approach represents a first look at of innovative research, since only a few studies in this field have used a systemic approach, favouring experiments related to the use and energetic performance of buildings, energy productions and transportation systems, rather than the urban system itself. Under this approach, the interpretative model is based on the development of different urban features, especially the "physical-environmental", in order to determine the relationships that can be considered determinant factors in energy consumption.

This research was divided into 5 operational phases geared to developing an interpretative model (Figure 1).
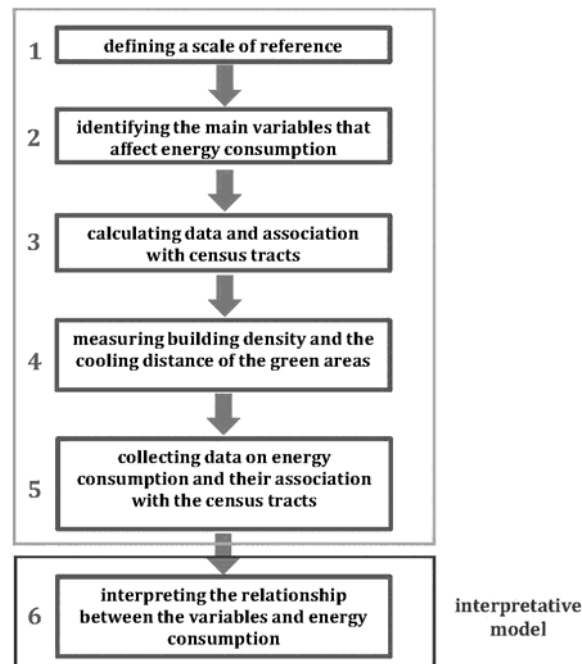

Fig. 1 The phases for the development of the interpretative model

Phase 1. *Defining a scale of reference*

Selecting which neighbourhood to take as a territorial scale of reference, requires the knowledge that a thorough reasoning at this level of space may facilitate analysis of the complex relations between urban systems and energy consumption.

Taking the neighbourhood scale as the base unit actually makes it to possible to establish the relationships between activities, physical characteristics and energetic consumption that could not be identified if we considered one single building, and at the same time makes it possible to identify the portions of territory characterized by different levels of energy consumption within the larger urban scale.

The area where the model was implemented and tested includes the neighbourhoods of Chiaia, Vomero and Arenella, located in the city centre of Naples, and their different geological and functional characteristics, make this a meaningful experiment for the development of an easily replicable model in diverse urban surroundings.

Phase 2. *Identifying the main variables that affect energy consumption*

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The few authors that have addressed the issue of energy on an urban scale have all agreed in their identification of the variables that have a significant impact on energy consumption (Steemers, 2003; Lin et al., 2010; Feng and Zhang, 2012; Soltani et al., 2012; Howard et al., 2012; Ko and Radke, 2013; Papa et al., 2014b). Based on these studies and a thorough knowledge of this area, a set of variables has been established in three categories: physical, environmental, and building.

The physical variables mainly describe the geometry of the urban fabric, while the environmental variables refer to the climatic and morphological characteristics and those for building illustrate the physical characteristics of a building.

PHYSICAL VARIABLES	ENVIRONEMNTAL VARIABLES	BUILDING VARIABLES
Mean building density	Green Plot Ratio[1] (GnPR)	Mean building age
Mean building height	Cooling distance green area[2] (R_i)	Mean surface
Mean aspect ratio	Index Green Ratio[3] (IGnR)	Old masonry buildings
Coverage ratio medio	Slope	Newer concrete buildings
Compactness factor		

Tab.1 Variable's set

Phase 3. *Obtaining data to calculate physical, environmental and building variables and their association with the census tracts for the three neighbourhoods.*

The data to calculate the physical, environmental and building variables were obtained using statistical sources (data from the ISTAT 2011 census) and cartographic data, and the creation of GIS maps based on the three neighbourhoods analysed (plans and orthophotos).

These data were then geo-referenced, or associated with census tracts in order to carry out a series of thematic maps using the variables and significant processed data. All the data obtained were also systematized into two matrices, one for the census tracts, that represent the territorial unit of reference, and the other for buildings.

The choice of census tracts as a territorial unit of reference was made for two main reasons: it consists of the minimum unit of integration of census data, which allows a comparison of the relative data from different areas other than the territorial unit of reference itself.

Phase 4. *Defining a method for measuring building density and the cooling distance of the green areas.*

Almost all the variables were classified using significant intervals so as to allow the joint of the census tracts. The measurement operations also took into account several studies carried out at building level.

For the variables concerning building density and cooling distance of the green areas, it was necessary to develop a specific measurement methodology capable of relating these variables to energy consumption.

This fourth phase basically aims to show the building density and cooling distance of the green areas on the basis of the external surface temperature of the buildings and the air temperature, in order to measure the

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[1]   The Green Plot Ratio is calculated as the ratio between the total green surface within the census tract and its total surface.

[2]   The green areas' *radius of influence* is the maximum distance of cooling beyond which the presence of a green area has no more effects.

[3]   The Green Ratio Index (IGnR) is the ratio between the total green surface within the census tract, including the *radius of influence*, and its total surface.

incidence that these variables have on temperature changes in the urban fabric, and to determine the relevant landmarks for the development of the interpretative model.

According to various authors (Newman and Kenworthy, 1989; Givoni, 1998; Ratti et al., 2005; Salat and Nowacki, 2006; Ewing and Rong, 2008; Doherty, 2009) the building density and the cooling distance of green area variables have a major impact on urban energy consumption.

In addition, the choice to relate them to temperature is also linked to the fact that some researchers have shown that urban morphology and density in particular, influences the urban heat island phenomenon (Oke, 1997; Baker and Ratti 1999; Rizwan et al. 2008) that produces a warmer microclimate within urban areas, and therefore results in an increase in energy consumption especially during the summer months.

A simulation software ENVI-met4, was used to stimulate micro-climatic behaviour and the geometrical and environmental characteristics of the three neighbourhoods. The results of these simulations have made it possible to obtain 'reference values' for both variables, which thus, also measure the incidence of the cooling effect of the green areas in urban areas.

Phase 5. *Obtaining data on energy consumption and their association with the census tracts for the three neighbourhoods*

The data on energy consumption were obtained through the online SIATEL system from the Revenue Agency (Financial law of 2005) and refer to the individual consumers for both, the use of electricity and natural gas; the data also reflect annual turnover (€) and the kWh and cubic metres consumed.

The geolocation of consumption, or in other words, association of the data to the census tracts, comes from the creation of two different geo-databases, for electricity and gas, containing the relationship between consumption and the census sections to which they belong.

Phase 6. *Interpretation of the relationship between the physical, environmental and building variables and energy consumption.*

In order to be able to determine how the urban and environmental characteristics impact on energy consumption, the three neighbourhoods studied were divided into different types of areas, with physical, environmental and homogenous building characteristics for each. Each of these categories has been represented on a thematic map, where comparison with those related to both electric and gas consumption has made it possible to identify the relationship that may depend on energy consumption.

3.2 METHODOLOGY

The aim of this interpretative model is to identify of the physical, environmental and building characteristics that have greatest impact on the consumption of electricity and gas, using a type of 'systemactic' logic at neighbourhood level. The approach used in this research "looks", contextually and simultaneously, at the elements and the relevant relationships in the area of study, emphasizing the physical, environmental and building characteristics that are used to join an urban area. Different classes of census tracts have been identified on the basis of the significant intervals of the variables used.

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[4] Regarding building density, the worst weather conditions during summer and winter have been simulated in order to study the effects of this variable, on energy consumption (cooling) and gas consumption (heating) respectively. The simulations for green areas have been carried out on the hottest day of the last ten years.

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Based on the significant intervals of the values assigned to all the variables, different classes of census tracts were identified with homogeneous internal physical, environmental and building characteristics but different from each other.

To be able to "enforce" all sixteen variables to identify the spatial structure that defines the area under examination, a correlation was mase between each of the urban variables and energy and gas consumption, by means of statistical analysis. The exception is building age and the building density variable, for which the Analysis of Variation (ANOVA) was made as ordinal variables. The Bravais Pearson statistical index was applied for all other alternatives. However, neither the values of the indexes of correlation obtained, nor the ANOVA results, showed significant relationship between any of the variables, including energy consumption, electricity or gas (Tab. 2).

VARIABLES	AVERAGE ELECTRICITY CONSUMPTION	AVERAGE GAS CONSUMPTION
Mean building density	-0,031	-0,037
Mean building height	-0,026	-0,010
Compactness factor	-0,056	-0,058
Mean coverage ratio	-0,026	-0,021
Mean aspect ratio	-0,068	-0,045
GnPr	0,119	0,101
IGnR	0,077	0,093
Mean surface	-0,041	-0,024
Old masonry buildings	-0,024	-0,026
Newer concrete buildings	-0,045	-0,012

Tab. 2 Indexes of correlation between urban variables and energy consumptions

BUILDING AGE

		SUM OF SQUARE	MEAN OF SQUARE	SIG.
	Among groups	49239044,783	12309761,196	
Average energy	Within groups	4439828932,299	11502147,493	0,371
	Total	4489067977,083		
	Among groups	7005,370	1751,343	
Average gas	Within groups	9975628,630	28021,429	0,993
	Total	9982634,000		

Tab. 3 ANOVA results for building age

BUILDING DENSITY (SUMMER)

		SUM OF SQUARE	SUM OF SQUARE	SIG.
	Among groups	461550713,846	115387678,462	
Average energy	Within groups	67950732120,751	164928961,458	0,593
	Total	68412282834,597		
	Among groups	217982,371	54495,593	
Average gas	Within groups	10467628,141	27402,168	0,096
	Total	10685610,512		

Tab. 4 ANOVA results for building densities as a function of surface summer temperature

BUILDING DENSITY (WINTER)

		SUM OF SQUARE	SUM OF SQUARE	SIG.
Average energy	Among groups	200585872,917	100292936,458	
	Within groups	68208960084,303	165154867,032	0,545
	Total	68409545957,220		
Average gas	Among groups	97598,285	48799,142	
	Within groups	10570026,368	27597,980	0,172
	Total	10667624,653	100292936,458	

Tab. 5 ANOVA results for building densities as a function of surface winter temperature

In a literature review on this topic, four variables stand out because they can summarize the entire information content: building density, the green areas' radius of influence, building height and age. Building density can especially be considered an indicator of the synthesis of the morphological characteristics of the city, since it refers to factors such as volume and compactness.

The Green Index Ratio (IGnR), which describes the cooling distance of green areas and takes into account the portion of territory affected by the presence of a green area (radius of influence), has been chosen rather than the Green Plot Ratio (GnPR) because the latter has a less relevant information content in terms of energy consumption since it is calculated just as the percentage of green areas respect the total area. The software ENVIMET has been used to calculate the radius of influence of a green area, because it is able to simulate the effets of vegetation evapotranspiration on adjacent urban areas.

The building age also provides information related to the materials used, and therefore the variables related to old masonry buildings and newer concrete buildings. Lastly, the building height, represents one of the most relevant variables in literature.

A classification of the census tracts was carried out for each of these variables, based on the values that the variables adopt (Figures 2,3,4,5 and 6).

Then, in a GIS environment, different stepwise queries were used in order to classify the census tracts based on the sixteen characteristics considered.

In other words, some geo-processing operations relating to spatial analysis were carried out, such as 'overlay', i.e. the overlap of the different variables through the following stages of recalibration of the ranges of the variables, so as to bring out the features of the area of study that best represent the differences between the three neighbourhoods (Figure 7).

Furthermore, in order to ease the interpretation of the results, the 56 sections of open spaces were removed (parks and squares).

The relationships between the four substantial variables were used to define the classes of areas, in particular by referring to both the range of variation within each class and its average value compared with the average value of the entire urban system (Tables 6,7,8).

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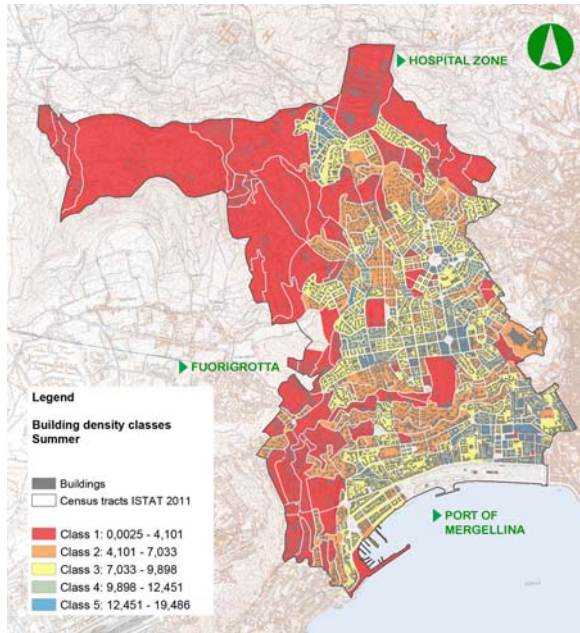*Copenhagen, 12-14 May 2015*
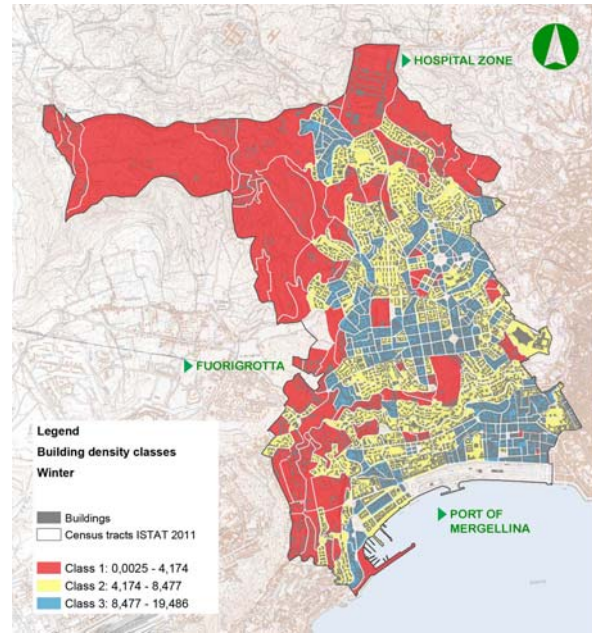
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Fig. 2 Building density ranges summer

Fig. 3 Building density ranges winter
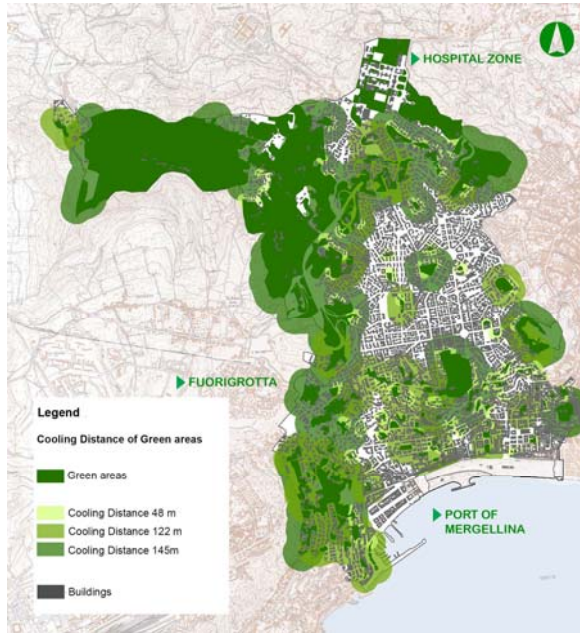
Fig. 4 Cooling distance of green areas

Fig. 5 Age of buildings

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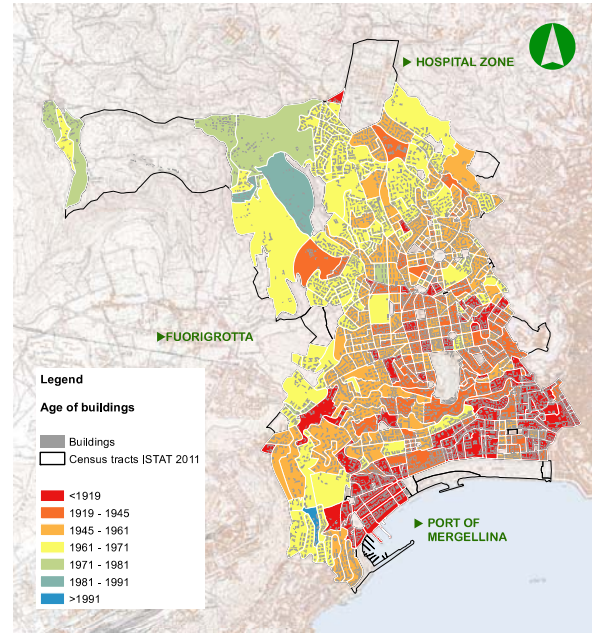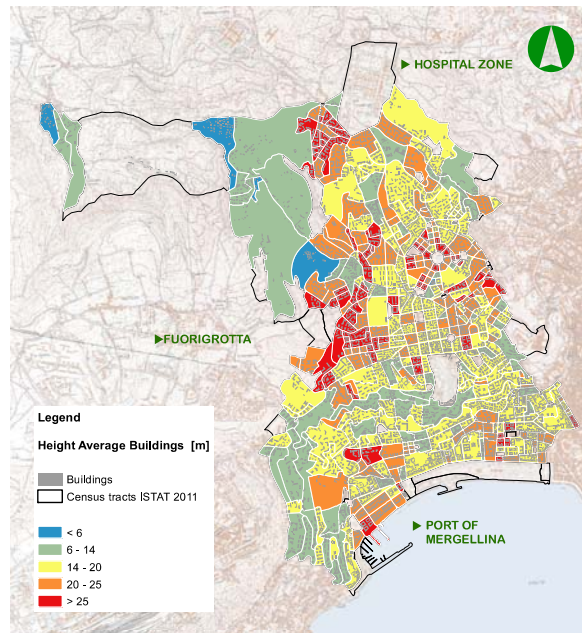
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Fig. 6 Height average buildings

The three classes of census tracts identified are:

— Census tracts characterized by low building density, building age 1961-1971, and buildings at least 4 floors in height, with lower residential density values than the average for the overall system of reference. Most of the buildings in this class of census tracts developed unevenly with no clear planning pattern, connected by rather narrow "interweaving" roads, thus providing limited available space free from buildings.

This can be defined as the *"No planned areas"* class.

— Census tracts characterized by low building density, the significant presence of green areas, and tall buildings of around three floors in hilly locations. In other words, the Class 2census tracts are located mainly in the areas of Chiaia and Arenella, particularly those located in Posillipo in the first case and Camaldoli in the second case.

This can be defined as the "*High Green Index Areas"* class.

— Census tracts characterized by high building density, buildings of at least six floors, and compact and predominately historical buildings. The census tracts of this type seem to represent a planned and compact urban fabric, built according to one single plan. It is based on a "foundation area" in neighbourhoods that have been drawn and designed, providing a woven chessboard framework as is the case of "Piazza Vanvitelli" and "Medaglie d'Oro". It is no coincidence that most of the census tracts in Vomero and the different parts of Chiaia such as Viale Gramsci belong to this class.

This can be defined as the "*Organized Medium To High Density Areas*" class.

3.3 RESULTS

The intersection of physical, environmental and building variables made it possible to establish three classes of areas within the areas of study.

Both the gas and electricity consumption have been compared for each of these types of areas, in order to identify the characteristics that impact on energy consumption.
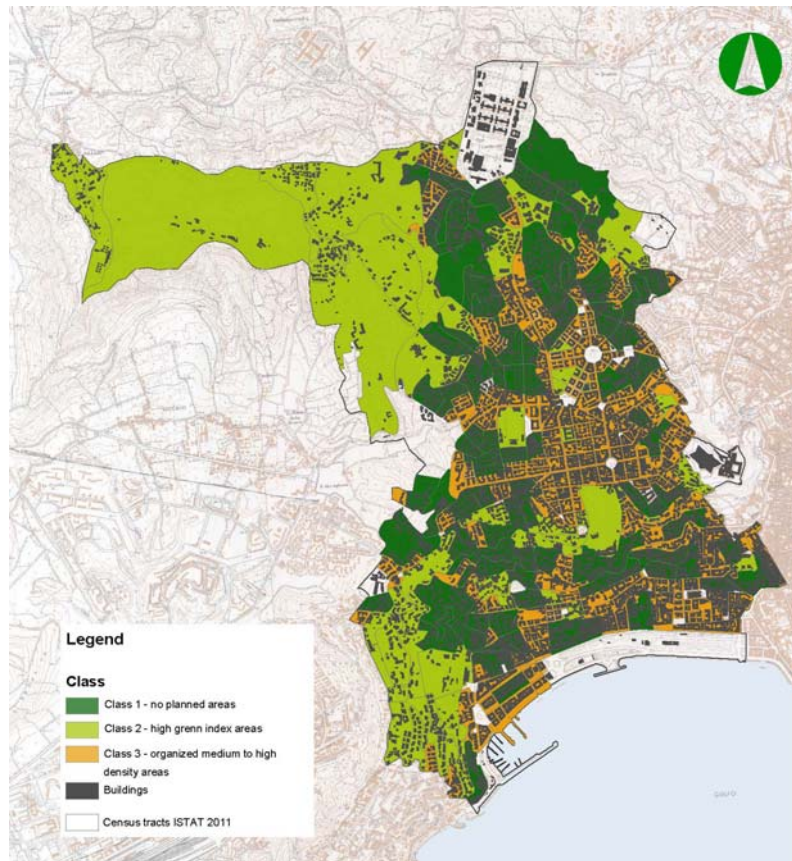
Fig. 7 Classes of census tracts identified within the three neighbourhoods of study

	VALUE RANGE	AVERAGE VALUE
Building Density	2,2 mc< d <19,5 mc	7,81 mc
IGnR	-	0,50
Height Average Buildings	11,5 m< h <31,4 m	18,84 m
Building Age	most '61 - '71	-

Tab. 6 Average values for the first class. No planned areas

	VALUE RANGE	AVERAGE VALUE
Building Density	0,44 mc< d <7,15 mc	2,76 mc
IGnR	-	0,84
Height Average Buildings	5,46 m< h <21,4 m	10,87 m
Building Age	most after '61	-

Tab. 7 Average values for the second class. High Green Index Areas

	VALUE RANGE	AVERAGE VALUE
Building Density	2,2 mc< d <19,5 mc	8,92 mc
IGnR	-	0,16
Height Average Buildings	9,8 m< h <32,6 m	19,6 m
Building Age	most before '45	-

Tab. 8 Average values for the third class. Organized Medium To High Density Areas

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Because of the systemic approach on which this research is based, a comprehensive interpretation of the different variables taken into consideration was carried out, i.e. urban and energy variables, to provide the first indications of the physical elements that have more impact on energy consumption. Basically, within each of these areas, the census tracts with the highest level of energy consumption were identified and these were recognized as the most widespread urban features, able to provide useful information to identify urban intervention and reduce energy consumption.

THE "NO PLANNED AREAS" CLASS AND ENERGY CONSUMPTION

The census tracts within this class have a high level of energy consumption (> 3822kWh / year) at about 11%, mostly in Chiaia, a neighbourhood characterized by a gentle slope (<150 m above sea level).

This information may be a useful initial indicator, as of the other sections with the same characteristics, it presents a lower consumption, located in steeper areas, for example, the census tracts around Cardarelli hospital.

Also taking into consideration building density and the average height of the buildings, the census tracts are characterized by a medium building density (0.0025 to 9.9 m³ / m²) and medium-to-tall buildings (at least 12 m).

As for the green areas, there seems to be a detrimental element in terms of consumption, and the level of electricity consumption is high, being strongly affected by the cooling effect of the green areas.

Changing the focus to the census tracts characterized by higher gas consumption, the first indication is that only two out of ten (20%) energy-intensive sections, in terms of electric consumption, present higher gas consumption.

Moreover, it appears that the few sections that present higher gas consumption, roughly 5%, are characterized by medium building density (4 - 9 m³ / m²) and buildings at least 18 m tall. Also in this case the presence of green areas distinguishes the energy-intensive sections in terms of gas.

Unlike the findings concerning electricity consumption, increased gas consumption does not seem to have been influenced by slope variations.
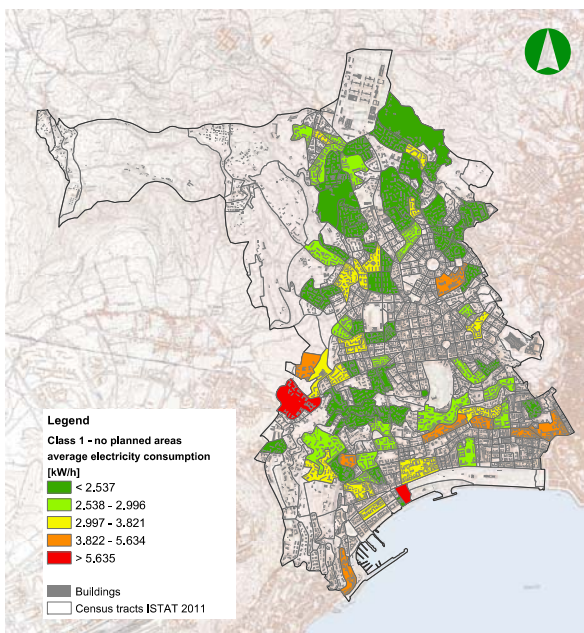
Fig. 8 Average electricity consumption class 1

Class 1 - *No Planned Areas*

AVERAGE ELECTRICITY CONSUMPTION

% highest consumption census tracts	11%

Tab. 9 Average electricity consumption class 1

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST ELECTRICITY CONSUMPTION CENSUS TRACTS

Building density	Medium 0,0025 – 9,9 mc/mq
Height average buildings	Medium to tall, at least 12 m
Green areas	yes
Elevation	low 0 - 150 m.a.s.l.

Tab. 10 Common characteristics class 1

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Class 1 - *No Planned Areas*

AVERAGE GAS CONSUMPTION

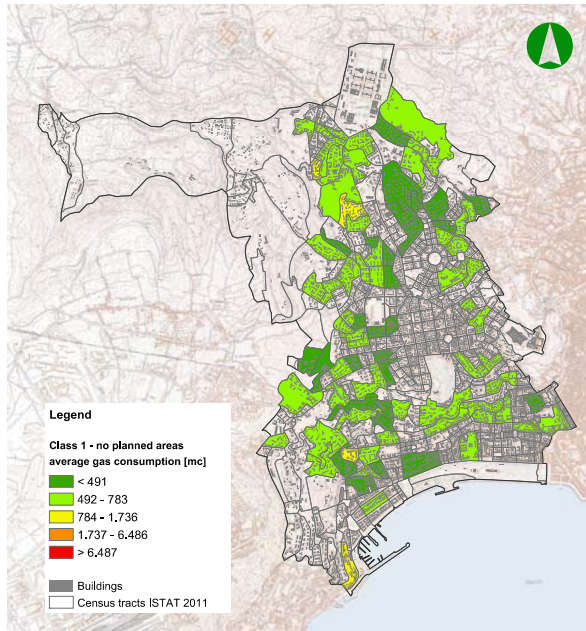| % highest consumption census tracts	5%

Tab. 11 Average gas consumption class 1

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST GAS CONSUMPTION CENSUS TRACTS

Building density	Medium 4 – 9,9 mc/mq
Height average buildings	Tall, at least 18m
Green areas	yes
Elevation	-

Fig. 9 Average gas consumption class 1

Tab. 12 Common characteristics class 1

THE "HIGH GREEN INDEX AREAS" CLASS AND ENERGY CONSUMPTION

In terms of electricity consumption this class is characterized by a greater number of energy-intensive census tracts (27%), compared to the other two classes.

This condition can be explained by the low values of building density (0.002 to 7 m³ / m²) and the strong presence of green areas. These elements distinguish this class, in particular the features that showed increased consumption in energy-intensive census tracts belonging to class 1.

The census tracts with high electrical consumption within this class (Class 2) also seem to be mainly characterized by the low average height of the building (maximum 12 m).

Class 2 - *High Green Index Areas*

AVERAGE ELECTRICITY CONSUMPTION

% highest consumption census tracts	27%

Tab. 13 Average electricity consumption class 2

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST ELECTRICITY CONSUMPTION CENSUS TRACTS

Building density	Medium 0,0025 – 7 mc/mq
Height average buildings	Low at most 12 m
Green areas	yes
Elevation	-

Fig. 10 Average electricity consumption class 2

Tab. 14 Common characteristics class 2

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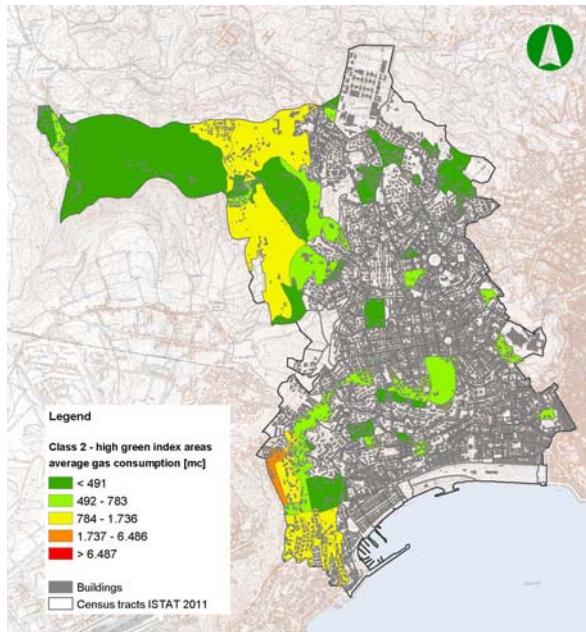
Fig. 11 Average gas consumption class 2

Class 2 - *High Green Index Areas*

AVERAGE GAS CONSUMPTION

% highest consumption census tracts	8%

Tab. 15 Average gas consumption class 2

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST GAS CONSUMPTION CENSUS TRACTS

Building density	Medium 4 – 9,9 mc/mq
Height average buildings	Low at most 12 m
Green areas	yes
Elevation	-

Tab. 16 Common characteristics class 2

Some census tracts marked by high electricity consumption, also present higher average gas consumption values (16%).

The interesting aspect is that the presence of high consumption both electricity and gas is found in those sections located in the hilly areas of Posillipo and Camaldoli, areas in which, as mentioned before, the strong presence of green areas is associated with low building values.

This result seems to support previous studie showing that urban areas with low density values are characterized by higher energy consumption (Andrews 2008; Ewing & Rong 2008).

Unlike the energy consumption findings for Class 1, the clinometric index for Class 2 does not seem to be significant.

THE "ORGANIZED MEDIUM TO HIGH DENSITY AREAS" CLASS AND ENERGY CONSUMPTION

The several census tracts of this class with high electricity consumption (24%) are characterized, in most parts, by high building density values (> 10 m³ / m²) and also by tall buildings of at least 18m.

The majority of these energy-intensive sections also seem to be characterized by the absence of green areas or appear to be located beyond the maximum distance of cooling of the green areas.

This element confirms the different studies that support the importance of green spaces in a positive reduction of energy consumption (Akbari *et al.* 2001; Hong Ye *et al.* 2013).

Moving now to the census tracts characterized by higher gas consumption, the first findings show that 16 out of 24 (66%) energy-intensive sections also have high gas consumption, compared with electricity consumption. Moreover, it appears that the census tracts with higher gas consumption (13%) are largely characterized by medium to high building density values (> 7mc / sqm) and have tall buildings at least 18m. These are the census tracts most are affected by the areas of influence of some of the green areas existing in this class located within the Chiaia area, especially those areas with a low slope (0-150 m above sea level).
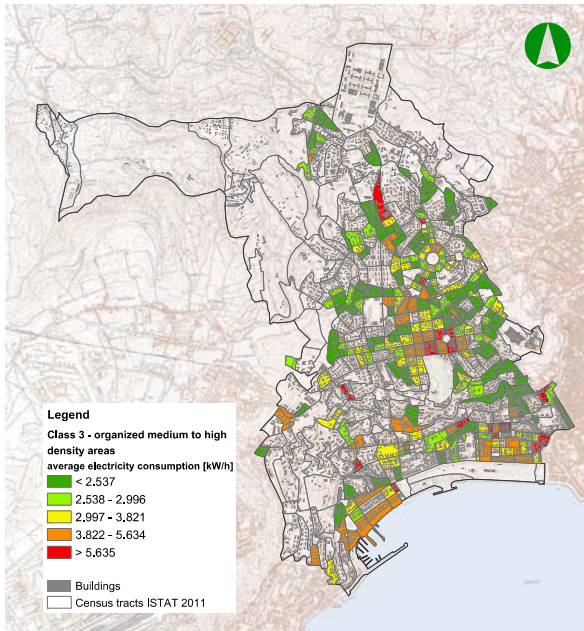
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Fig. 12 Average electricity consumption class 3

Class 3 - *Organized Medium To High Density Areas*

AVERAGE ELECTRICITY CONSUMPTION

% highest consumption census tracts	24%

Tab. 17 Average electricity consumption class 3

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST ELECTRICITY CONSUMPTION CENSUS TRACTS

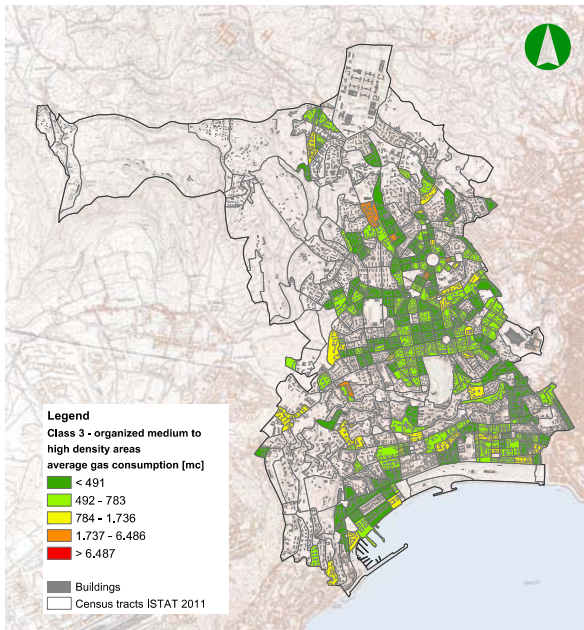| Building density	high >10 mc/mq
Height average buildings	High, at least 18 m
Green areas	no
Elevation	-

Tab. 18 Common characteristics class 3

Fig. 13 Average gas consumption class 3

Class 3 - *Organized Medium To High Density Areas*

AVERAGE GAS CONSUMPTION

% highest consumption census tracts	13%

Tab. 19 Average gas consumption class 3

COMMON CHARACTERISTICS OF MOST OF THE HIGHEST GAS CONSUMPTION CENSUS TRACTS

Building density	Medium to high ›7 mc/mq
Height average buildings	Tall, at least 18 m
Green areas	yes
Elevation	low 0 - 150 m.a.s.l.

Tab. 20 Common characteristics class 3

4   DISCUSSION

The interpretative model is the "translation key application" of the systemic approach, adopted to identify which of the physical, environmental and building variables can be deemed responsible for possible electricity and gas consumption.

These characteristics were defined for each of the three classes of areas in which the three neighbourhoods of study were divided, thanks to the variables common to most of the census tracts defined as energy-intensive. Class 1 is characterized by buildings built after the 60s, buildings at least 4 floors tall, and medium building density values. These features seem to distinguish both the energy-intensive sections from an

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electric energy point of view and gas, with less than the height of the buildings more extensively elevated in accordance to the second type of consumption.

The presence of green areas can represent an additional element to attribute to the increased consumption of energy-intensive census tracts in terms of electricity and gas.

Class 2 is strongly characterized by a physical and environmental variable: low building density and the considerable presence of green areas. These features, together with three-storey buildings built in mostly hilly locations after 1960, can be identified as the elements that affect the consumption in energy-intensive sections both in terms of electricity and gas.

Class 3 is characterized by buildings of at least six floor, mostly compact and built before 1945 ('historic buildings'). These features are common to energy-intensive census tracts in terms of both electricity and gas. They differ with regard to those green areas which seem to be a 'worsening' element, but only in terms of gas consumption.

The following charts show the characteristics of energy-intensive census tracts described above:

ELECTRICITY CONSUMPTION

	CLASS 1 NO PLANNED AREAS	CLASS 2 HIGH GREEN INDEX AREAS	CLASS 3 ORGANIZED MEDIUM TO HIGH DENSITY AREAS
% highest consumption census tracts	11%	27%	24%
CHARACTERISTICS OF THE ENERGY-INTENSIVE CENSUS TRACTS			
Building density	Medium	Low	High
Average height buildings	Medium to tall	Low	Tall
Green areas	Yes	Yes	No
Elevation	Low	-	-

Tab. 21 energy-intensive tracts' characteristics in relation to energy consumption

GAS CONSUMPTION

	CLASS 1 NO PLANNED AREAS	CLASS 2 HIGH GREEN INDEX AREAS	CLASS 3 ORGANIZED MEDIUM TO HIGH DENSITY AREAS
% highest consumption census tracts	5%	8%	13%
CHARACTERISTICS OF THE ENERGY-INTENSIVE CENSUS TRACTS			
Building density	Medium	Low	Medium to high
Average height buildings	Tall	Low	Tall
Green areas	Yes	Yes	Yes
Elevation	-	-	Low

Tab. 22 Energy-intensive tracts' characteristics in relation to gas consumption

A qualitative comparison between the physical, environmental and building characteristics that seem to affect the consumption of electricity and gas, prompts the following considerations:

- Low values of building density and low building height of are associated with higher values of electricity and gas consumption. The reasons for such consumption levels are offset in several studies, according to which the parts of the urban territory with few built-up areas show a higher level of energy consumption and have residences of considerable size (terraced houses) that

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require greater quantities of energy for various purposes (heating, cooling, etc.) and, being located randomly throughout the territory, have more external dispersed surfaces which require a greater amount of energy. Furthermore, the strong presence of green spaces on one hand thighlights a negative influence in terms of gas consumption, because of the need for a greater use of heating during the winter, but on the other, it does not seem to be reflected in those studies that support the positive effect of green spaces on the reduction of the temperature and subsequently the reduction of energy consumption during the summer.

— The medium building density values and high buildings are associated with higher consumption of electricity and gas. Such levels of energy consumption are due to the fact that they belong to densely constructed portions of urban areas with numerous business activities and consumers, as well as the increased need for artificial lighting, and air conditioning in the summer season. Moreover, the high consumption of gas is most likely due to the greater shadow effect created by the proximity of the buildings. Inside the portions of urban areas possessing these building density and building height characteristics, the influence of green spaces on energy consumption is not easy to determine.

The foregoing considerations seem to suggest that the highest consumption of electricity and gas within some census tracts of the three areas of study are not totally influenced by the sixteen variables considered. Firstly, in order to help clarify some of the issues that for have long captured the attention of researchers, it is possible to say that building density by itself is not enough to analyse energy phenomena. Although building density cannot be overlooked when studying the relationship between energy consumption and urban systems, energy issues at neighbourhood level and thus on an urban scale, cannot be addressed by reducing everything in terms of building density.

The oversimplification that characterizes research related to energy consumption on an urban scale, especially that relating to the form and dimension of cities, studying the parameters that work independently of each other, has been evaluated in this research work, but an attempt has been made to improve it through an interpretation of the different variables examined in order to identify which physical, environmental or building features have greater impact on the consumptions of energy and gas.

High levels of building density or low density with the presence or the absence of green areas, high buildings or low buildings have different impacts on energy consumption and therefore the possibility of identifying an "ideal" sustainable urban form able to maximize the energy efficiency is still theoretical (Doherty et al., 2009). These results suggest a serious analysis of the validity of this ambitious goal of identifying a unique pattern that correlates urban form and energy consumption, opening up the possibility of reformulating this goal based on the assumption that there is not only one, but several consumption patterns due to the different physical, environmental and building characteristics of different urban areas.

In conclusion, the decision to adopt an integrated holistic approach rather than a sectorial one and to consider the dimensions of the neighbourhood rather than the building, made it possible to explore the relationship between city and energy, taking into account the many features of the physical level. This type of approach has confirmed the complexity of the relationships between these characteristics and energy consumption and therefore, the inadequacy of using a sectorial approach. In addition, along with the physical and social characteristics, if one adds the financial and social characteristic, the relationship between urban space and energy consumption would become even more complex and multi-dimensional, and the definition of a unique solution of interpreting the relationship between cities and energy becomes extremely difficult as already pointed out by Doherty et al. in 2009.

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Furthermore, the use of a holistic approach also represents a fundamental requisite in the development of more smart and resilient cities to better face the local challenges dictated by climate change.

Deepening the knowledge of the complex relationship between the characteristics of the urban space and energy consumption makes it possible to define on which "site-specific" elements to intervene, in order to make a more rational and efficient use of available resources and so to enhance the urban resilience.

In other words, this work represents the step in the more and more widespread and broad debate on which features allow to create a resilient and smart city (EEA 2008; Jabareen 2013).

The complex and multi-dimensional nature of both the energy phenomena and urban systems, provide many interesting ideas for the future development of this research work.

Firstly, one of the possible subjects of study is to expand the application of the interpretative model to an urban area, including different variables, for example those describing functional specialization, such as climate and the transportation behaviour of the consumers.

A further point of interest might be to deepen the impact of the green areas on the consumption of electricity and gas, as the results obtained in this research work do not appear to be sufficiently clear.

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