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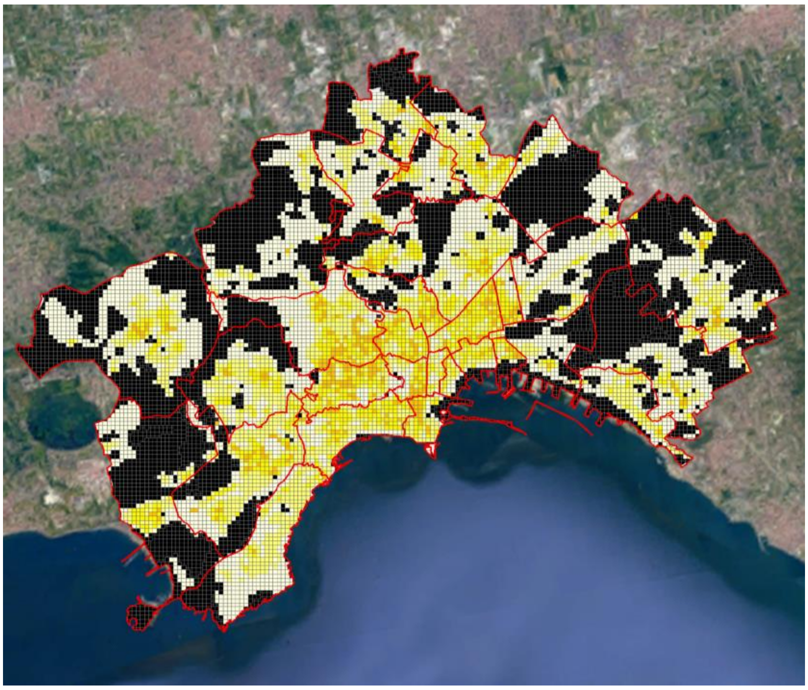

THE END-USE ELECTRIC ENERGY CONSUMPTION IN URBAN AREAS: A GIS-BASED METHODOLOGY.

AN APPLICATION IN THE CITY OF NAPLES.

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ABSTRACT

This work is part of the scientific research sector concerning the Government of Urban and Territorial Transformations in order to promote efficiency and reduction of energy consumption in urban areas. The contribution proposes a further deepening of the research work already carried out under the project Pon "Smart Energy Master" by the research group of the Laboratory of Territory, Mobility and Environmental (TeMA Lab) of Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II. The aim is to assist public authorities, that also deal with the Urban Energy Governance, in determining the quantitative distribution of domestic and non-domestic electric energy consumption. Toward this goal, we use the Big Data, the Open Data and the Geographic Information System (GIS) techniques. In particular, this work developed a innovative GIS-based methodology that allows the knowledge, classification and representation of real electric energy consumption at micro scale for the domestic and non-domestic. Also, we validate the GIS-based methodology by an application at the city of Naples. We used the electric energy consumption data of year 2011 were given by Municipality Authority and Italian Revenue Agency. This will allow the identification of the electric energy problems present in the area of analysis in order to plan any intervention strategies. This contribution is divided into three main parts. In the first part, an analysis of the scientific literature is proposed on the theme of the Government of urban and territorial transformations and opportunities arising by Big Data, Open Data and GIS in the reduction of electric energy consumption. The second part explains the theoretical and technical phases that led to the development of the GIS-based methodology. In the last part, the application of the GIS-based methodology at the City of Naples is described.

KEYWORDS:
GIS; Big Data; Smart City; Electric Energy Consumption.

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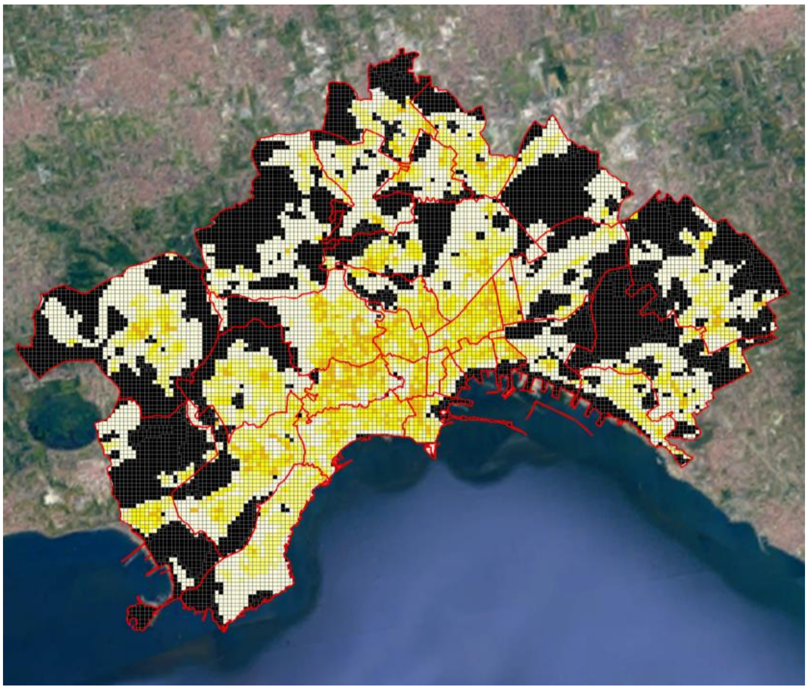

城市区域终端用电能耗：基于 GIS的研究方法。

摘要

本文为“城市管理与区域转换”相关的系列科研区域的组成部分，旨在促进城市区域能源高效和减少能耗。本文进一步深入研究了领土实验室、不流动性和环境博物馆、建筑与环境工程和那不勒斯费德里克二世大学组成的科研团队曾主持研究的“智源大师”项目。旨在推动公共管理，同时处理城市能源管理问题，了解国内外能耗的数量分布。为实现这一目标，我们采用了大数据、开放数据和最新地理信息系统（GIS）进行分析。本文尤其分析了可确定、划分和描述城市电能耗问题的 GIS 研究方法。这将有利于确定分析领域出现的能源问题，方便拟定干预策略。本文正文可分为三大主要部分。第一部分分析了城市管理和区域治理为主题的科学文献，它们希望减少能耗并利用大数据、开放数据和GIS应用过程产生的减少能耗的机会第二部分解释了促进以 GIS 为基础的研究方法的理论发展阶段和技术发展阶段。最后，第三部分叙述了以 GIS 为基础的研究方法在那不勒斯市的应用及分析结果。

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关键词：
GIS、大数据、智慧城市、电能耗

1 INTRODUCTION

The paper proposes another step forward in the scientific research work carried out under the project Pon "Smart Energy Master" (SEM) by the research team of the Laboratory of Territory, Mobility and Environmental (TeMA Lab) - Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II – aimed at developing a model of governance for the energy efficiency of the territory. After more than three years of work the project finished in January 2016. During which a series of topics closely related to the functioning of urban systems were explored like growing unsustainability urban systems, the possible advantages to apply a smart approach and the probable future evolutionary trajectories (Papa et al., 2016). A specific and innovative feature of the SEM project has been the definition, both in qualitative and quantitative terms, of the causal relationships between energy consumption and urban form of the city.
The purpose of this study is to support public administrations, also dealing with the Urban Energy Governance, in determining the distribution and variation of urban energy consumption. These two characteristics facilitate the identification of strategies and actions useful to the reduction and optimization of domestic and non-domestic electric energy consumption. The objective is to develop, starting from the electric energy data of the individual users, a methodology able to quantify and geolocalize the distribution and intensity of electric energy consumption of the domestic and non-domestic users. This methodology thus allows the public administrations to identify and to analyse the high energy-consuming areas, in order to be able to intervene in the resolution of any critical issues, linked to the excessive and unsustainable use of the energy resource. In the following paragraphs are described the theoretical and practical research work phases to aimed at the collection, geolocalize and represent of the data related to electric energy consumption on an urban scale. In particular, the methodology has been developed thanks to the availability of Big Data, Open Data and Geographic Information System (GIS) software that can collect, store, manage and analyse such data types.

2 THE ENERGY GOVERNANCE OF THE TERRITORY

This work arises in a context where the number of urban inhabitants is increasing rapidly with, 54 per cent of the world’s population residing in urban areas in 2014. In particular, for the Europe continent this percentage is over 73 per cent and by 2050, 66 per cent of the world’s population is projected to live in urban area. (UN, 2014).
The growth of the urban population makes the study of the negative consequences of this phenomenon an essential activity (Barles, 2010; Papa et al., 2014a). In particularly, one of the most worrying aspects connect to this phenomenon is the finding of the resources necessary to the livelihood and development of urban areas and their citizens (Anderson et al., 1996; Havranek, 2009). Over During the last few decades, some critical events have already occurred as a result of temporary difficulties in the finding of indispensable resources for life (oil crisis 1970s). The occurrence of these events has generated greater awareness in the finding and use of non-renewable resources, which has also led to greater sensitivity in the preservation of the environmental component. One of the first international documents that dealt with this issue is the Brundtland Report. In 1983, the United Nations General Assembly entrusted the World Commission on Environment and Development (WCED), composed of representatives from twenty-one countries, with the objective to write a report on status of the world environment and development (Our Common Future). The report highlighted the need to implement a strategy that would integrate the needs of development with the need to safeguard the environment component. These indications, in the following years, have been further deepened and have been concretized in laws and programmatic documents (UN, 1998; EU, 2004). Among the sectors concerned by the indications of the Brundtland report, there is also the sector that deals with the Government of urban and territorial transformations. Therefore, energy demand in cities should be a dominant issue. In the EU, the

residential building sector is responsible for about 22% of total energy consumption (IEA, 2011). The increase of energy consumption by the urban population could endanger economic development because the consumption of energy reducing the resources available to productive sectors.

The most important Italian regulation introducing prescriptions on energy planning issues, is Law n.10/1991 "Regulations for the national energy plan for the rational use of energy, energy saving and development of renewable sources of energy". This law, rather outdated by now, introduced the drafting of plans that address the deployment of energy from renewable sources, the identification of territorial energy basins, the localization of the electric energy systems and the energy balance of territorial jurisdiction (Battarra, 2014).

In recent decades, the researchers have concentrated their efforts on design and management solutions that can improve the environmental sustainability of urban and territorial systems. In this sector, one of the components that has attracted particular interest is that of energy. The production, distribution and end use of energy has a strong impact on the consumption of environmental resources and the placing in the environment of polluting substances. There are numerous research and projects aimed to improving the sustainability of this component. In particular, two macro sectors that study this aspect can be identified, related to:

- improving the sustainability of production and distribution processes (Orgerie et al., 2014);
- reducing and optimizing energy consumption by end users (Omer, 2008; GhaffarianHoseini et al., 2013).

As regards the second aspect in the scientific field is now shared the need to use an integrated approach that points to consider all the components that contribute to determine the demand for energy consumption (Steemers, 2003; Papa et al., 2014b). One of the main questions of research formulated in recent years has focused on the calculation of energy consumption on an urban scale for different categories of users. It is particularly important to know the energy consumption from a quantitative and distributive point of view in order to be able to foresee appropriate intervention strategies which are able to affect significantly improvement in the sustainable use of this component. There are numerous operational and technical solutions developed on a national and international level to attain a reliable quantitative and distributive calculation of energy consumption (Frayssinet et al., 2017; Šćepanović et al., 2017).

These solutions are principally aimed at the realization of energy models that differ in the method of calculation for different scales of analysis (single real estate unit, building, district and urban area) and for the type of users analysed (residential, business, industry, transportation). In generally, the methodologies for calculating energy consumption can be divided into two distinct approaches: top-down and bottom-up (Swam and Ugursal, 2009). Predictions models evaluate, in a parametric way, the response of a system to a given set of technical variables and identify the possible impacts and likely costs/benefits of the analysed configuration (Zhao and Magoulès, 2012). The top-down approach treats the domestic sector as an energy sink and is not concerned with individual end-uses. The bottom-up approach extrapolates the estimated energy consumption of a representative set of individual buildings to regional and national levels.

In recent years, the increasing availability of hardware and software tools able to collect, manage and process high amounts of data, has also allowed an improvement in the quality of results. In particular, the possibility of using detailed input data has allowed the development of new ways of calculating energy consumption, improving the level of detail and accuracy of results.

2.1 BIG DATA AND OPEN DATA

One of the main problems in the study of urban and territorial systems is the difficulty of finding adequate data, both in terms of quantity and quality. The actually complexity that characterizes both urban and territorial systems and the activities it takes place, makes the data have become a torrent flowing into every area of the economy (Economist, 2010). In recent years, a growing support has been lead from the new sources of data

obtained by the use of the latest hardware and software technologies. Among the categories of data, which have a greater interest and use within the technical-scientific community in recent years, there are big data and open data.
Big Data is an extensive data collection in terms of dimension, collection speed and variety that requires the use of specific technologies and analytical methods (De Mauro et al., 2016). The progressive increase in the size of the databases, which characterize Big Data, allows the extraction of additional information from that obtainable by analysing small data sets. There is no limit of size in the collection and analysis of Big Data other than that linked exclusively to the capacity of the instrumentation used in its collection, storage and processing. On the basis of a study carried out in 2001, the Big Data growth model is defined as three-dimensional: over time the volume, speed and variety of data increase (Laney, 2001). In many cases this model is still valid, although in 2012 a fourth variable was inserted, the veracity.
The second category of data considered is Open Data, which is a type of freely accessible data, without patents or other forms of control that restrict its reproduction and whose copyright restrictions may be limited to the obligation to cite the source or the issue of the changes in the same way. Open Data invokes the wider Open Government discipline, whereby public administration should be open to citizens, in terms of transparency, but also through the use of new information and communication technologies (European Parliament, 2007). The Open Data frequently refers to information represented in the form of databases and related to the most disparate issues.

2.2 THE GEOGRAPHICAL INFORMATION SYSTEM

The growing availability of data has required the development and use of new computer tools able to manage and process it. Among the software computer tools currently most used in the field of Government of urban and territorial transformations are the Geographical Information System (GIS) (Burrough, 1986). Through the use of GIS alphanumeric data (numbers, textual information, documents) can be elaborated, organized, stored and connected to specific geometrical elements that can represent territorial entities (urban areas, infrastructure networks, mobility networks, buildings). In general, the GIS software is configured as an "operating environment" within which it is possible to develop management and decision support tools for the analysis, transformation and management of the territory (Fistola, 2009). The structure of GIS is composed of two components closely connected and interrelated: Cartography and alphanumeric data. The first component is the cartographic base that contains the geometrical elements (vector and raster), that have specific references and coordinates. The second component consists of the set of information and data that can be connected to every single geometrical element. Through the application of specific procedures, it is possible to connect elements belonging to both components in order to define a system that can provide not only information on individual elements in a static way, but also descriptions of the evolution of territorial phenomena or to highlight the areas where common values are manifested (Papa, 2009). In addition, GIS allows the development of numerical cartographies that represent and identify the elements and phenomena present on the study area. Therefore, GIS is a valuable technical support tool for decision-making processes, which enable the identification of choices in order to respect the principles of objectivity, transparency and environmental sustainability (Campagna & Matta, 2014).

3 GIS-BASED URBAN ENERGY CONSUMPTION TOOL

The following paragraphs describe the structure of the GIS methodology developed, which allows one to quantify the real energy consumption, for domestic and non-domestic users, located in the study area (Papa et al., 2017). This GIS-based methodology, called Urban Energy Consumption Tool, solves some of the main limits of traditional energy consumption calculation techniques that mainly involve the use of simulation models top-down and bottom-up (Swam and Ismet, 2009). The limits of the top down models are the reliance on historical consumption information, no explicit representation of end-uses and the coarse analysis. The Bottom-up models presents some limits that depend to multicollinearity, large survey sample to exploit variety and determination of end-use qualities based on simulation. These methodologies have some issues that relate to the reliability of the results, which depend on the complexity of the computation model and the level of detail of the data used input (Kavgic et al., 2010). These limits also restrict applicability, because the model's reliability varies in relation to variation in the structural and morphological characteristics of the context and the availability of data. For these reasons this study proposed a new GIS-based methodology to calculate the real energy consumption for domestic and non-domestic users. The methodology is composed of three main steps described below: (i) The individuation and retrieval of the data; (ii) The structuring and processing of data by GIS; (iii) The classification and representation of results by GIS.

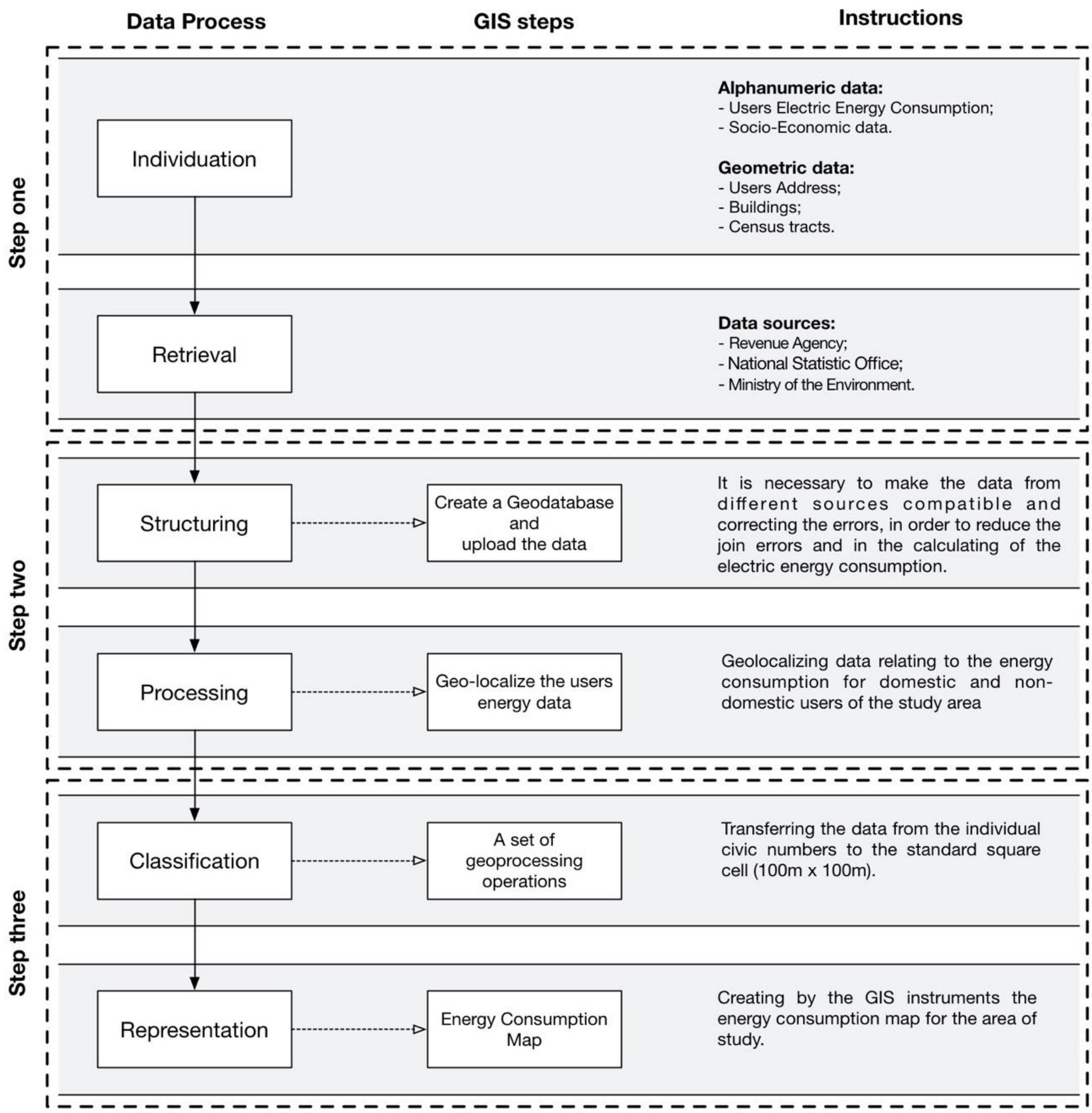

Fig. 1 GIS-based methodology workflow of Urban Energy Consumption Tool

3.1 THE INDIVIDUATION AND RETRIEVAL OF THE DATA

This first step concerns the individuation and retrieval of the data necessary to calculation the electric energy consumption for the study area. In order to solve some of the main problems that characterized the previous methodologies of calculating the electric energy consumption for the domestic and non-domestic users, only the alphanumeric and geometrical data freely accessible to the technicians of the public administrations and to the researchers were used. Based on these indications, the sources of the data individuated were the Italian Revenue Agency, the municipal authority, the National Institute of Statistics and the National Geoportal of the Italian Ministry of the Environment and Protection of Land and Sea. Thus, through the open access databases provided by these sources, the alphanumeric and geometrical data needed to set up the GIS methodology were found, as shown in Tab. 1.

Data	Type	Source
Electric Energy Consumption	Alphanumeric	Italian Revenue Agency and Municipality of Naples
Socio-Economic	Alphanumeric	National Statistic Office ISTAT
Address	Geometric	Ministry of the Environment
Buildings	Geometric	Ministry of the Environment
Census tracts	Geometric	National Statistic Office ISTAT

Tab. 1 The list of data necessary for the application of the GIS methodology

In particular, the information platform SIATEL 2.0 of the Italian Revenue Agency, allows local authorities to consult and download the alphanumeric data present in the tax registry for any individual or company throughout the national territory.

Among the available data there are those relating to electricity users, with the annual electric energy consumption of the residents since 2005. It is worth clarifying that the consumption data on the platform does not consider the production of energy obtained from production plants installed on the individual buildings. The availability of this data to public administrations was ensured by the 2005 Financial Act (art. 1 com. 332, 333 e 334 of the low n. 311 31/12/2004), which obliges all companies providing electricity, water and gas services to inform the Italian Revenue Agency of the consumption data of the users. As part of the GIS methodology developed, further data found are those provided by ISTAT relate the censuses of the censuses of Population and Housing and Industry and Services. These two ISTAT censuses, which analyse the economic, social, territorial and built environment aspects, are held every ten years throughout the national territory and the data are available in open aggregate format for single census section. In general, a census area is the "homogeneous" part deriving from a subdivision of the municipal territory. The different size of each census area is influenced by the physical and socio-economic structure.

In order to geolocalize the alphanumeric data of the energy consumptions of the single users, it is necessary to use a GIS software, with which it is possible to manage and visualize in a combined way the alphanumeric and geometric data. The National Geoportal operates within the regulatory framework established by the D.Lgs. 32/2010 e s.m.i., that implements the European directive INSPIRE (2007/2/CE) aimed at implementing the diffusion of geometric data infrastructure in the European Community.

Through the open access web portal of National Geoportal, technicians and researchers can access the search services (CSW), visualization (WMS), download (WFS and WCS) and transformation (WPS), of the available geometric databases. These services can be used through the online interface and GIS software.

For the development and application of the GIS methodology, we use the geometric database of buildings and civic numbers.

3.2 THE STRUCTURING AND PROCESSING OF DATA

This second step allows one to define the structuring and processing of all data necessary to apply the GIS-based methodology able to quantify the real electric energy consumption of the domestic and non-domestic users. In particular, the structure of the geodatabase has been defined as containing all the alphanumeric and geometric data identified in the previous phase. Geodatabase is a relational data storage format used in GIS, that is designed for storing simple vector geometries (dots, lines and polygons), raster images, and alphanumeric data tables, which can be related to each other.

To organize all the data within the geodatabase, it is necessary to make data from different sources compatible, in order to reduce the join errors. In particular, one of the most complex operations carried out at this stage was to identify an operating mode to uniform the data of the addresses of the electrical users downloaded from the SIATEL 2.0 to the geometrical and numerical data relating to the addresses obtained from the National Geoportal. This difficulty arose due to the differences in both the text formatting of the address and the numbering. The SIATEL 2.0 platform uses the data provided by the public administrations and the operators of the different services (water, electricity, gas, telephone). These enter billing addresses, based on information provided by users. In many cases this information is incomplete and incorrect, due to changes of type toponymical not communicated by users to the managers.

These correction and processing operations are fast when applying the GIS methodology to small municipalities, while for large cities the work of implementing the GIS methodology is more complex because it is necessary to organize and process databases of alphanumeric and geometrical data that possess a high level of complexity. The completion of this phase allows one to obtain the geo-localized data relating to the energy consumption for domestic and non-domestic users throughout the study area.

3.3 THE CLASSIFICATION AND REPRESENTATION OF RESULTS

After completing the structuring and processing step, that allows the creation of a single geodatabase containing the input, a GIS tool has been developed, which contains all operations necessary for the classification and representation of the output data calculated in the previous phases. Then, a model builder and the graphical interface of the GIS-based urban energy consumption tool were created. These consist of a set of automated commands in GIS that allows one to classify and represent the output data, taking into account the geometry and dimensions of the reference territorial unit and the size of the numerical ranges that one intends to assign to the output variables for the mass point of the graphic representations. The default reference unit in the tool consists in a standard square cell of 100m x 100m. It was decided to use this modality, to display the output results of the GIS-based methodology, as the electrical energy consumption data are initially associated with the individual civic numbers, which correspond at a single point. To allow the display of data related to a reference surface, it was carried out by means of some geoprocessing operations in GIS. Furthermore, it was considered that the sections do not have a standardized dimension but are characterized by a different territorial extension, according to the urban and socio-economic characteristics of each area. This aspect involves a difficulty in immediately reading and comparing the data associated to each census sections, because it is necessary to take into account the different size of census sections in the analysis of the results obtained. Then, the calculation operations included in the GIS-based methodology enable the improvement in the reading and comparison of the output data between the different portions of the territory and to graduate the classification and representation of the electric energy consumption. This GIS-based methodology automatically divides the entire study area into square grids, with a standard square cell of 100m x 100m. The methodology performs additional geoprocessing operations that allow to the transfer of data from the census sections to the cell grid, through the factors of numerical and geometrical proportionality that also take into account of the buildings. In conclusion, the GIS methodology allows one to obtain a "photograph" of the electric energy consumption of the study area, in addition to knowing how the electricity consumption is distributed according to the type of users considered. This type of analyse is thus no longer based on the simulation and optimization models but on the actual data of end-use electric energy consumption.

4 THE CASE STUDY OF NAPLES

In order to test the GIS methodology, described in the previous paragraphs, it was applied to a specific case study. In particular, it was selected for the application of the GIS-based urban energy consumption tool to the City of Naples. The resident population of the city is 974,074 inhabitants (ISTAT, 2016), and it is the fifth largest Italian city in terms of population density, that is equal to 8,184 inhabitants/Kmq. The city in the last twenty years has been affected by a gradual reduction of the resident population that prefers to live in the neighbouring municipalities or in the peripheral neighbourhoods of the city. Relative to urban structure, in the city of Naples there are approximately 39,000 buildings, of which about 34,000 are mainly residential. The degree of occupancy of the housing is high, for the whole city the unoccupied dwellings are about 4%. In particular, there are 0.71 inhabitants/room in the municipality and 0.71 inhabitants/room in the province, while the national average values fluctuate around 0.6 inhabitants/room.
With regard to the composition of households, data shows that families with more members are located in the peripheral neighbourhoods. While the families in the main residential neighbourhoods (Chiaia, Posillipo, Vomero, Fuorigrotta and Bagnoli) have a reduced composition, averaging 2.5 components for each family. Moreover, it is interesting to note that the presence of small families and singles also characterizes the neighbourhoods located in the historical city center (Pendino, Porto, San Giuseppe, San Lorenzo, Montecalvario e Mercato). This phenomenon is presumably due to a process of ageing of residential population and the high cost of real estate. Therefore, the choice of this study area, is due to the high complexity and magnitude of city, that allows to test effectively the developed GIS methodology.

Fig. 2 The territory of the city of Naples with different *neighbourhoods* (in red)

4.1 THE IDENTIFICATION AND RETRIEVAL OF DATA

This section describes in detail the alphanumeric and geometrical data selected for the application of the GIS-based methodology at the City of Naples. In the Tab. 2, the data that are need for the test are listed. The alphanumeric data are composed of the data of the addresses and the electric energy consumption provided by the web platform "SIATEL 2.0" of Italian Revenue Agency and the socio-economic data provided by the ISTAT. The data of electrical energy consumption by users were obtained with the collaboration of the city authority. This alphanumeric database contains data relating to 443,185 users for the year 2011. These data can be divided into categories according to the following factors:

- type of subject, for this category there are two types of category "Natural person" and "Legal person”;
- type of user, in order to carry out a more detailed analysis of the variation of energy consumption in the municipal territory of study, it is possible to classify the users in: "Residential natural person", "Non-residential natural person".

Data	Type	Source	Year
Energy consumption	Alphanumeric	Italian Revenue Agency and Municipality of Naples	2011
Socio-Economic	Alphanumeric	National Statistic Office ISTAT	2011
Address	Geometric	Ministry of the Environment	2012
Building	Geometric	Ministry of the Environment	2003
Census tracts	Geometric	National Statistic Office ISTAT	2011

Tab. 2 List of data collected for the application to the case study of Naples

In this application to the case study of Naples, the data of electric energy consumption related to domestic and non-domestic users has been considered.

During the research, it was necessary to find an additional type of numerical data, namely those related to the socio-economic characteristics collected in the ISTAT census of the year 2011.

About the geometrical data used, these were downloaded from the National Geoportal and ISTAT. Those downloaded from the Ministry portal relate to the localization of the addresses present in the city of Naples. The available database is composed of approximately 109,000 items, each one corresponding to an address (Street and House number). During the elaboration of the GIS methodology there was the potential problem of the inadequacy of the databases provided in the case of large cities, where the localization of all civic numbers can be complicated. The forecast was correct at this stage of collection: it was in fact noted that the database on the National Geoportal was not complete, as it lacked data related to the neighbourhood of Scampia. The database was then updated by inserting all the missing house numbers. For a city of considerable size such as Naples, achieving a high level of precision in the retrieval of missing data has also required the use of databases consultable online (e.g. Google Maps, all city, Municipal Road) and site surveys. Consequently, one of the outcomes of this study was also the realization of a geolocalised database of all the updated house numbers throughout the city of Naples. The geometric and numeric census data, download from the ISTAT web portal, are related to the census area. For the city of Naples census 4,301 sections were identified. By means of the web portal of ISTAT, it was also possible to obtain the division of the study area into neighbourhoods, which was used in the subsequent phase of validation of the results obtained by the application of the methodology.

4.2 THE STRUCTURING AND PROCESSING OF DATA

The main operation that has characterized this phase concerned the correction of the data relative to the addresses of the users contained in the alphanumeric database downloaded from the platform of the Italian Revenue Agency of the revenue, through the competent offices of the municipality of Naples. As already clarified in the previous paragraphs concerning the GIS-based methodology developed, the addresses associated with energy consumption have some types of errors that can be derived from erroneous naming of roads and incomplete numbering of addresses. By making a first attempt to merge it became apparent that on a total of 443,185 users, only for 189,000 users do the addresses correspond to those present in the geodatabase of the addresses provided by the Ministry of the Environment. Thus, thanks to the alphanumeric data correction functions implemented in the GIS-based urban energy consumption tool, it was possible to achieve a union percentage of more than 96% of the users. In Fig. 2, two sample screens of the Address table are shown before and after the correction done by the correction functions implemented in the developed of the methodology.

ID	Indirizzo
241789	VIA S.DOMENICO FAB.CETIPA 29C A 4 1
182635	VIA S.EFR.VEC. 35A IS.6
215374	VIA S.F.SCO DE GERONIMO 10
212721	VIA S.F.SCO DE GERONIMO 13
183864	VIA S.F.SCO DE GERONIMO 2A
186786	VIA S.FERRARA 7
19488	VIA S.FILIPPO 30/E
291839	VIA S.FRANCESCO 9
231120	VIA S.FRANCESCO 9
302165	VIA S.FRANCESCO 9A
299852	VIA S.FRANCESCO 9A
60712	VIA S.FRANCESCO 9A
165602	VIA S.FRANCESCO 9A
392103	VIA S.FRANCESCO 9A
71771	VIA S.FRANCESCO 9A
236812	VIA S.FRANCESCO 9A
232455	VIA S.FRANCESCO 9A
12703	VIA S.G DEI CAPRI PALAZZO ASTINO SN
187584	VIA S.G. CAPRI 52
187585	VIA S.G. CAPRI 52
55833	VIA S.G. DEI CAPRI 53 SCALA A1P.IN2
167526	VIA S.G. DEI CAPRI 63/E
228975	VIA S.G. DEI CAPRI15

ID	Indirizzo
241789	VIA SAN DOMENICO 29
182635	VIA SANT'EFRAMO VECCHIO 35
215374	VIA SAN FRANCESCO DE GERONIMO 10
212721	VIA SAN FRANCESCO DE GERONIMO 13
183864	VIA SAN FRANCESCO DE GERONIMO 2
186786	VIA SALVATORE FERRARA 7
19488	VIA SAN FILIPPO 30
291839	VIA SAN FRANCESCO 9
231120	VIA SAN FRANCESCO 9
302165	VIA SAN FRANCESCO 9
299852	VIA SAN FRANCESCO 9
60712	VIA SAN FRANCESCO 9
165602	VIA SAN FRANCESCO 9
392103	VIA SAN FRANCESCO 9
71771	VIA SAN FRANCESCO 9
236812	VIA SAN FRANCESCO 9
232455	VIA SAN FRANCESCO 9
12703	VIA S.G DEI CAPRI PALAZZO ASTINO SN
187584	VIA SAN GIACOMO DEI CAPRI 52
187585	VIA SAN GIACOMO DEI CAPRI 52
55833	VIA SAN GIACOMO DEI CAPRI 53
167526	VIA SAN GIACOMO DEI CAPRI 63
228975	VIA SAN GIACOMO DEI CAPRI 15

Fig. 3 Example of correcting the address database as result of the application of the tool

Therefore, as a result of this correction, only 4% of the users were unable to merge the data of the SIATEL 2.0 database and the geo-localized address data, due to the absence of adequate information.

4.3 THE CLASSIFICATION AND REPRESENTATION OF RESULTS

This paragraph shows and describes the results obtained following the application in the city of Naples of the GIS methodology, developed to quantify the electric energy consumption, for domestic and non-domestic users, located in the selected study area. The Figure 4 shows the results obtained for domestic users. The black zones represent the areas of city with zero or negligible electric consumption. The consumption of less than 2,500 kwh, equal to the average of annual electric energy consumption estimated per user, was considered negligible. It can be noted that black areas are located in the most peripheral parts of the city while those with high consumption are concentrated in the central areas. Among the areas with low domestic consumption, it is possible to identify some of the areas with a prevalent non-residential vocation, such as the airport area, the former Italsider of Bagnoli, the eastern area of the territory for industrial use and the headquarters of the main offices of the city.

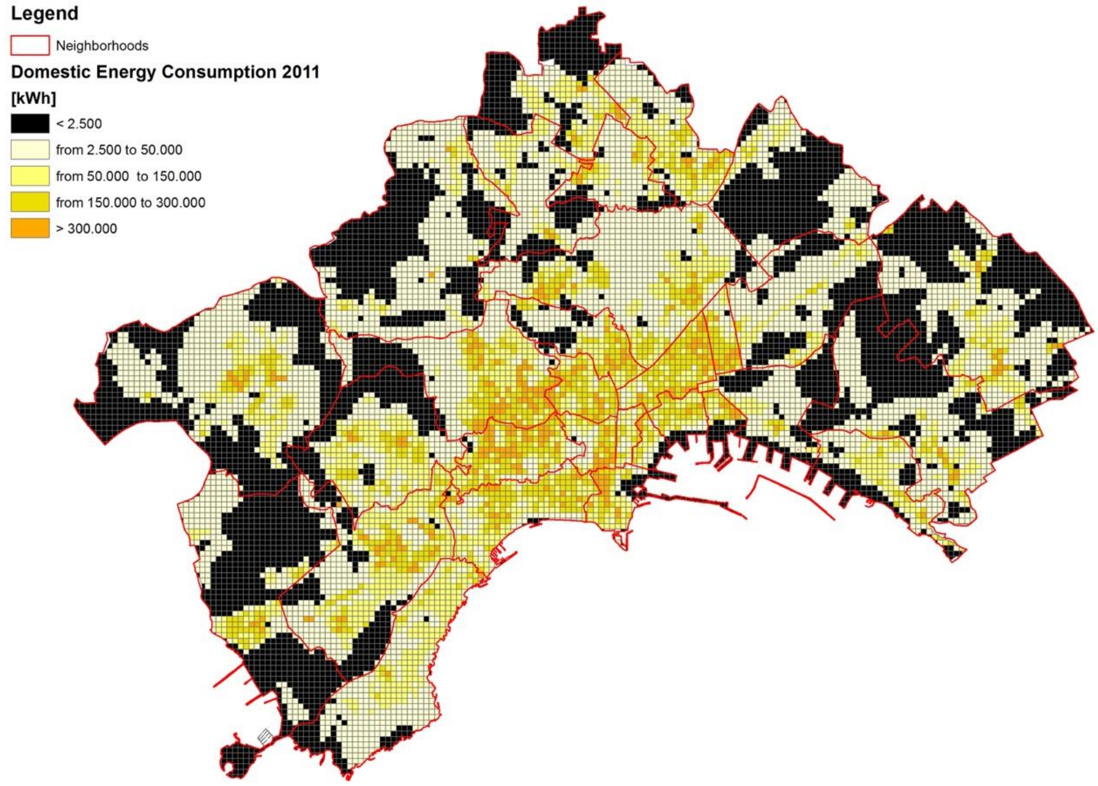

Fig. 4 Electric energy consumption map in kWh for domestic users in 2011

The zones with a high domestic electric energy consumption are those of the City Centre and the main residential areas. The Figure 5 shows the graph of domestic electric energy consumption for the individual neighbourhoods of the city of Naples, in the 2011.

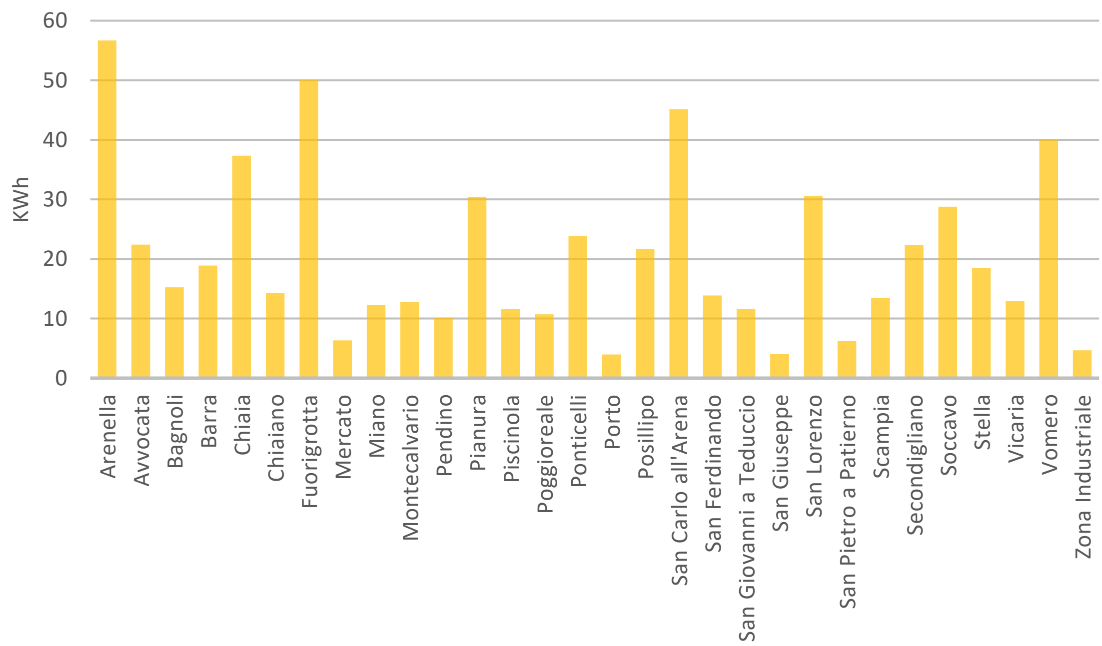

Fig. 5 Electric energy consumption of domestic users for the neighbourhoods of the city of Naples in the 2011

It can be noted that the neighbourhoods with high consumption are those with a prevalent residential vocation. In order to show such correspondence, in the following Table 3, there is the data for the resident population of the neighbourhoods with a prevalent residential vocation.

Neighbourhood	Number of apartments
Fuorigrotta	71.808
San Carlo all'Arenella	69.094
Arenella	67.634
Pianura	57.821
Ponticelli	52.284
San Lorenzo	48.078
Soccavo	45.314
Vomero	44.791

Tab. 3 Number of apartments for the most densely populated neighbourhoods in the City of Naples (source ISTAT 2011)

According to Figure 4, the central areas are characterized by a consumption below the minimum consumption threshold identified (2,500 kwh). Furthermore, in these black areas there is some urban equipment such as the Villa Floridiana, the wooded areas near the district of the city and the area of the San Paolo football stadium.

As regards non-domestic users, it can be noted that high-consumption areas are concentrated in specific areas of the municipal territory. In particular, the peripheral areas are in most cases characterized by consumption less than the minimum threshold of 20,000 kwh or are entirely null. While, as shown in Figure 6, it is possible to find a high concentration of consumption in the neighbourhood of Poggioreale.

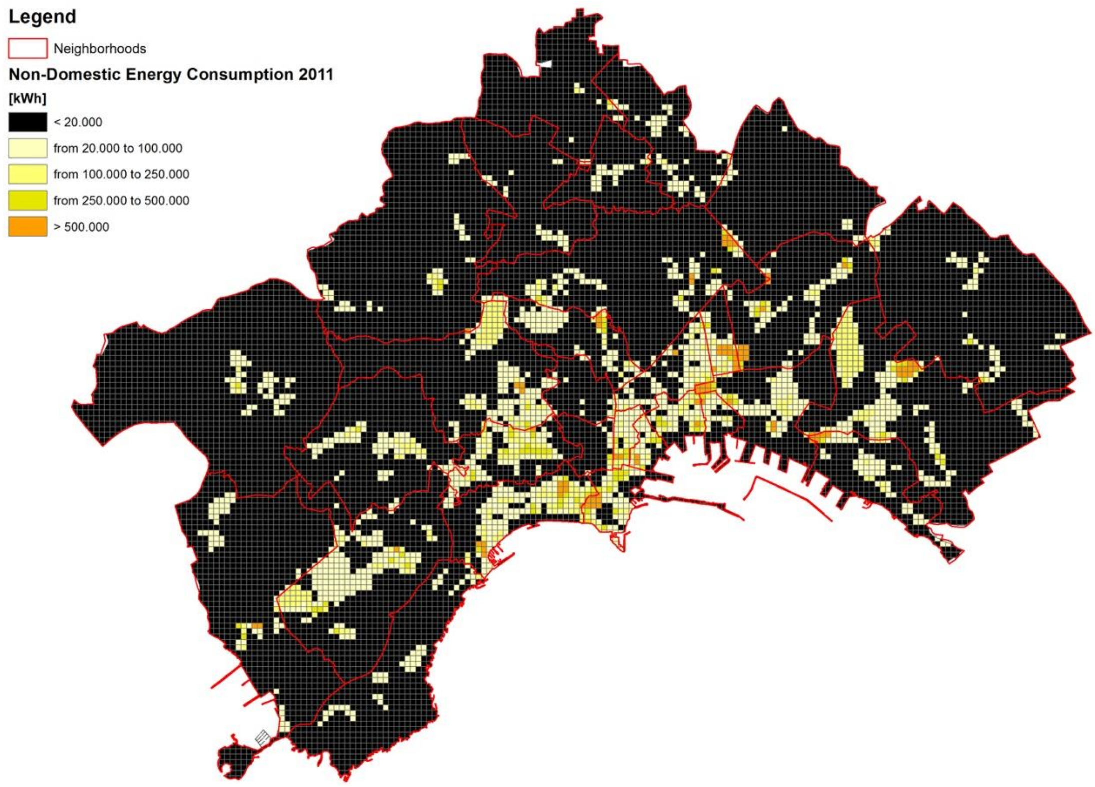

Fig. 6 Electric energy consumption map in kWh for the non-domestic users in the 2011

The result obtained is consistent because in this area there is a large number of private activities and urban services such as the law courts and the central business district. Portions of territory with a high consumption of non-domestic are also that of the Barra neighbourhood and of the industrial area where many companies and industries are located. It is possible to identify other parts of the territory with significant non-domestic consumption for the presence of commercial areas and offices in the neighbourhoods of Chiaia, Fuorigrotta and in the city centre.
These results become apparent by observing the results shown in the graph in Figure 7.

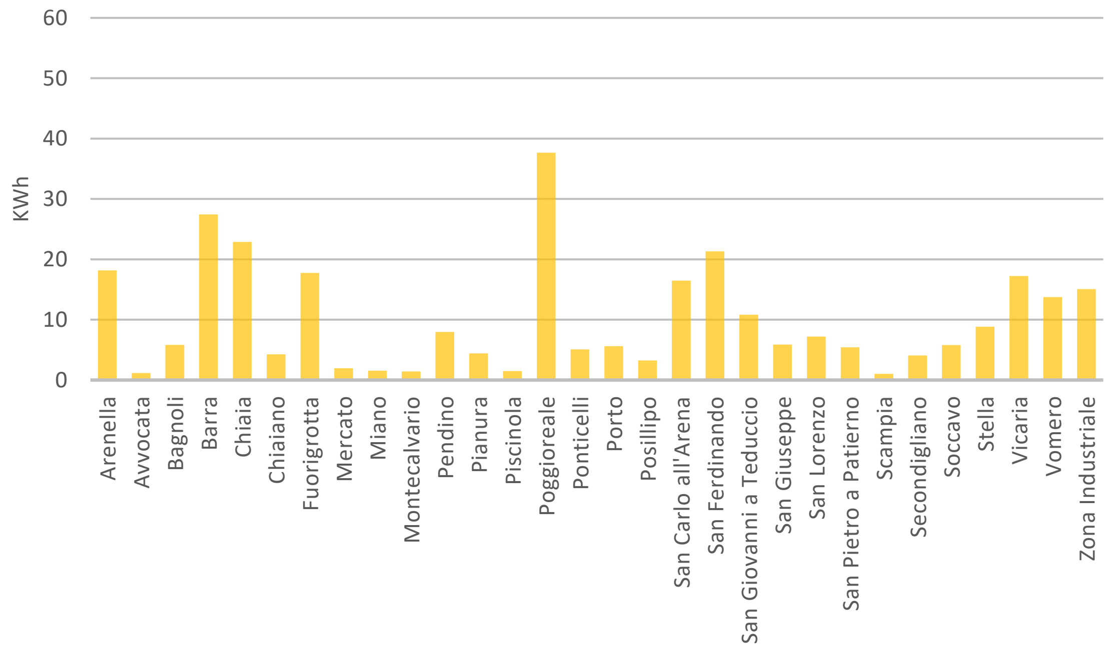

Fig. 7 Electric energy consumption of non-domestic users for neighbourhoods of the municipality of Naples in 2011

4.4 THE VALIDATION OF THE METHODOLOGY

In order to verify the results obtained following the application of the GIS methodology to the city of Naples, a validation step was carried out through a comparison of the data obtained in the output and those of the average electric consumption derived from the surveys/studies carried out by ISTAT and in the field of the SEAPs (Sustainable Energy Action Plans submitted under the 2020 Covenant of Mayors) by the municipal authority of Naples. This validation step is therefore aimed at verifying whether the results obtained are consistent with the values obtained through other studies that have calculated the consumption of energy through the use of estimation models. For the validation, starting from the outputs following the application of the methodology to the municipality of Naples, the average consumption for the individual quarters was calculated. Some of the calculated values are shown in Table 4.
The comparison data found are in both cases referred to the average consumption per user for the entire city of Naples. The ISTAT reports the end-use electric energy consumption per users of 2,556 kwh for the year 2011, while the SEAPs reports a value of 2.600 kwh calculated in 2011. However, this data is provided at an urban scale, not at a neighbourhood scale such as those analysed and therefore represent an average between the maximum and minimum values.
The comparison shows that the data calculated using the GIS methodology are similar to those found, so the validation can be considered satisfied.

Neighbourhood	**Average consumption [kWh/year]**
Arenella	2.221
Chiaia	2.517
Posillipo	2.854
Fuorigrotta	2.105
Pianura	2.268
Chiaiano	2.201
Vomero	2.333
San Giuseppe	2.292
San Pietro a Patierno	2.149
San Ferdinando	2.182
Soccavo	2.173
Vicaria	2.165

Tab. 4 Average electric energy consumption of some neighbourhoods of Naples

5 CONCLUSIONS AND FUTURE DEVELOPMENTS

This paper describes the technical-scientific activities that lead to the development of a GIS-based methodology able to quantify the electric energy consumption for domestic and non-domestic users.

For the development of this methodology, the computing capacity offered by the latest generation of GIS software has been used. These systems allow the collection, management and elaboration of the new types of data like Big Data and Open Data. There are three working steps that led to the development of the GIS-based methodology. The first step has provided data individuation and retrieval, through the choice of data freely usable by public administration necessary for the calculation of electric energy consumption of domestic and non-domestic users.

The second step involved the structuring and processing of data, which allowed both the development of an automated process of degree to relate data belonging to the different sources and the setting point of a GIS tool capable of performing the operations of geoprocessing and numerical calculation. The third and final step concerns the definition of the methods of classification and representation in GIS the results in output from the methodology. Therefore, through the application of the GIS-based methodology it is possible to obtain a real quantitative "photograph" of the variation of electric energy consumption for the study area analysed. Subsequently, in order to verify the real applicability and reliability of the GIS methodology, a study area has been identified. The City of Naples was chosen for the complexity of the urban system and for the collaboration of the municipal offices that provided the energy data by the web platform SIATEL 2.0. The alphanumeric data related to the electric energy consumption has allowed the identification of 443,185 domestic and non-domestic users while the national Geoportal database containing the alphanumeric and geometric data of the addresses for the City of Naples consists of 109,000 civic numbers. To geolocalize the electric energy consumption data, to each individual user has been joined the correspondent element of the addresses database. In order to carry out this operation, a process of correcting the addresses was applied, which joined of the data belonging to the two databases with a match of 96%. It was not possible to reach a complete association because for some of the users the civic numbers were not reported or addresses were not comprehensible.

Moreover, in order to facilitate the reading and interpretation of the results, a procedure was also developed to report the consumption of electricity compared to a standard territorial unit. It was selected, as standard territorial unit, the one entered by default in the GIS-based methodology, that is the rectangular cell of the size 100 m per 100 m. Through this technique it was possible to realize in GIS the representation of electric energy consumption for domestic and non-domestic users. In order to be able to verify the accuracy of results, it was be a validation phase through the comparing the average consumption values per user calculated by ISTAT and by local authority (SEAPs) with the average consumption data calculated for the individual neighbourhoods of city by the GIS-based methodology. The outcome of this comparison confirmed the correctness of the values calculated with the developed GIS-based methodology.

In conclusion, it was possible to identify two categories of products both linked to the development of the GIS-based methodology and to the application of the methodology to the study area of the City of Naples. As regards the first category, the work carried out allowed the development of the GIS-based Urban Energy Consumption Tool, which allows the application of the developed GIS-based methodology through a graphical interface in the GIS. While the second category of products concerns the numerical and graphic results obtained for the territory of the municipality of Naples both in the stage of organization and processing of data such as for example, the updated version of the geodatabase addresses both in the classification and representation of electric energy consumption for domestic and non-domestic users. These results constitute a cognitive asset that local administrations can use to improve the energy sustainability. Among the strengths of the GIS-based methodology developed is the quantification and detailed distribution of electric energy consumption, using the actual data. In addition, the results obtained support the decision making processes related to improve the urban sustainability to optimize the energy consumption and reduce the greenhouse gas emission through a smart and integrate strategies that involve the different components of urban system.

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IMAGE SOURCES

Fig. 1, 2, 3, 4, 5, 6,7: elaborated by the author

Tab. 1, 2, 3, 4: elaborated by the author

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