

# TeMA

Journal of  
Land Use, Mobility and Environment

This special issue collects a selection of peer-review papers presented at the 8th International Conference INPUT 2014 titled "Smart City: planning for energy, transportation and sustainability of urban systems", held on 4-6 June in Naples, Italy. The issue includes recent developments on the theme of relationship between innovation and city management and planning.

Tema is the Journal of Land use, Mobility and Environment and offers papers with a unified approach to planning and mobility. TeMA Journal has also received the Sparc Europe Seal of Open Access Journals released by Scholarly Publishing and Academic Resources Coalition (SPARC Europe) and the Directory of Open Access Journals (DOAJ).

# INPUT 2014

papers selected

## Smart City

planning for energy, transportation  
and sustainability of the urban system

## SMART CITY

## PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

Special Issue, June 2014

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# TeMA

Journal of  
Land Use, Mobility and  
Environment

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science, and complex systems.

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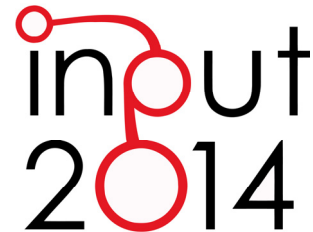
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# TeMA

Journal of  
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This special issue of TeMA collects the papers presented at the 8th International Conference INPUT 2014 which will take place in Naples from 4th to 6th June. The Conference focuses on one of the central topics within the urban studies debate and combines, in a new perspective, researches concerning the relationship between innovation and management of city changing.



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## EIGHTH INTERNATIONAL CONFERENCE INPUT 2014

### SMART CITY. PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

This special issue of TeMA collects the papers presented at the Eighth International Conference INPUT, 2014, titled "Smart City. Planning for energy, transportation and sustainability of the urban system" that takes place in Naples from 4 to 6 of June 2014.

INPUT (Innovation in Urban Planning and Territorial) consists of an informal group/network of academic researchers Italians and foreigners working in several areas related to urban and territorial planning. Starting from the first conference, held in Venice in 1999, INPUT has represented an opportunity to reflect on the use of Information and Communication Technologies (ICTs) as key planning support tools. The theme of the eighth conference focuses on one of the most topical debate of urban studies that combines , in a new perspective, researches concerning the relationship between innovation (technological, methodological, of process etc..) and the management of the changes of the city. The Smart City is also currently the most investigated subject by TeMA that with this number is intended to provide a broad overview of the research activities currently in place in Italy and a number of European countries. Naples, with its tradition of studies in this particular research field, represents the best place to review progress on what is being done and try to identify some structural elements of a planning approach.

Furthermore the conference has represented the ideal space of mind comparison and ideas exchanging about a number of topics like: planning support systems, models to geo-design, qualitative cognitive models and formal ontologies, smart mobility and urban transport, Visualization and spatial perception in urban planning innovative processes for urban regeneration, smart city and smart citizen, the Smart Energy Master project, urban entropy and evaluation in urban planning, etc..

The conference INPUT Naples 2014 were sent 84 papers, through a computerized procedure using the website [www.input2014.it](http://www.input2014.it) . The papers were subjected to a series of monitoring and control operations. The first fundamental phase saw the submission of the papers to reviewers. To enable a blind procedure the papers have been checked in advance, in order to eliminate any reference to the authors. The review was carried out on a form set up by the local scientific committee. The review forms received were sent to the authors who have adapted the papers, in a more or less extensive way, on the base of the received comments. At this point (third stage), the new version of the paper was subjected to control for to standardize the content to the layout required for the publication within TeMA. In parallel, the Local Scientific Committee, along with the Editorial Board of the magazine, has provided to the technical operation on the site TeMA (insertion of data for the indexing and insertion of pdf version of the papers). In the light of the time's shortness and of the high number of contributions the Local Scientific Committee decided to publish the papers by applying some simplifies compared with the normal procedures used by TeMA. Specifically:

- Each paper was equipped with cover, TeMA Editorial Advisory Board, INPUT Scientific Committee, introductory page of INPUT 2014 and summary;
- Summary and sorting of the papers are in alphabetical order, based on the surname of the first author;
- Each paper is indexed with own DOI codex which can be found in the electronic version on TeMA website ([www.tema.unina.it](http://www.tema.unina.it)). The codex is not present on the pdf version of the papers.

## SMART CITY PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM Special Issue, June 2014

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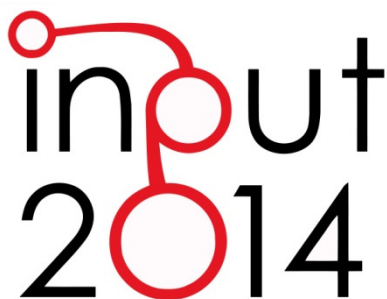
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## SPECIAL ISSUE

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Smart City - Planning for Energy, Transportation and Sustainability  
of the Urban System

*Naples, 4-6 June 2014*



## INTEGRATED URBAN SYSTEM AND ENERGY CONSUMPTION MODEL: RESIDENTIAL BUILDINGS

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### ABSTRACT

This paper describes a segment of research conducted within the project PON 04a2\_E Smart Energy Master for the energetic government of the territory conducted by the Department of Civil, Architectural and Environment Engineering, University of Naples "Federico II".

In particular, this article is part of the study carried out for the definition of the comprehension/interpretation model that correlates buildings, city's activities and users' behaviour in order to promote energy savings. In detail, this segment of the research wants to define the residential variables to be used in the model. For this purpose a knowledge framework at international level has been defined, to estimate the energy requirements of residential buildings and the identification of a set of parameters, whose variation has a significant influence on the energy consumption of residential buildings.

Then, the goals of the work are the analysis and the comparison of the different models related to the energy requirements of residential buildings at urban scale, and the selection of a set of parameters, that according to the scientific literature, has a direct influence on the energy consumptions of buildings.

### KEYWORDS

Residential building energy model; Residential energy consumption.

## 1 INTRODUCTION

The paper describes a segment of the research activity carried out within the project PON 04a2\_E Smart Energy Master for the energetic government of the territory, which aims to develop a comprehension / interpretive model at territorial level between city, buildings and user behaviours to promote energy savings. For the development of the model, the first phase of research has focused on the review of the scientific literature produced at international level related to these issues, considering all the sectors constituting the urban system.

The comprehension phase aimed to identify the relationships between energy consumption, urban, building and socio-economics characteristics and users' behaviours. In particular, this paper aims to identify the parameters that affect residential buildings energy consumption.

This research activity is part of a broader analysis which includes the study of all the different aspects – urban form and function, public buildings, mobility and socio-economic characteristics – influencing city energy consumption, in order to develop a model for the understanding and the interpretation of the whole phenomenon.

The first part of the paper analyses the main policies introduced in Europe to reduce energy consumption in the residential sector. Then, the research identifies, describes and compares the most recent models for estimating energy consumption, in order to choose a comprehension/interpretive synthetic model common to all analysis fields of the project. Finally, the studies that analyse separately the environmental, structural, social and economic factors that directly affect the energy requirements residential buildings have been carried out.

## 2 COMMUNITY STRATEGIES TO REDUCE ENERGY CONSUMPTION OF RESIDENTIAL BUILDINGS

The European Union, in order to identify a new community strategy for future growth based on higher levels of sustainability, has started a few years ago, a process of negotiation between the member states to define shared future goals of intervention, following the expiry of the *Kyoto Protocol* (2012). In 2009 this negotiation has led to a first concrete result, with the approval by the legislative bodies of the European Directive 2009/29/EC that commits Member States to reduce overall emissions of greenhouse gases by at least 20% by 2020 compared to the emission values recorded in 1990.

In particular, within that time horizon, the member states, through the definition of the 20-20-20 strategy, target to achievement of three main objectives: the reduction of global energy consumption (-20%), the reduction of greenhouse gases (-20%) and the increase of the consumption of energy produced from renewable sources (+20%).

In defining these strategies, the European governing bodies, based on the economic crisis that affected many European cities, identified the need to integrate different policy objectives such as reducing greenhouse gas (GHG) emissions, securing energy supply and supporting growth, competitiveness and jobs through a high technology, cost effective and resource efficient (European Commission Bruxelles, 27.3.2013 COM(2013) 169 final).

To continue with greater conviction in this direction, the European Union has recently also launched a review of the Climate-Energy Package, with the aim of providing a framework of sufficient certainty to the investors, with the identification of new objectives for the more longer time horizon of 2030. This extension of time, as recently clarified by the European Commission in the Green Paper (2013) "A 2030 framework for climate and energy policies", aims to stimulate further innovation and application technologies low carbon content and to



allow the European Union, in view of future global agreements for post-2020 climate, to have a clear policy line to follow during negotiations.

In the last years, the application of European strategies for sustainability required a major effort by the Member States in order to adapt the different economic and regulatory systems to achieve the set objectives. In addition, one more complicated step of the implementation process was the definition of the individual targets that each Member State was committed to achieve.

In Italy, these EU guidelines have been implemented with the approval of some laws, regulations compliances and programming documents: the National Action Plan for Renewable Energy (2010) and the National Action Plan for Energy Efficiency (2011) are among the most important documents.

The achieving of a significant improvement in the energy efficiency of residential buildings is one of the main measures planned to reach the objectives set by the 20-20-20 strategy. The analysis of data on energy consumptions shows (Tab.1) the importance of this measure, in fact, not surprisingly, the sector with the highest energy consumption is the residential, which accounts for approximately 23% of total energy consumption in Europe (Eurostat, 2013).

	TOTAL		INDUSTRY		TRANSPORT		RESIDENTIAL		SERVICES	
	2001	2011	2001	2011	2001	2011	2001	2011	2001	2011
EU-28	1.150	1.109	330	288	346	366	303	275	128	141
Italy	125,98	122,31	38,77	30,13	42,94	42,04	28,92	31,32	11,99	15,75

Tab. 1 Final energy consumption, by sector, in million ton. of oil equivalent (Eurostat 2013)

In particular, for this sector has been expected to achieve the specific objectives of efficiency, to reduce power consumption drastically.

With the Directive 2010/31/EU that updates the previous Directive 2002/91/UE, it was determined that the Member States must establish a shared method for calculating the integrated energy performance of buildings, adopt the measures necessary to ensure that minimum requirements are set to energy performance requirements for buildings or building units and introduce a system of certification of the energy performance in order to achieve optimal levels of costs.

In Italy the implementation of these directives has happened gradually over the years with the adoption of different legislative instruments, in particular, Law 10/91 – *Rules for the Implementation of the national Energy Plan in the field of rational use of energy, energy conservation and development of renewable sources of energy* – has been the first to address energy savings for buildings and to rationalize the consumption of renewable energy. In particular, this law proposed a method for the evaluation of winter energy balance of a building.

Subsequently, the Legislative Decree N°192 of 19/08/2005 established the criteria, conditions and procedures for improving the energy performance of buildings in order to promote the development, enhancement and integration of renewable energy sources and energy diversification. Finally, with the Ministerial Decree of 26/06/2009 the previous regulatory guidance regarding the definition of national guidelines for energy certification of buildings have been implemented and integrated.

### 3 THE DETERMINANT ELEMENTS OF RESIDENTIAL BUILDINGS ENERGY CONSUMPTION

#### 3.1 KNOWLEDGE FRAMEWORK OF MODELS

As previously mentioned, this part of the research has the purpose of supporting the choice of the comprehension/interpretation model common to all fields of analysis within the Project Smart Energy Master and of identifying the key factors that influence the energy consumption of the urban residential sector. Therefore, an in-depth analysis was carried out for the selection of the most important models for estimating the energy consumption of residential buildings proposed by the scientific literature and developed worldwide. For greater relevancy of the objectives of the research project, it has been decided to focus on the models that use a statistical and engineering bottom-up approach. The statistical techniques determine the final energy consumption by analysing the energy bills and through sociological researches. The engineering techniques are based on the study of the physical characteristics of the building and they also allow identifying the effects deriving from the use of new building technologies.

The choice of the models to be described and analysed has been based on two main criteria: the most recent developed models and those applicable also to a territorial level of suburban scale.

The *Residential Building Energy Consumption Model* is a model developed as part of a research conducted at the Faculty of Urban Construction and Environmental Engineering of Chongqing University, in China. This is a bottom-up model of statistical type that implements the method of neural networks, which in its operation tends to reproduce the structure of the human brain. The benefits arising from the application of a neural model are multiple and one of these is the extraordinary adaptability of the model to the system that is object of the study, particularly if applied to a complex nonlinear system.

This model was developed on the NET platform and uses the language Csharp, which is based on SQL Server 2005, and allows simulating the energy consumption of residential buildings at urban scale. To make more reliable predictions, the model has been trained through the use of historical energy data.

This study has been divided into two phases: in the first phase, nineteen indicators have been selected, then the application of the neural model has allowed to identify meaningful relationships between each indicator and energy consumptions, so that the list of indicators was reduced to sixteen.

One of the main limitations of this study for the verification of the potential application of the neural networks model is the use of a small number of indicators respect to the real computing capacity.

In conclusion, this work has allowed us to define the direct dependence of the energy consumptions not only with the physical characteristics of buildings, but also with the socio-economic factors.

The *Method to Analyze Large Data Sets to Inform of Residential Electricity Consumption Data-Driven Energy Efficiency* was developed as part of the research activities carried out at the Department of Civil and Environmental Engineering at Stanford University. This method seeks to overcome some of the major limitations present in other models. In particular, the research activities for the implementation of this model have focused on the identification and classification of the most significant variables related to the physical properties of buildings affecting the consumption of electricity, to the choice of data collected through smart devices and to the development of a method based on the factor analysis that allows the model to identify the most influential variables (Kavousian *et al.* 2012).

Specifically, the study has led to the identification of four main categories of variables: location of buildings and weather conditions, physical characteristics of the building, home appliances and electrical systems and occupants' behaviour. This articulation was also used as the basic scheme for structuring an online survey

consisting of 114 questions, to collect part of the necessary information for the construction of the model. Other data were collected through the installation of devices for measuring energy consumption. The sample selected for this study consists of nine hundred and fifty-two households. A limitation of this model is that households selected for the collection of data belong exclusively to upper-middle class and have a high standard of education.

In order to reduce the initial large number of variables, the researchers have used the method of factor analysis (regression) that allowed them to eliminate the variables that were not significant.

In particular, they have identified 22 variables that are most representative of the households' behaviour with respect to energy consumption.

*The Residential electricity consumption* in Portugal analyses the energy consumption in the residential sector, paying particular attention to the influence of the housing and households characteristics. In Portugal, the residential sector accounts for about 17% of total final energy consumption of the country and for 21% of total consumption of electricity.

The study determines the residential electricity consumption per capita at two different scales: they use data to 2001 aggregated for municipality (top-down) and data collected through surveys on the consumer expenditure conducted among 2005 and 2006, aggregated for single family (bottom-up).

The study area analysed includes a total population of 10 million people living in 278 municipalities of mainland Portugal.

Although the scale of detail of data is different, the models were chosen in such a way as to be comparable. In particular, for both models, researchers used the method of Ordinary Least Squares (OLS) regression to estimate the coefficient of the model, and the dependent variable in both scales is the natural logarithm of electricity consumption per capita. For both scales of analysis, the income, the number of people per household and the age of the dwelling were the considered variables. In the bottom-up model has been included the number of electrical appliances used, a dummy variable for the presence of children, a dummy variable for the type of employment, the surface, the type of dwelling, the level of urbanization and a dummy variable for the different geographical areas. These variables have been put into the bottom-up model, because in the previous studies many of these were found to be among the most influential on electricity consumption.

Most of the data on the characteristics of the municipalities for the top-down models have been collected from the online database of the Statistical Office Portuguese, the Instituto Nacional de Estatística (INE), while the demographics of the population and housing characteristics from the Portugal census (INE 2003). The data for the bottom-up analysis have been collected through a survey on consumer spending (INE 2008). The survey was conducted on a sample of 7,925 households in the period between October 2005 and October 2006.

A first finding of the analysis of the results of the two models is that they are consistent with each other and with the other examples present in the scientific bibliography. All the statistically significant coefficients have the sign expected at both levels of analysis. In terms of exposure R-squared, the top-down model shows a better goodness of fit compared to the bottom-up one.

This results suggest that policy decisions that take into account only the income of families don't affect much on the variation in energy consumption for residential buildings, because other aspects such as the demographic structure of the population and housing characteristics are more influential.

The *Residential Building Typology* is a bottom-up model of engineering type that uses the method of archetypes. This study was carried out by the research group THEBES of Polytechnic University of Turin, and

has the objective to determine the energy requirements (heating and domestic hot water) of residential buildings through the analysis of buildings' characteristics.

The various studies carried out in different countries participating in the project aim to identify a common structure for the classification of building types. The data on building types developed during the project are published and can be accessed through a special web tool. For each country participating in the project, the national typology will be presented in the form of a matrix-type photograph of the buildings, organized according to the period of construction and building size.

The study conducted by the research unit of the Polytechnic of Turin, through the analysis of the Italian existing building stock, identified a matrix of building types, consisting of 32 buildings-types. In the matrix, the different types of building have been divided by two main variables: the time of construction and the average size. Depending on the construction period, eight different categories are identified (up to 1900, 1901-1920, 1921-1945, 1946-1960, 1961-1975, and 1976 to 1990, 1991 to 2005, from 2005), while the average size of construction allow to identify four categories (single-family homes, townhouses, multifamily buildings, blocks of flats).

Specifically, for each building-type, the annual energy consumptions of primary energy for heating and domestic hot water have been identified, and the numerical value assigned was calculated taking into account the different physical characteristics of the building (construction type and type of plants). For each type of building, a technical data sheet has been compiled, including all the features necessary for the calculation of building energy consumptions.

One of the problems emerging from the analysis of this study is the lack of information regarding the energy demand of buildings for cooling.

The Community Domestic Energy Model (CDEM) is a bottom-up model of engineering type that uses the method of archetypes for estimating CO<sub>2</sub> emission, basing on the study of the physical characteristics of the building, the leaks heat, the internal temperature and the energy flows of dwellings (Kavgic 2010).

This model calculates energy consumption through a classification of the residential buildings according to two main features, which are the form and the age of the building. By the combination of these two features, 47 different classes of buildings have been identified, each of which have been assigned primary and secondary input parameters.

The secondary input parameters were used exclusively to support the calculation of the primary input parameters. In total, in order to implement the model, 27 input parameters have been considered and divided into five primary categories: location, geometry of buildings, construction features, services and population.

To complete the identification of the classes, the next step was to determine the energy consumption and CO<sub>2</sub> emissions totals for each class of buildings. With this goal, they used the Building Research Establishment Domestic Energy Model (BREDEM) that allows to calculate the final energy consumption for space and water heating, cooking, lighting and operation of appliances.

This model developed in the United Kingdom is based on Standard Assessment Procedure (SAP) standards and it is among the most widely used and reliable models; it uses a combination of physical and empirical relationships to compute the energy consumption of a house (Anderson *et al.* 2002).

In conclusion, the description of the study of comprehension models for calculating of energy requirements for residential buildings, has allowed us to get to the definition of a general framework (Tab. 2) on the progress of the research, identifying the main problems and possible future developments.

MODEL	TYPE OF BOTTOM-UP MODEL	NATION	YEAR	POSITIVE ASPECTS	CRITICAL POINTS
Residential Building Energy Consumption Model	Neural Network	CHN	2012	Identification of the influence that the 16 parameters have on the energy consumptions.	Selection of a reduced number of parameters in the initial phase.
Method to Analyze Large Data Sets of Residential Electricity Consumption to Inform Data-Driven Energy Efficiency	Factor analysis	USA	2012	The building characteristics determine 42% of the variability in residential electricity consumption, whereas occupant behaviour explains 4.2%.	The data for energy consumption are referred to a sample of persons belonging to one social category.
Residential electricity consumption in Portugal	Regression	PRT	2011	The results indicate that policy measures that only take into consideration the income of households in Portugal might not be as effective as expected.	The importance of the demographic structure of the population and the characteristics of the dwellings and their equipment should be taken into account.
Residential Building Typology	Archetypes	EU	2010	Identification of 32 different archetypes of buildings.	In the study is neglected the estimation of the energy needed to cool buildings.
Community Domestic Energy Model (CDEM)	Archetypes	GBR	2009	Identification of 47 different archetypes of buildings.	In the study is neglected the behaviour of the occupants and their influence on energy consumptions.

Tab. 2 Summary Table of bottom-up models analyzed

### 3.2 THE SET OF PARAMETERS

As a final result of this segment of the research, it has come to identify the set of parameters that have a direct correlation with the energy consumptions of residential buildings. To arrive at the definition of this set of parameters, an in-depth literature analysis has been carried out to study some researches that analyse individual aspects belonging to environmental, structural, social and economic sectors were selected.

A first important result of this study is that the scientific literature produced in recent years, for this particular area of research, is very wide. Among these researches, the privileged studies that have come to the determination of the relations between the parameters and energy consumption by using a large sample of data are essential.

The parameters identified are classified according to subsystem of reference (environmental subsystem, physical subsystem, socio-anthropogenic subsystem) and for each one of these, a summary table containing all the information collected with bibliographic study was created (Tab. 3). In addition, when possible, a weight is assigned to the parameter, calculated as the average percentage change in energy consumption, with every other condition unchanged, moving from one class, (number range) in which each parameter is subdivided, to the next.

ID	SUBSYSTEM	PARAMETERS	NATION	YEAR	SAMPLE OF SURVEY	Weight
1	Environmental	Climatic zone	GRC	2007	Greek residential building heritage	23%
2	Environmental	Green areas	USA	2002	178 buildings	10%
3	Physical	Building size	NLD	2012	300.000 buildings	14%
			NLD	2009	15.000 buildings	
4	Physical	Building age	ITA	2011	Italian residential building heritage	14%
			NLD	2012	300.000 buildings	
5	Physical	Surface	CHN	2009	124 households e 3 building types	19%
			GBR	2008	200 buildings	
6	Physical	Compactness factor	ITA	2013	40.000 buildings	n.d.
7	Socio-Anthropic	Size of households	Olanda	2009	180.000 households	n.d.
8	Socio-Anthropic	Household income	Olanda	2009	180.000 households	n.d.
9	Socio-Anthropic	Age of residents	USA	2002	United States Census	n.d.

Tab. 3: The main parameters that affect significantly on energy consumption in residential buildings.

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