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GIS tools towards a renovation of the building heritage

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Abstract

Our proposal is to enhance information on the actual building stock and on barriers and drivers that influence the decision of public or private buildings 'owners toward renovation. With this information and with dedicated services, local authorities could persuade owners to undergone renovations on their buildings. We developed a methodology that allows to create a GIS model and tools quickly for virtually every Italian municipality and already tested in an Italian medium size municipality. With these tools it is possible to select buildings that need most the renovation and buildings that could be more easily renovated, considering barriers and drivers.

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Keywords: GIS model; renovation; barriers and drivers; public and private heritage.

1. Introduction

The reduction of climate change and the path to carbon neutral communities represent long lasting and urgent challenges for all the governments.

In Europe, the "Roadmap for moving to a competitive low carbon economy in 2050" (EU COM 112/2011) implies important efforts to reduce the energy consumption and to drastically integrate renewable sources, looking especially at built environment. In fact, in Europe buildings are responsible of 41% of the total final energy consumption in 2010 [1], representing an important energy saving opportunity. New dwellings built in 2009

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consumed 30% to 60% less than dwellings built in 1990 [1] and by 2021 all new buildings will be "nearly zero-energy buildings", thanks to the Energy Performance of Buildings Directive (2010/31/EU). However, it should be noted that most EU countries extend their dwelling stock by less than 1% per year, so the impact of the new energy-efficient buildings is limited and policies to regulate the energy performance of new buildings are not sufficient. The scientific community agrees about the need of operating on the already existing building stock.

However, this energy saving objective clash with the conservation of the Architectural Heritage, a valuable resource in Europe and especially in Italy.

As explained by [2], the Italian cultural heritage is diffused on the territory and as a whole it represents the historic memory of that site.

As summarized clearly by [3], in Italy, several acts, plans, national and local guidelines have been produced on Cultural Heritage Conservation, dealing specifically with Architectural Heritage Conservation; the most important is the Code of Cultural Heritage and Landscape [4]. At the local scale, specific actuation rules are reported in technical municipality regulations (i.e. "Regolamento Urbanistico Edilizio"), specifying what kind of intervention can be made (rehabilitation, refurbishment, etc.) on any listed building.

Indeed, the EPBD and EPBD Recast (2010/31/EU) only indirectly and weakly refer to renovation of protected buildings that could be not done if they "would unacceptably alter their character or appearance". [3] underlines how "the technical problems related to the energy retrofitting feasibility within a historic context were almost neglected or generally derogated."

The Italian transposition of the European Directives (Decree 192/2005) provides in the same way a derogation regime for the Cultural Heritage, yet underling the historical, artistic and landscape features. In Italy it is possible to declare if or if not a historic building may undergo to a full or partial renovation, but the level of intervention and the most compatible available technologies are not precisely defined [3].

Recently the Minister of Heritage and Tourism (MiBACT) has published guidelines for an energy renovation of the Architectural Heritage [5]. The guidelines include a rich collection of measures suitable to historical buildings, but they do not indicate specific of mandatory methods and measures to be applied directly. The reason lies in the fact that, due to the complexity of the building heritage, advices from the responsible local institution as well as architectural and peculiar technical features have to be taking into account simultaneously and considered case by case.

The Italian Association of Air Conditioning, Heating, Refrigeration (AiCARR) has developed guidelines for "Energy Efficiency in Historic Buildings" [6], focused on HVAC systems, which aim is to provide an insight into the relationship between restoration and installations that today is still little explored from a theoretical point of view.

The issue of the selection of appropriate measures that are well-balanced for a suitable architectural or landscape integration for historic building has been stressed by [2, 3, 7] that underline that energy saving is one of the several parameters involved in a conscious environmental improvement of historic and historical buildings.

The research presented in this paper lies precisely in this framework because provides a method and tools that can support a widespread, effective and conscious renovation of the building heritage. This approach is in accordance to the concept of integrated conservation, described in [7], and to the suggestion of the harmonization of energy retrofit and role of the Cultural Heritage administrations in the management of historic and historical building, described in [3].

In fact, the method and tools described in the following sections are aimed at stimulating all the stakeholders involved in buildings management, detecting the possible drivers towards a progressive and global improvement of the built environment.

The work here presented is a continuation of a wider research. The first part of the research, recalled in brief in section 2, was devoted to a method related and tools for overcoming the inertia of building energy retrofit at municipal level in Italy [8]. The second part of the research, recalled in brief in section 3, was devoted to identifying policies and innovative GIS-based tools to support and boost the energy renovation rate of the private building stock in Italy [9]. The third part, focus of the present paper, shows how the method and tools previously developed could be enriched to support a rational overlapping of the improvement of the energy performance and of the global conservation of the building heritage.

2. Public stakeholders: barriers toward effective LEP and suggestions

Effective local energy plans (LEPs) are the foundation for transforming the existing building stock in a more efficient asset and the widespread building heritage should be included in the energy planning. The municipal energy plan involves the measurement of energy consumption of the city, grouped by sectors and the identification interventions for saving fossil fuels and for promoting the use of local renewable energy sources. To develop a municipal energy plan in Italy two guidelines are available [10, 11], but they are not compulsory so it is possible to see plans different from each other and sometimes not comparable.

In Italy, the municipal energy plan is mandatory since 1991 (L 10/1991) for cities with more than 50,000 inhabitants. It is evident that this obligation encompasses only a small part of Italian municipalities, since only 142 of the 8,092 Italian municipalities (1.8%) have more than 50,000 inhabitants; moreover, only 48 cities approved their mandatory energy plan [12].

The lack of compulsive requirements, especially for small and medium municipalities, and the lack of coordination at national or regional level generate a shortage of detailed knowledge about the building stock. The situation is also aggravated by the long lasting economic crisis that has reduced funding availability of public administrations, and has drastically slowed investments in the buildings sector during the last years.

We can state that the energy plan, as it is, is not sufficient to challenge massive energy refurbishment, but there is the need to focus on implementation and monitoring phases. According to [8], for the Italian municipalities the most prominent barriers are lack of energy expertise by the technical office; data scattering and lack of coordination among the different offices and entities; lack of awareness and political commitment at decision-making level. This barrier can be overcome with a concerted effort at the national and local levels, gathering all the needed data into a new Municipal Energy Model (called MEM in the following). As described also in section 4.1, the MEM is able to give a geo-referenced representation of the state of the entire building stock of the municipality, with information about energy consumption, production and features.

To foster more effective LEP we proposed a national framework for the energy and buildings issue, which will implement the following the policies and practices:

- national coordination and support;
- local burden sharing and monitoring;
- national data collection;
- reform and an upgrade of the existing technical office (energy and statistics expertise);
- new approach to LEP.

In fact, we believe that to exploit the local potential, we have to move from exceptional best-case to widespread daily practice, making the energy planning process more smooth and effective, reducing barriers and providing a common basis for all municipalities. Ideally, each municipality in Italy should have a LEP in order to put all the Italian building stock under some energy planning and legislation.

3. Private stakeholders: barriers, drivers and suggestions

Public entities and privates are both involved in the management of building heritage. While it is important that the LEP proposes interventions on public buildings in order to give a shining example and promote best practices, it is essential that the implementation phase is focused on private buildings, that represent the large majority of our building stock. Therefore, to have an appreciable improvement of the overall energy performance of the building stock it is crucial to persuade private stakeholders to act on their buildings, analysing the barriers and drivers toward energy-oriented renovations.

Actually national and local policies overlook barriers and drivers that influence the decision to undergone energy-oriented renovations private stakeholders. As mentioned in section 1, we investigated these barriers and drivers in a previous part of the research [9]. The barriers could be categorized as: knowledge-based; economical and financial; technical, structural and social; political; individual and psychological.

It should be noted that there is more literature on barriers respect to drivers. This is also because often drivers are seen only as reversed barriers (e.g. insufficient vs. generous financial incentives). The decision to renovate of two phases: first if an energy measure has to be taken or not; and second how deep carry out the energy measure [13]. We thus divided the drivers in ones that activate the decision process and those that improve the depth of the intervention.

An effective LEP should address the barriers and exploit the drivers in order to persuade private stakeholders to take action on their buildings. In [9] we proposed to create specific services provided by the municipality dedicated to lessen the barriers and to exploit the drivers. More in detail, two services for the two different typology of users are proposed: an energy advisory service (called Energy Advisor in the following) for lay people (e.g. building owners, building manager, citizen); an advanced scouting service (recalled in the following as the tool Energy Scout) for energy and buildings companies. The Energy Advisor builds and structures the demand of the market (owners request interventions on their buildings), while the Energy Scout informs and helps the supply of the market (utilities provide design and construction services).

4. Method and tools

One important innovation of our research as a whole is the collection, the harmonization and the connection of all the useful available information at building level in a GIS. According to the aims and results reported in the previous parts of the research, we developed a set of innovative GIS-based tools able to support the proposed policies and services. Further, we successfully tested our method and tools on a medium municipality in Lombardy (a Region in Northern Italy) in order to verify the overall feasibility and reliability. Due to the importance of the building heritage in Italy and considering the difficulties related to its management as reported in section 1, we focus the last part of our research in developing a GIS tool specifically devoted to this issue. In practice, we include the building heritage in the set of tools that help to boost the energy renovation rate in the whole building stock.

The architecture of the tools developed in our proposal is reported in Figure 2 and therefore includes: Municipal Energy Model (MEM) and Municipal Heritage Map (MHM) as foundation maps; Energy Planning, Energy Advisor and Energy Scout as supporting tools.

4.1. Foundation maps

According to the considerations reported in [8], the MEM can be defined as a bottom-up hybrid model, because it uses both collected data of the specific building and archetypal approach to fill the lack of data. The focus is on a model that could be quickly implemented for each Italian municipality, thus the research gave more importance to diffusion rather than accuracy of the model.

The MEM is able to give a geo-referenced representation of the state of the entire building stock of the municipality, with information about energy consumption, production, and features with a level of detail of the single building. With the proposed national data collection framework, it will be possible to develop MEM for every Italian municipality, since the methodology uses data publicly available, or will be available, for each Italian municipality. Therefore, the MEM is effectively a GIS based tool able to support a massive energy retrofit.

In order to investigate and support the sensitive challenge of the energy improvement of the building heritage, we propose to connect the energy model with a new Municipal Heritage Map (MHM in the following). This map permits the collection at the local level of all the information about architectural heritage in a GIS map, as reported in Figure 1. This proposal may seem trivial, but, as resumed in section 2, the first part of our research shows that Italian municipalities have huge problems with dispersion of data among several municipal offices and other administrative entities; lack of coordination among the different offices; and different archives systems for data and/or lack of digital archives. As a result, in general, public entities are not aware of data available or collected and they do not organized systematic data set in a coherent framework. For example, usually municipality have historical maps (i.e. the maps related to old and historic cadaster, maps that report the state of the built environment at different stages and ages) and a register of the building permits. Nevertheless, they do not have a map of the age of construction for all the building stock, also because often maps and registers are not available in digital format and are not connected together. The age of construction is a pivotal parameter not only in the MEM, but also for heritage conservation.

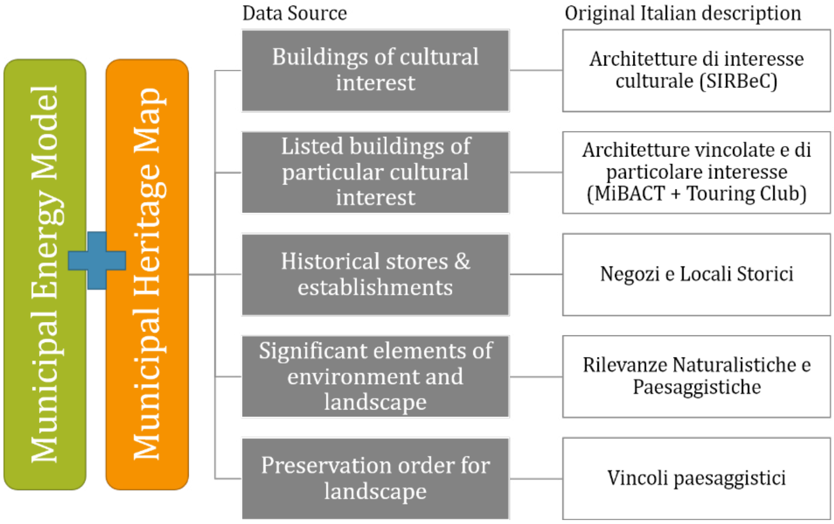

Fig. 1. - Elaboration of the map of the building heritage in the framework of the local energy plan and in connection to the municipal energy model.

The MHM could work as a stand-alone map to be used mainly for heritage preservation planning and source for tourist information. However, the true potential is to use it in the broader planning, such as the LEP. Since it is possible to assign the same identification code to each building in MEM and MHM, it is also possible to link the data collected and therefore to share and overlap information about energy or heritage features for each building.

4.2. Framework of the supporting tools

The supporting tools already developed in the previous works could thus be enriched by data about the building heritage. The intended users and the main features of the tools that arise from the MEM and linked MHM are listed in Figure 2.

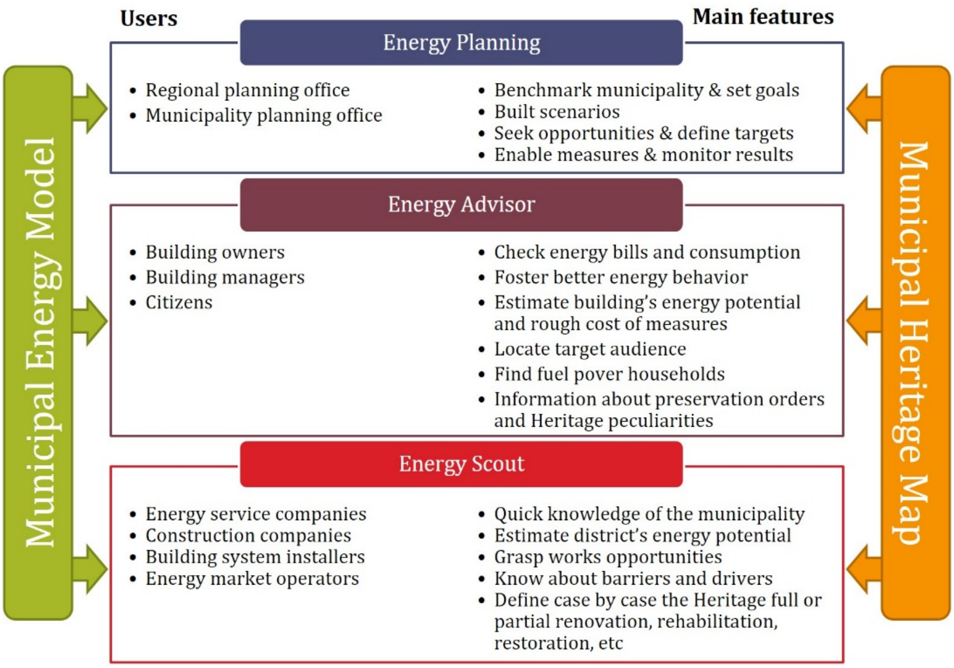

Fig. 2. – Overall architecture of the GIS based tools based on MEM and MHM.

The Energy Planning tool represent the support to LEP provided by the MEM, as described in [8]. In this framework, the building heritage will be thus part of the process and specifically addressed. One of the features is to benchmark the municipality and set feasible goals targeted on the municipality: the peculiarity of the local heritage should be considered when comparing municipalities and when setting realistic goals, and this is easier with the Energy Planning tool.

The purpose of the Energy Advisor is to help the municipal Energy Office to advise and involve building owners, building managers and citizens about energy measures that could be taken on their buildings. Indeed, among the barriers expressed by privates there the lack of technical knowledge to evaluate an energy measure and the need of trustworthy advice. The local administration is best placed to provide a non-partisan energy advice to their citizens. Moreover, there is the need of more tailored campaign to raise awareness about the energy & buildings issue and lead to action. Thanks to data contained in the MHM it will be possible to consider also legal acts, rules and other constrains related to the building heritage. This could support the definition of measures aimed at obtaining a more efficient building stock according to the peculiarities of each building.

The main purpose of the Energy Scout is to help the municipal Energy Office to meet the needs of the companies of the buildings/energy sector such as energy service companies (Esco), construction companies, building systems installers, energy market operators; mobilizing thus private investments. The features focus on providing general energy data about the municipality and specific data about building's features to grasp the size of the local market. For example, Energy Scout could help in give a territorial representation of areas suitable for developing micro grids or district energy measures; using knowledge about the barriers and drivers present in the building stock to find and choose buildings that could be a real work opportunity for companies of the building/energy sector. A feature added thanks to the MHM is to prioritize heritage buildings, signalling those under strict preservation order versus the ones that could undergone renovation, with the possibility to detail it (full or partial renovation, rehabilitation, restoration, etc.) and what are the most compatible available energy retrofit technologies. Moreover, the local administration may promote measures and projects involving a particular group or cluster of buildings (joint projects), i.e. those belonging to a historical centre. This lets also to directly taking into account the architecture typologies of those buildings, i.e. in the case of courtyard or adjoining buildings that are very popular in the Italian historical centre. A joint project is important for the energy results, but even more for a correct historical restoration and for the economic benefits of an entire revitalized area.

5. Capabilities of the method and tools: test results

In order to test the feasibility, reliability and applicability of the method after the insights about the building heritage, we follow the same method reported in [9]. Therefore, we develop the MHM for the same municipality already used as a case study in the previous part of the research. It is an average municipality in Lombardy Region, in the northern suburb of Milan, with roughly 21.000 inhabitants. Obviously, we follow the same approach used for MEM, i.e. using data publicly available for each Italian municipality (at least now available for each municipality in Lombardy and soon available for the municipalities located in the other Italian Region). For the case study, we selected the following database in the geoportal managed by Lombardy Region:

- Buildings of cultural interest (Architetture di interesse culturale), archive managed by the regional informative system of the cultural heritage (Sistema informativo regionale dei beni culturali - SIRBeC) ;
- Listed buildings of particular cultural interest buildings (Architetture vincolate e di particolare interesse), archive managed by the central institute for restoration (Istituto Centrale per il Restauro - ICR) and the regional secretariat for Lombardy of the Italian Ministry (Segretariato Regionale per la Lombardia del MiBACT) ;
- Historical stores and establishments (Negozi e Locali Storici), archive managed by Economic development Department ;
- Significant elements of environment and landscape (Rilevanze Naturalistiche e Paesaggistiche), database managed by the Cartography Department ;
- Preservation order for landscape (Vincoli paesaggistici), database managed by the informative system of the cultural heritage and landscape ambits (Sistema Informativo Beni e Ambiti paesaggistici - SIBA) .

As could be seen in Table I, the Heritage in this municipality is composed by 30 buildings. It should be noted that there is some overlapping from the different sources but, however, there are 6 buildings that are not present in the SIRBeC.

Table 1. Analysis of information about the building heritage for the case of study.

a: buildings of cultural interest; b: listed buildings of particular cultural interest buildings; c: historical stores and establishments; d: industrial activities; e: civil architecture; f: fortified architecture; g: religious architecture; h: rural architecture; *: not correctly georeferenced.

					Significant elements of environment and landscape				
Heritage	ID code in SIRBeC	a	b	c	d	e	f	g	h
Corte Via Don Minzoni 4	AMI100-06688	x							
Villa Merico, Merlo, Creppi di Belgiojoso	AMI100-06689	x							
Chiesa dell'Assunta	AMI100-06690	x							
Corte dell'Alpino	AMI100-06692	x							
Corte Via Volta 3	AMI100-06693	x							
Corte Via Volta 13	AMI100-06694	x							
Corte Via Mazzini 6	AMI100-06695	x							
Corte del Fante	AMI100-06696	x							
Corte rurale Via Repubblica	AMI100-06697	x							
Villa Borromeo D'Adda	AMI100-06698	x	x			x			
Villa Corbella Martinelli Sioli	AMI100-06699	x	x						
Villa Po, Degli Occhi	AMI100-06700	x				x			

Villa Ponti	AMI100-06701	x				x			
Villa Verzolo Monzini	AMI100-06702	x	x						
Corderia	AMI100-06703	x							
Chiesa dei SS. Martino e Bernardo	AMI100-06705	x							
Chiesa di S. Maria Nuova	AMI100-06706	x							
Chiesetta di S. Pancrazio	AMI100-06707	x						x	
Cascina della Villa Origoni, Marietti	AMI100-06713	x							
Cascina Traversagna	AMI100-06714	x							
Oratorio di S. Bernardino	AMI100-06715	x							
Cascina Marietti	AMI100-06716	x							x
Fornace Parodi	AMI100-06717	x			x				
Campanile Cascina S. Giuseppe	AMI100-06718	x*						x	
Cascina Carcagna	-								x
Cascina Gennari	-								x
Cascina delle Monache	-								x
Cimitero	-							x	
Macelleria Polleria Salumi Meneghello	-			x					
Torre	-								x

By the integration of the available information in the GIS, it was possible to create quite rapidly the MHM and integrating it with the already existing MEM and derived tools. The result of the integration is shown in Figure 3. The possibility to collect and interrogate information about the same building with different oriented database should not be underestimated. For example, the building selected and reported in Figure 3 is a rural courtyard built before 1721 and is owned by several privates. If we look at the Energy Performance Certificate Register (*Catasto Energetico Edifici Regionale* – CEER, www.cened.it), we found 14 energy performance certificates, one of them that show that the propriety undergone some energy retrofit.

Thanks to Energy Scout, it would be easier to involve the private owners into a joint project to improve the overall energy performance and at the same time to preserve the historical value of the courtyard. Some proprieties of the courtyard are located, so a joint project could help in lessening the tenant-landlord dilemma.

Certainly this type of application is only one example of the multiple interesting application of the GIS tools developed in the framework of the research. The features of the method developed could support many interesting insights also towards a harmonious, but diffuse and effective retrofit of the building heritage.

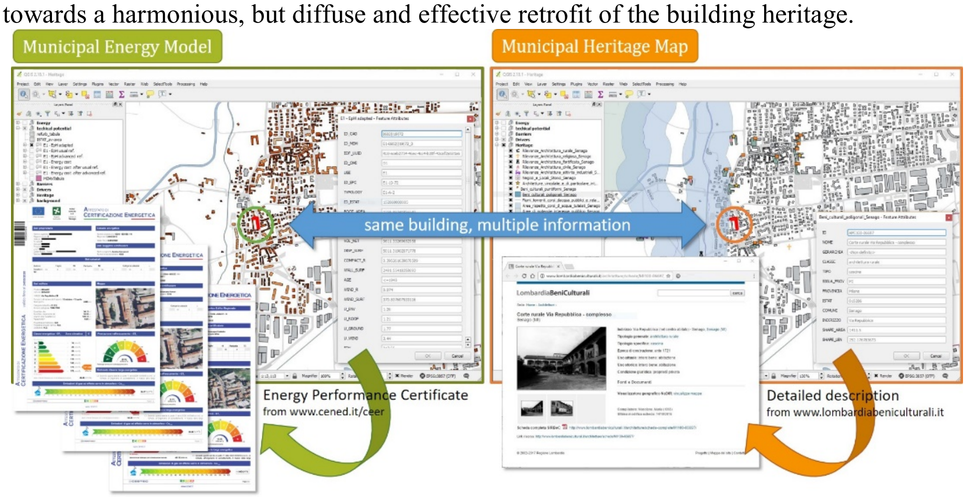

Fig. 3. – Example of application of MEM and MHM; representation of the available information and use.

6. Conclusions

The method and tools developed in the framework of the authors' research constitute a robust support to effective local energy plans that are the foundation for transforming the existing building stock, including the widespread heritage, in a more efficient asset.

Further, the same method and tools can contribute to individuate and overcome barriers that obstacle the actual improvement of the energy performance of the existing public and private buildings.

The Municipal Energy Model (MEM) and derivate GIS tools permit to activate drivers towards the involvement of different stakeholders of the energy and buildings sector interested in providing services, technologies, systems and components. In fact, these tools can support in meeting the interests of buildings owners, ESCOs, and other potential investors, bringing important results from the economic, energy, and environmental point of view, especially if accompanied by a scrupulous monitoring of the expected goals.

Furthermore, the possibility to integrate in the model the available information about the heritage through the Municipal Heritage Map (MHM) and to overlap this to the energy features is an important step towards the definition of the most compatible available energy retrofit technologies, even in a situation of lack of general rules.

The use of GIS model for each municipality (with the energy features at building level but also mapping the figures of the heritage) represents a fundamental added value of the method since it supports the identification of particular buildings or clusters of buildings, their quantification and their distribution. The GIS tool developed (Energy Scout) can help in immediately identifying the most promising areas to be involved in the process of energy renovation and in simulating possible energy scenarios. A clear knowledge of the regulation framework and of the available incentives can contribute in overcoming the non-technical barriers and attracting potential investors and stakeholders. The method permits also the definition of customized scenarios and statistical analysis that can be analyses in order to evaluate energy, economic and social impacts of selected technical measures.

In order to verify the applicability of the method and tools, we carried out a test to an Italian municipality as a case study. Despite some activities for implementing the GIS tools were time consuming, the results support the success and replicability of the method.

All these features can evidently contribute to boost the market of the building renovation following a more massive but harmonious, rational, energy conscious and cost effective approach.

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